Celebrating Nepal's Heritage with Electric Mobility

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Abbreviations

CAPEX	Capital expenditure
COVID-19	Coronavirus disease 2019
EIRR	Equity internal rate of return
FOB	Free on board
GDP	Gross Domestic Product
GHG	Greenhouse gas
IRR	Internal rate of return
LMC	Lalitpur Metropolitan City
MCA	Multi-criteria assessment
NMVOC	Non-methane volatile organic compounds
NPTO	Non-profit public transport operator
NPV	Net present value
OPEX	Operating expenditure
PDS	Patan Durbar Square
PIRR	Project internal rate of return
PM2.5	Particulate matter (diameter of less than 2.5 micrometers)
PSTO	Private sector transport operator
KDS	Kathmandu Durbar Square
KMC	Kathmandu Metropolitan City
UNESCO	United Nations Educational, Scientific and Cultural Organization
VAT	Value added tax

Contents

Executive Summary

Background

Electric vehicles can be a clean and affordable option for tourists and locals visiting cultural sites within Kathmandu Valley. The tourism industry in Nepal contributed to 7.9% of the country's GDP by generating NPR 240 billion (US$ 2.14 billion) revenue and supporting the creation of just over one million direct and indirect jobs in 2018.[1] Many tourists visit Nepal to experience its numerous cultural and heritage sites, in addition to the natural beauty of the country. Adequate transport infrastructure and services play a major role in increasing international as well as local mobility, which has a direct positive impact on both income generation and a country's GDP. In addition, in a country like Nepal where emissions in the transport sector have been steadily increasing at an average growth rate of 11% between 1994 and 2014, the provision of clean transport options will attract tourists by decreasing GHG and other local pollutant emissions.

This study aims to assess the feasibility of electric transport options as a viable alternative for tourists, and the local population, including the elderly and mobility impaired, when visiting areas of high cultural significance. When in Nepal, tourists mostly rely on private tour services or taxis for mobility. This can be generally quite expensive. This study also assesses the types of electric vehicles suitable for both tourists and the local population when visiting three main tourist areas in Kathmandu Valley, namely Patan Durbar Square, Kathmandu Durbar Square, and the UNESCO World Heritage Sites. To provide affordable and clean transport options to international and local tourists, as well as the elderly and mobility-impaired, this study estimates the optimum passenger tariff required to cover all operational expenses if all three services were operated by a single public transport operator. In addition, this study also estimates the return on investment (ROI) that would be attractive for a private transport entity to operate electric buses servicing the UNESCO Heritage Sites.

Route and Vehicle Selection

Most appropriate route and vehicle options were identified through a set of steps starting from desk research, followed by ground surveys, technical consultations, market surveys and multi-criteria analyses (MCA). "Same route" selection criteria were identified for routes in PDS and

[1] World Travel and Tourism Council. 2019. Annual Research Report.

KDS, due to similarities in route characteristics in those defined areas. A separate set of selection criteria were identified for the route servicing the UNESCO World Heritage Site, as it covered a wider area within Kathmandu Valley. Both desk research and ground surveys supported the identification of any roadblocks along potential routes. Two potential routes in each PDS and KDS were identified through multi-criteria analysis and consultations with key stakeholders, whereas for the UNESCO Heritage Site routes, potential route selection was only based on stakeholder consultations. Appropriate vehicle types were identified through market surveys and stakeholder consultations for all three types of services.

Current Assignment

This study is divided into eight chapters. Chapters 1, 2, and 3 provide background to the study, provides a description of some of the major heritage sites in Kathmandu, and presents examples of comparable electric shuttle services in other countries around the world respectively. Chapter 4 presents a conceptual framework of the study, highlighting the two layers of transport services that are being analyzed. Chapters 5, 6, and 7 provide detailed analyses on identification of route and vehicles, along with operational and financial analyses of the service for the UNESCO Heritage Site, Patan Durbar Square and Kathmandu Durbar Square. Environmental and social risks and benefits associated with the project are discussed in Chapter 8.

Heritage and Tourism in Nepal

Kathmandu Valley is rich in culture, with ancient temples and monuments spread across the valley. Tourism to these sites is increasing every year. There are seven UNESCO Cultural Heritage Sites in Kathmandu, within a radius of 30 km. Tourist arrivals in these Heritage Sites dipped in 2015/2016 due to the April 2015 earthquake. However, tourism numbers have increased ever since, with an annual average growth rate (CAGR) of 44% between 2016 and 2019 in Boudhhanath alone. Boudhhanath Stupa recorded the highest number of international tourist arrivals, at 36,184 in October, and the lowest number, at 9,876 in July. A total of 240,000 tourists visited Kathmandu Durbar Square, Patan Durbar Square, and Boudhhanath Stupa in 2019.

Case Studies

Successful examples of operation of electric shuttle and large buses for the purpose of touring cities can be seen in Vietnam, London, Slovenia, and Poland. There are all Hop-on, Hop-off type services, catering specifically for tourists. Electric shuttles in Slovenia and Vietnam are being operated in pedestrianized zones so that tourists have a choice between walking and taking the service. All cities in the survey operate 8-10 seater electric shuttles, except in London where large electric buses are in operation.

Integrated Service Framework

Two levels of Hop-on, Hop-off type electric mobility service is designed to improve tourism mobility inside Kathmandu Valley. The first level, or higher-level service, aims to service tourists traveling between major cultural heritage sites such as: Swyambhunath, Thamel, Pahshupatinath Temple, Boudhanath Stupa, Patan Durbar Square, Kalmochan Temple, Kathmandu Durbar

Square, and the National Museum. Mid-sized electric bus options have been explored for this level of service. A complementary second layer service is designed for passengers traveling in core areas of Kathmandu Durbar Square (KDS) and Patan Durbar Square (PDS). In the second level of service, electric shuttles (or carts) will be operated to improve mobility of the elderly, the differently-abled, and tourists looking to traverse culturally-rich core residential areas and other tourist sites close to Durbar Square. The conceptual framework of these two-layered services is presented in Figure A below.

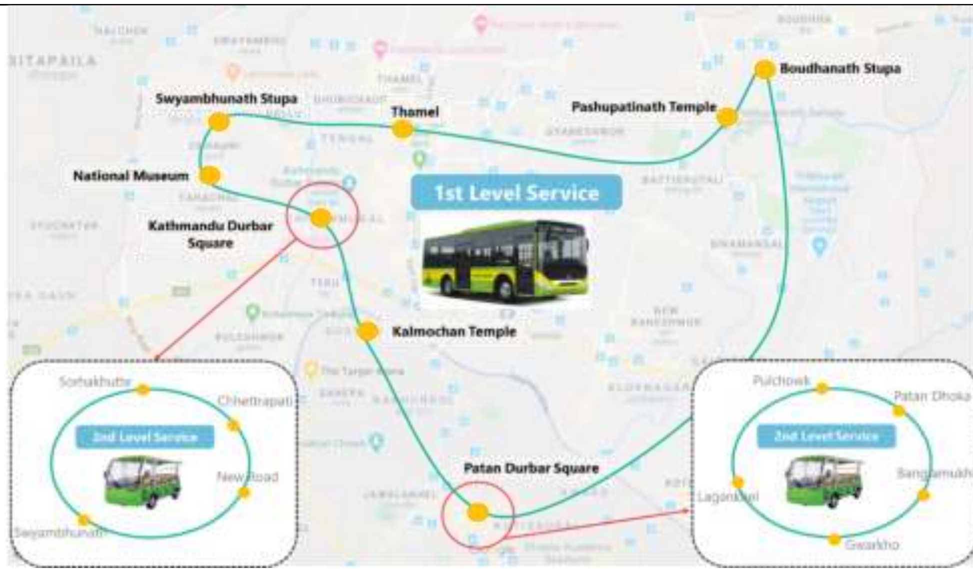

Figure A: Illustration of two level electric mobility service in Kathmandu Valley

The two service levels have been designed with convenient interchange points. The interchange point between mid-sized buses in the UNESCO Heritage site route and shuttle services in KDS is located at the Juddha Statue in New Road. In PDS, the interchange point is located in front of the Lalitpur Metropolitan City (LMC) office in Pulchowk. The second layer of shuttle service is designed in such a way that it provides last mile connectivity and connection to other major transport hubs. Since large buses are not allowed on the road leading to PDS from the LMC Office, if core area shuttle services are not implemented in both PDS and KDS, then tourists would need to walk about 950 meters and 300 meters from their respective stops to reach Durbar Square.

i. Route and Vehicle Information

Two route options servicing UNESCO World Heritage Sites were identified, based on set criteria and the findings from stakeholder consultations. Route 1, with a total distance of 70.5 km, services all seven UNESCO World Heritage Sites, whereas Route 2, with less than half the distance of Route 1, services five of the seven sites. These were then presented to stakeholders for consultation. Route 2 contains two sub-routes. One sub-route services Patan Durbar Square, Kathmandu Durbar Square, and Swayambhunath Stupa. The second sub-route services Patan Durbar Square, Kathmandu Durbar Square, Boudhhanath Stupa, and Pashupatinath Temple.

Route 2 was identified as the preferred route for this study. Through consultations, it was determined that Route 2 is preferred, since as 70% of the UNESCO World Heritage Sites are covered within a radius of less than 30km. These five UNESCO Sites are Patan Durbar Square, Kathmandu Durbar Square, Swayambhunath Stupa, Boudhhanath Stupa, and Pashupatinath Temple, and are conveniently located in Lalitpur and Kathmandu City. The study recommends that a route servicing the two remaining World Heritage Sites - Changunarayan Temple and Bhaktapur Durbar Square - be assessed in the next phase of the study.

Mid-sized electric buses are highly suitable for the identified routes. A market survey was carried out in Chinese India, where the majority of mid-sized buses are manufactured with larger battery banks to maximize their range. Also, Chinese manufacturers were better able to provide full battery bank sizes. However, some manufacturers like JBM and Kinglong claim to offer customizable battery banks, depending on requirements. Proposed specifications for the mid-sized electric buses are provided in Chapter 5.

ii. Operational Plan for the Proposed Route

Fleet size, required number of trips, number of passengers, and battery bank size was estimated using the distance of the route and proposed headway. It has been assumed that for both sub-routes renamed as Pashupati Loop and Swayambhu Loop, the time interval between two arriving buses will be maintained at 60 mins. Since the distance of Pashupati Loop is 19.3km and distance of Swayambhu Loop is 17.4km, the number of buses in each of the two loops is estimated as three and two respectively. The buses will be making a one-way round trip, starting from Pulchowk in the south, going north through Kathmandu Durbar Square. In the Pashupati Loop, they will turn east toward Boudhhanath Stupa and Pashupatinath Temple. In the Swayambhu Loop, they will turn west toward Swayambhunath Stupa. The annual vehicle kilometers traveled by all vehicles in both loops is estimated at a total of 208,823 km. Since each vehicle will be making six trips covering a daily distance of 126km in the Swayambhu Loop, and five trips covering a daily distance of 117km in the Pashupati Loop, the battery bank size required for each (assuming a minimum SOC of 25%) has been calculated at 140 kWh.

iii. Financial Performance of Vehicles along the Proposed Route

Both non-profit transport operators (NPTOs) and private sector transport operators (PSTOs) have been considered in the financial analysis. The assumption here is that an NPTO would only be interested in recovering the operational cost of the service, whereas a PSTO would be looking to recover both capital expenditure (CAPEX) and operational costs (OPEX). A base passenger load factor of 65% is estimated in both the NPTO and PSTO cases. In the case of PSTOs, it has been assumed that passenger fares in the base case should yield an equity internal rate of return (IRR) of 18%, which is considered attractive to a private sector operator. Sensitivities have been applied in both cases to assess fares and its implications on returns on investment (ROI).

Financial analysis shows that the service will be feasible for both types of operators in the base case scenario. Since non-profit transport operators such as Sajha Yatayat would only be interested in recovering the operational costs related to the service, a flat fare of NPR 29 per passenger from years 1-8 and NPR 33 from years 9-15 have been estimated to meet the criteria. On the other hand, for a private sector transport operator who is driven by a return on investment (ROI), with average fares of NPR 105, equity related IRR has been estimated as 18%, yielding an NPV of NPR 19 million.

Battery replacement costs in Year 15 are possible with savings from previous years for a PSTO, but not for an NPTO.

Electric Shuttle Servicing Core Area of Patan and Kathmandu

i. Route and Vehicle information

Out of four route options, two preferred routes each were identified for the Patan and Kathmandu core areas, based on stakeholder consultations and multicriteria analysis (MCA). Routes L4 and L3* were preferred in Patan Durbar Square (PDS) and routes K1 and K4 were preferred in Kathmandu Durbar Square (KDS). A set of nine criteria were identified, based on the scoring of different route options in an MCA. All were selected, since they scored higher in an MCA, and key stakeholders such as Lalitpur Metropolitan City office and Kathmandu Metropolitan City office preferred those routes over others.

8-seater electric shuttles were highly preferred by the stakeholders in each of the Kathmandu and Lalitpur areas. Out of the seven electric shuttles identified in a market survey, 8-seater electric shuttles are highly preferred by the Kathmandu Metropolitan and Lalitpur Metropolitan City officials. This is mainly due to the narrow roads in PDS and KDS and this vehicle's ability to easily maneuver through the core area roads with minimum impact on pedestrian and existing vehicular traffic (key specifications are outlined in Chapters 6 and 7).

ii. Operational Plan for the Proposed Route

Fleet size, required number of trips, number of passengers, and the battery bank size was estimated, using route distance and proposed headway.
PDS – For the proposed routes L3* and L4 in Patan: given respective route lengths of 3.9km and 4.5km and a headway of ten minutes, a total of 14 8-seater electric shuttles would need to be procured. Assuming an SOC of 30%, the battery bank size is estimated to be 10 kWh for route L4 and 7.2 to 8.8 kWh for route L3.* This is based on the number of round trips per vehicle in a day, which has been calculated at c.17 trips along route L4 and c.15 trips along route L3.*
KDS - For the proposed routes K1 and K4 in Kathmandu: given respective route lengths of 3.9km and 3.4km and a headway of ten minutes, a total of 21 8-seater electric shuttles would need to be procured. Assuming an SOC of 30%, the battery bank size, is estimated to be 5.8 to 7.5 kWh for Route K4 and 4.9 to 7.9 kWh for Route K1. This is based on the number of round trips per vehicle in a day, which has been calculated at c.12 to 15 trips along Route K4 and c.12 to 17 trips along Route K1.

iii. Financial Performance of Vehicles along Proposed Routes

Passenger fares account for a one-time battery replacement cost in Year 5 and are estimated based on recovery of operational expenses. Passenger fare estimations don't take into account the CAPEX since the operator is interested in only recovering its operational expenses. Thus, passenger fares estimated for the base case of a 70% passenger load factor are as discussed below. With these fares, the operator will be able to replace the batteries once in Year 5 but will not be able to extend the life of the vehicles beyond Year 10. Even when the load factor of the vehicles is assumed to be low at 60%, passengers would not have to pay more than a NPR 20 flat fare in all of the routes.

PDS – NPR 13 per passenger for route L4 and NPR 15 per passenger for route L3.*
KDS - NPR 17 per passenger four Route K4 and NPR 16 per passenger for Route K1.

Similarities Between All Three Services

Overnight charging regimes have been identified as the most suitable in all three services. Since services will be in operation throughout the day and with breaks only at lunchtime, the most appropriate time for charging is overnight at the depot. A potential depot location for the vehicles servicing PDS and the UNESCO World Heritage Sites is the Sajha Yatayat depot as it is very close to Pulchowk where vehicles start and end operation. For KDS, a potential depot location could be on the Kathmandu Municipality's land in Teku, where vehicles can be parked and charged overnight. Also, the size of battery packs available for electric shuttles is limited to 10 kWh, requiring a minimum of 6.6 hours and upt to 10 hours to fully charge. Thus, other than overnight depot charging, no other charging scheme can be considered feasible.

With affordable fares and convenient service, the electric shuttles will aid tourists, elderly and mobility-impaired passengers in visiting different Heritage Sites within Kathmandu Valley. The two-layered service has been designed such that elderly and mobility-impaired passengers can conveniently take alternative transport options while visiting cultural sites within the core areas as well as the UNESCO Heritage Sites.

Environmental and Social Risks and Benefits

Significant reductions in both GHG and local pollutant emissions is estimated during the 10-year life of the electric shuttles and 15-year life of the electric mid-sized buses, as they replace ICE vehicles such as two-wheelers, four-wheelers, and buses. It is estimated that the electric shuttle fleets in PDS and KDS will replace about 7.5 million kilometers during the life of the vehicles and in the UNESCO Heritage Site route, mid-sized electric buses will replace around 8.4 million kilometers. With this, more than 3,500 tCO2e will be avoided. In addition, 3.7 tons of PM2.5, 28 tons of NOxs and 62 tons of NMVOC will also be avoided.

Environmental risks such as hazards due to decreased noise from electric vehicles, increased traffic to cultural heritage sites, and battery waste may be addressed through effective measures. The project will seek to learn from other countries in terms of adding noise-reducing devices onto vehicles for added safety, extending battery life by using them for energy storage, and aligning tourist traffic management practices with the Government of Nepal's regulations.

Significant socio-economic benefits in terms of job creation, social inclusion, and provision of quality mobility services can be achieved through these projects. Although this is a small project creating around 100 new jobs, it has the potential of transforming that segment of the transport sector that caters to tourists, and in doing so, creating direct and indirect jobs in hotel accommodation, tourist attractions, shops, restaurants, etc. Since electric vehicles are clean transport options, these projects allow the provision of quality and affordable mobility services to the elderly, mobility-impaired, and disadvantaged groups. This project will also prioritize training for women so that they can operate and maintain the vehicles, thereby increasing the share of women employees who can contribute to the tourism sector.

Part 1. Introduction to the Study

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Chapter 1 Introduction

1.1. Background

Tourism is widely regarded as a priority sector in Nepal. In 2018 alone, the sector recorded total revenues of NPR 240 billion (US$ 2.14 billion) and supported just over one million direct and indirect jobs, contributing 7.9% to the country's GDP.[2] Each year, thousands of tourists are attracted to Nepal's numerous cultural and heritage sites as well as the country's natural beauty. To maintain this attraction and encourage more tourists to visit, Nepal introduced its *Visit Nepal 2020* campaign.

Tourism, however, is affected by many factors including infrastructure and services, and the transport sector plays a significant role in the efficient operation of any country's tourism industry. Without proper transportation systems in place, local and international tourists have limited mobility options, discouraging them from visiting any country. In addition, in a country like Nepal where fossil fuel vehicles increased at an annual average growth rate of 14% between 1990-2018 and transport sector emissions increased by 11% between 1994 and 2014, provision of clean transport options, such as public transport and tour bus services in Europe, can help reduce greenhouse gases as well as local pollutant emissions. [3,4]

Currently, transport options predominantly used by tourists include taxis and private tour company vehicles. These are generally very expensive, with a minimum charge of NPR 4000 if booked for the day. Very few alternatives exist that provide affordable tour services catering to the movement of tourists and locals, especially elderly and mobility-impaired people. This represents a tremendous potential for implementing electric mobility as an alternative transport option in Nepal. This is mainly thanks to the increasing supply of electricity in the country as a result of the 7679 MW projects currently under various stages of construction.[5]

Electric vehicle tours that focus on heritage sites would be a highly supported inititiative of the Government of Nepal, which aims to increase the number of tourists to two million in 2020 as

[2] World Travel and Tourism Council. 2019. Annual Research Report.
[3] UNCRD. 2015. National Sustainable Transport Strategy (NSTS) for Nepal (2015~2040). NINTH REGIONAL ENVIRONMENTALLY SUSTAINABLE TRANSPORT (EST) FORUM IN ASIA.
[4] Ministry of Science and Technology, 2014. Second National Communication to the UNFCCC. Government of Nepal.
[5] Department of Electricity Development. 2020. Generation License Issued for Hydro Projects.

part of its *Visit Nepal 2020* campaign. The *Visit Nepal 2020* campaign has, however, been postponed due to the COVID-19 pandemic. Since both international and domestic flights have been canceled in many places around the world, including in Nepal, the tourism sector is one of the sectors that has been hit very hard by the lockdown issued due to COVID-19. In this scenario, there is a need to implement sustainable transport services such as electric vehicles, which can help boost domestic tourism and local mobility in the short run and international tourism in the long run.

1.1.1 Objectives

The objectives of this study are:

1. to assess the need for an electric shuttle service in the core areas of Patan, Kathmandu, and the UNESCO World Heritage Sites in Kathmandu Valley;
2. to identify the suitability of electric mobility options for boosting the mobility of tourists, the elderly, and disabled passengers in the core areas of Patan, Kathmandu, and the UNESCO World Heritage Sites in Kathmandu Valley;
3. to understand the passenger tariff structure required to cover operational costs of electric shuttle services in the core areas of Kathmandu Durbar Square and Patan Durbar Square;
4. to understand the passenger tariff structure required to cover operational costs of the electric shuttle servicing the UNESCO World Heritage Sites in Kathmandu Valley; and
5. to assess the efeasibility of operating electric mid-sized buses servicing the UNESCO World Heritage Sites in Kathmandu Valley.

1.2. Methodology

The steps below broadly outline the methodology adopted in this study:

Step 1: Identification of criteria for pre-selection of route options
A list of criteria based on road conditions and demand was identified for pre-selection of route options around Kathmandu Durbar Square, Patan Durbar Square, and the UNESCO Heritage Sites.

Step 2: Desk research and ground survey
Based on the above identified criteria and on the basis of desk research and ground surveys, a list of potential routes around Kathmandu Durbar Square, Patan Durbar Square, and the UNESCO Heritage Sites were identified (see Chapters 5, 6 and 7). Routes were first identified using Google Maps and then a ground level survey was performed to compare the actual time taken to traverse the routes.

Step 3: Technical consultation with stakeholders
These identified potential routes were then presented to stakeholders from Lalitpur Metropolitan City (LMC) and Kathmandu Metropolitan City (KMC) for discussion. Improvements and changes were made to the identified routes based on the stakeholders' feedback and

suggestions. Chapters 5, 6 and 7 present the discussion and outcomes of the technical consultation in more detail.

Step 4: Multi-criteria analysis of identified routes
All identified potential routes for Patan Durbar Square and Kathmandu Durbar Square were then analyzed using a simple multi-criteria analysis (MCA) framework to identify the preferred route. However, out of all the criteria identified in Step 1, only a selected few criteria were selected for the MCA. Details of the MCA are presented in Chapters 6 and 7.

The two highest-scoring routes are then stated as the recommended routes, which are then further analyzed for operational and financial feasibility.

Step 5: Consultation process
The consultation process included focus group discussions with Kathmandu Metropolitan City and Lalitpur Metropolitan City officials. The discussions also included officials at Kathmandu Durbar Square and Patan Durbar Square, as well as with personnel working across different UNESCO Heritage Sites. Key officials at the Ministry of Tourism, the UNESCO office in Kathmandu, and the Kathmandu Valley Preservation Trust were also consulted. Furthermore, extensive discussions with Sajha Yatayat were held on numerous occasions to discuss progress and receive feedback. Report preparation followed the process outlined below:

1. **Inception**: a meeting between Sajha Yatayat and GGGI was held in October 2019 to discuss potential electric mobility service options to service the core areas of Lalitpur and Kathmandu, in addition to an electric tour bus servicing the five UNESCO World Heritage Sites within Kathmandu and Lalitpur. It was decided that a similar study on a service to Bhaktapur may be conducted at a later date.
2. **Review of similar services in other countries**: a review of comparable tour services with electric buses servicing either heritage sites or popular tourist destinations was carried out. This provided a broader understanding of electric vehicles operations, ranging from route length to fare charged, and battery capacity deployed.
3. **Consultations with key stakeholders regarding proposed routes and vehicles were carried out as follows:**
    a. **Focus group discussion with Lalitpur Metropolitan City and Kathmandu Metropolitan City:** this discussion was conducted in November 2019 with the Mayor and officials of the Lalitpur Metropolitan City (LMC) and officials of the Kathmandu Metropolitan City (KMC). Representatives of the City Planning Commission (CPC) in KMC were also present at the meeting. Potential routes and different vehicle options were presented for feedback.
    b. **Focus group discussion with Lalitpur Metropolitan City**: this discussion was conducted in November 2019 with the Mayor and officials of LMC and was focused on the type of vehicle preferred by LMC.
    c. **Focus group discussion with Kathmandu Metropolitan City:** this discussion was carried out in January 2020 with the Mayor and officials of KMC and the staff of CPC. Potential routes in the Kathmandu core areas, along with the route servicing the UNESCO Heritage Sites was presented for feedback.

d. **Key Informant Interviews:** key informant interviews were carried out with Kathmandu Valley Preservation Trust, UNESCO, Ministry of Tourism and Boudhha Area Development Committee, KMC office at Kathmandu Durbar Square, and LMC office at Lalitpur Durbar Square.

The identified routes were presented to high-ranking officials from the entities outlined below.

Table 1.1 List of stakeholders for KII and FGD

	Entity	FGD	KII
1	Kathmandu Metropolitan City	√	√
2	Lalitpur Metropolitan City	√	√
3	Kathmandu Durbar Square		√
4	Patan Durbar Square		√
5	Kathmandu Valley Preservation Trust		√
6	UNESCO		√
7	Ministry of Tourism		√
8	Boudhha Area Development Committee		√
9	City Planning Commission, KMC	√	

1.3. Current Assignment

The current assignment is structured such that the first chapter provides the background and objectives of the study. The second chapter outlines the UNESCO Heritage Sites in Nepal and discusses the need for additional transport options to access these sites as well as those in core areas of Kathmandu and Patan. In the third chapter, we aim to understand comparable electric shuttle service operations in other countries. Chapter 4 presents a conceptual framework of the study, highlighting the two layers of transport service under study. This leads to the set of analyses on operation and financing of mid-sized electric buses servicing the UNESCO Heritage Sites in Kathmandu Valley (Chapter 5) and smaller shuttle service in the core areas of Patan Durbar Square (Chapter 6) and Kathmandu Durbar Square (Chapter 7). The final chapter (Chapter 8) presents the environmental and social benefits and risks of electric vehicle operations in the said areas.

Chapter 2. Heritage and Tourism in Nepal

2.1. UNESCO World Heritage Sites in Kathmandu Valley

Kathmandu Valley is rich in culture, with ancient temples and monuments spread across the valley. There are seven UNESCO Cultural Heritage Sites in Kathmandu, within a radius of 30 km. Tourists from all over the world visit Kathmandu to experience the diverse culture developed during the Licchavi and Malla era. All seven UNESCO Cultural Heritage Sites in Kathmandu are taken as a whole and regarded as *one* of the four main heritage sites in the UNESCO World Heritage Site listing. The seven sites include Kathmandu Durbar Square, Patan Durbar Square, Bhaktapur Durbar Square, Swayambhunath Stupa, Bouddhanath Stupa, Pathupatinath Temple, and Changu Narayan Temple.

Swayambhunath and Bouddhanath Stupas are revered mainly by Buddhists, and the temples in Kathmandu Durbar Square, Patan Durbar Square, Bhaktapur Durbar Square, Pashupatinath Temple and Changu Narayan Temple are of significance to the Hindu faith. Specific areas within the heritage sites have been declared as protected monument zones under the *Ancient Monument Preservation Act*, *1956*. The areas are managed through the coordinated efforts of the Federal Government, Local Government, and non-governmental organizations such as the Kathmandu Valley Preservation Trust, and UNESCO. Roles and responsibilities for management have been clearly outlined in the *Integrated Management Plan* for the Kathmandu World Heritage Property adopted by the Government of Nepal in 2007.

Short descriptions of the seven UNESCO Heritage sites are presented below.[6]

[6] Information adapted from the UNESCO.

1. **Kathmandu Durbar Square**

Kathmandu Durbar Square, also known as *Basantapur Durbar Khsetra* in Nepali, is situated in the center of Kathmandu City. The Palace of the Malla kings (1484-1520) and Shah kings (1769-1896) is situated within the Kathmandu Durbar Square. It is estimated that the square was built betwee 1069 and 1083 AD. Along with the palace, there are temples, quadrangles and courtyards within the Durbar Square.

Figure 2.1 Kathmandu Durbar Square

2. **Patan Durbar Square**

Patan Durbar Square is situated in Lalitpur City, 8km southeast of Kathmandu City. The Malla Kings of Lalitpur resided in the palace within Durbar Square. Around 55 major temples and 136 courtyards can be found within the Durbar Square. The entrances of some of the main temples, such as Krishna Temple, Bhimsen Temple, Vishwanath Temple, and Taleju Bhawani Temple, all face toward the palace. Old Newari houses can also be found within the square. Although it is not clear when the Durbar Square was built, the four main temples can be dated back to the 16th Century.

Figure 2.2 Patan Durbar Square

3. Bhaktapur Durbar Square

Bhaktapur Durbar Square is located in Bhaktapur, which lies 13km east of Kathmandu. The Durbar Square consists of four squares, namely Durbar Square, Taumadhi Square, Dattatreya Square, and Pottery Square. The Durbar Square has a 55-window palace, which is regarded as one of its main attractions. Other attractions include the Golden Gate, Lion Gate, various art galleries, and the statue of King Bhupatindra Malla.

Figure 2.3 Bhaktapur Durbar Square

4. Swayambhunath Stupa

The Swayambhunath Stupa, also popularly known as the “Monkey Temple,” is one of the most ancient stupas in Kathmandu Valley, and is regarded as one of the most sacred Buddhist pilgrimage sites in Nepal. The Stupa is surrounded by a variety of shrines and temples, which date back to the Licchavi period (400-750 A.D). The iconography in Swayambhunath was developed by specific streams in Newar Buddhism. Although the Stupa is considered Buddhist, it is revered by Hindus as well.

Figure 2.4 Swayambhunath Stupa

5. Pashupatinath Temple

Pashupatinath Temple is known to be a holy temple in Hinduism. It is located around 6km east of the center of Kathmandu. The temple is situated on the banks of the holy Bagmati River. The temple was included in the UNESCO World Heritage Sites list in 1979 and is one of the 275 Tamil Paadal Petra Sthalams (Holy Abodes of Shiva) on the continent. It was re-built in the 5th century by Lichchavi King Prachanda Dev after the old temple was consumed by termites.

Figure 2.5 Pashupatinath Temple

6. Bouddhanath Stupa

The Bouddhanath Stupa is a Buddhist shrine located 11km northeast from the center of the Valley. The Stupa has a large mandala, which makes it one of the largest spherical stupas in

Nepal. Boudhhanath Stupa is known as one of the largest stupas in the world. There are different theories as to when the stupa was built. It was added to the UNESCO World Heritage Site List in 1979.

Figure 2.6 Bouddhanath Stupa

7. Changu Narayan Temple

Changu Narayan Temple is situated in the Changunarayan Municipality in Bhaktapur city. The hill on which the temple sits is located about 12km east of Kathmandu. The shrine within the temple is dedicated to lord Vishnu and is considered to be the oldest temple in the history of Nepal.

Figure 2.7 Changu Narayan Temple

2.2. Tourists Visiting the UNESCO Heritage Sites

Tourist arrivals in these Heritage Sites dipped in 2015/2016 due to the April 2015 earthquake. Numbers have since increased, with an annual average growth rate of 44% between 2016 and 2019 in Boudhhanath for example (cf. Figure 2.8). International tourist arrivals in Boudhhanath Stupa are at their peak (36,184) during October, and at their lowest (9,876) during July. An average 240,000 tourists visited Kathmandu Durbar Square, Patan Durbar Square, and Boudhhanath Stupa in 2019.[7]

As shown in Figure 2.9, the number of international tourists arriving in Boudhhanath and Pashupatinath were very similar, whereas the number tourists visiting Patan Durbar Square increased only after the earthquake in 2015, with an annual average increase of 281% between 2015/16 and 2018/19.[8]

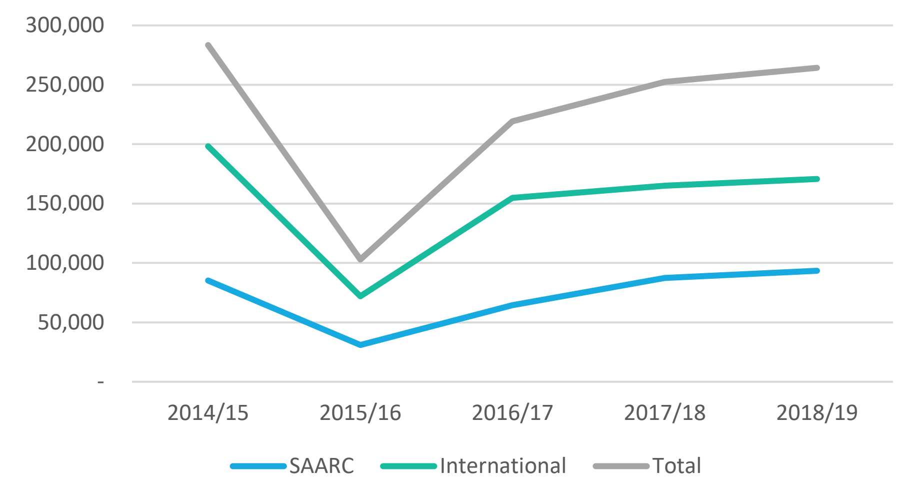


Figure 2.8 Tourist arrivals in Boudhhanath Stupa between 2014-2019

[7] Received from Boudhhanath Development Trust.
[8] Ministry of Culture, Tourism and Civil Aviation. 2019. Nepal Tourism Statistics 2018. Government of Nepal.

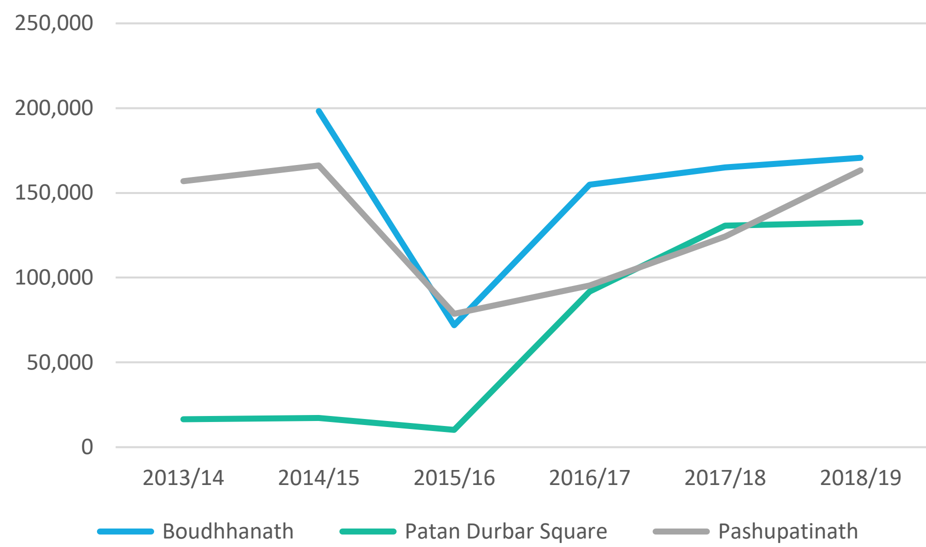


Figure 2.9 International tourist arrivals in Boudhhanath, Patan Durbar Square and Pashupatinath between 2013-2019[9]

2.3. Accessing Heritage in Kathmandu Valley

2.3.1. Current options

Public transport options in core areas of Kathmandu and Patan

Currently, the core area Heritage Sites within Kathmandu Durbar Square are accessible only in private vehicles such as four-wheelers and two-wheelers. Parts that are closer to Thamel are also being serviced by rickshaws. There are no convenient public transport options for the elderly and differently abled population who are not able to walk from one cultural site to the other. Due to the lack of public transport service, tourists in the area either take a taxi to navigate through the roads or walk. They are usually dropped off at the Durbar Square or at Thamel in microbuses or large buses by private tour companies.

Similarly, there are no public transport options in the Patan Durbar Square area, except electric three-wheelers (known as *safa tempos*) that are being operated from Pulchowk to Gwarko (cf. Figure 2.10). Tourists are dropped off at Patan Durbar Square in microbuses since larger buses are not allowed inside the Durbar Square area.

[9] Ministry of Culture, Tourism and Civil Aviation. 2019. Nepal Tourism Statistics 2018. Government of Nepal.

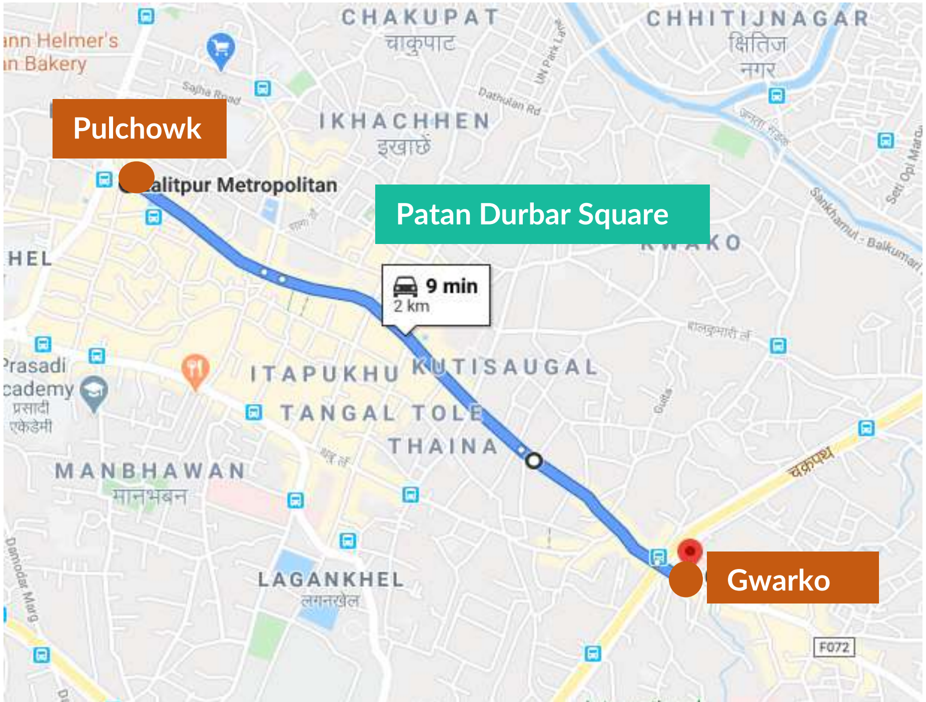


Figure 2.10 Electric three-wheeler (*safa tempo*) routes within Patan Durbar Square

Public transport options for UNESCO Heritage Sites

There are plenty of public transportation options such as Nepal Yatayat, Deego Yatayat, etc. that provide regular service along the different routes with pickup points designated at the UNESCO Heritage Sites, if it falls on their way. These are mid-sized public buses that generally run on specific routes. There are no bus services dedicated to serving only the UNESCO Heritage Sites. A passenger wanting to travel from one UNESCO Heritage site to the other - for example, from Swayambhu to Pashupati - would need to switch multiple buses and pay multiple times in order to reach the destination.

2.3.2. Need for additional transport services

Need for additional transport options in core areas of Kathmandu and Patan

Additional public transport services in the core areas of Kathmandu Durbar Square and Patan Durbar Square are essential for tourists and local passengers due to very limited mobility options. Although the cultural sites within the core area are very close by and can be easily accessed by walking, an additional "clean" public transport service would help the elderly and differently abled passengers to reach multiple destinations easily. In addition, tourists with time limitations could take this service easily to visit as many cultural and Heritage Sites as possible.

Need for additional transport options servicing UNESCO World Heritage Sites

There is a need to initiate clean transport services, dedicated to servicing all UNESCO World Heritage Sites as well. Since the existing public transport services service only one or two of the

Heritage Sites, passengers, both local and tourist, willing to visit multiple UNESCO World Heritage Sites cannot do so without taking either expensive taxi services or changing buses at multiple points. In addition, the passengers currently need to pay every time they change a bus, when traveling from one heritage site to the other. A dedicated service charging a fixed rate would ease travels of local pilgrims, especially the elderly and disabled.

Chapter 3. Case Studies

3.1. Introduction

A global review was carried out to identify emerging practices related to operation of electric mobility services in the tourism sector. Altogether, five cities were reviewed from Asia and Europe in which hop-on hop-off type services were being operated by electric vehicles. These are listed in Table 3.1 below:

Table 3.1 List of cities reviewed

Name of city	Type of vehicle and beneficiaries
Westminster, London	Electric bus service for tourists
Hanoi, Vietnam	Electric shuttle service for tourism
Da Nang, Vietnam	Electric shuttle service for tourism
Ljubljana, Slovenia	Electric shuttle service for tourism and locals
Krakow, Poland	Electric shuttle service for tourism

This chapter presents information on the benefits of identified electric mobility services, route length, tariff structure, type of vehicles in use, passenger carrying capacity of the vehicles and the type of service operator. Examples of electric shuttle service in Hanoi, Vietnam and electric bus service for tourists in Westminster, London are discussed in detail. Other similar examples are then discussed very briefly, highlighting key features associated with the service. The chapter then ends with a set of high-level lessons and findings to support the development of a local transport operator's activity in this sector. This type of service has not been introduced in Nepal, mainly due to the anxiety that operators face in adopting a new technology. Lessons are drawn from global best practice to serve as an important indicator for a local operator in understanding the viability of a similar potential electric mobility service in Nepal.

3.2. Case Study of Electric Tourist Buses in London, England

The *Original Tour Company* provides themed tours on five routes in London and has been in operation since 1951. In October 2018, the company added an electric bus into its fleet, which is being operated in the company's Yellow Original Route. This electric bus is a hop-on-hop-off open-top sightseeing bus in Westminster and has a drive range of 150 km. The electric bus can make six loops of the *Original Tour's Yellow Route* and can carry up to 75 passengers at a time. It takes approximately two hours for the bus to complete the loop. The bus makes around 125 stops on a single charge and is charged overnight at the depot. It takes around 4.5 hours to fully charge the bus.

Figure 3.1 Electric open-top buses being operated by the Original Tour Company

While the remaining buses in the tour company are typically red or red and blue in color, the all-electric buses are green and can be easily identified on the route. The bus was produced by UNVI, which has known to be the largest manufacturer of city tour buses in Europe. Batteries for the electric bus were manufactured by BMZ, the powertrain was manufactured by Zeihl-Abegg Automotive, and system integration was carrued out by SAV Studio.[10]

Guided Tours

The *Original Tour* provides live guided tours in all buses along the Yellow Route. These live guides take place every 45-60 mins. The service also provides audio commentaries in 11 languages, including English, German, French, Spanish, Italian, Russian, Japanese, Portuguese, Mandarin, Arabic, and Brazilian Portuguese.

Ticketing and Fares

The *Original Tour Company* provides three different types of tickets. There are different fare schemes for an Adult, Child, and Family (2 adults + 2 children) based on 24-hour ticket, 48-hour ticket, and a 72-hour ticket. In addition, a 30% discount is awarded to differently-abled customers and their registered caregivers.

[10] Sustainable bus. 2020. Sightseeing in the silent. The debut of the first electric open top in London, by Unvi/Zeihl-Abegg. Retrieved from: https://www.sustainable-bus.com/electric-bus/sightseeing-bus-electric-silent-london-ratp-unvi-ziehl-abegg/.

Passengers can travel on all of the *Original Tour Company's* routes with just one ticket, as long as it's within the duration of the ticket.

3.3. Case Study of Electric Shuttle Services in Hanoi, Vietnam

Electric shuttle services have been operating in different parts of Vitenam since 2010, including the cities of Hanoi, Da Nang, Ho Chi Minh City, as well as the provinces of Khanh Hoa, Hai Phong, Lao Cai, Thua Thien–Hue, and Ba Ria–Vung Tau.[11] A variety of shuttles with different passenger carrying capacity can be seen across the country and a lot of services are aimed specially toward the provision of transportation services to tourists. In the following section, two examples of Hanoi are presented. Among them, tourists have the option of choosing a shorter route around the Old Quarter area, or take the longer tour option around the West Lake route.

Old Quarter area (Shorter tour option)

As a celebration of Hanoi city's 1000th birthday, a public electric shuttle service was first introduced in Vietnam in July 2010. This shuttle service provides a short city tour around the Old Quarter area in Hanoi and services mostly tourists. The route travels through commercial streets, pagodas, historical sites, and tourist destinations, is 7km in length, has a total of ten stops, and starts and ends at the same stop. The service is operated by the Dong Xuan Joint Stock Company and it's estimated that the vehicles service around 300,000 passengers every year. [12]

Each shuttle can carry a maximum of seven passengers, excluding the driver. The shuttles are of the open-air type (without external hard covering). As of 2019, 40 shuttles are in operation along this route, with 20 of them powered by solar energy.

Source[13]

Figure 3.2 Electric shuttle service in operation around the Old Quarter route

[11] Nhan Dan. 2016. Electric car service to be launched in Hoi An. Retrieved from: https://en.nhandan.org.vn/travel/sightseeing/item/4784602-electric-car-service-to-be-launched-in-hoi-an.html.
[12] Based on GGGI's enquiry with the operator.
[13] Vietnam Online. 2018. Electric car tours around West Lake. Retrieved from: https://www.vietnamonline.com/destination/hanoi/electric-car-tour.html.

West Lake Area (Longer tour option)

Source[14]

Figure 3.3 Electric shuttles used on the West Lake route

In February 2012, an additional electric shuttle service was introduced in Hanoi city, and operated around the historical sites and tourist destinations in the West Lake area. The route around West Lake is 18km in length and has ten stops.[15] Routes begin at West Lake Park and finish at the Ha Noi Trade Union Hotel.

The state-owned TLC Ho Tay Joint Stock Company is owner and operator of the vehicles.[10] The shuttles are of the open-air type and each can carry up to seven passengers excluding the driver. As of 2019, there are 20 such shuttles operating along the West Lake route.

The ticket price is the same for locals as well as for overseas visitors, and the service is free for children under 3 years old.[16] Prices are based per cart and for a 35-minute tour, the cost is US$8.70, 200,000 VND. For a 60-minute tour, the price per cart is US$12.73, or 300,000 VND).[17] Individuals or couples who do not want to book the whole cart can usually wait to join other groups.

[14] Trip Advisor. 2015. Retrieved from: https://www.tripadvisor.com/Attraction_Review-g293924-d2062747-Reviews-Hanoi_Electrical_Bus_Tour-Hanoi.html#photos;aggregationId=101&albumid=101&filter=7&ff=150654069
[15] Viet Nam News. 2012. Electric car tours around West Lake. Retrieved from: https://vietnamnews.vn/life-style/220595/electric-car-tours-around-west-lake.html#zr8xyQwmyDuy1qk1.97
[16] Vietnam Visa Easy. 2018. Hanoi City Tour by Electric Cars and Cyclos. Retrieved from: http://www.vietnamvisa-easy.com/blog/hanoi-city-tour-by-electric-cars-and-cyclos/
[17] Travelfish. 2017. Tour the town: Electric Cars. Retrieved from: https://www.travelfish.org/transport_detail/vietnam/hanoi_and_surrounds/hanoi/hanoi/33

3.4. Other Examples of Electric Tour Services Found Globally

Da Nang, Viet Nam
Da Nang is a coastal city in the northern part of Vietnam. In 2012, the provincial government of Da Nang introduced electric shuttles for the first time in order to to provide an environmentally-friendly transport service to tourists. The Thinh Hung Trade & Tourism Co. Ltd commenced operations with a fleet of ten shuttles. These shuttles are smaller in size when compared to the ones introduced in Hanoi, and can accommodate up to five passengers.[18] By 2018, slightly larger shuttles with a seven-passenger capacity were also being operated in the city. Some examples of larger shuttles in use can also be seen throughout Vietnam, with shuttles in Ho Chi Minh City and Can Tho City both accommodating up to 13 passengers.

Source[19]

Figure 3.4 electric shuttles used in Da Nang

[18] Vietnam Online. 2018. Retrieved from: https://www.vietnamonline.com/news/da-nang-operates-electric-vehicle-for-tourism.html
[19] Tura Vietnam. 2018. How to get around in Da Nang. Retrieved from: https://turavietnam.com/da-nang-travel-guide/how-to-get-around-in-da-nang/

Source[20]

Source[21]

Figure 3.5 Example of larger shuttles in Ho Chi Minh City (left) and Can Tho City (right) Ljubljana, Slovenia

Source[22]

Figure 3.6 Open-aired (left) and closed type(right) electric shuttles used in Ljublana

Slovenia's capital city, Ljubljana, was awarded "Europe's Green Capital" in 2016 by the European Commission. Among other measures taken by the city to lower traffic congestion and improve environmental conditions, Ljubljana has deployed shuttles in pedestrianized zones across major inner-city routes since 2009. The shuttle service aims to provide service to the elderly and mobility-impaired, as well as visitors to the city. The service is provided for free the whole year

[20] Vietnam News. 2017. HCM City operates electric buses on 3 routes. Retrieved from: https://vietnamnews.vn/society/350246/hcm-city-operates-electric-buses-on-3-routes.html#d3CvAsCGlWYKQMze.97

[21]Cantho City. 2018. Discovering Can Tho city with electric buses. Retrieved from: https://www.cantho.gov.vn/wps/portal/!ut/p/z1/vVJNU8IwFPwr9cAxk9e0hfZYBuRDBERBmgtTkthGS1raUMVfb3Q8gIMyXMzpvZndze6bxRQvMVVxLZNYy1zFmdkj2lz5cNO1hy4ZTeyeD3d-ZxDOiQeTMeDHLwAcvRDaM9J2AHoTgukhH_wQDH9xPeiHPQIdgheYYsqULnSKIxYrneYNECrJZJWualGSBqzFU14KxEURl3pnJi03ogG6jGuRoWQnudm4rFhu8FIllpGxjI7FpN5br1KnlsgE06Vk1npXierzy4JJjiMCIuDcs1HgBB5yWy0HBYwx5HDGgAsXvDU5GfEw7HHEUyeiPyAwNrzRw7Dbd6cEbt1vwF9XPAE48hAZk63fXNjTJr6_MPUZQe9iweG5O5muyeftloamELnS4k3j5X81otjMN76zRy8zHxyvqN9H4dUHVQZQZg!!/dz/d5/L2dBISEvZ0FBIS9nQSEh/

[22] Visit Ljubljana. 2020. Retrieved from: https://www.visitljubljana.com/en/visitors/travel-information/getting-around/kavalir-getting-around-the-city-centre-by-electric-car/

round. The shuttles can even be called to desired pickup points (within service area) by phone calls.

The shuttle service is operated by Ljubljanski Potniški Promet d.o.o. (LPP), which is a public city bus company. LPP's fleet consists of six shuttles, three of which are open-air and three are closed.[23] Each shuttle can carry five passengers at a time. The service claims to have carried more than 1.2 million people since operations began.[24]

Krakow, Poland

The city of Krakow in Poland also has an electric shuttle service currently being operated by numerous private operators. Tour length is generally 60 to 90 mins,[25] but they can be extended or shortened, depending on a passenger's specific interests. Shuttles are operated within tourist areas, which are mostly closed to other vehicular traffic.

Passengers have the option to pass through tourist areas such as the Old Town Center, the Jewish Quarter, Oscar Schindler's Factory, the Jewish Ghetto, and other historic sites. Departure points are normally fixed by the operator, but centrally-located hotel, pickup and drop-services are also provided. Shuttle services are accompanied by driver-guides, and audio guides also available in 26 different languages. Tour costs vary according to time of day, sites visited, number of passengers, and the operator.

Source[26]

Source[27]

[23] LPP. 2019. Electric vehicle Kavalir. Retrieved from: https://www.lpp.si/en/informations-passensgers/electric-vehicle-kavalir-and-electric-train-urban

[24] WHO 2020. Electric Vehicles Cavalier (Kavalir) in the City of Ljubljana. Status. Retrieved from: https://extranet.who.int/agefriendlyworld/afp/electric-vehicles-cavalier-kavalir-in-the-city-of-ljubljana/

[25] Trip Advisor. 2020. Krakow City Sightseeing Private Tour by Eco Friendly Electric Car With Audio Guide. Retrieved from: https://www.tripadvisor.co.nz/AttractionProductReview-g274772-d11452689-Krakow_City_Sightseeing_Private_Tour_by_Eco_Friendly_Electric_Car_With_Audio_Guide.html

[26] Trip Advisor. 2019. Cracking Krakow Tour. Retrieved from: https://www.tripadvisor.com/Attraction_Review-g274772-d4053792-Reviews-Golf_Cart_Tours_Day_Tours-Krakow_Lesser_Poland_Province_Southern_Poland.html#photos;aggregationId=101&albumid=101&filter=7&ff=405717553

[27] Trip Advisor. 2014. Golf Cart Tours - Day Tours. Retrieved from: https://www.tripadvisor.com/Attraction_Review-g274772-d4053792-Reviews-Golf_Cart_Tours_Day_Tours-

 Source[28]	 Source[25]

Figure 3.7 Types of electric shuttles found in Poland

A three-hour tour normally costs around NPR. 2,385[29] (US$20 per person). Various types of shuttles are deployed by the operators. The smallest shuttles service five passengers, while the larger shuttles can carry up to 13 passengers. Some shuttles also have wheelchair accessibility features.

3.5. Key Lessons for Nepal

This chapter has illustrated several successful examples of electric bus and electric shuttle services around the world which aimed to service both domestic as well as international tourists. Below, we highlight some key lessons that private and public operators in Nepal can learn from the case studies presented.

- The majority of electric shuttle services reviewed were aimed exclusively for both local and international tourists.
- The services are in operation on major road networks (e.g., Vietnam), as well as within vehicle-restricted or pedestrianized zones (e.g., Ljublana and Krakow) where they can also provide much needed transportation service for the elderly and mobility-impaired. Since the heritage core of KMC as well as LMC both have a pedestrianized zone at the center, electric shuttles could provide an environmentally-friendly transportation service in these areas for tourists, as well as for the elderly and differently-abled.
- Operation of these shuttles service are undertaken by private operators as well as public entities. The Hanoi case study demonstrates that an electric shuttle service could potentially be a profitable business for private operators. We found this to be true also for the Krakow case study, where most shuttles are being operated by independent, private

Krakow_Lesser_Poland_Province_Southern_Poland.html#photos;aggregationId=101&albumid=101&filter=7&ff=95311211

[28] Trip Advisor. 2014. Golf Cart Tours - Day Tours. Retrieved from: https://www.tripadvisor.com/Attraction_Review-g274772-d4053792-Reviews-Golf_Cart_Tours_Day_Tours-Krakow_Lesser_Poland_Province_Southern_Poland.html#photos;aggregationId=101&albumid=101&filter=7&ff=95311205

[29] Trip Advisor. 2020. Krakow in a Day: 3-Hours City Tour by Electric Car. Retrieved from: https://www.tripadvisor.co.za/AttractionProductReview-g274772-d13134993-Krakow_in_a_Day_3_Hours_City_Tour_by_Electric_Car-Krakow_Lesser_Poland_Province_So.html

players, again indicating the possibility of financial sustainability. Interestingly, Ljubljana's case study goes further by demonstrating that if the objective is to improve the overall public transportation service, then the shuttle service can also be provided free of charge.

- Typically, the passenger-load capacity of shuttles varied between 7 and 13 people. In Westminster, United Kingdom, the electric hop-on hop-off service also provided audio and video-guided tours for tourists.

Part 2. Proposed Electric Mobility Services for Heritage Sites in Kathmandu Valley

Chapter 4. An Integrated Service Framework

4.1. Conceptual Framework

4.1.1 Two levels of electric mobility services for tourists

Two levels of electric mobility service have been designed to improve tourism mobility inside Kathmandu Valley. The first level is the higher-level service and aims to service tourists traveling between major cultural World Heritage Sites in the valley. This service will cater to passengers traveling longer inter-city distances by offering mid-sized electric buses. The service will be provided at frequent intervals to ease travel across major cultural World Heritage Sites. Tourists can use the first level service to travel between major Heritage Sites and tourist destinations such as Swayambhunath, Thamel, Pahshupatinath Temple, Boudhanath Stupa, Patan Durbar Square, Kalmochan Temple, Kathmandu Durbar Square, and the National Museum. Since the electric buses arrive at frequent intervals at these destinations, tourists are able to stop at these destinations, as long as they want to explore and take the buses to the next destination.

This higher-level bus service will be complemented by a second layer of service for passengers traveling in the core areas within Kathmandu Durbar Square (KDS) and Patan Durbar Square (PDS). In the second level of service, electric shuttles (or "carts") will be operated for the elderly and differently-abled, as well as for tourists looking to traverse the culturally-rich core residential areas and other tourist sites in the vicinity of the Durbar Square. The service will be "hop-on, hop-off" in nature, meaning that passengers can board and alight the shuttles at their leisure if they fall within predetermined routes. The conceptual framework of these two-layered services are presented in Figure 4.1.

In the case of KDS and PDS, buses carrying tourists are not allowed to venture into the core Durbar Square areas and they must generally stop at allocated destinations outside the buffer zone.[30] The higher-level route is designed in such a way that passengers can access convenient interchange points with shuttle services in KDS and PDS, as shown in Figure 4.2 (cf. Chapters 6 and 7 for further details). The interchange point between mid-sized buses along the UNESCO Heritage Site route and shuttle services in KDS is located at the Juddha Statue in New Road and at the bus stop in front of the Lalitpur Metropolitan City (LMC) office in Pulchowk for PDS (cf. Figure 4.2). More importantly, the second layer of shuttle service is designed in such a way that it provides last-mile connectivity and connection to other major transport hubs.

Since large buses are not allowed on the road leading to PDS from the LMC Office, tourists would need to walk just under a kilometer meters to reach PDS unless a core area shuttle

[30] A 'buffer zone' is the protected heritage area, under the jurisdiction of the Department of Archeology.

services is implemented. In comparison, if a core area shuttle service is not implemented in the KDS area, then tourists would only need to walk about 300 meters to reach Durbar Square from the Juddha Statue.

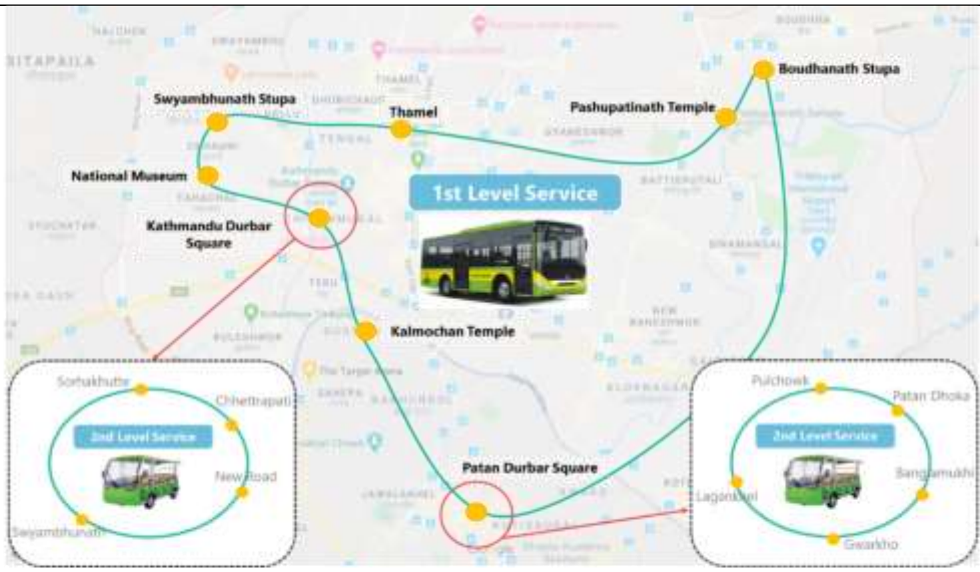
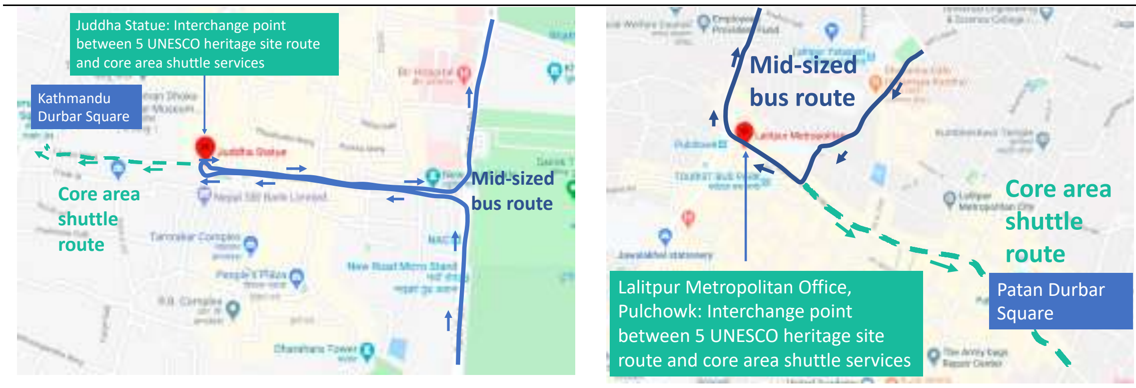


Figure 4.1 Illustration of two level electric mobility service in Kathmandu Valley



Interchange point for Kathmandu Durbar Square

Interchange point for Patan Durbar Square

Figure 4.2 Interchange points between core area shuttle services in Kathmandu Durbar Square and Patan Durbar Square

4.1.2 Modular approach in deployment

The entire electric mobility project described above can be divided into three separate packages.

The advantage of a multi-packaged project is flexibility and modularity. Out of these three packages, any of them can be implemented first, independent of the other two's status of operation. Below, we provide a brief description of each package and its possible stakeholders.

Package One: The higher-level e-bus service falls under Package One. As this package covers destinations in both LMC and KMC, the investment and control of the operations would likely be a joint initiative of both municipalities. In addition, approval and support is also required from those authorities and institutions managing specific tourist destinations, such as the Ministry of Tourism, the Pasupathi Development Trust, the Boudhha Area Development

Committee, Kathmandu and Patan Durbar Square, and the Department of Archaeology, to name but a few.

Package Two: This package consists of an electric shuttle service operating around KDS. KDS will likely have the jurisdiction, along with the support of Kathmandu Durbar Square. The Department of Archaeology's approval may also be required if the vehicles are running within buffer zones that fall under their jurisdiction.

Package Three: An electric shuttle service around PDS falls under the third package, with LMC taking the initiative and responsibility of purchasing and operating the vehicles. The Department of Archaeology's approval may also be required if the vehicles are running within buffer zone in PDS.

Passenger Tariff Structure for Nepali and Foreign Nationals

One-day or two-day combined package for tourists:
Foreign tourists may be offered combined package-based payment options which provide access to both services. A flat tariff, irrespective of the travel distance, may be set for foreign tourists, and can be either for a "one-day package" or a "two-day package." Both packages can include access to both the electric bus and electric shuttle services. A one-day package will be valid for a single day and tourists can take electric buses to any listed UNESCO World Heritage Site in addition to accessing any electric shuttle service inside KDS and PDS. Furthermore, since a single day may not be enough to explore most of the destinations, tourists can also opt for an extended package with two-day validity with similar service accessibility. With this two-day package, tourists can visit half of the destinations covered by the electric bus service in a single day and the other half on the next day, thereby exploring most of the major attractions offered by Kathmandu in just two days.

Single package fare for tourists:
Overseas tourists who wish to visit only KDS and PDS may access the e-shuttle service within the core areas by paying a flat fare, which will also be the same for Nepali nationals. And in order to boost mobility in tourism, shuttle services could be made free for tourists along similar lines to those offered in Ljublana (see Chapter 3 for more information).

Fare structure for Nepali nationals:
Special fare exemptions may be provided to elderly and mobility-impaired passengers, who would be able to avail of free access to electric bus as well as shuttle services. To avoid potential mis-use of the service, a preferential/cross-subsidized[31] fare may be charged to the general Nepali public for mid-sized electric buses servicing the UNESCO World Heritage Sites (cf. Chapter 5 for more information on fare structures for locals and tourists). A flat fare, independent of distance traveled, can be set for hop-on, hop-off e-shuttle service in KDS and PDS. The fare can be same for foreign tourists as well as locals.

Table 4.1 below summarizes the proposed passenger categories, their access to both types of services, and the nature of the set tariff.

[31] Cross-subsidized by fares collected from overseas tourists using the service.

Table 4.1. Proposed beneficiary category and tariff nature

Passenger category / Tariff	One-day or two-day tourist packages	Non-package	
	E-bus service + E-shuttle service	E-bus only	E-shuttle only
Nepali - privileged group	N/A	Preferential fare	Free
Nepali - general public	N/A	Preferential fare	Flat fare
Overseas tourists	Pre-fixed fare	Pre-fixed fare	Flat fare

N/A: Not applicable.
Flat fare: A one-off fixed amount irrespective of the distance traveled.
Pre-fixed fare: Fare applicable to overseas tourists, depending on the package taken. This is independent of distance traveled or destination.
Preferential fare: Fare applicable to general Nepali public, which can be lower than for overseas tourists and is independent of distance and destination.


Bluebell
Breakfast
Lunch
Dinner
Beans Coffee
Music
BRANDED SHOES SHOP

Chapter 5. Proposal for UNESCO World Heritage Sites Across Kathmandu Valley

5.1. Policy and Priorities

Cultural sites in Nepal have attracted a high volume of both local and foreign tourists over the past decade. The Ministry of Tourism, Culture and Civil Aviation (MOCTCA) has developed numerous acts and policies with the aim of conserving and promoting cultural heritage sites in the country. With a similar objective, the United Nations Educational, Scientific and Cultural Organization (UNESCO) has identified four World Heritage Sites in Nepal, of which Kathmandu is one. There are seven UNESCO World Heritage Sites in Kathmandu, three of which recorded approximately 2.5 million tourist arrivals in 2018 - Patan Durbar Square, Kathmandu Durbar Square, and Boudhhanath Stupa.[32]

Preserving the Nepali culture and promoting tourism to these cultural sites is a top priority of the country's government. The Ministry's Tourism Policy, developed in 2009, aims to provide affordable, secure, and reliable public transportation services for the promotion and development of tourist sites in Nepal. One such strategy outlined in the policy document supporting its objectives is the development of programs that encourage tourists in neighboring countries to visit Nepal.[33] In addition to this, the National Cultural Policy document of 2011 aims to increase local employment opportunities by promoting tourism across Nepal's cultural sites and by conducting activities related to conservation and research and development.[34]

The National Tourism Strategic Plan 2016-2025 has outlined the need to promote tourism in heritage sites throughout Nepal, including those in Kathmandu Valley. The strategic plan encourages projects that contribute to improving the environment and promoting heritage sites. Furthermore, the strategic plan focuses on developing skills of women and differently-abled locals and encouraging equal opportunities in the tourism sector to promote cultural sites.[35] The Government of Nepal has also declared 2020 as the *Visit Nepal Year*, envisioning an inflow of around 2 Million tourists.

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[32] Data received from the respective Heritage Sites.
[33] Ministry of Tourism, Culture and Civil Aviation. 2009. Tourism Policy. Government of Nepal.
[34] Ministry of Tourism, Culture and Civil Aviation. 2011. National Cultural Policy. Government of Nepal.
[35] Ministry of Tourism, Culture and Civil Aviation. 2016. National Tourism Strategic Plan 2016-2025. Government of Nepal.

Supporting MOCTCA's policies and VNY 2020's vision in promoting tourism in Nepal, this chapter analyses the operational and financial feasibility of operating electric mid-sized buses in routes servicing the UNESCO World Heritage Sites in Kathmandu Valley. This will be a hop-on, hop-off service of the type being operated in many cities around the world (cf. Chapter 3 for example case studies of electric tour bus operations in other countries).

The following section presents route options based on desk research and stakeholder consultations. The type of vehicle suitable for this service is presented next, in addition to the proposed specifications of the bus. Operational details are discussed in the section that follows the vehicle specifications. Since in Nepal, both non-profit transport operator, such as Sajha Yatayat, and private sector transport operator are actively providing transport services to locals and tourists, a financial analysis for both types of operators have been presented in the final section.

5.2. Routes Servicing UNESCO World Heritage Sites in Kathmandu Valley

There are seven UNESCO World Heritage Sites in Kathmandu Valley, which include Kathmandu Durbar Square, Swayambhunath Stupa, Boudhhanath Stupa and Pashupatinath Temple in Kathmandu, Patan Durbar Square in Lalitpur along with Bhaktapur Durbar Square and Changunarayan Temple in Bhaktapur. Route options servicing these Heritage Sites were identified based on desk research and consultations. The following section outlines the selection criteria used to identify the most preferred route.

5.2.1 Route identification

Routes were identified based on the criteria listed below.

A. Demand Criteria

i. **Route servicing UNESCO World Heritage Sites and other tourist sites**: the primary purpose of these routes is to provide service to tourists and locals willing to visit multiple UNESCO World Heritage Sites on the same day.

ii. **Provision of convenient interchange points**: the routes should provide convenient interchange points for tourists and locals to avail of the service and be able to travel from one heritage site to the next.

B. Service Criteria

i. **Maximizing additional secondary tourist sites:** the routes should service other tourist sites in addition to the existing UNESCO World Heritage Sites in Kathmandu and Lalitpur.

ii. **Optimizing for integration with core area shuttle services: t**he routes should provide convenient interchange points for passengers switching to shuttle services servicing the core areas of Kathmandu Durbar Square and Patan Durbar Square (cf. Chapters 6 and 7 for more information on the shuttles servicing core areas of Kathmandu and Lalitpur).

iii. **Convenient pickup and drop-off at major tourist areas**: the routes should be designed to provide convenient access points for tourists using the service. The service should also connect major tourist areas where hotels and tourist accommodation areas are available.

5.2.2. Route options

Two routes were identified based on the selection criteria discussed above:

Route 1: This route is a single loop providing hop-on, hop-off services to tourists and locals traveling from Patan Durbar Square to Kathmandu Durbar Square and Bhaktapur Durbar Square. The route covers all seven UNESCO World Heritage Sites in Kathmandu Valley, such as Pashupatinath Temple, Boudhhanath Stupa, Swayambhunath Stupa, Swayambhu Buddhist Museum, the National Museum of Nepal, and Pulchowk, in addition to the three Durbar Squares. Vehicles on this route would also be able to cater to tourists in Thamel, Durbar Marg, and Jhamsikhel, since pickup and drop-off points are within walking distance of any Bed & Breakfast services in those areas. The total distance of the route is 70.5km and the estimated time taken to traverse the whole route is 3 hours and 19 minutes. Figure 5.1 shows Route 1.

Figure 5.1 Route 1

Route 2: This route option has two sub-routes, in which Swayambhu Loop services Kalmochan Temple, Kathmandu Durbar Square, Thamel, Swayambhunath Stupa, Swayambhu Buddhist Museum, National Museum of Nepal and Pulchowk. The second route, Pashupati Loop, services Kathmandu Durbar Square, Thamel, Boudhhanath Stupa, Pashupatinath Temple and Patan Durbar Square. This route option is easily accessible to tourists residing in Thamel, Durbar Marg, and Jhamsikhel, where most of the bed & breakfast services, along with restaurants, and retail outlets are located.

Figure 5.2 Route 2

Table 5.1 lists the sites in the Swayambhu Loop and the Pashupati Loop.

Table 5.1 Stops in the corresponding loops

Stop number	Swayambhu Loop	Pashupati Loop
1	Pulchowk	Pulchowk
2	Kalmochan Temple	Kalmochan Temple
3	Kathmandu Durbar Square	Kathmandu Durbar Square
4	Thamel	Thamel
5	Swayambhunath Stupa	Boudhhanath Stupa
6	Swayambhu Buddhist Museum	Pashupatinath Temple
7	National Museum of Nepal	UN Park
8	Pulchowk	Patan Durbar Square
9		Pulchowk

5.2.3 Selection of route options

i. Optimizing for integration with shuttle services in the core areas of Kathmandu and Patan. Both route options provide convenient interchange points with shuttle services in Kathmandu Durbar Square and Patan Durbar Square (cf. Chapters 6 &7 for more detail). The interchange point for mid-sized buses along the UNESCO World Heritage site route and shuttle services in Kathmandu Durbar Square is located at the Juddha Statue at New Road and at the bus stop facing the Lalitpur Municipality Office in Pulchowk for Patan Durbar Square (cf. Chapter 4 for further information).

ii. Servicing UNESCO World Heritage sites and optimizing tourist areas. Both routes provide service to the UNESCO World Heritage Sites in Kathmandu Valley. Route 1 differs from Route Route 2 in that Route 1 services all seven UNESCO World Heritage sites, whereas Route 2 services only five of the sites. However, both loops service major tourist areas such as Thamel as well and are within walking distance from Jhamsikhel and Durbar Marg.

5.2.4 Recommended route

These route options were presented to stakeholders for their feedback. Following discussions with KMC and LMC, it was agreed that, of the available options, Route 2 is preferred for the initial implementation phase. With additional investment, Bhaktapur and Changunarayan may be integrated into a second phase. In this next phase, additional cultural sites within Kathmandu Valley may also be explored.

Specific reasons for the preference of Route 2 over Route 1 is as follows:

i. **Route 2 length is shorter and more convenient for passengers:** When Bhaktapur Durbar Square and Changunarayan are added into the loop, as in Route 1, the route length is more than double that of the Route 2 route which services only Pashupatinath Temple, Boudhhanath Stupa, Swayambhunath Stupa, Kathmandu Durbar Square, and Patan Durbar Square. In Route 1, however, traffic at the Koteshwor Junction can be severe at times and this may have a significant impact on travel times and electric bus schedules.

ii. **Route 1 requires a higher capital outlay:** Since Route 1 is around 70km, the battery size required to service the route would need to be larger than that required for Route 2. If the operator were to opt for a smaller battery size, then terminal charging regimes in addition to depot charging would need to be implemented in order for buses to provide multiple trips throughout the day. However, since the buses are only in operation during daytime, overnight depot charging is considered the most practical charging regime. In addition, an additional number of buses would need to be added to the route to maintain the same headway, due to the long distance.

For these reasons, Route 2 is preferred for the initial phase of implementation, since it meets its purpose of servicing the UNESCO Heritage Sites within Kathmandu Valley. In addition, since two routes have been presented in Route 2, passengers willing to switch between the two loops can easily do so at interchange points at Kathmandu Durbar Square and Thamel. In the second phase of implementation, an additional loop servicing Bhaktapur Durbar Square, Changunarayan Temple, and other tourists sites may be designed.

Figure 5.3 Preferred route for Phase 1 implementation

Table 5.2 Characteristics of the recommended route

Criteria	Swayambhu Loop	Pashupati Loop
Length (km)	17.4	19.3
Time taken by car to travel the route under normal conditions	1h 10min	1h 26min
Total number of sites on each route (round trip)	7	8

5.3 Market Review of Mid-Sized Buses and Proposed Specifications

Bus types considered most suitable for this service would be those that with large transparent windows to enhance the sightseeing experience. Although various stakeholders preferred the double-decker buses such as those being operated by tour services in London, these cannot be operated in Kathmandu Valley due to road constraints. Thus, a market review of electric mid-sized buses was carried out for this study.

The market review was conducted in China and India to identify mid-sized (8-9m) electric buses and their specifications. The tables below present the specific battery type, battery size, seating capacity, and braking system provided in the buses reviewed. Almost all mid-sized buses reviewed come with a full-sized battery bank (close to 280 kWh for large buses and 140 kWh for mid-sized buses). Based on the market review, only one bus (Yutong [E8]) was found to have a much smaller battery bank size (63 kWh).

5.3.1 Vehicles identified from market review

Table 5.3 Sample of mid-size buses from Chinese manufacturers

Dongfeng (EQ6850CBEVT1)[36]		
	**Bus make**	Dongfeng
	Bus model	EQ6850CBEVT1
	Length	8.4 m
	Battery size	150 kWh
	Battery type	Lithium-ion based
	Battery warranty	Not stated
	Seating	31 seats
	Air conditioning	Optional
	Regenerative breaking	No
King Long (XMQ6850G)		
	**Bus make**	King Long
	Bus model	XMQ6850G[37]
	Length	8.5 m
	Battery size	Customizable
	Battery type	Lithium-ion based
	Battery warranty	Not stated
	Seating	30 seats
	Air conditioning	Optional
	Regenerative breaking	Not given
Sunda New Energy (CDK6810CBEV)		
	**Bus make**	Sunda New Energy
	Bus model	CDK6810CBEV[38]
	Length	8.1 m
	Battery size	141 kWh
	Battery type	Lithium-iron phosphate
	Battery warranty	Not stated
	Seating	61 passengers in total
	Air conditioning	Optional
	Regenerative breaking	No
Yutong (E8)		
	Bus make	Yutong
	Bus model	E8[39]

[36] Dongfeng-bus. 2019. Retrieved from: http://www.dongfeng-bus.com/index.php/product/product_show/artid/60.html
[37] Kinglong-bus. 2019. Retrieved from: http://kinglong-bus.com/5-3-4-8m-electric-bus/
[38] Sundaev. 2019. Retrieved from: http://m.sundaev.com/electric-vehicle/electric-bus/8-meters-pure-electric-city-buses.html
[39] Alibaba. 2019. Yutong E8 Pure Electric Bus. Retrieved from: https://www.alibaba.com/product-detail/Yutong-E8-Pure-Electric-Bus-electric_60390382375.html

	**Length**	8 m
	Battery size	63 kWh
	Battery type	Lithium-ion based
	Battery warranty	Not stated
	Seating	20 seats
	Air conditioning	Optional
	Regenerative breaking	No

Table 5.4 Sample of mid-size buses from Indian manufacturers

Olectra-BYD (K7)		
	**Bus make**	Olectra-BYD
	Bus model	K7[40]
	Length	8.6 m
	Battery size	
	Battery type	Li-iron phosphate
	Battery warranty	8 years
	Seating	29 seats
	Air conditioning	Yes
	Regenerative breaking	Yes
TATA (Starbus Ultraelectric 6/9EV)		
	**Bus make**	TATA
	Bus model	STARBUS ULTRAELECTRIC6/9EV[41]
	Length	9 m
	Battery size	Customizable
	Battery type	Lithium-ion based
	Battery warranty	
	Seating	26 seats
	Air conditioning	Optional
	Regenerative breaking	No
JBM (ECOLIFE9M)		
	**Bus make**	JBM
	Bus model	ECOLIFE9M[42]
	Length	9.4 m
	Battery size	Customizable
	Battery type	Customizable
	Battery warranty	Depends on battery type
	Seating	35 seats
	Air conditioning	Optional
	Regenerative breaking	Yes
Ashok Leyland (Circuit S)		
	Bus make	Ashok Leyland

[40] Olectra. 2019. Retrieved from: https://olectra.com/k7/
[41] TATAMOTORS. 2019. Retrieved from: https://www.buses.tatamotors.com/products/brands/starbus-ultra/starbus-ultra-electric-6-9-ev/
[42] JBMbuses. 2019. Retrieved from: http://jbmbuses.com/JBM-Eco-Life-Brochure.pdf

Bus model	Circuit S (Swappable)[43]
Length	9 m
Battery size	
Battery type	Lithium-ion based
Battery warranty	
Seating	25 seats
Air conditioning	Optional
Regenerative breaking	Yes

5.3.2. Proposed specification of the electric mid-sized bus

Mid-sized buses are preferred bus types for both the Swayambhu and Pashupati Loops. The length proposed for the mid-sized buses range from 8 to 9m. In addition, a minimum of 26 seats for a mid-sized bus has been proposed. Since the road conditions in Kathmandu are not suitable for low-floor buses, semi-low floor step buses with a minimum floor height of 650mm, are recommended. There are no preferred options for the remaining specifications in relation to wheelbase, curb weight, gross weight vehicle, etc., which will need be recommended by the vehicle manufacturer.

Table 5.5: Proposed general specifications of the vehicle

Description Of Specification	Mid-sized Bus
Length (mm)	8,500 +/-0.5
Width (mm)	2100-2600
Height (mm)	Max: 3600
Floor height (mm)	Semi-low floor or standard high floor (650mm -900mm)
Ground clearance (mm)	Minimum ground clearance to be 170 mm
Seating capacity (including driver)	At least 25+1
Energy Consumption and Battery Bank Size	
Minimum battery bank size (kWh)	To be specified by manufacturer*1
Drive range per single full charge	At least 126 km on a single full charge for specified GVW with AC (cooling) on during battery lifetime (warranty period)*2
Battery cell type	Lithium-based battery
Minimum battery life	At least 8 years of guarantee
Battery management system	Required
Battery cooling system	Required
Chassis	
Transmission system	Automatic transmission system

[43] TEAM-BHP. Retrieved from: https://www.team-bhp.com/forum/commercial-vehicles/195366-ashok-leyland-circuit-s-bus-auto-expo-2018-a.html

Front brake system	Drum brakes
Rear brake system	Drum brakes
Anti-lock braking system [ABS]	Required
Regenerative braking system	Required
Steering system	Assisted power steering
Suspension system: front	Air suspension
Shock absorber: front	Hydraulic telescopic type
Suspension system: rear	Air suspension
Shock absorber: rear	Hydraulic telescopic type
Powertrain and Other Features	
Cooling/heating system	Air conditioner
Minimum speed	At least 60 km/h
Minimum gradient climbing ability (%)	At least 15%
Extendable ramp	Preferable
Public announcement system	Preferable
Vehicle Body System	
Steering position	RHD
Wheelchair area	Reserved area for wheelchairs
Door arrangement	Front and central door
Passenger seat type	City bus type
Handrail	Required
Hanging ring	Required

*[1] This is dependent on the specified drive range and gross vehicle weight.

*[2] The specified drive range is for the Swayambhu Loop. For the Pashupati Loop, the required drive range will be 117km.

5.4 Operational Plan for the Proposed Route

5.4.1 Methodology

An operational plan was developed to estimate the fleet size, number of trips required in each loop, number of passengers served annually, and the battery bank size. The methodology used for these estimations are presented below:

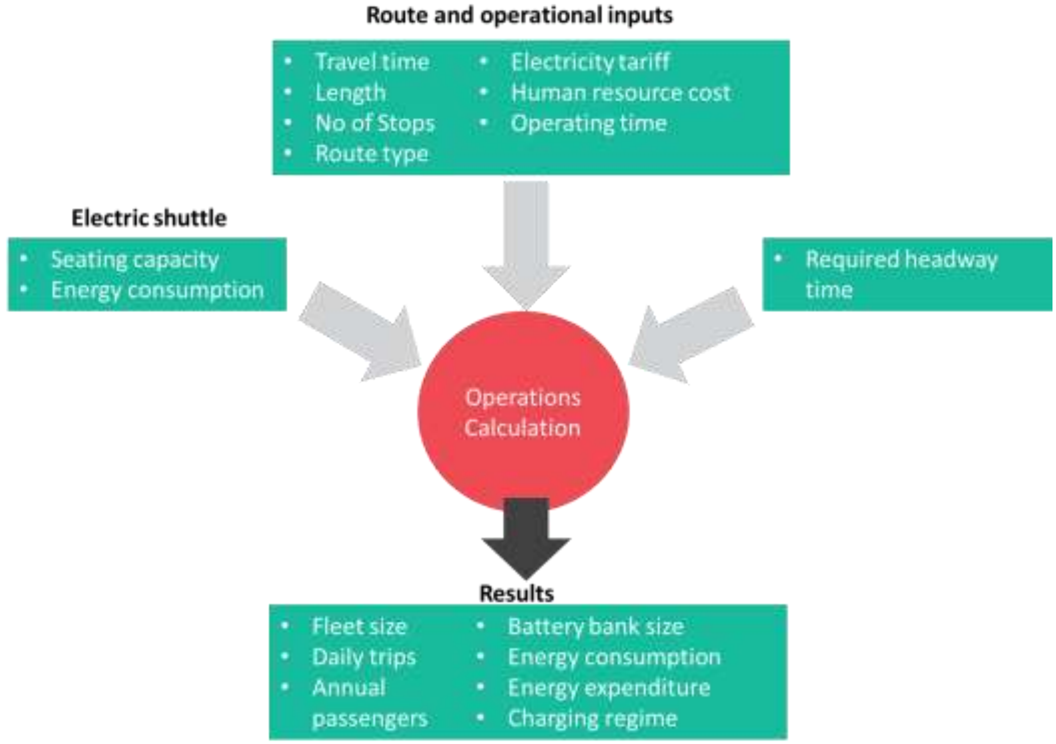

Figure 5.4 Block diagram of operational analysis

i. Estimating fleet size

The total number of buses required for each route was based on a specific headway[44] for each of the routes. This headway, which includes time taken for a round trip, stoppage time at each site, number of sites, total time a vehicle is stuck in congestion, and lunch breaks, was used to estimate the number of vehicles required in the fleet for each loop.

The equation to calculate the total fleet size is as follows:

$$Fleet\ size = \frac{(t+(s*s_t)+c}{h} \qquad \text{(i)}$$

where,

t = time taken by a car to complete a loop under normal traffic conditions;

s = number of sites;

s_t = stoppage time at each site;

c = time a vehicle is stuck in traffic due to congestion; and

h = headway for each loop.

A route survey was carried out to determine the actual time taken to complete the two loops. This methodology was adopted mainly because demand estimation fell beyond the scope of the

[44] Time between bus arrival at a stop.

study. A demand estimation, through origin destination surveys, would be more relevant in case of a full feasibility study.

ii. Estimating time required per trip

During the initial desk research, route length and time taken for a vehicle to complete the route was determined using Google Maps.

A route survey was then conducted to validate the time shown by Google Maps. The time required to complete a trip in each of the Swayambhu and Pashupati Loops was estimated based on the route survey. The survey was carried out twice with three timestamps, namely. 09.00 – 10.00, 13.00 – 14.00, and 16.00 – 17.00. An average of the time taken across all trips was taken as the time required per trip.

The total time taken for each bus to traverse the full route and the number of round trips in the operational plan was estimated based on the average time taken for a vehicle in the survey, in addition to time delays due to traffic congestion and stoppage time at each site.

iii. Estimating number of passengers served

The annual number of passengers expected to use the service has been estimated using the following formula:

$$Annual\ passengers = o * b * t * c * l \qquad \text{(ii)}$$

where,
o = number of days of operation in a year;
b = number of buses in the route;
t = number of trips per bus per day;
c = seating capacity of each bus; and
l = passenger load factor in the route.

iv. Estimating battery bank size

The energy consumption of an electric bus is mainly dependent on the type and size of battery packs being installed, in addition to the presence of air conditioners. Battery performance is affected by factors such as the operation of air conditioners, traffic congestion, gross vehicle weight, and passenger load. To determine the battery bank size, it has been proposed that a maximum drive range be used for both the Swayambhu Loop and the Pashupati Loop.

The maximum drive range was calculated using the equation below.

$$Drive\ range = [(a * b) + c] * 1.15 \qquad \text{(iii)}$$

where,
a = total distance traveled by the bus to complete a loop;
b = maximum number of one-way trips per day; and
c = round trip distance between the depot and the closer terminal in the route.

A 15% safety margin is then added to account for any disruption due to traffic congestion and diversions. There are three major areas where traffic congestion during peak hour could hamper electric bus tour service. One is located at the Thapathali junction, the second one at the Jamal Road, and the third one is at the Chabahil Junction.

5.4.2 Assumptions and input

All assumptions and inputs for the operational plan is outlined in Table 5.6 below. These assumptions were drawn from stakeholder consultations. The time taken at each stop was estimated as three minutes and any potential delay caused due to traffic was recorded as an average of 20 minutes. The service was assumed to start at 08:00 and would continue operations until 20:00 except for a lunch break of 40 minutes in between. A total of 347 operating days has been assumed for a year, which accounts a for monthly maintenance break of 1.5 for each vehicle.

The passenger capacity of each bus has been assumed as 31. This seating capacity was specified for mid-sized buses during the market review. The electric vehicle system efficiency has been assumed as 84%. Since commercial electricity rates apply to companies operating such bus services, NPR 11.2/unit has been taken as the electricity tariff.

Table 5.6 Assumptions and inputs for the operational plan

Description	Unit	Swayambhu Loop	Pashupati Loop
Route length	km	17.4	19.3
Travel time by car under normal traffic conditions	mins	56	68
Average number of sites per trip	stops	7	8
Time taken to board and alight passengers	mins	5	5
Delay due to traffic congestion per trip	mins	20	20
Service start time	A.M	08:00	08:00
Service end time	P.M	20:00	20:00
Proposed headway	mins	60	60
Lunch break	mins	40	40
Operating days per year	days	347	347
Electric shuttle			
Passenger seating	people	31	31
Specific energy consumption of bus	kWh/km	0.84	0.84
Electric vehicle supply equipment (EVSE) and electricity cost			
EVSE system efficiency	%	84	84
Average cost of electricity per unit	NPR	11.2	11.2

Since the road from Kathmandu Durbar Square to Jamal is one way, the buses will provide a one-way service only.

5.4.3 Results of operational calculation

i. Fleet size and trip number

The number of vehicles and corresponding number of trips on each of the routes are outlined in Table 5.7 below. It has been estimated that with a headway of 60 mins, two mid-sized buses would be required in the Swayambhu Loop and three mid-sized buses would be required in the Pashupati Loop.

The distance traveled by the fleet in a year is 208,823 km. The travel times in each of the loops have been estimated based on the route survey.

Table 5.7 Operational details of the two loops

Description	Swayambhu Loop	Pashupati Loop
Number of mid-sized buses required	2	3
Number of round trips	6	5
Total time per route with three mins stoppage time at each stop and 20 mins delay due to congestion	1h 51m	2h 10m
Estimated annual vehicle kilometer by entire fleet (km)	87,312	121,511

i. Battery bank size, charging scheme, and annual energy expenditure

A battery bank of 140 kWh capacity would be required for the buses. This has been determined, based on a minimum SOC of 25% and the required drive range. The selected capacity of the chargers has been estimated at 20 kW. If charged overnight at a depot, these buses would be fully charged in seven hours with the above charger capacity.

Using formula (iii) to determine the battery bank size, it has been proposed that the buses on the Swayambhu Loop and Pashupati Loop have a minimum drive rage of 126km and 117km respectively for the specified gross vehicle weight during the life of the battery and integrated AC components.

Buses on the Swayambhu Loop will consume 75% of their battery capacity in a day, and those on the Pashupati Loop will have a reserve of about 30%.

Table 5.8 Energy consumption of an electric bus in the Swayambhu and Pashupati loops

Description	Unit	Swayambhu Loop	Pashupati Loop
DC energy consumption by shuttle per day	kWh	105.7	98
Reserve in case of emergency	%	25	30
Required battery bank size	kWh	140	140

ii. Charging regime

There are three different charging regimes that can be adopted for the buses. These include:

- overnight charging at the depot, allowing a full re-charge;
- an opportunistic charging regime whereby buses would be charged at intermediate stops along the route by fast chargers;
- terminal station-based charging regimes whereby buses would be charged by fast chargers present at terminal stations (or at selected stops).

The optimal charging regime depends on the operational environment and takes into account factors such as route characteristics, distance, and available charging time. A recent study compared the economic efficiency of three charging infrastructures for Daegu city, South Korea: plug-in, battery swapping, and wireless charging. Results show that the best charging regime for the same bus depends on the operating environment, such as route type, charging time, operating distance, and initial infrastructure investment. Furthermore, rather than focusing on just individual trips, it is essential to focus on the entirety of fleet operations while analyzing overall battery and charging power requirements.

Since the buses are operated only during the day, a more affordable charging regime would be overnight depot charging. This provides more flexibility to buses during daytime. Overnight depot charging would also be more economical, since any implementation of terminal and opportunistic charging regimes would require the procurement of additional land.

With overnight depot charging, buses on both routes is estimated to consume a total of 208,823 kWh of energy. Annual electricity expenditure is estimated to be NPR. 2,338,816 (cf. Table 5.9).

Table 5.9 Energy consumption and related expenditure

Description	Unit	Swayambhu Loop	Pashupati Loop
Daily DC energy consumption per bus	kWh	105.7	98
Daily AC energy consumption per bus	kWh	125.8	116.7
Annual electricity consumption per fleet	kWh	87,312	121,511
Annual electricity expenditure	NPR	977,896	1,360,920

iii. Depot location

Sajha Yatayat has a bus depot which has an estimated 2,685 square meters of parking area at Pulchowk, Lalitpur. Currently, around 70 large-sized buses are parked overnight at the depot. Through consultations with Sajha Yatayat, it has been determined that space is available for at least five additional electric buses.

Figure 5.5 Location of the proposed depot

5.4.4 Proposed ticket and promotional schemes

Different ticketing schemes will be offered to passengers. Since passengers cannot visit all sites comfortably in a single day, both one-day and two-day tickets will be available. A passenger with a two-day ticket will then be free to use the bus service on two consecutive days when visiting multiple sites.

In addition to the ticket schemes, the Nepal Tourism Board will be contributing to the audio guides with information on the history of the various UNESCO World Heritage Sites and additional stops. A visual guide that covers the specific Heritage Sites will also be included to enhance the tour experience.

The proposed passenger tariff options are presented in Section 5.5.

Online booking services and apps may be developed at a later stage, providing tourists with ticket purchasing flexibility for tours prior to their trip. This will also help passengers ensure availability of seats before turning up at their designated pickup points.

5.5 Financial Performance of Vehicles on Proposed Routes

5.5.1 Introduction

The results of the financial analysis for operating electric mid-sized buses in the Swayambhu Loop and Pashupati Loop are discussed in this section.

Two main cases are discussed. Case 1 is related to a non-profit public transport operator (hereafter referred to as “NPTO”), operating electric buses on the two recommended routes with investment from local and federal government bodies. With this investment from the Government of Nepal, the transport operator’s financial goals for the deployment of electric buses will primarily be focused on ensuring that revenue collected is adequate to cover fleet operating costs.

On the other hand, since a "tour bus" type service is proposed, which is comparable to countries such as the UK where private sector operators can levy higher fares, we deploy traditional metrics of investment evaluation such as IRR, NPV, and Payback for considering a private sector transport operator scenario (hereafter referred to as "PSTO"). Therefore, Case 2 analyses the financial performance of the PSTO's operating electric buses along the same routes.

Table 5.10 below shows the different cases and corresponding objectives alongside each scenario. In the base case, a 65% passenger load factor has been assumed. There are three scenarios in Case 1 in which a low, medium, and high passenger load factor has been taken into consideration.

In Case 2, the passenger fare is estimated to generate a return on investment (ROI), which covers the base case project costs. There are three scenarios in Case 2 in which low, medium, and high passenger fares have been taken into consideration in order to calculate project NPV, IRR, and payback period.

Table 5.10 Cases, corresponding objectives and scenarios

Case	Description	Objectives	Scenarios
1	**Non- profit transport operator (NPTO)**	Assess the fare required to estimate revenue required to cover operational expenses	1. Base case: 65% passenger load factor 2. Low case: 50% passenger load factor 3. Medium case: 80% passenger load factor 4. High case: 90% passenger load factor
2	**Private sector transport operator (PSTO)**	Assess the fare required for lucrative return on investment and appropriate payback period	1. Base case: passenger fare for 18% return on equity investments 2. Low case: 20% less passenger fare than in the base case 3. Medium case: 20% more passenger fare than in the base case 4. High case: 40% more passenger fare than in the base case

5.5.2 Methodology

Relevant technical and financial information related to electric mid-sized bus operation has been referenced from GON and GGGI's *Pre-Feasibility Study on Deploying Electric Buses in Kathmandu Valley*, *Investment Projects for Electric Mobility and Going Green: Technical and Investment Analytics for Sajha Yatayat's First Electric Bus Fleet*.

Fare Estimation

Fares in both cases have been calculated on a per passenger basis, since this is a hop-on, hop-off type service. Once paid for, passengers can hop-on and off along the route as many times as they wish, depending on the type of ticket purchased. All fares determined by the Department of Transport Management for public transportation are determined on a per kilometer basis.

Case 1: Fare estimation for NPTO
In Case 1, the NPTO aims to cover just the vehicle's operating expenses. Thus, fares are determined based on the annual operating expenses and annual passenger demand. Battery replacement costs have been included in the annual OPEX. The resulting fares are then averaged for Years 1 to 8, assuming that battery replacement takes place in Year 8, and then in Years 9-15.

$$Fare\ (n) = \frac{\sum_{n=1}^{k}\frac{OE(n)}{P(n)}+\sum_{m=1}^{k}\frac{B/(m)}{P(m)}}{n} \qquad \text{(iv)}$$

where:
OE = annual operating expenditure which includes cost of battery replacement;
P = annual passenger number;
B = cost of the battery in Year m;
m = battery replacement Year; and
n = number of years the vehicle is in operation.

Case 2: Fare estimation for PSTO
In Case 2, the fare was determined based on the required rate of Return on Equity (RoE) (cf. Section 5.6.3 for more information on the types of fare introduced).

5.5.3 Assumptions

General Macroeconomic Parameters
As shown in Table 5.11, the operating life of electric mid-sized buses has been assumed to be 15 years, during which batteries will need to be replaced once during Year 8. Assuming it takes 1.5 days to maintain each vehicle, the total operating days in a year has been estimated as 347.

An average annual inflation rate of 6% has been assumed for NPR and 2% for US$ and the average Forex rate has been taken as NPR 112 per US$.

The interest on loans has been taken as 12%, which is the minimum prevailing rate being charged by commercial and development banks in Nepal. The loan tenure has been assumed to be 10 years.

Table 5.11 Key Parameters

Particulars	Value
Operating life of e-bus fleet	15 years
Operating days in a year	347 days
Average annual inflation rate in Nepal	6.0%
Average annual inflation rate in USA	2.0%
Average Forex Rate: NPR – US$ (2019)	112
Interest on loan	12%
Loan tenure	10 years

Capital Costs

The total investment required by the transport operator has been outlined in Table 5.12. A breakdown of the capital cost requirement per unit has been discussed below.

Mid-sized electric bus

Routes under consideration are the Swayambhu and Pashupati Loops presented in Section 5.2. A headway of 60 mins was taken on each route to determine the total number of buses required. The investment required to purchase an electric mid-sized bus is estimated as NPR 15.9 Million (US$ 140,000).[45] Total CAPEX, including cost of buses and charging stations, is around NPR 83.2 Million (US$ 743,527) (cf. Table 5.12). A customs duty of 1% and a VAT rate of 13% was added to the cost of the vehicles.

Charging stations

Overnight charging at the depot is preferred by Sajha Yatayat, KMC, and LMC. Thus, it has been estimated that for overnight charging, the unit cost of charging stations will be around NPR 687,000, with the assumption that installation costs will be 10% of the cost of the charger.

Table 5.12 Capital Expenditure (CAPEX)

	Amount (NPR)	Amount (US$)*
Cost of 5 electric mid-sized bus	79,750,000	712,054
Cost of 5 charging stations	3,435,000	30,670
Vehicle registration fee for e-bus fleet (NPR 18,000 per bus)	90,000	804
Total	**83,275,000**	**743,527**

** NPR – US$ exchange rate; US$ 1 = NPR 112*

[45] Taken from '*Going Green: Technical and Investment Analytics for Sajha Yatayat's First Electric Bus Fleet.*'

Asset ownership

Case 1: Asset ownership in case of NPTO

It has been assumed that a non-profit transportation company would operate these vehicles with investment from federal and local governments. In this case, Sajha Yatayat is a non-profit making transport operator that is only looking to recover its operating costs throughout the life of the bus.

Case 2: Asset ownership in case of PSTO

If a PSTO were to operate these vehicles with equity investment, it would then look to recover its CAPEX and OPEX. Fares would then need to be designed such that the transport operator achieves an 18% Return on Equity (RoE). The capital structure will need to be designed such that the Debt Service Coverage Ratio (DSCR) does not exceed 1.2 during the loan tenure. The DSCR here measures the cashflow required to pay all debt obligations.

A simple depreciation method has been used to account for the earnings from all assets in Case 2. The electric mid-sized buses have been depreciated for the first 10 years with the assumption that its salvage value is zero at the end of the ten-year period. Batteries which are beingreplaced in Year 8, have been depreciated for the remaining eight years, assuming the salvage value in Year 15 is zero.

Operating Expenses

Electricity tariff: to estimate the variable operating expense, NPR 11.2/kWh is taken as the electricity tariff, which is the rate that is currently being levied to commercial operators. An annual escalation of 1% has been imposed on the electricity tariff.

Staff salary: fixed operating expense related to staff and miscellaneous costs have been estimated based on rates applied for standard commercial activities.

Battery replacement expenses: this study has conservatively estimated that the lithium-ion battery pack on electric buses would be replaced at the end of eight years of operation. The cost of a replacement battery pack is based on the *Bloomberg New Energy Finance* (BNEF) forecast for the cost of a lithium-ion battery. In 2018, the cost of a lithium-ion battery ranged between US$175 to $200 per kWh, and by 2028 the price is expected to drop to approximately US$78 per kWh (in 2018 real terms).

Passenger demand and fare

Case 1

Annual passenger demand has been estimated based on a monthly load factor, with the assumption that the load factor will be 50% during low tourist season and 80% during peak tourist season. March, April, May, September, October, and November are regarded as high tourist seasons in Nepal. From this, an average of 65% load factor was estimated for the base case. With this load factor, the total passenger demand of both the Swayambhu and Pashupati loops have been estimated to be 188,785.

It has been assumed that a flat fare will be levied to both locals and overseas visitors for this service. The annual passenger demand has been assumed to remain constant throughout the life of the vehicle.

Table 5.13 Load factors and corresponding passenger count in each loop.

Load Factor	50%	65%	80%	90%
Passengers in Swayambhu Loop	64,542	83,905	103,267	116,176
Passengers in Pashupati Loop	80,678	104,881	129,084	145,220
Total passenger demand	145,220	188,785	232,351	261,395

<u>**Case 2**</u>
Taking a more conservative approach with respect to Case 2, it is assumed that with a 65% passenger load factor, 80% of the passengers will be locals and 20% will be tourists. Among these passengers, it has been assumed that 70% of the tourists and 80% of the locals will be purchasing the one-day tour ticket.

To provide convenient travel options to local residents, it has been assumed that local passengers will be charged a nominal fee.

5.5.4 Key findings

<u>**Case 1**</u>
Since the NPTO is expecting to recove costs only from the vehicle operation, then fares for the service in this case are determinant by operating expenses, which include battery replacement costs and passenger demand.

Two fare structures have been determined based on battery replacement. Since battery replacement has been assumed to take place in Year 8, the average base case cost per passenger from Years 1 to 8 has been estimated at NPR 29 and NPR 33 from Years 9 to 15.
Table 5.14 presents the estimated fare per passenger for Case 1.

Table 5.14: Estimated fare per passenger, savings and TCO for case 1

	Unit	Low load factor scenario	Base load factor	Medium load factor scenario	High load factor scenario
Load factor	**%**	**50**	**65**	**80**	**90**
Average cost per passenger (yr 1 – yr 8)	NPR	37	29	23	21
Average cost per passenger (yr 9 – yr 15)	NPR	43	33	27	24

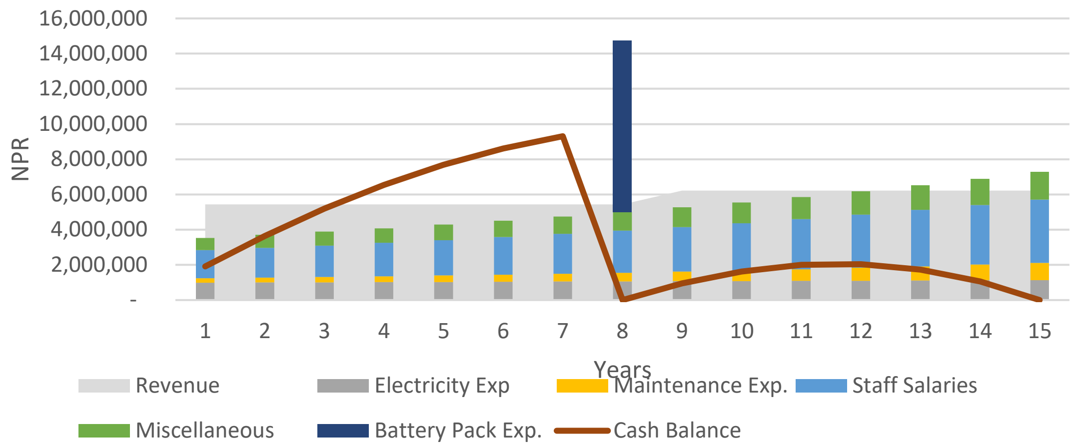

Figure 5.6 Financial projections for NPTO

- **Cash balance at the end of 15 years is zero.** Since the NPTO is not expecting any profits from the bus operations, the cash balance at the end of the life of the bus is zero.
- **The revenue collected in Years 1 through 7 can be leveraged for battery replacement in Year 8.** With the fare estimated for each load factor, savings of up to Year 7 can be used to purchase replacement batteries in Year 8. However, funding will need to be secured through external sources if the operator wants to extend the life of the vehicle beyond 15 years, since another battery replacement will be due in Year 16.

<u>**Case 2**</u>

Passenger fares in Case 2 were determined based on the return on investment (ROI) to a private operator. Three scenarios are analyzed based on low, medium, and high passenger fares.

The results of the base case as well as different scenarios are presented in Table 5.15 below.

Table 5.15 Fare per passenger, savings and return on investment in Case 2

		Unit	Low passenger fare	Base passenger fare	Medium passenger fare	High passenger fare
Fare per local passenger	One-day ticket	NPR	19	25	50	75
	Two-day ticket	NPR	19	25	50	75
Fare per tourist passenger	One-day ticket	NPR	272	340	408	476
	Two-day ticket	NPR	496	620	744	868
Project related	NPV	NPR	(6 M)	19 M	62 M	104 M
	IRR	%	7	14	22	30
	Payback period	Yrs.	10	0	0	0

Equity related	NPV	NPR	(10 M)	18 M	62 M	107 M
	IRR	%	5	18	39	61

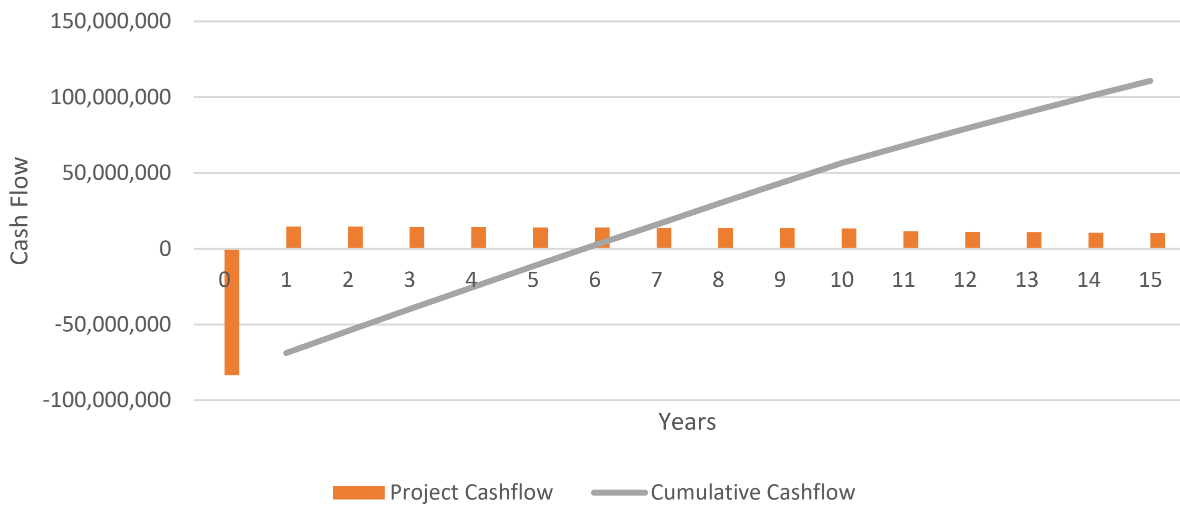

Figure 5.7 Cashflow forecast for PSTO - base case scenario

- **In the base case scenario (65% passenger load factor), at an estimated passenger fare of NPR 320 per passenger for a one-day ticket and NPR 620 per passenger for a two-day ticket, the PIRR will be 14% and** the NPV is around NPR 19M. This is assuming 70% of the tourists purchase the one-day ticket and the remaining 30% purchase the two-day ticket. The payback period for the base case is 0 years and the return on equity is 18%. This is a required EIRR and is therefore considered attractive for a private transport operator. In the low-fare scenario, the PIRR is 7%, EIRR is 5%, but the payback period of the project on the other hand is 10 years.
- **The cumulative cashflow for the project shows that the investment will be recovered within 5 years.** When base fares are considered, the investment will be recovered in 5 years. Thus, this project represents a very attractive proposition to a private sector operator.
- **From a passenger's perspective, the fare in the high passenger fare scenario is still economical when visiting multiple sites, when compared to a taxi service.** A taxi charges NPR 39 per km in addition to NPR 14 as a flat at the start of the ride.[46] With these charges, a passenger would have to pay a minimum of NPR 692 to complete the Swayambhu Loop and NPR 767 to complete the Pashupati Loop. The total fare in both the Loops will be around NPR 1,460. The estimated taxi fares do not account for waiting times at the various sites. Thus, the same service in an electric bus will be more economical to a passenger wanting to visit the different UNESCO World Heritage Sites.
- **This electric tour bus service will be economical when compared to a four-wheeler provided by a tour company.** A travel and tour company has been known to charge a minimum of NPR

[46] DOTM. Fares for public passenger vehicles. Ministry of Physical Infrastructure and Transport. Government of Nepal.

4,000 per vehicle per day. With the assumption that a maximum of four passengers can fit in the vehicle comfortably, this is easily 1.4 times more than the per passenger fare of NPR 868 in the high passenger fare scenario.

- **ROI is positive, even when 80% of the passengers, assumed as locals, are charged a nominal fee.** Considering the 65% load factor, where 80% of the passengers are locals who are charged a nominal fee of NPR 25 per passenger, the EIRR will be 18%, which is attractive to a private sector operator. In this study, a nominal fare structure has been designed for locals to decrease the potential for abuse of the service (see Table 5.15).

5.6 Conclusions and Recommendations

- For a NPTO aiming to recover only the cost of operations, an annual average tariff of about NPR 29 per person between Years 1 and 8 and NPR 33 per person between Years 9 and 15, assuming 65% load factor, would be viable. As load factor decreases, the fare would have to be increased in order to recover the OPEX. The operator will be able to accrue savings between Years 1 and 7 to purchase replacement batteries in Year 8, but will not be able to extend the life of the vehicle beyond 15 years (i.e., buy additional batteries for replacement) without additional external funding sources.
- When a PSTO charges locals NPR 25 and overseas visitors NPR 340 for one-day and NPR 620 for two-day tickets, the projected IRR is estimated to be 14% and the EIRR is estimated to be 18%, which is enough to cover the interest on debt, which is currently at the 12% rate being charged by financial institutions. This is an attractive proposition for private sector operators who might be hesitant about invest in electric buses.
- The fare being charged by PSTO is economical when compared to taxis and tour companies, who charge more than NPR 1000 per day providing services along the same routes. Thus, the project will be attractive to the private sector.
- This study only considers flat fares for tourists and locals. Different fare structures for family members and preferential fares for the elderly and differently-abled or mobility-impaired passengers may be tailored for the service. These types of fare would ease travel for the elderly, differently-abled passengers and children.

Chapter 6. Proposal for Patan's Heritage Core

6.1 Policy and Priorities

Besides a small pedestrianized zone in the heart of Patan Durbar Square and a time-sensitive one-way section for vehicles, motorbikes and cars are the preferred means of transport which are generally free to travel anywhere. As a result, the roads surrounding PDS have seen rise in traffic congestion, air pollution, and loss of walkways and sidewalks for pedestrians. Tourists visiting this area are not able to walk with ease when visiting the Heritage Sites without being disturbed by vehicles. The quality of life of local residents in the areas has also deteriorated.

In an effort to improve environmental conditions, ease traffic congestion, and transform this ancient city's transportation infrastructure from motor-vehicle-centric development to a city with non-motorized, low-carbon and inclusive mobility options, Lalitpur Metropolitan City (LMC) has planned the implementation of several transport strategies in the near future. Essentially, LMC's plan is to give priority to pedestrian and bicycle traffic, then to public and cargo vehicles, and finally to private vehicles. To achieve this objective, strategies adopted by LMC include the building of a network of cycle lanes and pedestrianized zones.[47,48]

Despite the significant benefits achieved through pedestrianization, it can limit the mobility of elderly and mobility-impaired people. It is therefore important to include public transport options that can continue to service these individuals. Currently, electric three-wheelers (called '*safa tempo*') are the only means of public transport option linking Pulchowk to Gwarkho. Also, tourist buses are not allowed to venture deep into PDS and tourists generally walk to and from the bus stop facing the LMC office. For the majority of tourists, walking and exploring is still the best way to visit PDS, but a small number of tourists do prefer some kind of mobility option.

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[47] The Kathmandu Post. 2019. Patan wants to become a cycle city. But can it pull it off?. Retrieved from: https://kathmandupost.com/valley/2019/04/07/patan-wants-to-become-a-cycle-city-but-can-it-pull-it-off

[48] Setopati. 2018. Patan Durbar Square to be vehicle-free zone from April 14. Retrieved from: https://en.setopati.com/social/119566

An electric public shuttle service which traverses core residential areas and tourist attractions, servicing both locals andtourists would help address this problem. Such an effective shuttle service, designed to cater to the needs of the locals, can also improve 'last mile connectivity' in addition to driving a modal shift from private vehicle use to public transport.

This chapter begins with an identification of route options and then presents several recommended routes for electric shuttle services around PDS. It is then followed by market research of electric shuttles, in addition to identifying key required specifications. An operational plan is then devised for recommended route options and preferred shuttle type. The chapter then ends with a financial analysis section which assesses the initial capital requirement, operational expenditures, and the expected tariff that a non-profit transport operator would need to charge its customers.

6.2 Route Servicing the Heritage Core of Patan

6.2.1 Procedure for identifying routes

The objective of this section is to identify several routes that are suitable for running an electric shuttle service and then recommend a number of options. The section begins with the description of several potential routes designed around PDS which are suitable for deploying an electric shuttle service. After a series of ground-level surveys and stakeholder consultations, followed by a route survey using a simple multi-criteria analysis framework, two routes were then recommended as optimal for running an electric shuttle service. The steps involved in identifying the preferred routes are given below:

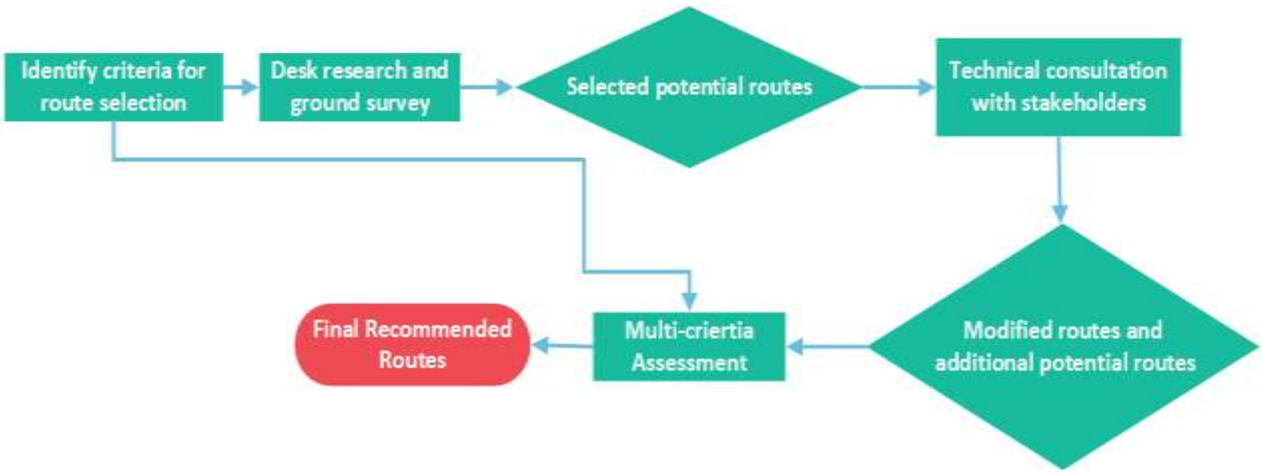

Figure 6.1 Steps involved in identifying recommended routes

Step 1: identification of criteria for route selection

A list of criteria was identified for selecting the preferred routes around PDS. Criteria used to identify potential routes can be broadly classified into two types: road criteria and demand criteria. These criteria also contain several sub-criteria which are described below:

A. Road criteria

- **Sufficient road width:** all road sections within the route should be wide enough to accommodate an electric shuttle. Routes also need to have "stopping spots"[1] where passengers can board or get off the shuttles with ease.
- **High quality of roads:** the overall physical quality of the routes must be in good condition. Routes with a lot of potholes, speed-breakers, and those that are not paved are to be avoided.
- **Adequate fluidity of traffic:** routes with heavy traffic congestion will be given lower priority. Also, routes with road sections occupied by motorcycle parking zones and footpath shops should be avoided wherever possible.
- **Appropriate gradient:** considering the limitation of a shuttle's climbing ability, routes with any road section with gradient above 15% are not selected.
- **Improved mobility service:** routes which have high degree of competition with other operators such as *safa tempo*, micro bus, etc., are not considered. Preferably, routes must pass through areas which currently do not have any other means of public transport.
- **Appropriate route length:** routes must of be of appropriate length. The length of the entire route (including all sub-routes) is kept under 10km. Also, if route lengths are very short, then people will prefer to walk. So the overall length of all routes (including sub-routes) is kept to a minimum of 1.5km in length.
- **Avoiding major trunk roads:** electric shuttles have a low top speed of generally 40km/h. Deploying such shuttles along major trunk routes and highways where other vehicles travel at a much faster speed will be dangerous and contribute to congestion. Therefore, routes with significant overlaps with major trunk routes should be avoided.

B. Demand criteria

- **Service tourist destination:** routes must pass through tourist destinations and attractions.
- **Service core areas:** routes must access core and densely-populated residential areas.

Step 2: Desk research and ground survey

Based on the above-identified criteria, a list of potential routes around PDS were selected on the basis of desk research and ground surveys (cf. Section 6.2.2). Routes were first identified using Google Maps, followed by a ground-level survey to identify technical aspects.

Step 3: Technical consultation with stakeholders

These identified potential routes were then presented to stakeholders from Lalitpur Metropolitan City (LMC) for discussion. Based on stakeholders' feedback and suggestions, improvements and changes were made to the identified routes. One more route designed and recommended by the stakeholders was also added as a potential option. Section 6.2.3 presents the discussions and outcomes of the technical consultation in more detail.

Step 4: Multi-criteria analysis of identified routes

All identified potential routes were then analyzed using a simple multi-criteria analysis (MCA) framework to assign a numerical score to them. However, out of all the criteria identified in step 1, only the selected criteria were used for the MCA. Details of the MCA are presented in Section 6.2.4.

The top two scoring routes were then selected as the recommended routes, for which operational and financial analysis were then carried out.

6.2.2 Potential routes identified based on desk research and ground surveys

On the basis of the defined criteria and ground surveys, three route options were identified around PDS. Route L1 and L2 are circumferential routes, while route L3 is a combination of two linear sub-routes.

Route L1

Route L1 is a circumferential route which connects PDS to transport hubs such as Jawlakhel, Patan Dhoka, Lagankhel, and Gwarkho. It also passes through major commercial destinations such as Labim supermarket, Bhatbhateni supermarket, Mangalbazar, Kumaripati, and Lagankhel market. Jhamsikhel area is located toward the north-west of the route and consists of restaurant chains and bed & breakfast services. The route also passes through the Institute of Engineering, Patan Multiple Campus and Patan Hospital.

With a total length of 7.3km, this route is relatively longer than other routes that were identified. The section between Jawlakhel and Pulchowk, as well as Jawlakhel and Lagankhel, are both major trunk routes with wide roads of two lanes per direction. Larger transport services are operated along the route.

Figure 6.2 Route identified for PDS (L1)

Route L2

Route L2 is a circumferential route connecting PDS to the ring road at two different transport hubs: Gwarkho in the south-east and Ekantakuna in the south-west. This is a relatively smaller route, and unlike route L1, it does not pass through Jhamsikhel, northern Pulchowk (Bhatbhateni), and the Patan Dhoka areas. A stretch of this route from Ekantakuna to Pulchowk falls on the north-south trunk route. Similarly, the road section between Lagankhel and Jawlakhel is usually busy with high-speed vehicles and the roads are also wide with two lanes per direction.

Figure 6.3 Route identified for PDS (L2)

Route L3

Route L3 is an “X” shaped route and it consists of two linear sub-routes which meet at the center of PDS. Sub-route A runs along the north-west to south-east direction, connecting Pulchowk to Gwarkho (via Mangalbazar and Sundhara). Sub-route B runs north-west to south, connecting Patan Dhoka to Lagankhel. The point where the two routes intersect is Mangalbazar. Both routes pass through dense residential areas which are also rich in tourist attractions. Both routes are populated with art galleries, temples, heritage homes, handicraft stores, and eateries. Boths sub route A and B are 1.9km in length. A small section of sub-route B passes through a pedestrianized zone in PDS.

Figure 6.4 Route identified for PDS (L3)

6.2.3 Consultation of potential routes with stakeholders

All identified potential routes for PDS were presented to stakeholders in a technical workshop held in November. A series of discussions on the range of identified options indicated a strong preference for route L3, but with some modifications. Some of the points expressed by stakeholders supporting route L3 are presented below.

- Considering the low travel speed of shuttles, it may be very dangerous to deploy shuttles on major routes, such as those in L1 and L2 where high-speed vehicles are operating. When compared to other route options, the majority of road sections along route L3 pass through narrow streets filled with pedestrians. The route is therefore favorable for the operation of low-speed vehicles.
- The route services the needs of locals as well as tourists. Both sub-routes of route L4 pass though core residential areas of Patan and connect to major transport hubs such as Lagankhel, Gwarkho, Patan Dhoka, and Pulchowk. Also, both sub-routes pass through tourist attractions such as temples, handicraft shops, water sprouts, and restaurants. The routes originate from Patan Dhoka and Pulchowk, which are currently are the spots where tourist buses drop off visitors to PDS.
- The route length for both sub-routes is very short, but coverage area and population density are high in the area covered by the routes.
- The route has less competition from other transport service providers, especially in sub-route B, which currently does not have any public transport services.

A few stakeholders recommended modification to route 3, which is as follows:

- Operating electric shuttles in pedestrianized zones could result in numerous political and social challenges. So, instead of sub route B passing through the pedestrianized zone of PDS, the sub-route can take an alternate route and circumvent PDS. It can head east, then south, and then join sub-route A at Pradhan Chuka. The route can then connect to Lagankhel via Prayag Pokhari.

Based on this recommendation, a modified version of route L3 was prepared which is hereafter referred to as L3*. This is illustrated in Figure 6.5.

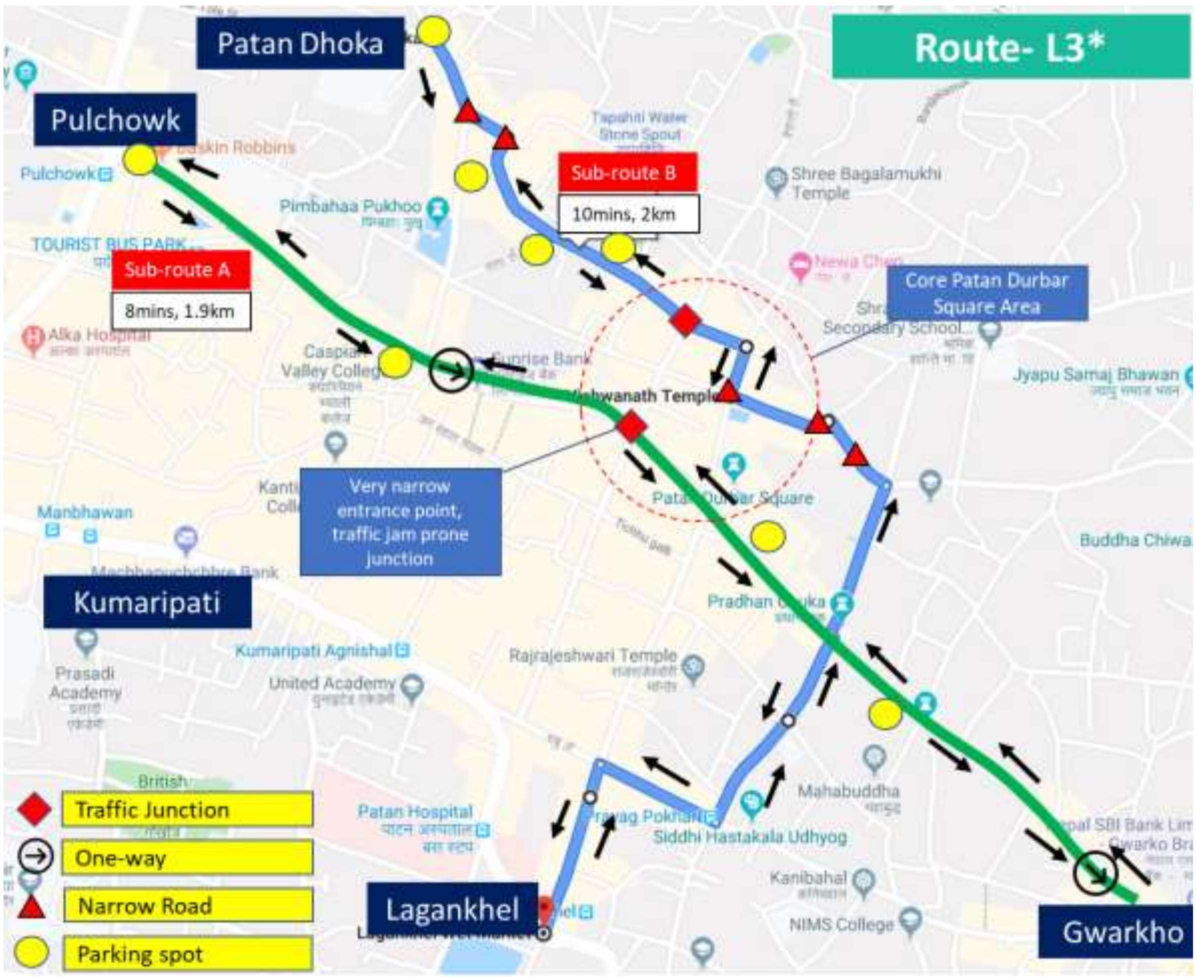

Figure 6.5 L3*-Modified version of route option L3

In addition, based on the stakeholders' knowledge of local road and traffic conditions, stakeholders also recommended an additional route option for PDS. This additional options is termed as L4 and is described below.

Route L4

Route L4, shown in Figure 6.6, encircles core residential areas of Patan as well as PDS. It begins and ends at Pulchowk (near the Lalitpur Metropolitan Office). Compared to the other routes, this route touches on more tourist areas, and some of the tourist attractions it passes through are Golden Temple, Bangalamukhi Temple, Patan Durbar Square, Thapahity Water Tap, Machhindranath Temple, Mahabuddha, Rudra Varna Mahavir, Purnachandi Temple, Buddhist Stupa, and other attractions such as handicraft stores, eateries, and art galleries.

The entire route length is 4.5 km, and only a small section, between Pulchowk and Gabahal Chowk, is a major road with high-speed vehicles running along it. Unlike all other identified potential routes, this route does not pass through road sections with high traffic congestion (indicated by the blue dotted line) between Gabahal Chowk and Gwarkho. This road stretch consists of a junction that is prone to high traffic congestion (indicated by a red rhombus within the red dotted circle) and route L4 avoids this junction.

Figure 6.6 Route added by stakeholders (Option L4)

6.2.4 Multicriteria assessment of identified routes

Routes have many complex characteristics and identifying the most suitable for the needs of the stakeholders requires a more formal approach. To make identification easier, the route characteristics were first qualitatively assessed against a set of key criteria. These criteria were designed to assess optimal operations of an electric shuttle service (cf. Section 6.2). Except for the "appropriate gradient" and "appropriate route length" criteria, all other criteria were used to compare route options L1, L2, modified L3,* and L4, and numerical scores were then assigned to each route based on the comparison.

The following steps were involved in the analysis:

- A five-point score scale was used to assign a relative score for all four routes against those selected criteria identified at the beginning of Section 6.2.
- These five-point scores obtained for each route were then multiplied by the weight of the criterion in order to arrive at a score per criterion. For simplicity, equal weights were considered for all criteria, as illustrated in Table 6.2. Scores received by all the routes in each criteria is illustrated in Figure 6.
- The final score of each route was obtained by adding all the scores received by the route for each of the seven criteria, which is shown in
- Table **6.3**.

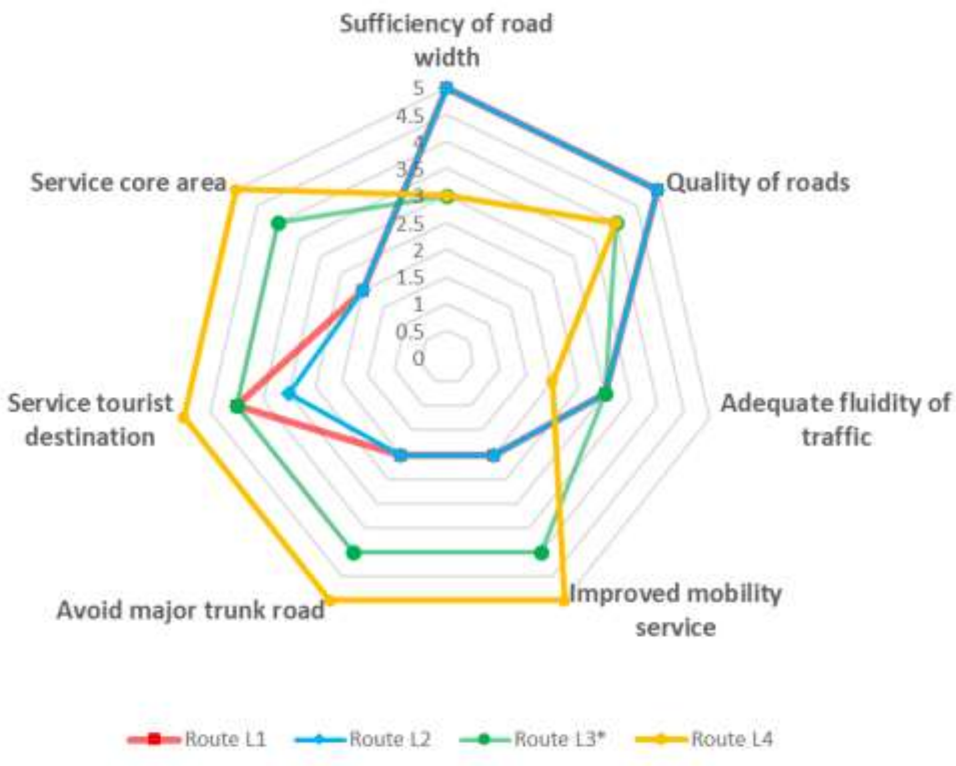

Figure 6.7 Scores received by all the route identified for PDS

The scoring is done relatively, meaning that all routes are compared against each other for a particular criterion. A score of 1 corresponds to an unsuitable/unfavorable route condition for that particular criterion, while a score of 5 represents a highly-favorable condition.

For example, while scoring for sufficiency of road-width criterion, routes with wide roads throughout all the sections are given a score of 5, while routes where the majority of sections have very narrow roads are given a score of 1. Similarly, routes which are paved with asphalt in most of the sections and do not have lots of potholes are given a score of 5.

For the criterion “increased fluidity of traffic,” routes with heavy traffic congestion and sections occupied by motorcycle parking zones are given lower scores. The “improved mobility service” criterion captures the additional benefit or value added by the shuttle service in the form of a new public transport service. If the majority of sections of the route do not have any form of public transport service available, they are then awarded the highest score of 5. Considering their limited top speed, electric shuttles are not safe to be deployed alonga major trunk routes. So, routes which have a large number of road sections falling on major trunk routes are given the lowest score.

The beneficiaries of this shuttle service are local residents near PDS as well as tourists visiting PDS. So, for the demand criteria, if the route traverses though many densely-populated core residential areas, it is given the highest score. Similarly, if the route contains relatively more tourist destinations, it is also given a higher score. The result of the MCA analysis is presented in
Table **6.3** below. With a score of 4.1, Route L4 is the highest-scoring route, followed by Route L3* in second place with a score of 3.7.

Table 6.1 Scores given to all the routes for all criteria

Criteria	Route L1	Route L2	Route L3*	Route L4
Sufficiency of road width	5	5	3	3
Quality of roads	5	5	4	4
Adequate fluidity of traffic	3	3	3	2
Improved mobility service	2	2	4	5
Avoid major trunk road	2	2	4	5
Service tourist destination	4	3	4	5
Service core area	2	2	4	5

Table 6.2 Weightage of each criterion

Criterion	Weightage
Sufficiency of road width	14%
Quality of roads	14%
Adequate fluidity of traffic	14%
Improved mobility service	14%
Avoid major trunk road	14%
Service tourist destination	14%
Service core area	14%
TOTAL	**100%**

Table 6.3: Final total score received by the routes

Description	Route L1	Route L2	Route L3*	Route L4
Total	3.3	3.1	3.7	4.1
Rank	3	4	**2**	**1**

6.2.5 Recommended routes for Patan Durbar Square

The final two routes recommended for the operation of a shuttle service are options L4 and L3,* the details of which are presented below in Figure 6.8 and Figure 6.9 respectively. The yellow dots along the route indicate place of interest and tourist sites. These two routes are analyzed for operational and financial performance in the following chapters.

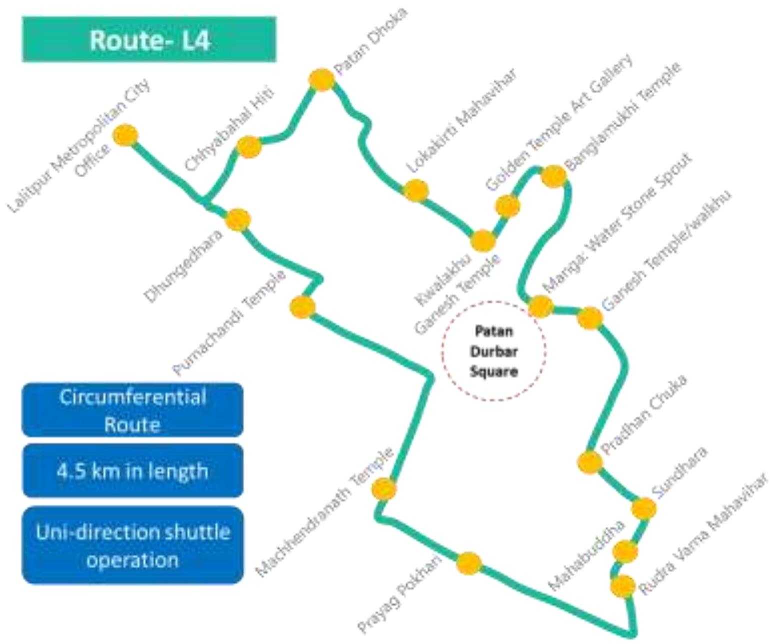

Figure 6.8 First recommended route for LMC (Option L4)

Figure 6.9 Second recommended route for LMC (Option L3*)

6.3 Market Review of Electric Shuttles and Proposed Specifications

In this section, a range of electric shuttles available in the market are identified. The shuttles, along with their key specifications, are presented in Table 6.4. Reviews were based on online market surveys followed by direct enquiries in the case of a few manufacturers. Besides the models and manufacturers mentioned here, there are many other manufacturers and models available in the market. The objective of this review is to draw the reader's attention to the wide range of electric shuttle models available in the market.

The market review focused on several type of shuttle models, such as the golf cart type, the open sightseeing type, and the closed sightseeing type. Also, shuttles powered by lead acid-based batteries were available globally. This review is strictly limited to shuttles powered by lithium-ion batteries.

6.3.1 Vehicles identified in the market review

The table below lists some models of electric shuttles identified from market review. The models have a seating capacity of between 3 to 13 passengers, excluding the driver. Broadly, they can be categorized as a golf cart type, closed sightseeing type, and open sightseeing type.

Table 6.4 Selected models of electric shuttles identified in the market review

Option-S1		
	**Shuttle make [country] / model**	Lvtong [China] / LT-A8+3.A
	Shuttle type	Golf cart type, Open
	Dimension (mm)	4120*1200*1900
	Battery size/range	12.1 kWh, 90-100km
	Battery type	LiFeP04
	Ground clearance (mm)	100
	Seating	11+1
	Gradeability	15%
	Energy consumption	9 kWh/100km
	Charger	Off-board
	Maximum speed	25 km/h
	Price (US$)	6,800 (FOB Shenzhen)
Option-S2[49]		
	**Shuttle make [country] / model**	Smart Car [USA] / SC6-48
	Shuttle type	Golf cart type, Open
	Dimension (mm)	3352*1219*8
	Battery size/range	N/A / 190 km
	Battery type	LiT® Advanced lithium-iron phosphate
	Ground clearance (mm)	114
	Seating	5+1
	Gradeability	35%
	Energy consumption	N/A
	Charger	On-board – Delta Q
	Maximum speed	45
	Price (US$)	N/A
Option-S3		
	**Shuttle make [country] / model**	Hefei Huanxin Technology Development [China] / S8.F
	Shuttle type	Sightseeing type, open
	Dimension (mm)	4230*1480*2100
	Battery size/range	N/A / 90 km
	Battery type	Lithium-ion based
	Ground clearance (mm)	180
	Seating	8+1
	Gradeability	20%
	Energy consumption	10.5 kW/100km
	Charger	Off-board charger
	Maximum speed	30 km/h
	Price (US$)	10,650
Option-S4		

[49] Smart EV. 2019. Retrieved from: https://www.smartcartev.com/product/sc6-48/

	Shuttle make [Country] / model	Lvtong [China] / LT-S8.HAF
	Shuttle type	Sightseeing type, closed
	Dimension (mm)	4185*1490*2010
	Battery size/range	10.8 kWh / 90-90km
	Battery type	Lithium-ion based
	Ground clearance (mm)	150
	Seating	8+1
	Gradeability	15%
	Energy consumption	10 kWh/100km
	Charger	Off-board charger
	Maximum speed	30 km/h
	Price (US$)	9,400 (FOB Shenzhen)
Option-S5		
	Shuttle make [Country] / model	Lvtong [China] / LT-S11.B
	Shuttle type	Sightseeing type, open
	Dimension (mm)	4590*1480*2100
	Battery size/range	12 kWh/90-100km
	Battery type	Lithium-ion based
	Ground clearance (mm)	180
	Seating	11+1
	Gradeability	20%
	Energy consumption	12 kWh/100km
	Charger	Off-board charger
	Maximum speed	30 km/h
	Price (US$)	9,800 (FOB Shenzhen)
Option-S6		
	Shuttle make [Country] / model	Lvtong [China] / LT-S14.F
	Shuttle type	Sightseeing type, closed
	Dimension (mm)	5100*1560*2010
	Battery size/range	18 kWh/80-100km
	Battery type	Lithium-ion based
	Ground clearance (mm)	170mm
	Seating	13+1
	Gradeability	18%
	Energy consumption	14 kWh/100km
	Charger	Off-board charger
	Maximum speed	30 km/h
	Price (US$)	11,400 (FOB Shenzhen)

Option-S7[50]

Shuttle make [Country] / model	Mahindra [India]/Treo Yaari
Shuttle type	Tempo
Dimension (mm)	2746*995*1757
Battery size/range	3.69/129km
Battery type	Lithium-ion
Ground clearance (mm)	N/A
Seating	4+1
Gradeability	N/A
Energy consumption	N/A
Charger	N/A
Maximum speed	24 km/h
Price (US$)	2,280 (ex-showroom, India)

6.3.2 Required basic specifications

On the basis of our market review of electric shuttles, key features of the shuttles were isolated and discussed with the stakeholders in order to identify the most appropriate features required. Also, we consider that specifications cannot be based purely on what is available in the market. They also need to be based on the actual reality of route and ground conditions, as well as service demand. It is therefore imperative to consider additional technical features associated with the routes such as road width, ground clearance, and available turning radius while designing the technical specifications.

Table 6.5 delineates the basics proposed specification of electric shuttles and chargers. The specifications were designed in such a way that desired of the electric shuttle features and components and features can be made sourced from the manufacturers without much difficulty.

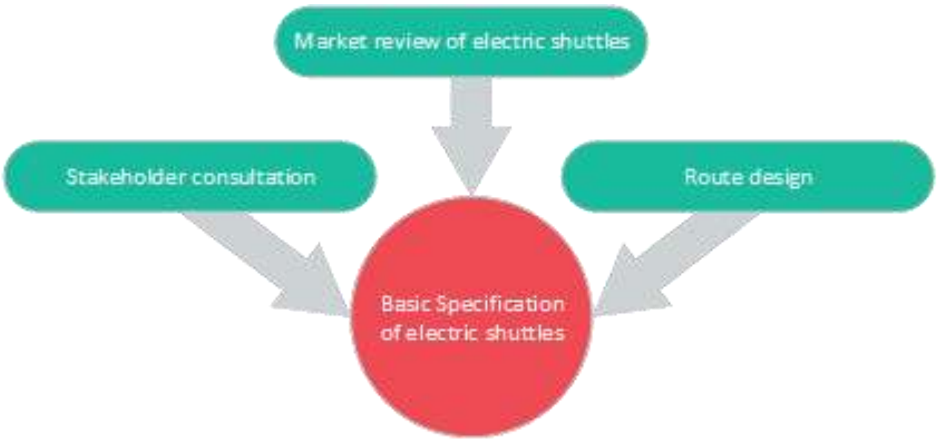

Figure 6.10 Block diagram of technical specification design process

[50] Rushlane. 2018. Mahindra Treo 3, 4-seater electric rickshaw launch price Rs 1.36 L, 2.22 L – Including FAME subsidy. Retrieved from: https://www.rushlane.com/mahindra-treo-3-4-seater-electric-rickshaw-launch-12287590.html

Table 6.5 Proposed basic technical specification of electric shuttles

Dimensions	Proposed Specification
Length (mm)	4000 ± 300
Width (mm)	1400 ± 100
Height (mm)	Not more than 2500
Ground clearance (mm)	At least 150
Seating capacity	At least 8 passengers excluding driver
Gross vehicle weight (kg)	To be specified by manufacturer
Chassis	Proposed Specification
Chassis/frame material	*Metal based*
Battery Bank and Energy Consumption	Proposed Specification
Type of battery	Lithium-based battery
Battery bank size (watt-hour)	At least 12,000
Minimum battery life	At least 5 years of guarantee
Battery management system	Required (Preferably with 1. Over-voltage, under-voltage, and temperature protection 2. Should have charging control mechanism 3. Should be able to monitor insulation between battery and frame and shut down power supply from battery if the insulation level is not sufficient 4. Should be able to monitor data and be able to communicate with PC
Range	At least 90km on a single full charge for specified GVW on a flat road @20 km/hr
Powertrain and Electrical Components	Proposed Specification
Motor size	Capacity of the motor should be enough to: 1. Reach top speed of 45 km/hr on a flat road at G.V.W 2. Maintain gradeability of at least 15 % at G.V.W
Motor type	To be specified by manufacturer
Motor controller	Required
Vehicle Body System	Proposed Specification
Front suspension	At least spring type
Front shock absorber	At least hydraulic type shock absorber
Rear suspension	At least spring type
Service brake	Disk brake
Parking brake	Required
Minimum turning radius	Not more than 6.5m
Steering position	RHD
Steering	Assisted power steering
Seat material	Artificial leather or cloth
Roof material	High tensile steel, wielded, high strength
Body side covering	High tensile steel, wielded, high strength

Front windshield	High-strength, laminated, transparent glass
Rear windshield	High-strength, laminated, transparent glass
Number of doors	At least two doors on each side (including for driver)
Door material	High-strength laminated or tempered transparent glass, mounted on metal column
Window type	Slidable window attached to door body
Dashboard	Proposed Specification
State of charge meter	Required
Speedometer	Required
Motor/engine problem system	Required
Front windshield wiper	Required
Safety Features	Proposed Specification
Passenger exit doorbell	Required
CCTV surveillance system	Preferable
Front and rear bumpers	Required
ABS	Preferable
Other Features	Proposed Specification
Gradient/climbing ability at GVW (%)	At least 15%
Top speed at GVW	At least 45 km/hr
Cooling/heating system	Air conditioner
Public announcement system	Preferable
Battery Charger	Proposed Specification
Type of battery charger	On-board or off-board AC to DC charger
Capacity of battery charger (Watt)	At least 1,200
AC input, Frequency	230 V, 50 Hz
Power factor	At least 0.98 at nominal input current
Display	LED or LCD-based indicator panel showing SOC of battery & faults
Reverse polarity protection	Required
Battery temperature compensation	Required
Enclosure	At least IP46 rated
Charging algorithm	Should be suitable for charging proposed Lithium-based battery pack. Constant current and constant voltage charging setting should be strictly suitable for the proposed battery bank cell type
Over-temperature and under-temperature protection	Required (should stop charging below 0°C and above 45°C)
Short circuit protection	Required
Over-charge protection	Required (Depending on the cell material of the battery pack charger, discharge should stop if the voltage per cell rises above specified safety limit of the cell)

Over-discharge protection	Required (Depending on the cell material of the battery pack, discharge should stop if the voltage per cell falls below the specified safety limit of the cell)

6.4 Operational Plan for the Proposed Route and Vehicles

This section presents the operational aspects related to operation of electric shuttle service for the two recommended routes for PDS. For both routes, this section presents the analysis on:

- total number of shuttles required to maintain fixed headway time;[51]
- estimated total number of passengers carried by the shuttles annually;
- estimated annual energy consumption and related expenditure;
- proposed battery charging scheme; and
- proposed location of depot where shuttles are parked overnight and charged.

6.4.1 Methodology

An appropriate method for estimating the required electric shuttle fleet size would be to first evaluate overall transport demand and service area characteristics, and then to estimate the extent to which a shuttle service can be provided. Based on this, the total number of shuttles required for the route can then be calculated.

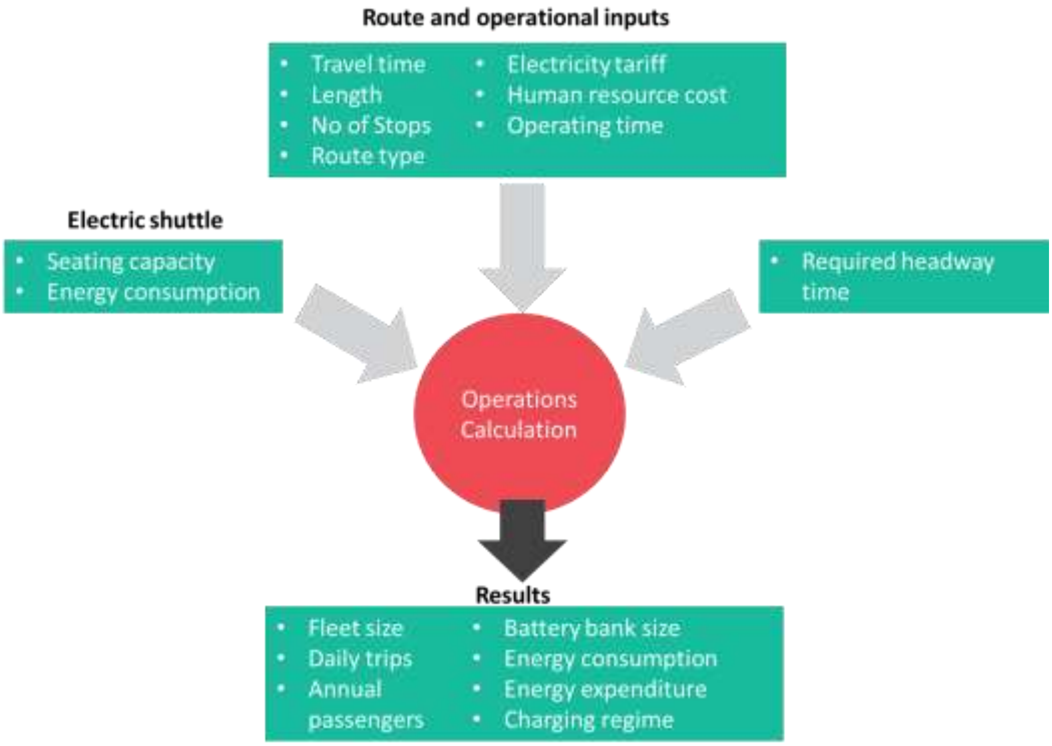

Figure 6.11 Block diagram of operational analysis

However, estimating overall transport demand in LMC falls outside the scope of the current study. If demand were to be assessed, considering the high population density around PDS,

[51] Time between shuttle arrival at a stop.

then a large number of shuttles would be required if these shuttles service were to be designed as the major service provider in the area. As reiterated by stakeholders during the consultations, adding a large number of shuttle services would only exacerbate traffic congestion. Therefore, the proposed service would specifically target tourists, the mobility-impaired people, and elderly locals only. This would then ensure that the number of shuttles doesn't increase in uncontrolled fashion.

Estimating fleet size

Headway time was taken as the basis for estimating electric fleet size. For example, for any particular route (or sub-route), depending on other technical parameters such as length, time taken for a single round trip, number of stops etc., the required fleet size for that route (or sub-route) is the minimum number of shuttles required to maintain the proposed headway time . After estimating the fleet size, and using all accounted-for assumptions and inputs (cf. Table 6.6), all other operational aspects such as annual passenger and annual vehicle kilometers traveled (VKT), etc., were then estimated accordingly.

Estimating number of passengers served

The total annual number of passengers expected to use the shuttle service is estimated using the formula below:

$$Px = Dx * \mathrm{Si} * \mathrm{Ti} * \mathrm{P} * \mathrm{LFi}$$

Where,

Px = passenger numbers in Year x;
Dx = number of days of operation in Year x;
Si = number of shuttles in route I;
Ti = number of trips by a shuttle per day in a route I;
P = seating capacity of a shuttle;
LFi = load factor for a shuttle in route i (%).

In case of route L3*, which as two sub-routes for which the number of shuttles operating in the sub-routes and the number of trips completed by them are different, the above equation is used separately for both sub-routes. The final annual estimated passenger for L3* is then the sum of annual passengers estimated for both sub-routes.

The load factor reflects the capacity utilization of shuttle services. A high load factor indicates that a higher percentage of available seating capacity is filled with passengers, and vice-versa. Four scenarios are then created which reflect varying load factors, ranging between 60% to 90%, with 70% taken as the base case.

6.4.2 Assumptions and input

To calculate the operational details associated with both routes for LMC, several assumptions and data were used which are described below.

The time taken to travel along the route was obtained from a route survey conducted by GGGI. Other factors such as time taken for passengers to board and alight as well as delay due to congestion were also considered in order to estimate the actual time required by a shuttle to service the route. Data related to electric shuttles and chargers were obtained by contacting regional vendors. The electricity tariff was taken as set by the Nepal Electricity Authority for the "Commercial" consumer category.[52] Number of days of operation in a year is assumed to be 347 and the seating capacity is assumed to be 8 per shuttle.

Assumptions and input for option L3 and L4*

Table 6.6 below lists the assumptions made to estimate the operational details for option L3*. Since both sub-routes are linear, shuttles must return to the starting point. Therefore, shuttles will need to be operated in both directions.[53] To estimate the time required for a single round trip, travel time obtained from Google Maps is then added to the time it takes for passengers to board and alight the shuttle, as well as the average expected delay due to traffic congestion, obtained from the route survey.

Table 6.6 below also lists all assumptions deployed to calculate the operational details for route L4. Since L4 is a circumferential route, it is assumed that shuttles will operate only in a clockwise direction.

Table 6.6 Assumptions and inputs for analysis of operational aspects for route L3*and L4

Description	Unit	L3*		L4
		Sub route A	Sub route B	
Route				
Type of route		Linear route (two way)		Circumferential route (one way)
Route length (one way)	km	1.9	2	4.5
Travel time by car under normal traffic conditions (one way)	mins	12	10	24
Average number of stops per trip (one way)	stops	10	10	20
Time taken to board and alight passengers (one way)	mins	5	5	10
Delay due to traffic congestion (one way)	mins	5	5	5
Service start time	A.M	8:00	8:00	8:00
Service end time	P.M	20:00	20:00	20:00
Proposed headway	mins	10	10	10
Lunch break	mins	40	40	40
Operating days per year	days	347	347	347
Electric shuttle				
Passenger carrying capacity of shuttle excluding driver	people	8	8	8
Specific energy consumption of shuttle	kWh/km	0.1	0.1	0.1
Electric vehicle supply equipment (EVSE) and electricity				
EVSE system efficiency		85%	85%	85%
Average cost of electricity per unit	NPR	11.2	11.2	11.2

[52] NEA. 2019. *Annual Report of Nepal Electricity Authority*. Retrieved from: https://www.nea.org.np/annual_report
[53] Currently, there is a time sensitive one-way policy in the section between Gabahal and near Gwarkho, which prevents shuttles operating in both directions.

6.4.3 Results of operational calculations

Required fleet size, trips per day and estimated passengers served annually

To maintain headway time of ten mins, four units of electric shuttles are required for route L4. For route L3,* a total of ten electric shuttles are needed for two sub-routes. A single shuttle is estimated to complete 17 round trips per day for route L4. For route L3,* the estimated total number of round trips for sub route A as well as sub route B by a single shuttle per day is 15. The estimated annual vehicle kilometers traveled and the expected number of passengers served by each vehicle annually are presented in

Table 6.7.

Table 6.7 Operational aspects for option L4 and option L3*

Description	Route L4	Route L3*		
	Total	Sub route A	Sub route B	Total
Number of shuttles needed (units)	4	5	5	10
Number of round trips completed by single shuttle per day	17	15	15	-
Estimated annual vehicle kilometers traveled (VKT) by entire fleet	106,182	98,895	97,160	202,995

Table 6.8 Estimated passengers served annually w.r.t load factor

Load Factor	Route L4	Route L3*
60% (Low-scenario)	113,200	249,000
70% (Base-scenario)	132,000	291,000
80% (Med-scenario)	151,000	333,000
90% (High scenario)	169,000	374,000

Four scenarios are created which reflect load factor, ranging between 60% to 90%, with 70% taken as the base case. Using these scenarios, rounded figures of estimated passengers serviced annually in both routes are presented in Table 6.8.

Battery bank size, charging scheme and annual energy expenditure on energy

Battery bank size

The average specific DC energy consumption of an 8-seater shuttle, as gathered from our market review, was found to be around 0.1 kWh/km. [54] To obtain the total DC energy consumption per shuttle for a particular route in a single day, the specific DC energy consumption was multiplied by the estimated total distance traveled on a per shuttle, per day basis. To estimate the required minimum battery bank size, 30% additional capacity was added to the expected daily DC energy consumption value.

[54] DC energy refers to the energy drawn into and out of the battery pack. It does not include electric vehicle supply equipment (EVSE) losses. AC energy consumption is the sum of DC energy consumption and the associated losses of EVSE. While calculating battery bank size, DC energy consumption is used. However, for estimating total annual electricity bill, AC energy consumption is used.

The DC energy consumed by a single shuttle for route L4 and L3,*as well as the required minimum battery bank size are presented in the Table below.

Table 6.9 Daily DC energy consumption and required battery bank size

Description	Unit	Route L4	Route L3*
DC energy consumption per shuttle per day	kWh	7.7	5.7 – 6
Reserve in case of emergency	%	30	30
Required battery bank size	kWh	10	7.2 – 8.8

Charging scheme

Table 6.10 Energy consumption and related expenditure

Description	Unit	Route L4	Route L3*
DC energy consumption per shuttle per day	kWh	7.7	5.6 – 6.8
AC energy consumption per shuttle per day	kWh	9	6.7 – 7.0
Annual electricity consumption by entire fleet	kWh	12,492	23,882
Annual expenditure on electricity for route	NPR	139,910	267,476

Three main charging regimes are currently being implemented by comparable shuttle services around the world. These are as follows:

- **Overnight charging at depot**: shuttles return to the depot or overnight parking spot and are charged overnight.
- **Opportunistic charging regime:** shuttles are charged at intermediate stops along the route by fast chargers.
- **Terminal station-based charging regimes:** fast chargers present at terminal stations (or a few selected stops) charge the batteries.

The following key points were taken into consideration while deciding upon the optimum charging scheme:

- The rate at which energy can be delivered into the batteries depends on the size/capacity of the charger, the size of the battery (C rating, ampere-hour rating), and the cell construction material of the battery being charged.
- From the market review, it was observed that unlike currently available electric vehicles, which are charged by high-capacity off-board chargers with pre-defined standards (such as CHAdeMo, CCS, GB/T *etc.*), electric shuttles generally use much smaller chargers with a capacity ranging from 1 kW to 1.5 kW.

Considering the charger limitation of capacity for electric shuttles available in the market, shuttles with a 10 kWh battery pack will need 6.6 to 10 hours[55] in order to fully charge an empty battery. Given the long charging time required, the implication here is that charging schemes other than overnight charging at depot are simply not feasible.

[55] Charging time of 1 kW charger= 10 kWh/1kW=1hr. Charging time of 1.5 kW charger= 10 kWh/ 1.5= 6.6 hrs.

6.4.4 Depot location

Sajha Yatayat has a bus depot which has 2,685 sq.m of estimated parking area at Pulchowk, Lalitpur. Currently, 45 large-sized buses are parked overnight at the depot. Through consultations with Sajha Yatayat, it has been determined that space is available for 10 to 15 electric shuttles.

The starting point of route L3* as well as route L4 is near the LMC Office, which is just 450m from the proposed depot location.

Figure 6.12 Location of proposed depot

6.5 Financial Performance of Vehicles along the Proposed Route

In this section, the results of the financial analysis performed for the two recommended routes (L4 and L3*) for LMC are presented.

It is LMC's intention to focus on service-oriented rather than profit-oriented operation. So, rather than evaluating the project using classic financial metrics such as IRR, NPV, and payback period, the approach here is to evaluate *financial sustainability*. In other words, throughout the shuttle's, total revenue from passenger fares must cover the total operating cost of electric shuttles. Initial capital outlay required for purchasing shuttles and chargers is considered to be a "grant" and is therefore not assumed to be amortizable or recoverable out of passenger fare revenue streams.

Specific, the financial analysis objectives were to estimate:

- the capital investment required to purchase vehicles for both routes;
- the fare required for financial sustainability of both routes; and
- adequacy of passenger revenues to meet operating expenses.

6.5.1 Methodology

Steps involved in the financial calculation for each route are given below:

Step 1: Annual OPEX is estimated for the route
Step 2: Annual passengers using the shuttles for the route is estimated (see Table 6.12)
Step 3: Battery replacement costs for the entire fleet are calculated
Step 4: Cost per passenger for Year "i" is calculated using the formula given below.

$$PFi = \frac{\sum OPi + (BR/n)}{\sum Pi}$$

Where,
PFi = passenger fare in Year I (NPR/passenger);
OPi = annual OPEX in Year I (NPR);
BR = battery replacement cost of entire fleet (NPR);
N = number of years of operation; and
Pi = annual passengers for all routes in Year i.

Step 5: Check the adequacy of cumulative passenger revenue to meet the lifetime operating expenses of vehicle for the route.

6.5.2 Assumptions and inputs

General and macroeconomic parameters

General and macro-economic parameters required for the analyses are presented in Table 6.11. Note all US Dollar values (US$) in this analysis are based on a starting exchange rate of US$1 = NPR 112. The NPR is assumed to depreciate every subsequent year by the difference in the annual inflation rate between Nepal and USA, which is currently around 4%.

Table 6.11 Key parameters

Particulars	Value
Operating life of e-bus fleet (years)	10
Operating days in a year (years)	347
Average annual inflation rate in Nepal (%)	6.0
Average annual inflation rate in USA (%)	2.0
Average Forex Rate: NPR – US$ (2019)	112

Capital costs

Electric shuttles and chargers

The free on board (FOB) cost obtained from the market review is subject to shipping charges, value added tax (VAT), and customs duty. In the case of bulk purchase under a competitive bidding process, the price can be lower than the FOB rate. Based on these, the estimated landed cost of electric shuttles and chargers is calculated in Table 6.12 below. The FOB cost and the shipping cost is assumed to be from a manufacturer in China for a covered 8-seater shuttle with a lithium-ion based battery pack. In cases where customs taxes are applicable, for electric vehicles under 10 seat capacity, the applicable custom charge is not clearly stated in Nepal's official custom rate book.[56] While for buses, mini buses, and microbuses the custom rate is 1%, the highest applicable custom tax per electric vehicle is 10% for jeeps,

[56]Ministry of Finance. 2018. Customs Tariff 2017/2018. Government of Nepal.

cars, and vans (under sub-heading 8702.40.40). So, taking a conservative approach, the applicable customs rate is taken as 10%.

Table 6.12 Estimated landed cost of 8-seater shuttle and charger

Description	FOB	Competitive bidding & bulk purchase discount	Shipping	Custom	VAT	Total	Total
	(US$)	%	(US$)	%	%	US$	NPR
	A	B	C	E	F	G= [Ax(1-B) x(1+E)+C]x(1+F)]	H=G*112
Shuttle	9,500	10%	2500	10%	13%	13,452.7	1,506,697
Chargers*	225	10%	0	15%	13%	292.4	32,747

*Shipping cost of charger is included in shipping cost of the shuttle.

Operational expenses

The operational expenses assumed include maintenance costs, electricity expenditure, salaries, and miscellaneous costs (registration and renewal).

Maintenance costs

These include preventive and running costs required for general maintenance and upkeep of shuttles. It is forecasted to increase at annual inflation rate of 6%. The cost of exceptional repairs (accidents, vandalism, etc.) is excluded from the financial analysis.

Electricity costs

Based on the Nepal Electricity Authority's electricity tariff for the "Low-Voltage 230/400V Commercial" category, the cost per unit of electricity is taken as NPR 11.2. Based on historical trend data, the electricity tariff is assumed to increase by 1% annually.

Salaries expenses

This includes expenses on salaries of drivers and mechanics. It is assumed that the annual salary for a driver as well as mechanic is NPR 250,000. The salary is assumed to increase with an inflation rate of 6% annually.

Battery replacement expenses

Although lithium-based batteries have been known to last for seven to nine years, taking a conservative approach, the battery replacement for the shuttles is expected to occur at the end of six years. Replacement battery pack costs are based on the *Bloomberg New Energy Finance* (BNEF) forecast for the cost of a lithium-ion battery.[57] In 2018, the cost of a lithium-ion battery ranged between US$175 to $200 per kWh. By 2026 (i.e, the battery replacement year), if the shuttles are operated in 2020, the cost is expected to drop to US$100 per kWh.

[57] Bloomberg NEF. 2019. A Behind the Scenes Take on Lithium-ion Battery Prices. Retrieved from: https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

So, for a 12.1 kWh battery pack, the cost of replacement is expected to be US$1,210 in 2026.

Registration renewal expenses
Annual insurance costs are taken as 2% of the cost of the shuttles and the annual registration renewal charge is assumed to be NPR 10,000 per shuttle. Both are expected to increase with an annual inflation rate of 6%.

6.5.3 Key findings of the financial analysis

Initial capital requirement and annual operating expenses

Operating shuttles in route L3* require more than twice the investment than those on L4 since they have more than double the number of shuttles (cf. Table 6.13).

Table 6.13 Initial capital requirement for two recommended routes for LMC

Items	Route L4	Route L3*
Number of shuttles and chargers required	4	10
Cost per shuttle (NPR)	1,478,506	1,478,506
Cost per chargers (NPR)	28,980	28,980
Installation cost per charger (NPR)	2,898	2,898
Total Investment Required (NPR)	**6,041,536**	**15,103,836**
Total Investment Required (US$)	**53,942**	**134,855**

Table 6.14 Estimated operational expenditure for first year

Items	Route L4	Route L3*
Electricity expenditure [NPR (% of OPEX)]	139,910 (8.7%)	267,476 (6.4%)
Maintenance costs [NPR (% of OPEX)]	57,120 (3.6%)	142,800 (3.4%)
Staff cost [NPR (% of OPEX)]	1,250,000 (77.9%)	3,000,000 (71.4%)
Miscellaneous cost [NPR (% of OPEX)]	158,280 (9.9%)	791,402 (18.8%)
Total operational expenses (NPR)	**1,605,311**	**4,201,678**
Total operational expenses (US$)	**14,334**	**37,514**

Table 6.14 presents a breakdown of annual operating expenses estimated to incur in the first year of operations. Staff costs are the considered the largest expense (71% to 77% of total OPEX), while fuel expenses account for only around 6% to 9%.

Estimated cost per passenger required for financial sustainability

The table below presents the estimated fare per passenger for the first year for route L4 and L3.*
For the load factor assumed, it is estimated that this cost per passenger would just about be sufficient to cover the annual operating expenditure for that year as well as the battery bank replacement costs allocated for that year. It can be seen that cost per passenger is lower for route L4 than for route L3.* The fare accounts for a one-time battery replacement cost in Year 5. However, by Year 10, the operator will not have sufficient savings for a second battery replacement round in to extend vehicle beyond 10 years.

Table 6.15 Estimated fare per passenger for route L4 and L3*

Case	Low	Base	Medium	High

Load Factor	60%	70%	80%	90%
Estimated cost per passenger - route L4 (NPR)	15.2	13.0	11.4	10.1
Estimated cost per passenger - route L3* (NPR)	18.0	15.45	13.5	12.0

6.6 Conclusions and Recommendations

Routes L3* and L4 recommended by this study would be ideal for an electric shuttle operation servicing elderly and differently-abled passengers, in addition to tourists visiting the area. This service would support LMC's plans to pedestrianize the roads leading to various cultural sites within the Patan Durbar Square. Among the two recommended routes, L3* will require ten shuttles, mainly due to the two sub-routes within L3,* whereas L4 would require only four shuttles. Although investment will be higher (a total of NPR 21.5 million) if electric shuttles are operated on both the recommended routes, the benefits to elderly and mobility-impaired passengers, in terms of the provision of clean and efficient mobility options, would definitely be greater.

The passenger fare on both routes is lower than NPR 20 per passenger. Since this is a flat fare, passengers can enjoy any number of trips with one-time payment per day. This is extremely beneficial to the locals in the area who would otherwise have used their personal vehicles, as well as for those who would not have been able to visit different cultural sites without such a service.

In terms of battery replacement, since the operator is only aiming to recover its operational costs, battery replacement costs in Year 5 have been accounted for in the fare. However, with this fare, the operator will not have sufficient savings for a second round of battery replacement in Year 10. The operator would therefore need to seek additional funding in order to extend vehicle life through battery replacement again in Year 10.

Chapter 7. Proposal for Kathmandu's Heritage Core

7.1 Policy and Priorities

To improve ease traffic congestion and improve both environmental conditions and the overall of life, Kathmandu Metropolitan City (KMC) has planned several transport-related strategies for the future. In essence, KMC's plan is to improve public existing transport service conditions and make Kathmandu's environment favorable to pedestrians. KMC plans to achieve this by adopting a modal shift from private vehicles to public transportation, and also by effectively managing the city's traffic conditions.[58] Along these lines, recent developments by KMC include the pedestrianization of Kathmandu Durbar Square and the Thamel area, as well as the planning of cycle lanes throughout the city.[59]

The Kathmandu Durbar Square (KDS) area is both a UNESCO World Heritage site as well as a core residential area, located very close to other tourist attractions such as Swyambhunath Stupa and Thamel. Despite significant public transportation demand by locals as well as tourists, KDS currently does not have any form of public transportation services in the area. The implementation of such a service is therefore vital to serve to both the local population as well as visitors. Currently, for the majority of tourists, walking and exploring is the best way to visit KDS, but a small number of tourists, especially those who are mobility impaired, may prefer some kind of mobility option. The case is similar for local residents who have no other options except to depend on their private vehicles, especially two-wheelers.

An electric public shuttle service which traverses the core residential areas and tourist attractions, servicing locals as well as tourists, would help address this problem. Such an effective shuttle service, which needs to be designed to cater to the needs of the local population can also improve "last mile connectivity." This kind of public shuttle service would also help KMC to execute its vision of a modal shift from private to public vehicles.

This chapter begins with an identification of route options and then presents few recommended routes for an electric shuttle service around KDS. It is then followed with a discussion of research results of the electric shuttle market as well as an identification of key required specifications. An operational plan is then devised for the recommended route options and preferred shuttle type. The chapter then ends with a financial analysis section

[58] Kathmandu Metropolitan City. 2011. Kathmandu Sustainable Urban Transport Project.

[59] The Kathmandu Post. 2019. Kathmandu proposes its own 3.1 km cycle lane after Lalitpur. Retrieved from: https://tkpo.st/36mq9zv

which assesses the initial capital requirement, operational expenditures, and the expected tariff that a non-profit transport operator can charge its customers.

7.2 Route Servicing the Heritage Core of Kathmandu

7.2.1 Procedure for identifying routes

The objective of this section is to identify several routes that are suitable for running an electric shuttle service and then recommend the most viable options. This section begins with a description of several potential routes designed around KDS which are suitable for deploying an electric shuttle service. After a series of ground-level surveys and stakeholder consultations followed by a route evaluation using a simple multi-criteria analysis framework, two routes were then recommended as optimal routes for running an electric shuttle service. The steps involved in identifying the preferred routes are given below:

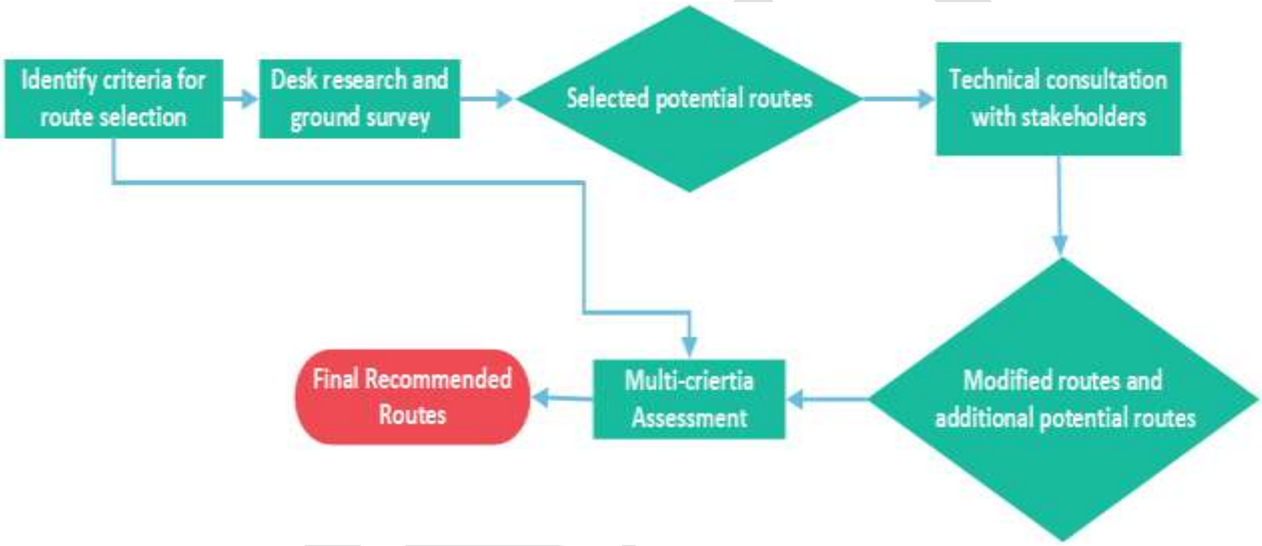

Figure 7.1 Steps involved in identifying recommended routes

Step 1: Identification of route selection criteria

A list of criteria was identified for selecting the preferred routes around KDS. Criteria used to identify potential routes can be broadly classified into two types: road criteria and demand criteria. These criteria also contain several sub-criteria which are described below:

A. Road criteria

- **Sufficient road width:** all road sections within the route should be wide enough to accommodate an electric shuttle. Routes also need to have stops[1] where passengers can board or alight the shuttles easily.
- **High quality of roads:** the overall physical quality of routes must be in good condition. Unpaved routes, or routes with a lot of potholes and speed-breakers should be avoided.
- **Adequate fluidity of traffic:** routes with heavy traffic congestion are given lower priority. Routes with road sections occupied by motorcycle parking zones and footpath shops should be avoided to all extent possible.
- **Appropriate gradient:** considering limitations in a shuttle's climbing ability, any route with a that contains a gradient above 15% is eliminated.

- **Improved mobility service:** routes which have high degree of competition from other service providers such as *safa tempos*, micro buses, etc., are not considered. Preferably, routes must pass through areas which currently do not have any other means of public transport.
- **Appropriate route length:** routes must of be of an appropriate length. The length of the entire route, including all sub-routes, is kept to under 10km. Also, if any route is short in length, then people will prefer to walk. So, the length of all routes, including sub-routes, is kept to over 1.5km in length.
- **Avoid major trunk road:** electric shuttles have a low top speed and generally do not operate above 40 km/hr. Deploying such shuttles on major trunk routes and highways alongside high-speed traffic will be dangerous and will lead to congestion. Therefore, routes with significant overlaps with major trunk routes should be avoided.

B. Demand criteria

- **Service tourist destination:** routes must pass through tourist destinations and attractions.
- **Service core areas:** routes must access core and densely populated residential areas.

Step 2: Desk research and ground survey

Based on the above identified criteria, the desk research, and ground survey, a list of potential routes around KDS were identified (cf. Section 7.2.2). Routes were first identified using Google Maps and then a ground level survey was performed to identify technical aspects.

Step 3: Technical consultation with stakeholders

The identified potential routes were then presented to stakeholders from Kathmandu Metropolitan City (LMC) for discussion. Based on stakeholders' feedback and suggestions, improvements and changes were made to the identified routes. An additional route, designed and recommended by the stakeholders, was also added as a potential option. Section 7.2.3 presents the outcome of the discussions and technical consultations in more detail.

Step 4: Multi-criteria analysis of identified routes

All identified potential routes were then analyzed using a simple multi-criteria analysis (MCA) framework to assign a numerical score to them. However, out of all the criteria identified in Step 1, only the narrowly-selected criteria were used for the MCA. Details of the MCA are presented in Section 6.2.4.

The top two scoring routes are presented as the recommended routes, for which further operational and financial analysis are carried out.

7.2.2 Potential routes identified from desk research and ground surveys

Based on the identified criteria and ground surveys, four routes were identified around KDS. Routes K1 and K4 are two linear routes, whereas routes K2 and K4 are circumferential routes.

Route K1

Route K1 consists of two linear sub-routes which intersect at the Chettrapati Roundabout. Sub-route A starts at the New Road Gate, traverses though the pedestrianized zone within the KDS area, and finally terminates at the Metropolitan Police Circle (near the Sorhakhutte bus stop). Currently, the pedestrianized zone is open only for special purpose vehicles such as ambulances, fire engines, army and police vehicles. Sub-route B connects Chettrapati to Swyambhunath - another major tourist destination and busy transport hub.

The combined route length is 4.2km in length. Sub-route A consists of one lane per direction and has narrow road sections with several busy traffic junctions such as Paknajol, Chettrapati Roundabout and Naradevi. Most road sections of Sub-route B are wide, paved, and have one lane in each direction.

This route covers major tourist destinations such as KDS, Swayambhunath Stupa, and the South Thamel area. It also connects the three major transport hubs of Sorhakhutte, New Road Gate, and Swayambhu. Sub-route A connects the core populated areas of Naradevi, Chettrapati, and Paknajol, *whicl* Sub-route B connects Swayambhunath and the residential areas of Dallu to Sub-route A. A combination of these two sub-routes means that passengers willing to travel from Swayambhu area to New Road and vice-versa can easily interchange between the two sub-routes and reach their destination.

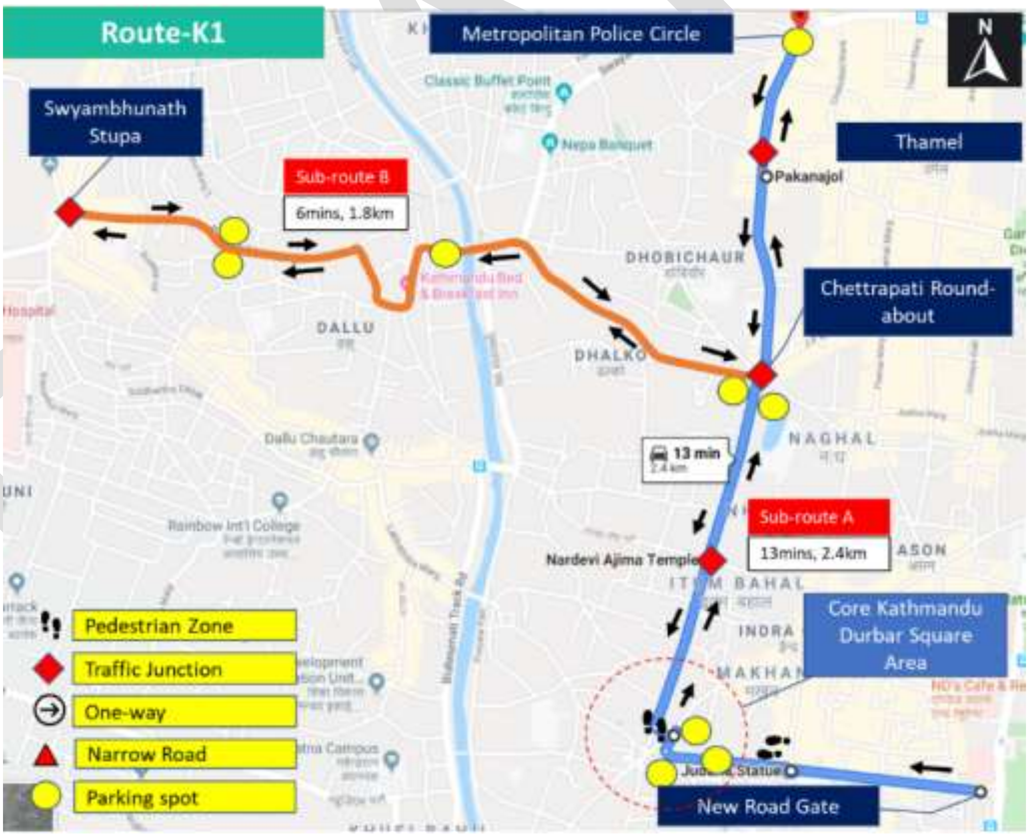

Figure 7.2 Route identified for KDS (K1)

Route K2

Route K2 is a circumferential route which encircles KDS and core areas such as Thamel, Nardevi, Chettrapati, and Paknajol. The route starts from Juddha Statue, passes through KDS, Nardevi, Chettrapati, Paknajol and Thamel, and reaches back to Juddha Statue via Thaiti.

The length of the entire route is 4.1km, the majority of which consists of narrow road sections which are used by smaller vehicles such as delivery vans, taxis, cars, and motorbikes. However, a small stretch of this route - from Sorhakhutte to the entrance point to Thamel - is a major trunk route. The route also contains several junctions that are prone to traffic congestion. One particular section in Thaiti is very narrow, allowing only one shuttle to pass at a time.

A portion of the route inside KDS is a pedestrianized zone, which is open for special purpose vehicles such as emergency, army, and police vehicles.

Figure 7.3 Route identified for KDS (K2)

Route K3

Route K3 is a relatively a longer circumferential route, passing through KDS, Chettrapati, Swayambhu, and then re-entering KDS via Dallu, a dense residential area. The entire route length is 5.7km.

The “L” shaped section from the Juddha Statue to the Chettrapati Roundabout is similar to the section in routes K1 and K2. However, when compared to K1 and K2, the coverage area of this route is also larger, as K3 covers residential and core areas toward South and East KDS. For example, Dallu in the East, Tahachal in the South-west and Maru in the South are just some of the populated residential areas serviced by this route.

The roads from Dhalkhu (near the Chettrapati Roundabout) to Swayambhu Stupa and the road from Dallu to Tahachal are major roads containing larger vehicles and fast-moving traffic.

Figure 7.4 Route identified for KDS(K3)

Route K4

Route K4 is a combination of two “L” shaped linear routes which service tourist destinations and core residential areas in the North as well as the South of KDS. Sub-route A traverses the Northern areas, while Sub-route B heads down toward the Southern areas. Route K4 also connects three major transport hubs such as Teku in the South, the Sorhakhutte Metropolitan Police Circle in the North, and New Road Gate to the East.

Route K4 is 3.9km long. Sub-route A is similar to the sections in Routes K1 and K3. A road section near KDS is paved with stones, while the remaining roads are topped with tarmac, although some sections contain potholes. The road section between New Road Gate and the pedestrianized zone of KDS is shared between both sub-routes. The pedestrianized open space within KDS can serve as the main interchange point for both sub-routes.

Figure 7.5 Route identified for KDS(K4)

7.2.3 Consultation of potential routes with stakeholders

All identified potential routes for KDS were presented to stakeholders at a technical workshop held in January. A series of discussions on all identified options indicated a strong preference by stakeholders for Route K1. The stakeholders expressed the following points underlining their preference for Route K1:

- Swayambhu is a popular destination among tourists as well as local residents. Since Route K1 presents a direct transport link from local residential areas around KDS and the tourist-dense Thamel area, a shuttle service could provide significant value.
- Passengers can travel to and from between Swayambhu and New Road via Chettrapati using the shuttles running on this route. Although there are other transport services connecting New Road and Swayambhu, a shuttle service on this route would be more direct and potentially even faster.

7.2.4 Multicriteria assessment of identified routes

Routes contain many complex characteristics and identifying the most suitable option for stakeholders' needs calls for a more formalized approach. To make route identification easier, route characteristics were first qualitatively assessed against a set of key criteria which were designed to assess the optimal operation of an electric shuttle service (cf. Section 6.2). Except for the "appropriate gradient" and "appropriate route length" criteria, all other criteria were used to compare route options K1, K2, and modified K3 and K4. Numerical scores were then assigned to each route, based on a comparative analysis.

Steps in the analysis included the following:

- A five-point score scale was developed in order to assign a relative score for all four routes against the selected criteria identified at the beginning of Section 6.2.
- The five-point scores obtained by all each route were then multiplied by the weight of the criterion to get a score per criterion. For simplicity, equal weights were considered for all the criteria, as presented in Table 6.2. Overall scores for all routes with in each criterion are illustrated in Figure 6.7
- The final score for each route was obtained by adding all the scores received by the route for each of the seven criteria, as illustrated in
- Table **6.3**.

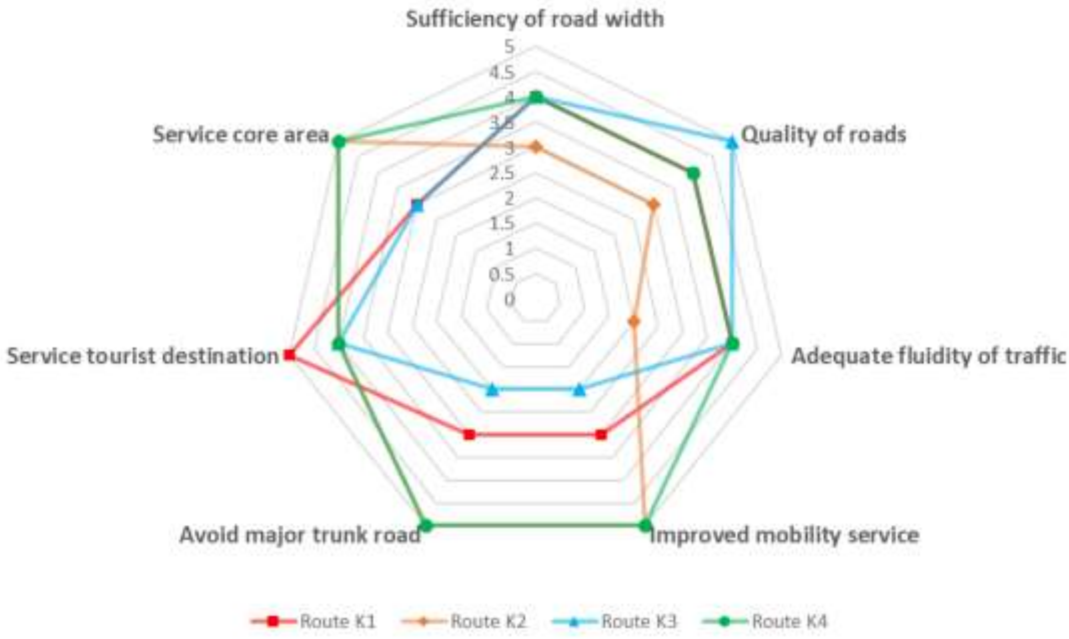

Figure 7.6 Scores received by all the routes identified for KDS.

Scoring was carried out on a relative basis, meaning that all routes are compared against each other for a particular criterion. A score of 1 corresponds to “unsuitable/unfavorable route conditions” of while a score of 5 represents “highly favorable conditions.”

For example, while scoring for the sufficiency of road width criterion, routes with wide roads along all the sections are assigned a score of 5, while routes where the majority of sections contain very narrow roads are given a score of 1. Similarly, routes which are paved with asphalt along most sections and/or do not have many potholes are assigned a score of 5.

For the criterion “increased fluidity of traffic,” routes with heavy traffic congestion and sections that contain motorcycle parking zone are given lower scores. The “improved mobility service” criterion captures the additional benefit or value added by the shuttle service in the form of a new public transport service. If the majority of the route sections route do not have any form of public transport service available, then they receive the highest score of 5. Considering their limited top speed, electric shuttles are not safe for deployment along major trunk routes. Therefore, routes which have a large number of road sections falling on major trunk routes are given the lowest score.

The real beneficiaries of this shuttle service are local residents near KDS as well as tourists visiting PDS. So, for the demand criteria, if the route traverses many-densely populated core residential areas, it is awarded the highest score. Similarly, if the route contains relatively more tourist destinations, it is also assigned a higher score.

Table 7.1 Scores given to all routes for all criteria

Criteria	Route K1	Route K2	Route K3	Route K4
Sufficiency of road width	4	3	4	4
Quality of roads	4	3	5	4
Adequate fluidity of traffic	4	2	4	4
Improved mobility service	3	5	2	5
Avoid major trunk road	3	5	2	5
Service tourist destination	5	4	4	4
Service core area	3	5	3	5

Table 7.2 Weightage of each criterion

Criterion	Weightage
Sufficiency of road width	14%
Quality of roads	14%
Adequate fluidity of traffic	14%
Improved mobility service	14%
Avoid major trunk road	14%
Service tourist destination	14%
Service core area	14%
Total	100%

Table 7.3 Final total score received by all routes

	Route K1	Route K2	Route K3	Route K4
Total	3.7	3.9	3.4	4.4
Rank	3	**2**	4	**1**

With a total score of 4.4, Route K4 is the highest scoring route, which is followed by Route K2 in second place with a score of 3.9. Result of the analysis are presented in Table **7.**7.3.

7.2.5 Recommended routes for Kathmandu Durbar Square

From the multicriteria assessment (MCA), routes K4 and K2 were identified as the two most preferred route options for an electric shuttle service. However, consultation with stakeholders revealed their preference for Route K1, which received the third highest score in the MCA. Considering stakeholders' significant knowledge of local transportation demand, road conditions, as well as existing traffic conditions, Route K2 was replaced by Route K1 which was preferred by the stakeholders as one of the two most recommended options. Route K1 and Route K4 then become the final two recommended routes for KDS, the details of which are presented in Figure 7.6 and 7.7 respectively. The yellow dots along the route indicate places of interest and tourist sites. These two routes are analyzed for operational and financial performance in the following sections.

Figure 7.7 First recommended route for KMC (Route K4)

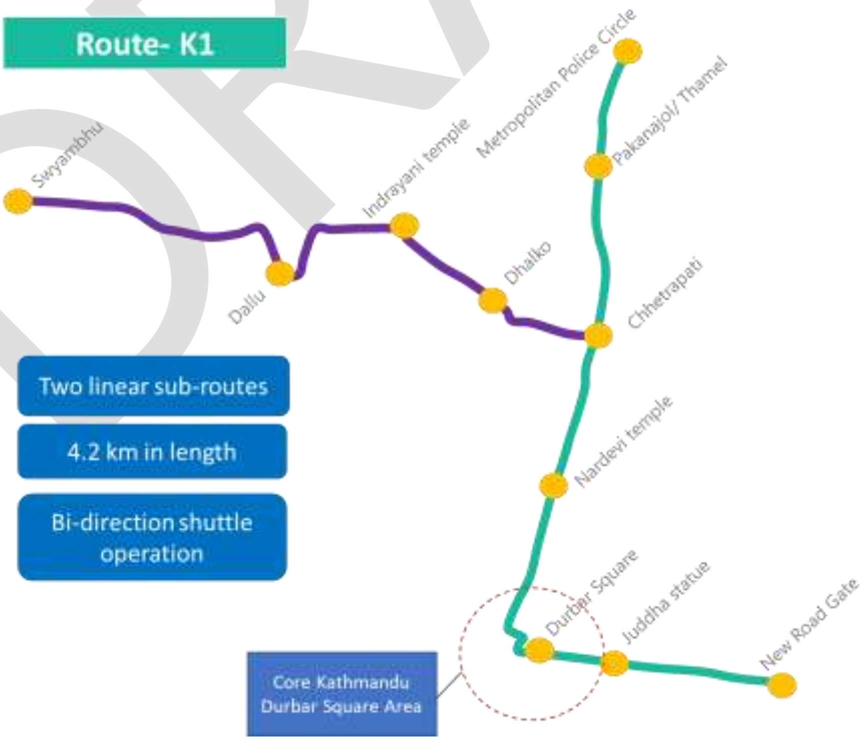

Figure 7.8 Second recommended route for KMC (Route K1)

7.3 Market Review of Electric Shuttles and Proposed Specifications

In this section, a range of electric shuttles available in the market are identified. The shuttles, along with their key specifications, are presented in Table 6.4. Reviews were based on online market surveys, followed by direct enquiries in the case of a few manufacturers. In addition to the models and manufacturers mentioned here, many other manufacturers and models are available in the market. The objective of this review is to draw the reader's attention to the wide range of electric shuttle models available in the market.

Our maarket review focused on several shuttle models, such as the golf cart, open sightseeing, and closed sightseeing types. Also, shuttles powered by lead acid-based batteries were available globally. This review is strictly limited to shuttles powered by lithium-ion batteries.

7.3.1 Vehicles identified from market review

The table below lists some electric shuttle models identified in our market review. Models have a seating capacity of between 3 to 13 passengers, excluding the driver. Broadly, they can be categorized as golf cart type, closed sightseeing type, and open sightseeing type.

Table 7.4 Selected electric shuttle models identified in our market review

Option-S1		
	**Shuttle make [Country] / Model**	Lvtong [China] / LT-A8+3.A
	Shuttle type	Golf cart type, open
	Dimension (mm)	4120*1200*1900
	Battery size/range	12.1 kWh, 90-100km
	Battery type	LiFeP04
	Ground clearance (mm)	100
	Seating	11+1
	Gradeability	15%
	Energy consumption	9 kWh/100km
	Charger	Off-board
	Maximum speed	25km/h
	Price (US$)	6,800 (FOB Shenzhen)
Option-S2[60]		
	**Shuttle make [Country] / Model**	Smart Car [USA] / SC6-48
	Shuttle type	Golf cart type, Open
	Dimension (mm)	3352*1219*8
	Battery size/Range	N/A / 190km
	Battery type	LiT® Advanced Lithium iron phosphate
	Ground clearance (mm)	114
	Seating	5+1
	Gradeability	35%
	Energy consumption	N/A

[60] Smart EV. 2019. Retrieved from: https://www.smartcartev.com/product/sc6-48/

	Charger	On Board – Delta Q
	Maximum speed	45
	Price (US$)	N/A
Option-S3		
	**Shuttle make [Country] / Model**	Hefei Huanxin Technology Development [China] / S8.F
	Shuttle type	Sightseeing Type, open
	Dimension (mm)	4230*1480*2100
	Battery size/Range	N/A / 90km
	Battery type	Lithium-ion based
	Ground clearance (mm)	180
	Seating	8+1
	Gradeability	20%
	Energy consumption	10.5 kW/100 km
	Charger	Off-board
	Maximum speed	30 km/h
	Price (US$)	10,650
Option-S4		
	**Shuttle make [Country] / Model**	Lvtong [China] / LT-S8.HAF
	Shuttle type	Sightseeing Type, closed
	Dimension (mm)	4185*1490*2010
	Battery size/Range	10.8 kWh / 90-90 km
	Battery type	Lithium-ion based
	Ground clearance (mm)	150
	Seating	8+1
	Gradeability	15%
	Energy consumption	10 kWh/100 km
	Charger	Off-board
	Maximum speed	30 km/h
	Price (US$)	9,400 (FOB Shenzhen)
Option-S5		
	**Shuttle make [Country] / Model**	Lvtong [China] / LT-S11.B
	Shuttle type	Sightseeing Type, open
	Dimension (mm)	4590*1480*2100
	Battery size/Range	12 kWh/ 90-100 km
	Battery type	Lithium-ion based
	Ground clearance (mm)	180
	Seating	11+1
	Gradeability	20%
	Energy consumption	12 kWh/100 km
	Charger	Off-board charger
	Maximum speed	30 km/h
	Price (US$)	9,800 (FOB Shenzhen)
Option-S6		
	Shuttle make [Country] / Model	Lvtong [China] / LT-S14.F

	**Shuttle type**	Sightseeing Type, closed
	Dimension (mm)	5100*1560*2010
	Battery size/Range	18 kWh / 80-100 km
	Battery type	Lithium-ion based
	Ground clearance (mm)	170mm
	Seating	13+1
	Gradeability	18%
	Energy consumption	14 kWh/100km
	Charger	Off-board charger
	Maximum speed	30 km/h
	Price (US$)	11,400 (FOB Shenzhen)
Option-S7[61]		
	**Shuttle make [Country] / Model**	Mahindra [India] / Treo Yaari
	Shuttle type	Tempo
	Dimension (mm)	2746*995*1757
	Battery size/Range	3.69 / 129 km
	Battery type	Lithium-ion
	Ground clearance (mm)	N/A
	Seating	4+1
	Gradeability	N/A
	Energy consumption	N/A
	Charger	N/A
	Maximum speed	24 km/h
	Price (US$)	2,280 (ex-showroom,India)

7.3.2 Required basic specifications

On the basis of the electric shuttle makret review, key shuttle features were extracted and discussed with the stakeholders to identify the most appropriate features required. In additions, since specifications alone cannot be driven by market availability, the actual realities of route surface conditions on and service demand must be taken into account. Therefore, it is also imperative to consider all technical aspects of the routes, such as road width, ground clearance, and available turning radius when designing the technical specifications.

Table 7.2 delineates the basic proposed electric shuttle and charger specifications. Specifications were designed in such a way that all desired electric shuttle components and features can be supplied by manufacturers without any difficulty.

[61] Rushlane. 2018. Retrieved from: https://www.rushlane.com/mahindra-treo-3-4-seater-electric-rickshaw-launch-12287590.html

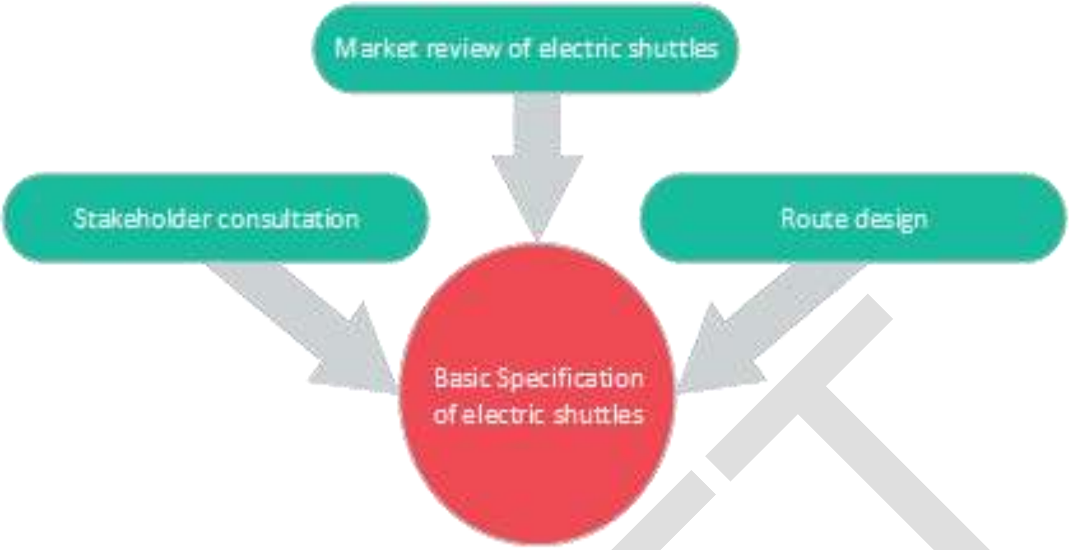

Figure 7.9 Block diagram of technical specification design process

Table 7.5 Proposed basic technical specification of electric shuttles

Dimensions	Proposed Specification
Length (mm)	4000 ± 300
Width (mm)	1400 ± 100
Height (mm)	Not more than 2500
Ground clearance (mm)	At least 150
Seating capacity	At least 8 passengers excluding driver
Gross vehicle weight (kg)	To be specified by manufacturer
Chassis	Proposed Specification
Chassis/frame material	*Metal based*
Battery Bank and Energy Consumption	Proposed Specification
Type of battery	Lithium-based battery
Battery bank size (Watt-hour)	At least 12,000
Minimum battery life	At least 5 years of guarantee
Battery management system	Required. Preferably with: 1. Over-voltage, under-voltage, and temperature protection 2. Charging control mechanism 3. Insulation monitoring between battery and frame and power supply shutdown from battery in event of insufficient insulation 4. Data monitoring and communication with PC
Range	At least 90km in a single full charge for specified GVW on a flat road at 20 km/hr
Powertrain and Electrical Components	Proposed Specification

Motor size	Motor capacity should be sufficient to: 1. Reach top speed of 45 km/hr on a flat road at GVW 2. Maintain gradeability of at least 15 % at GVW
Motor type	To be specified by manufacturer
Motor controller	Required
Vehicle Body System	Proposed Specification
Front suspension	At least spring type
Front shock absorber	At least hydraulic-type shock absorber
Rear suspension	At least spring type
Service brake	Disk brake
Parking brake	Required
Minimum turning radius	Not more than 6.5m
Steering position	RHD
Steering	Assisted power steering
Seat material	Artificial leather or cloth
Roof material	High-tensile steel, welded, high strength
Body side covering	High-tensile steel, welded, high strength
Front windshield	High-strength, laminated, transparent glass
Rear windshield	High-strength, laminated, transparent glass
Number of doors	At least two doors on each side (including for driver)
Door material	High-strength, laminated or tempered transparent glass mounted on metal column
Window type	Slidable window attached to door body
Dashboard	Proposed Specification
State of charge meter	Required
Speedometer	Required
Motor/Engine problem system	Required
Front windshield wiper	Required
Safety Features	Proposed Specification
Passenger exit doorbell	Required
CCTV surveillance system	Preferable
Front and rear bumpers	Required
ABS	Preferable
Other Features	Proposed Specification
Gradient/climbing ability at GVW (%)	At least 15%
Top speed at GVW	At least 45 km/hr
Cooling/heating system	Air conditioner
Public announcement system	Preferable
Battery Charger	Proposed Specification
Type of battery charger	On-board or off-board AC to DC charger
Capacity of battery charger (Watt)	At least 1,200
AC input, Frequency	230V, 50 Hz
Power Factor	At least 0.98 at nominal input current

Display	LED or LCD-based indicator panel showing SOC of battery/faults
Reverse polarity protection	Required
Battery temperature compensation	Required
Enclosure	At least IP46 rated
Charging algorithm	Should be suitable for charging proposed lithium-based battery pack. Constant current and constant voltage charge setting should be strictly suitable for the proposed battery bank cell type
Over-temperature and under-temperature protection	Required (should stop charging below0°C and above 45°C)
Short circuit protection	Required
Over-charge protection	Required (depending on the cell material of the battery pack, charger should stop if the voltage per cell rises higher than specified safety limit of the cell)
Over-discharge protection	Required (depending on the cell material of the battery pack, discharge should stop if the voltage per cell falls below the specified safety limit of the cell)

7.4 Operational Plan for Proposed Routes and Vehicles

This section presents all operational aspects in relation to running an electric shuttle service on both recommended routes for KDS, and includes an analysis on the:

- total number of shuttles required to maintain fixed headway time;[62]
- estimated total annual number of passengers carried by shuttles;
- estimated annual energy consumption and related expenditure;
- proposed battery charging scheme; and
- proposed location of depot where shuttles are parked overnight and charged.

7.4.1 Methodology

An appropriate method for estimating the required electric shuttle fleet size would be to first evaluate transportation demand as well as all characteristics of the service area. This will provide an estimation of the extent to which a shuttle service can be provided. Based on this, the number of shuttles needed in the route can then be calculated.

[62] Time between shuttle arrival at a stop.

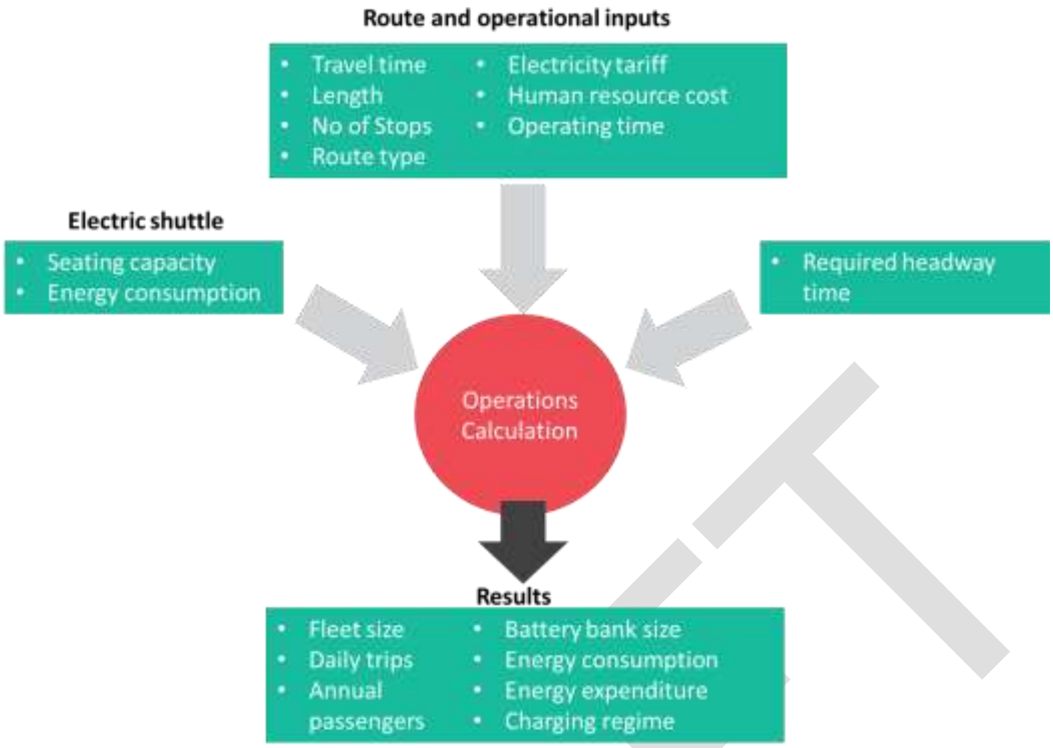

Figure 7.10 Block diagram of operational analysis

However, estimating overall transportation demand in KMC falls beyond the scope of the study. Given the high population density around KDS, if demand were to be assessed, a large number of shuttles would be required if the shuttle service were to be considered as the primary service provider in the area. As reiterated by stakeholders during the consultations, adding a large number of shuttles would only serve to exacerbate traffic congestion. Therefore, the proposed service would focus on narrowly targeting tourists, as well as mobility-impaired and elderly residents only. This would then ensure that the overall number of shuttles don't increase unnecessarily.

Estimating fleet size

Headway time was taken as the basis for estimating the electric fleet size. For example, for any particular route or sub-route, depending on other technical parameters such as length, time taken for one round trip, number of stops etc., the required fleet size for that route or sub-route is the minimum number of shuttles required to maintain the proposed headway time . After estimating the fleet size and using the assumptions and inputs (cf. Table 6.6), other operational aspects such as annual passenger and annual vehicle kilometers traveled (VKT) were then estimated accordingly.

Estimating number of passengers served

The annual number of passengers expected to use the shuttle service is estimated using the formula below:

$$Px = Dx * \mathrm{Si} * \mathrm{Ti} * \mathrm{P} * \mathrm{LFi}$$

Where,

Px = passenger number in Year x;

Dx = number of days of operation in Year x;

Si = number of shuttles in route I;

Ti = number of trips by a shuttle per day in a route I;
P = seating capacity of a shuttle; and
LFi = load factor for a shuttle in route i (%).

Since K4 and K1 have two sub-routes, and since the number of shuttles operating along the sub-routes and the number of trips completed by them are different, the above equation is deployed separately for both sub-routes. The final estimated annual number of passengers for each route is then the total number of passengers annually, estimated for both sub-routes.

The load factor reflects the capacity utilization of shuttle services. A high load factor indicates a higher percentage of available seating capacity is filled with passengers, and vice-versa. Four scenarios are created which reflect a load factor ranging between 60% to 90%, with 70% taken as the base case.

7.4.2 Assumptions and input

To calculate those operational details associated with both routes for LMC, several assumptions and data were used which are described in Table 7.3 below.

The time taken to travel along the route was obtained from a route survey conducted by GGGI. Other factors such as time taken for passengers to board and alight as well as any delay due to congestion were also considered to estimate the actual time required by a shuttle to service the route. Data related to electric shuttles and chargers were obtained by contacting regional vendors. The electricity tariff was taken as set by the Nepal Electricity Authority for the “Commercial” consumer category.[63] The operational number of days per year is assumed to be 347 and the seating capacity is assumed to be 8 per shuttle.

Table 7.6 below lists those assumptions made to calculate all operational details for Route K4 and Route K1. For both routes, their sub-routes are linear, meaning that shuttles *must* return to the starting point. For this reason, shuttles will need to be operated in both directions.[64] To estimate the time required for a single round trip, travel time obtained from Google Maps is then added to the time it takes for passengers to board and alight the shuttle, in additional to the average expected delay due to traffic congestion, which was obtained from the route survey.

[63] NEA. 2019. *Annual Report of Nepal Electricity Authority*. Retrieved from: https://www.nea.org.np/annual_report.
[64] Currently, there is a time sensitive, one-way policy on the section between Gabahal and near Gwarkho, preventing shuttles operating in both directions.

Assumptions and inputs for routes K4 & K1

Table 7.6 Assumption and inputs for analysis of Route K4 operational aspects

Description	Unit	Route K4		Route K1	
		Sub route A	Sub route B	Sub route A	Sub route B
Route					
Type of route		Linear route with shuttles operating in both directions		Linear route with shuttles operating in both directions	
Route length (one way)	km	2.4	1.5	1.6	1.8
Travel time by car under normal traffic conditions (one way)	mins	18	12	18	9
Average number of stops per trip (one way)	stops	10	10	10	10
Time taken to board and alight passengers (one way)	mins	5	5	5	5
Delay due to traffic congestion (one way)	mins	5	5	5	5
Service start time	A.M	8:00	8:00	8:00	8:00
Service end time	P.M	20:00	20:00	20:00	20:00
Proposed headway	mins	10	10	10	10
Lunch break	mins	40	40	40	40
Operating days per year	days	347	347	347	347
Electric shuttle					
Passenger carrying capacity of shuttle excluding driver	people	8	8	8	8
Specific energy consumption of shuttle	kWh/km	0.1	0.1	0.1	0.1
Electric vehicle supply equipment (EVSE) and electricity					
EVSE system efficiency	%	85%	85%	85%	85%
Average cost of electricity per unit	NPR	11.2	11.2	11.2	11.2

7.4.3 Results of operational calculations

Required fleet size, trips per day and estimated passengers served annually

Table 7.7 Operational aspects for option K4 and option K1

Description	Route K4			Route K1		
	Sub route A	Sub route B	Total	Sub route A	Sub route B	Total
Number of shuttles needed	6	5	11	6	4	10
Number of round trips completed by a single shuttle per day	12	15	-	12	17	-
Estimated annual vehicle kilometers traveled (VKT) by entire fleet	119,923	78,075	197,998	79,949	84,946	164,894

To maintain a headway time of 10 mins, 11 units of electric shuttles are required for Route K4. For Route K1, a total of 10 electric shuttle units are needed for both sub-routes. A single shuttle is estimated to complete 12 round trips and 15 round trips per day for the sub-routes in K4. For Route K1, the estimated total number of round trips per day for sub-route A is 12 trips and for sub-route B, the estimated total number is is 17 trips. The estimated annual vehicle kilometers traveled and the expected number of passengers served per vehicle annually are presented in

Table 7.7.

Four scenarios are created which reflect a load factor ranging between 60% to 90%, with 70% taken as the base case. Using these, the rounded figure illustrating the estimated number of passengers serviced annually in both routes are presented in
Table 7.8.

Table 7.8 Estimated passengers served annually w.r.t load factor

Load Factor	Route K4	Route K1
60% (Low load scenario)	244,000	233,000
70% (Base scenario)	285,000	272,000
80% (Medium load scenario)	326,000	310,000
90% (High load scenario)	367,000	349,000

Battery bank size, charging scheme and annual energy expenditure on energy

Battery bank size

The average specific DC energy consumption of an 8-seater shuttle, as gathered from the market review, was found to be around 0.1 kWh/km.[65] To obtain the total DC energy consumption per shuttle for a particular route in a single day, the specific DC energy consumption was multiplied by the estimated total distance traveled per shuttle in a day. For estimating the required minimum battery bank size, 30% additional capacity was added to the expected daily DC energy consumption value.

The DC energy consumed by a single shuttle for Route K4 and K1, as well as the required minimum battery bank size, are presented in the Table 7.9 below.

Table 7.9 Daily DC energy consumption and required battery bank size

Description	Unit	Route K4	Route K1
DC energy consumption by shuttle per day	kWh	4.5-5.8	3.8 – 6.1
Reserve in case of emergency	%	30	30
Required battery bank size	kWh	5.8- 7.5	4.9 – 7.9

[65] DC energy refers to the energy drawn into and out of battery pack. It does not include electric vehicle supply equipment (EVSE) losses. AC energy consumption is the sum of DC energy consumption and the associated losses of EVSE. When calculating battery bank size, DC energy consumption is used. However, for estimating a total annual electricity bill, AC energy consumption is used.

Charging scheme

Three different charging regimes are currently in operation around the world. These include:

- overnight charging at the depot, allowing a full re-charge;
- an opportunistic charging regime whereby buses would be charged at intermediate stops along the route by fast chargers;
- terminal station-based charging regimes whereby buses would be charged by fast chargers present at terminal stations (or at selected stops).

The following key points were considered while deciding the charging scheme:

- The rate at which energy can be delivered into the batteries depends on the size/capacity of the charger, the size of the battery (C rating, ampere-hour rating) and the cell construction material of the battery being charged.
- From the market review, it was observed that, unlike currently-available electric vehicles which are charged by high-capacity, off-board chargers with pre-defined standards such as CHAdeMo, CCS, GB/T etc., electric shuttles generally use much smaller chargers with a capacity ranging from 1 kW to 1.5 kW.

Given the capacity limitation of electric shuttle chargers available in the market, shuttles with a 10 kWh battery pack will need 6.6 to 10 hours in order to fully charge empty batteries. And given the long length of time required to charge the batteries, the implication here is that any charging scheme other than the overnight charging at the depot is simply not feasible.

Table 7.10 Energy consumption and related expenditure

Description		Route K4	Route K1
DC energy consumption by shuttle per day	kWh	4.5-6.7	3.8 – 6.1
AC energy consumption by shuttle per day	kWh	5.3 -6.8	4.5 – 7.2
Annual electricity consumption by entire fleet for both sub-routes	kWh	23,294	19,399
Annual expenditure on electricity for both sub-routes	NPR	260,892	217,273

7.4.4 Depot location

During the stakeholder consultation, it was discussed that KMC's land owned in Teku is available for establishing a depot. A scrap yard is present on the land currently, and if needed, space can be cleared for overnight parking and charging of shuttles. Proposed location of depot is only 650m from Route K4 and 1.5 km from Route K1.

Figure 7.11 Proposed location of depot for overnight parking and charging

7.5 Financial Performance of Vehicles on the Proposed Route

In this section, the results of the financial analysis of the recommended routes K4 and K1 for KMC are presented.

Since it is KMC's intention to provide a service-oriented rather than profit-oriented operation, Therefore, classic financial metrics such as IRR, NPV, payback period are replaced by an approach favoring *financial sustainability*. In other words, throughout the life of the shuttles, the total revenue from passenger fares must cover the total operating cost of electric shuttles. Initial capital investment needed for purchasing shuttles and chargers is considered to be a grant and is therefore not assumed to be recovered from passenger fare revenue streams.

The specific objectives of the financial analysis are to estimate the:

- capital investment required to purchase vehicles for both routes;
- fare required for financial sustainability in both routes; and
- adequacy of passenger revenues to meet operating expenses.

7.5.1 Methodology

The steps involved in the financial calculation for each route given below:

Step 1: Annual OPEX is estimated for the route
Step 2: Annual passengers using the shuttles for the route is estimated (cf. Table 6.12)
Step 3: Battery replacement costs for the entire fleet is calculated
Step 4: Cost per passenger for Year "i" is calculated using the formula given below.

$$PFi = \frac{\sum OPi + (BR/n)}{\sum Pi}$$

Where,
PFi = passenger fare in Year I (NPR/passenger);
OPi = annual OPEX in Year I (NPR);
BR = battery replacement cost of entire fleet (NPR);
N = number of years of operation; and
Pi = annual passengers for all routes in Year i.

Step 5: Check the adequacy of cumulative passenger revenues to meet the lifetime operating expenses of the vehicle along the route.

7.5.2 Assumptions and inputs

General and macroeconomic parameters

Both general and macroeconomic parameters required for the analyses are presented in Table 7.11. Note that all US Dollar values (US$) in this analysis are based on a starting exchange rate of US$1 = NPR 112 and the NPR is assumed to depreciate every subsequent year by the difference in the annual inflation rate between Nepal and USA, which is currently around 4%.

Table 7.11 Key parameters

Particulars	Value
Operating life of e-bus fleet	10 years
Operating days in a year	347 days
Average annual inflation rate in Nepal	6.0%
Average annual inflation rate in USA	2.0%
Average Forex Rate: NPR – US$ (2019)	112

Capital costs

Electric shuttles and chargers

The free on board (FOB) cost obtained from the market review is subject to shipping charges, value added tax (VAT), and customs duty. In cases of bulk purchase under competitive bidding, the price can be lower than the FOB rate. Based on these assumptions, the estimated landed cost of an electric shuttle and charger is calculated in Table 7.12 below. Both the FOB cost and the shipping cost is from a manufacturer in China for a covered 8-seater shuttle with a lithium-ion based battery pack. In the event of applicable customs tax, for electric vehicles under a 10-seat capacity, the applicable custom charge is not clearly stated in Nepal's official custom rate book.[66] However, for buses, mini buses, and micro-buses, the customs rate is 1%, and the highest applicable custom tax for electric vehicle is 10% for jeeps, cars ,and vans (under sub-heading 8702.40.40). So, taking a conservative approach, the applicable customs rate is assumed at 10%.

[66] Ministry of Finance. 2018. Customs Tariff 2017/2018. Government of Nepal.

Table 7.12 Estimated landed cost of an 8-seater shuttle and charger

Description	FOB	Competitive bidding & bulk purchase discount	Shipping	Custom	VAT	Total	Total
	(US$)	%	(US$)	%	%	US$	NPR
	A	B	C	E	F	G= [Ax(1-B) x(1+E)+C]x(1+F)]	H=G*112
Shuttle	9,500	10%	2500	10%	13%	13,452.7	1,506,697
Chargers*	225	10%	0	15%	13%	292.4	32,747

*Shipping cost of charger is included in shipping cost of the shuttle.

Operational expenses

The operational expenses assumed include maintenance costs, electricity expenditure, salaries, and miscellaneous costs (registration and renewal).

Maintenance costs

These include preventive and running costs required for general maintenance and upkeeping of shuttles. It is forecasted to increase at annual inflation rate of 6%. The cost of exceptional repairs (accidents, vandalism, etc.) is excluded from the financial analysis.

Electricity costs

Based on the Nepal Electricity Authority's electricity tariff for the "Low-Voltage 230/400V Commercial" category, the cost per unit of electricity is taken as NPR 11.2. Based on historical trend data, the electricity tariff is assumed to increase by 1% annually.

Salaries expenses

This includes expenses on salaries of drivers and mechanics. It is assumed that the annual salary for a driver as well as mechanic is NPR 250,000. The salary is assumed to increase with an inflation rate of 6% annually.

Battery replacement expenses

Although lithium-based batteries have been known to last for seven to nine years, taking a conservative approach, the battery replacement for the shuttles is expected to occur at the end of six years. Replacement battery pack costs are based on the *Bloomberg New Energy Finance* (BNEF) forecast for the cost of a lithium-ion battery.[67] In 2018, the cost of a lithium-ion battery ranged between US$175 to $200 per kWh. By 2026 (i.e, the battery replacement year), if the shuttles are operated in 2020, the cost is expected to drop to US$100 per kWh. So, for a 12.1 kWh battery pack, the cost of replacement is expected to be US$1,210 in 2026.

[67] Bloomberg NEF. 2019. A Behind the Scenes Take on Lithium-ion Battery Prices. Retrieved from: https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

Registration renewal expenses
Annual insurance costs are taken as 2% of the cost of the shuttles and the annual registration renewal charge is assumed to be NPR 10,000 per shuttle. Both are expected to increase with an annual inflation rate of 6%.

7.5.3 Key findings of the financial analysis

Initial capital requirement and annual operating expenses

The total up-front investment required for operating the shuttle services for both recommended routes are presented in Table 7.13 below. Since the number of shuttles needed is almost same for Route K4 and K1, the initial capital requirement for both routes also do not vary hugely.

Table 7.13 Initial capital requirement for both recommended KMC routes

Items	Route K4	Route K1
Number of shuttles and chargers needed	11	10
Cost per shuttle (NPR)	1,478,506	1,478,506
Cost per chargers (NPR)	28,980	28,980
Installation cost per charger (NPR)	2,898	2,898
Total investment required (NPR)	**16,924,323**	**15,385,748**
Total investment required (US$)	**151,110**	**137,372**

Table 7.14 below provides breakdown of the annual operating expenses estimated during the first year of operations. Staff cost represent the largest expense, at around 71-72 % of the total OPEX, while fuel expenses account for around only 5-6%.

Table 7.14 Estimated operational expenditures for the first year

Items	Route K4	Route K1
Electricity expenditure [NPR (% of OPEX)]	260,892 (5.7%)	217,273 (5.2%)
Maintenance costs [NPR (% of OPEX)]	157,080 (3.5%)	142,800 (3.4%)
Staff costs [NPR (% of OPEX)]	3,250,000 (71.4%)	3,000,000 (72.1%)
Miscellaneous costs [NPR (% of OPEX)]	882,947 (19.4%)	802,679 (19.3%)
Total operational expenses (NPR)	**4,550,918**	**4,162,751**
Total operational expenses (US$)	**40,633**	**37,167**

Estimated cost per passenger required for financial sustainability

Table 7.15 below presents the estimated fare per passenger for the first year for both Routes K4 and K1. For the load factor assumed, it is estimated that the cost per passenger would just be sufficient to cover the annual operating expenditure for that year and the battery bank replacement cost allocated for that year. It can be seen that the cost per passenger is lower for Route K1 than for Route K4. The fare accounts for a one-time battery replacement cost in Year 5. At Year 10, however, the operator will not have sufficient savings for a second battery replacement round in order to extend the vehicle life beyond ten years.

Table 7.15 Estimated fare per passenger for Route K4 and K1

Case	Low	Base	Medium	High
Load factor	60%	70%	80%	90%
Estimated cost per passenger - Route K4 (NPR)	19.9	17.1	14.9	13.3
Estimated cost per passenger - Route K1 (NPR)	19.1	16.4	14.3	12.7

7.6 Conclusions and Recommendations

Two potential routes, K4 and K1, have been identified as preferred routes for the operation of shuttle services. Route K4 services N-S areas of KDS, connecting major tourist attractions as well as transport hubs such as Teku to Sorhakhutte and New Road. K4 is preferable if the intention is to serve more of the local population in the core area. If shuttles are implemented along Route K1, elderly and mobility-impaired residents as well as tourists will be able to access Swayambhu easily, which is a very popular cultural site.

Even when the load factor of the vehicles is at a minimum of 60%, passengers would not have to pay more than a NPR 20 flat fare on both routes. This proves that for the elderly and mobility-impaired, local residents, and tourists, this will be a more affordable option when compared to taxis.
In addition, this is an extremely beneficial service to the locals in the area who would otherwise have used their own personal vehicles.

In terms of battery replacement, since the operator is only aiming to recover its operational costs, battery replacement costs in Year 5 has been accounted for in the fare. With this fare, however, the operator will not have any savings for a second battery replacement round in Year 10 and the operator would have to seek funding to extend the vehicle life by replacing the batteries again in Year 10.

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Chapter 8. Environmental and Socio-Economic Benefits and Risks

This study focuses on ensuring compliance with both environmental and social safeguard regulations as stated in the *Constitution of Nepal* (2015). This study is also in alignment with the *Constitution* which states that equal access to transportation facilities, in addition to systematic and safe transport options for differently-abled persons is a priority for Nepal. Environmentally-friendly transport technologies will also be given priority, while a modal shift to the use of public transportation will be encouraged. Furthermore, ensuring alignment with the *United Nations Sustainable Development Goals* (SDGs) and the most commonly-recognized environmental and social safeguard frameworks, such as the *World Bank Environmental and Social Framework* required by international investors and financiers, the study has carried out a preliminary review of potential ESS risks and opportunities. This includes a focus on gender and social inclusion, the environment, and climate change.

This section is created to ensure policy makers, investors, and other stakeholders that environmental and social benefits need not be regarded as “trade-offs” for the financial and technological viability of the project. On the contrary, significant net positive environmental and social co-benefits are expected from the intervention. Furthermore, deliberate actions can further maximize positive outcomes. Some of these opportunities are highlighted below, while additional project development considerations at later stages can generate further positive outcomes, not just in the mobility and tourism sector, but also for society and the economy at large.

The following section is structured into an assessment of the environmental benefits and risks, followed by an examination of the socio-economic benefits and risks.

8.1. Environmental and Climate Benefits

8.1.1. Background

Kathmandu’s air pollution levels have been on the rise, in line with an increasing number of vehicles. In addition to air pollutants, greenhouse gas emissions have also jumped, by 127% between 2007 and 2014.[68] To compound the problem, the transport sector has the highest energy-related emissions in the country, caused by increasing levels of petroleum consumption. The sector contributed 1,709 kilo tons of CO_2 in 2011, or 36% of total national

[68] World Bank 2019. CO2 Emissions From Transport (% of total fuel combustion). World Bank Group.

CO_2 emissions.[69] In addition, the World Bank has estimated that transport sector emissions have increased to 44% of the country's total emissions in 2014.[70]

In Kathmandu Valley, the 24-hour average exposure to fine particulate matter (PM2.5) according to the Department of the Environment was 226 μg/m³ in 2017, close to nine times higher than the WHO standard of 10 μg/m³.[71] The growing number of fossil fuel-powered vehicles in Nepal has had a severe negative impact on both the quality of the environment and the country's. Air quality, has been particularly low in Kathmandu Valley during the dry season, especially due to PM10 and PM2.5 emissions. The annual average exposure to PM2.5 in Nepal was recorded at 99.73 μg/m³ in 2017 by the *Global Burden of Disease Study*, close to ten times higher than the WHO standard of 10 μg/m³.[72] In addition, Nepal was ranked by EPI as having the worst level of air quality among 180 countries in 2019.[73] Coronary heart disease and lung disease, which are both linked to air pollution, are the primary causes of death in Nepal.[74]

In 2013, more than 22,000 deaths in Nepal were attributed to indoor and outdoor air pollution. In that same year, air pollution-induced loss of welfare was recorded at US$2.8 billion, equivalent to nearly 5% of the country's GDP.[75] This is also equivalent to approximately 40% of the losses and damages caused by the 2015 earthquake, which was estimated at US$7 billion. It is important to note that the economic losses due to air pollution occur annually. The projected increase of PM 2.5 will continue to have substantial effects on the economy, resulting in increased healthcare costs, lost working days which in turn affect labor productivity, and a decline in crop yields.[76]

Currently, the government is planning to procure large electric buses with an investment of US$27.3 million, which will aid in decreasing the emissions in and around Kathmandu. In addition, electric shuttle services in the core areas of Kathmandu and Patan as well as electric buses servicing the UNESCO World Heritage Sites will provide added benefits in terms of GHG emissions and a reduction in local pollutant emissions.

8.1.2. Emissions mitigation benefits

Methodology

This study estimates the GHG and local pollutant emissions avoided when electric shuttle services in core areas and electric bus services for the UNESCO Heritage site are introduced. It was assumed that the passenger kilometers for both localresidents and tourists would be the same had the electric shuttle and electric bus services not been introduced. It has been assumed that residents in the core areas would use two-wheelers and four-wheelers, and

[69] Tribhuvan University (2017). *Nepal's GHG Inventory - For Third National Communication to UNFCCC.*
[70] World Bank. 2019. CO2 Emissions From Transport (% of total fuel combustion). World Bank Group.
[71] Department of Environment (DoEnv), *Air Quality Monitoring* 2017, http://pollution.gov.np/
[72] Brauer, M. et al. 2017, for the *Global Burden of Disease Study* 2017.
[73] *Environmental Protection Index*, Yale University. 2019. https://epi.envirocenter.yale.edu/epi-indicator-report/AIR?country=&order=field_epi_rank_new&sort=desc
[74] *The Himalayan Times*. 2019. https://thehimalayantimes.com/kathmandu/nepal-ranks-second-in-lung-ailment-deaths/
[75] Clean Energy Nepal, 2014. *Air Quality Status and Management in Kathmandu Valley. Make the City Air Breathable.* Manav-kendrit Yatayat Abhiyan (MaYA) Fact Sheet #5. Clean Air Network Nepal. UNHABITAT.
[76] OECD. 2016. *The Economic Consequences of Outdoor Air Pollution*. Policy Highlights. Organization for Economic Co-operation and Development.

those visiting the UNESCO World Heritage Sites would use two-wheelers, four-wheelers and buses in the “business as usual scenario” (i.e., if electric shuttle and electric bus services were not introduced). Overseas visitors, on the other hand, would use either four-wheelers or buses in both core areas and while visiting the UNESCO World Heritage Sites if electric shuttle and electric bus services were not introduced.

The emissions factors were adapted from the Provincial Electric Mobility Strategy developed in 2020.

Greenhouse Gas Emissions

In this study, greenhouse gas (GHG) emission levels (CO_2, CH_4 and N_{20}) are mainly based on the passenger kilomters replaced by electric shuttles in the core area routes of Kathmandu and Patan as well as electric buses along the routes servicing the UNESCO World Heritage Sites.

The passenger kilometers for local residents traveling on the electric shuttle or electric bus on each of the routes was estimated as below:

$$L_{PKM} = L_{P,i,x} * OC_{i,x} * D_x$$

Where:

L_{PKM} = passenger-km for local passengers (PKM);
F_{PKM} = passenger-km for foreign passengers (PKM);
$L_{P,i,x}$ = percentage of local passengers in vehicle category i in Year x (%);
$F_{P,i,x}$ = percentage of foreign passengers in vehicle category i in Year x (%);
$OC_{i,x}$ = average occupancy rate of vehicle category i in Year x (passengers); and
D_x = total distance traveled by the shuttles in Year x (km).

The passenger kilometers for tourists taking the electric shuttle or electric bus service on each of the routes was estimated using the same formula.

With this assumption, the GHG emissions were estimated by using the formula below:

$$G_{i,x} = (L_{PKM} * V_{i,x} * EF_{CO2,i,x}) + (L_{PKM} * V_{i,x} * EF_{CH4,i,x} * 25) + (L_{PKM} * V_{i,x} * EF_{N2O,i,x} * 298)$$

Where:

$G_{i,x}$ = GHG emissions from vehicle type i in Year x (tCO2e);
$V_{i,x}$ = % of vehicle category I in Year x (%);
$EF_{CO2,i,x}$ = emission factor per passenger kilometer of ICE vehicle category i, in Year x (gCO_2/PKM);
$EF_{CH4,i,x}$ = emission factor per passenger kilometer of ICE vehicle category i, in Year x (gCH_4/PKM);
$EF_{NOx,i,x}$ = emission factor per passenger kilometer of ICE vehicle category i, in Year x (gN_2O/PKM);

GHG emissions from overseas tourist passengers is estimated using the same formula. The total emissions during the life of the vehicle is estimated by multiplying the yearly emissions by the life of the electric shuttle or electric bus.

Local Pollutant Emissions

Emissions related to PM2.5, NMVOC, NOX, BC, OC and SO2 was estimated in this study. The local pollutant emissions was calculated using the following formula:

$P_{i,x} = (L_{PKM} * V_{i,x} * EF_{p,i,x})$

Where:

$G_{i,x}$ = GHG emissions from vehicle type i in Year x (tCO2e);

$V_{i,x}$ = % of vehicle category i in Year x (%);

$EF_{p,i,x}$ = Emission factor per passenger-kilometer of pollutant type p for ICE vehicle category i, in Year x (g/PKM).

Local pollutant emissions from overseas visitor passengers using ICE passenger vehicles is estimated using the same formula. The total emissions during the life of the vehicle is estimated by multiplying the yearly emissions by the life of the electric shuttle or electric bus.

Assumptions and inputs

GHG emissions from two-wheelers, four-wheelers, and buses, where applicable, was estimated based on the load factor of the vehicles. The load factor assumed in LMC and KMC's case is 70%, whereas that assumed in the World Heritage Site route is 65%. It has been assumed that in the LMC and KMC cases, 70% of the passengers will be local residents, whereas in the World Heritage Site's case, local residents have been assumed to represent 80%. Since in the core areas, the principle mobility option is the use of two-wheelers, this study assumes that 80% of local residents will traverse the core areas on two-wheelers. On the World Heritage route, since it is equally likely that passengers will take four-wheelers and buses, it has been assumed that 50% of the locals will traverse the route on two-wheelers, 20% in four-wheelers, and 30% by bus. Since there are no public transportation options in the core areas, it is assumed that 100% of the tourists take either four-wheelers or taxis, whereas on the World Hheritage route, tourists have the option to take both four-wheelers and buses.

Two routes have been recommended in each of the analyses for the Patan and Kathmandu core areas (see Chapter 6 &7). There are two loops in route servicing the UNESCO Heritage Sites (cf. Chapter 5). The assumptions and inputs below are used to calculate emissions for all the recommended routes in Patan and Kathmandu core areas (see Table 8.1 below). Here, the electric shuttle life in the core areas has been assumed as 10 years and electric buses in the World Heritage Site areas have been assumed as 15 years.

Table 8.1. Assumptions and inputs for GHG emissions calculation

Criteria		LMC		KMC		Heritage	
		L3	L4	K1	K4	Swayambhu Loop	Pashupati Loop
Shuttles/buses		10	4	10	11	2	3
Occupancy		5.6	5.6	5.6	5.6	20	20
Local passengers (%)		70%	70%	70%	70%	80%	80%
Tourist passengers (%)		30%	30%	30%	30%	20%	20%
Total annual distance traveled (km)		202,995	106,182	164,894	197,998	87,312	121,511
Local (passenger km)		795,740	416,233	646,386	776,153	1,407,472	1,958,753
Tourist (passenger km)		341,032	178,386	277,023	332,637	351,868	489,688
Total passenger km)		1,136,772	594,619	923,409	1,108,790	1,759,340	2,448,441
Mobility options and related passenger-km							
Local Passengers	**% two-wheelers**	80%	80%	80%	80%	50%	50%
	Two-wheelers (pkm)	636,592	332,987	517,109	620,922	703,736	979,376
	% four-wheelers	20%	20%	20%	20%	20%	20%
	Four-wheelers (pkm)	159,148	83,247	129,277	155,231	281,494	391,751
	% mid-sized buses					30%	30%
	Mid-sized buses (pkm)					422,242	587,626
Overseas Passengers	**% four-wheelers**	100%	100%	100%	100%	70%	70%
	Four-wheelers (pkm)	341,032	178,386	277,023	332,637	246,308	342,782
	% mid-sized buses					30%	30%
	Mid-sized buses (pkm)					105,560	146,906

Results

<u>*Greenhouse gas emissions avoided during the life of the vehicles*</u>

The results below show that a total of 3,564 tCO_2e emissions will be avoided if electric shuttles can be used to service both recommended routes in the core areas of Kathmandu and Patan and both loops servicing the UNESCO World Heritage Sites route.

Figure 8.1 Total GHG emissions avoided during the life of the vehicles

There is tremendous potential to reducing greenhouse gas emissions from the transport sector by adding more of these electric shuttle services in core areas.

Local Pollutant Emissions Avoided during the Life of the Vehicles
The co-benefit of introducing these electric shuttle and electric bus services in Kathmandu Valley is a reduction in local air pollution levels. Both NOx and NMVOC emissions can be avoided through the introduction of electric shuttle and electric bus services. These are currently significantly high, at 28 tons of NOx and 62 ton of NMVOC when compared to the other pollutant emissions (cf. Figure 8.2). A total of 3.7 tons of PM2.5 emissions can be reduced with the introduction of electric hop-on, hop-off services.

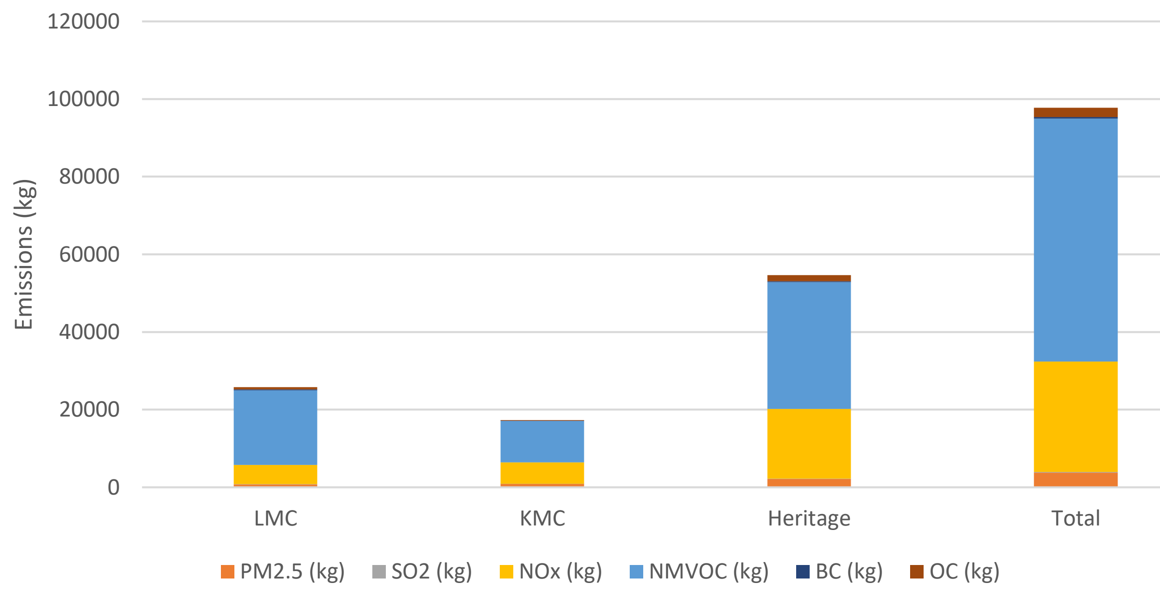

Figure 8.2 Local pollutant emissions avoided during vehicle life

With these reduced emissions, local residents in both the core areas and around the World Heritage Sites will incur a lower risk of health defects such as severe respiratory diseases, heart attacks, and hypertension caused by high pollution levels.

8.2. Environmental and Climate Risks

i. Risks related to management of battery waste

Countries in Europe and East Asia are introducing "Extended Producer Responsibility" (EPR) that requires consumers to pay a disposal tax at the time of purchase on any electronics item. Manufacturers and importers are then required to take back the end-of-life product to be safely disposed.

Nepal has seen an increasing amount of battery waste, mainly from inverters, vehicles, and solar systems. This is usually sorted and transported to India for recycling through an informal network of collectors. Since the acids are usually dumped without treatment, this is causing more pollution in the country. An estimated 25,000 tons of battery waste was recorded in Nepal for the year 2018, and without any proper waste management plans in place, this is increasing at an alarming rate. In 2011, Nepal introduced the *Solid Waste Management Act*, through which it aims to manage industrial and hazardous waste. However, it the country currently has no plans related to electronic waste disposal and management.[77]

Recommendations for managing lithium-ion battery waste from electric vehicles

With the rise of electric vehicle usage, the world will see a corresponding increase in lithium-ion battery waste. Since studies have suggested that batteries degrade to around 80% of their original capacity when used in electric vehicles, countries are increasingly looking at re-manufacturing the cells for a storage application life instead of recycling batteries,.[78] Currently, this option could be extremely useful in Nepal's context, since more stakeholders understand the benefits of adopting electric vehicles.

ii. Decreased noise from electric vehicles

Although less noise from electric vehicles is widely regarded as a major advantage in the transport sector, the reduced noise has also posed risks to pedestrians, as well as the blind and partially sighted in various countries around the world. The EU has mandated that noise-emitting devices be added to electric vehicles, especially when reversing and traveling below speeds of 19 km/h.[79]

Recommendations for managing noise levels from electric vehicles

In order to mitigate the above-mentioned risks, it is recommended that noise emitting devices be installed as a requirement, especially given vehicles in core areas will be operating at relatively slow speeds.

iii. Increased traffic to cultural heritage sites

The addition of electric vehicles will increase traffic to cultural heritage sites, ultimately contributing to a degradation of the cultural sites. In addition, more remote cultural sites with

[77] Nepali Times. 2018. What will Nepal do with its e-waste? Retrieved from: < https://www.nepalitimes.com/banner/what-will-nepal-do-with-its-e-waste/

[78] Drabik, E., Rizos, V. 2018. Prospects for electric vehicle batteries in a circular economy. CEPS Research Report: Thinking ahead for Europe. Brussels.

[79] BBC 2019. *Electric Cars: New vehicles to Emit Noise to Aid Safety*. Retrieved from: < https://www.bbc.com/news/business-48815968)

a previously low number of visitors may now be overwhelmed, given the surge in demand by tourists and local residents from the introduction of the electric shuttle service.

Recommendations to manage the surge of visitors in previously calm cultural sites
This risk can be mitigated during later stages of project design by aligning with the Government of Nepal's regulations and implementing sustainable management practices for World Heritage Sites (cf. Chapter 5 for further information on policies for sustainable tourism and the management of World Heritage Sites).

8.3. Socio-Economic Benefits and Risks

8.2.1. Background

Enhanced and improved mobility to tourism sites brings significant socio-economic co-benefits. The project is likely to include a maximum of 35 electric shuttles across both recommended routes in each of the Kathmandu and Patan core areas, as well as five mid-sized electric buses servicing the UNESCO World Heritage Sites. These will give tourists increasing accessibility to different locations, in particular to more remote sites. This intervention is likely to generate a range of risks and opportunities in the following areas:

i. Green jobs creation and skills development
    a. **Direct green jobs creation** in the e-mobility value chain (operations, maintenance etc.) and **indirect green jobs creation** in tourism-related service industries, as a consequence of improved accessibility;
    b. Proactive promotion of inclusion and gender equality in the e-mobility industry;
    c. Quality of jobs (labor conditions, health and safety).
ii. Quality of mobility services
    a. Inclusive access to services;
    b. Affordability of services;
    c. Road safety.

I. Creation of direct quality jobs

As a defined investment project, the level of net job creation is relatively low. With two drivers required for each of the 35 electric shuttles, two drivers and two conductors required for each of the five mid-sized electric buses, and eight technicians for both services, over 98 jobs are expected to be created as a direct result of the investment. This includes people engaged in installation, maintenance, and service operations.

With the introduction of electric mobility options, women and disadvantaged groups will gain opportunities to learn new skills related to electric vehicles operations and maintenance. Those that have already operated an ICE will quickly be able to learn that electric vehicle maintenance of is easier owing to fewer parts and the absence of an ICE engine. The technical skills gained through this service will be applicable across any electric mobility program.

a) Inclusion of disadvantaged groups

The proposed bus routes will create competition in particular among rickshaw drivers currently operating in these areas. These rickshaw drivers are part of an informal sector which, a couple of decades ago, were regarded as the primary mode of transport. Over the years however, modern two-wheelers and four-wheelers have displaced the workers in this informal sector. In order to avoid the negative social impact and potential community conflict, it is important to offer these existing mobility workers opportunities across the electric mobility sector value chain through reskilling programs (cf. links to Recommendation ii below).

b) Gender and the mobility labor market

In Nepal, the transition to e-mobility has been a platform for promoting gender equality. Since the early 1990s, over 350 women have owned and operated electric three-wheelers (*safa tempos*) in the streets of Kathmandu. Since then, 700 women have been trained to operate electric three-wheelers. The percentage of women drivers in the country has been increasing in recent years as they switch to driving private vehicles and company-owned cars that provide more opportunities in learning new skills and operating businesses. However, in the public transport sector, women's role in both ownership and operations have been limited to *safa tempos*. All other modes of public transport such as bus and microbus are being owned and operated by males (cf. links to Recommendation i below).

c) Labor conditions in the mobility sector

The Government of Nepal recently revised its *Labor Law* in 2018 to mandate employers to provide medical insurance and accidental insurance to all employees. This will cover disability, injury, and death compensation. This law prevails in the mobility sector and ensures that any incidence of child labor is minimized through frequent monitoring. The above business model scenarios are built on the assumption that drivers and O&M workers are paid living wages that are aligned with the *National Labor* Law (cf. links to Recommendation iii below).

Recommendations for the direct creation of quality green jobs and equality:

i. **Strengthening of women's roles across electric shuttle service operations:** both federal and local government, as well as public transport operator stakeholders, have expressed the need to encourage local women to drive the vehicles. Women residing the core areas will be trained to drive the smaller electric shuttles and mid-sized electric buses. In these cases, since there will be a total of 35 smaller electric buses and five larger buses across all core area routes, two women per vehicle may be trained as drivers.

   Additionally, since the five mid-sized buses will also need a conductor, two women per bus will be trained as conductors who will be responsible for collecting fares and maintenance of the buses during operations.

ii. **Strengthening indigenous and disadvantaged group's roles in electric shuttle service operations:** cycle rickshaws are currently being operated across Kathmandu core areas. Any pedestrianization of the routes recommended in Chapter 7 would not only limit traffic to just just the recommended electric vehicles, but it would also lead to the immediate displacement of cycle rickshaws. In order to minimize the resulting negative impact on rickshaw drivers, they would need to be trained as technicians, who would then be responsible for maintaining the vehicles.

iii. **Aligning human resource strategies with prevailing labor laws:** it is recommended that operators align their human resource strategies with Nepal's *Labor Law* (2018) and best practices. To ensure alignment with health and safety standards, operators will need to pay special attention to the provision of medical and life insurance as well as the creation of a social security fund for their drivers, conductors, and maintenance staff. With these conditions in place, the rickshaw drivers will have the security they need.

II. Creation of indirect jobs in tourism

This study does not quantify the potential of indirect green jobs across tourism-related industries. At this stage, no modeling has been carried out to estimate the impact on green jobs creation as a result of a potential future scale-up of e-mobility interventions. In addition, since the intervention does not primarily aim to increase the number of tourists visiting the area, no modeling illustrating the impact of the intervention on the number of visitors has been deployed. However, it is asssumed that improved mobility options will make the destinations more attractive and remote locations may also see an increase in the number of visitors. This in turn will likely create additional jobs in tourism-related industries and value chains such as tourist attractions, accommodations, shops, and restaurants. Additional opportunities to further promote an inclusive and sustainable tourism industry that benefit local communities, including women and disadvantaged groups can be clearly identified.

It would be possible to conduct further modeling for green jobs creation under the *Electric Mobility Program* to transition to e-mobility, and to include direct jobs creation across mobility value chains, indirect jobs in benefiting sectors such as tourism, and induced jobs created by workforce participation across the wider economy. Such modeling can create decision-making confidence in the socio-economic benefits of sustainable and climate-friendly smart transitions. However, we underlined again that this is not the focus of this preliminary study.

Recommendations for the promotion of equality and the indirect creation of quality green jobs:

i. **Training women and disadvantaged groups to become tour guides:** this project will also be aimed at promoting the inclusion of women and disadvantaged groups in the tourism sector by prioritizing their training as tour guides for tourists visiting the World Heritage Sites. With these skills, both women and disadvantaged groups in the area will be able to take up jobs in other tour companies. Women with knowledge of the World Heritage Sites will add significant value to the project because they can support the National Tourism Board in developing communications materials for locals and visitors to the core area cultural sites and the UNESCO World Heritage Sites.

III. Access to quality services

Social co-benefits also include improved access to quality mobility services for locals and international tourists. This in turn is expected to increase the number of visitors, particularly to more remote locations. Quality mobility services in this preliminary study are focused on accessibility, particularly for the elderly, differently-abled, and disadvantaged groups.

Recommendations for increasing accessibility:

i. **Labeled seats for women, the elderly and disadvantaged groups:** labeled priority seats for pregnant women and the elderly will be required, along with reserved seats for differently-abled passengers, as part of the act relating to the *Rights of Persons with Disabilities, 2017*. Therefore, in mid-sized buses, it is recommended that two seats be dedicated to women passengers and a further two seats reserved for differently-abled passengers. Provisions for a wheelchair area will also be inlcuded within the buses. It is also recommended that the elderly be prioritized over other customers wherever possible.

IV. Affordability of quality services

The business cases presented in Chapters 5, 6, and 7 have assumed a flat passenger fare for both international and local tourists in the case of a non-profit organization such as Sajha Yatayat operating the vehicles. However, in Chapter 5, a case has also been presented whereby international tourists will be charged a higher flat fare and locals will be charged a lower flat fare in the event that a profit-oriented transport company operates these vehicles. Locals are charged a minimum fee across all three cases in order to avoid potential abuse of the service.

Recommendations for increasing affordability for local passengers

i. Since this is the first time such a service is implemented, it is an opportunity for operators to learn and implement more affordable alternatives to locals, if so required. In addition, as already mentioned in the preceding chapters, the operators can consider making prices more affordable for the elderly, the differently-abled, and children in order to ease service accessibility to families and disadvantaged groups. It is recommendation that in more detailed stages of business planning, a diversified tariff to benefit the elderly, children, and disadvantaged groups (and perhaps also to local actors and vendors) be taken into consideration.

I. Road safety

The vehicles specified for the core areas are not aimed for use on main roads, but on small roads and at limited speed. New vehicles are assumed safe to operate, and it is recommended that operators implement regular maintenance and driver training, and enforce the installation of seat belts and other safety equipment as required. The mid-sized electric buses will be operating on main roads and therefore will be running at higher speeds. Clearly-marked pickup and drop-off locations along the route servicing the UNESCO World Heritage Sites can enhance road safety. Adequate lighting for night-time driving is also an important characteristic, especially for passenger safety and security. It is important to assess the routes and identify potential high-risk areas and to implement specific measures to mitigate related risks.

Recommendations for enhancing road safety for passengers

i. The smaller shuttles will be covered, so as to avoid any accidents related to passengers stepping outside a moving vehicle. The implementing agency will ensure the vehicles meet the Department of Transport Management's vehicle safety standards.

8.4. Conclusion

The project is considered medium risk and requires adequate considerations, particularly for vehicle lifecycle management and maintenance, as well as battery management. Moderate risks have been identified in terms of the potential exclusion of women, disadvantaged groups, and informal mobility services providers such as rickshaw drivers. Proactive measures for providing equal opportunities for these groups have been identified.

Overall, the project is expected to generate net positive environmental, climate, and social co-benefits, and considerable opportunities exist for scaling-up e-mobility operations in Nepal. Under such strategies, opportunities exist to bring down costs. On a broader level, opportunities also exist to develop strategies that ensure a soft landing for the existing mobility and transport labor market in terms of skills re-allocation and the creation of equal opportunities through new job creation. Formal employment opportunities are expected to bring improved livelihoods to people, when compared with the traditional informal sector. Furthermore, ample opportunities have been identified to leverage existing efforts for bringing more women into the e-mobility sector in Nepal. In turn, this will contribute to gender equality and the associated benefits this brings to the economy at large (e.g. McKinsey, 2015: *Power of Parity*. World Economic Forum Gender Gap Reports).

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