Operational Planning for E-Buses on Non-Urban Routes in Union Territory of Ladakh

Exploring the Role of Private Sector as a Catalyst for Accelerating Transition to E-Bus in India.

SHAKTI SUSTAINABLE ENERGY FOUNDATION

SGA sustainable mobility solutions

SGArchitects
6151/8, Sector D, Pocket 6
Vasant Kunj
New Delhi - 110070
www.sgarchitects.in

Key Contributors

Sandeep Gandhi, Ph.D.
SGArchitects

Satyajit Ganguly, Transport Planner
SGArchitects

Kanica Gola, Infrastructure Planner
SGArchitects

Shivanshu Singh, Architect
SGArchitects

Knowledge Partner

RITES Ltd.

Technical Partner

IIT Delhi

Cover Picture Credits
Satyajit Ganguly
(SGArchitects)

ACKNOWLEDGEMENT

The authors and editors would like to express gratitude to the various individuals, Institutional/technical/local partners, and organizations, who helped make this document possible. We are thankful to RITES Ltd. and IIT Delhi for providing technical inputs and valuable guidance in the development of this report.

We especially acknowledge Ms. Priyanka Kataria and Mr. Konchok Tashi from RITES Ltd., for extending their valuable support in data collection.

We are thankful to the industry partner PMI Foton for providing valuable information, data, technical support, and guidance in the study.

We would also like to thank Ladakh Bus Operator Co-operative Ltd. (LBOC), Leh and Ladakh Administration (LA) for their inputs.

Finally, we would like to thank the different Government functionaries, Mr. Swagta Biswas, IAS, Transport Secretary, UT of Ladakh; We especially acknowledge Jammu Kashmir Road Transport Corporation JKSRTC for their valuable support in conducting Pilot operations.

December 2022

Contents

1 Background ... 2
2 Existing E- Bus and Charging infrastructure ... 3
3 Non-Urban Routes for E-Bus operational planning ... 4
4 Operational Planning ... 8
4.1 Leh – Kargil ... 12
4.2 Leh – Alchi ... 14
4.3 Leh – Nyoma ... 16
4.4 Leh – Dahbheema ... 18
4.5 Leh – Nubra ... 20
4.6 Leh – Pangong ... 22
5 Charging Station Requirement and Design ... 24
Annexure ... 26
Bus Specification – PMI Foton ... 27
Bibliography ... 26

List of Figures

Figure 1:Electric Bus Fleet Acquired by Ladakh Administration (LA) ... 2
Figure 2:PMI Electric bus and Charger used in Leh ... 3
Figure 3 Selected routes and their existing midblock stops ... 7
Figure 4: Time to achieve SoC level over 80% SoC in constant voltage phase ... 10
Figure 5: Relationship between gradient and percentage change of SoC from that on flat terrain ... 10
Figure 6: Operational Route Plan – Leh to Kargil ... 12
Figure 7: Operational Route Plan – Leh to Alchi ... 14
Figure 8: Operational Route Plan – Leh to Nyoma ... 16
Figure 9: Operational Route Plan – Leh to Dahbheema ... 18
Figure 10: Operational Route Plan – Leh to Nubra ... 20
Figure 11: Operational Route Plan – Leh to Pangong ... 22
Figure 12: Routes with proposed charging stations ... 24
Figure 13: Schematic layout for the charging station ... 25

List of Tables

Table 1: Routes for non-urban E-bus operations ... 4
Table 2: Route Evaluation Matrix ... 6
Table 3: Six priority routes for operational planning ... 7
Table 4: Route Characteristics ... 7
Table 5: Technical Inputs ... 8
Table 6: Leh – Kargil Operational Plan ... 13
Table 7: Leh – Alchi Operational Plan ... 15
Table 8: Leh – Nyoma Operational Plan ... 17
Table 9: Leh – Dahbheema Operational Plan ... 19
Table 10: Leh – Nubra, Operational Plan ... 21
Table 11: Leh – Pangong, Operational Plan ... 23
Table 12: Proposed Chargers ... 24

1 Background

Ladakh has recently gained the status of Union Territory (UT) and is planning to implement various mobility intervention as part of its developmental agenda. The young UT envisions a green future and has earmarked actions to cut emissions of greenhouse gases (GHGs) from the union territory. It foresees operations of E-buses for both on Urban and Non-Urban routes as one of the pathways in achieving that. As part of this initiative Ladakh Administration (LA) has initiated a special purpose vehicle (SPV) named Sindhu Infrastructure Development Corporation (SIDCO), which will be responsible for bus operations in the Union Territory. LA has acquired about 10 electric buses (e-buses) with 5 chargers from PMI Electro Mobility Solutions Private Limited. Presently a few of these e-buses are operated on the urban routes inside city limits. LA envisages to deploy these e-buses on longer non-urban routes and desires to seek support to undertake such operations.

To achieve this SGArchitects (SGA) in partnership with RITES Ltd. (knowledge partner for this study). has initiated the development of an operational and a rollout plan for the E-bus services in the state. The current report presents the details of this plan. RITES Ltd. has been separately appointed by Ladakh administration to develop a mobility strategy for the UT

Figure 1: Electric Bus Fleet Acquired by Ladakh Administration (LA)

2 Existing E- Bus and Charging infrastructure

Ladakh administration (LA), currently owns a fleet of 10 electric buses, 8.5m in length with a model name of "PMI Foton Regio", along with 5 chargers. It has a total capacity of 32 seated and 14 number standing passengers. These buses have a 150 kw-h battery size and claim an energy consumption of about 1.2 km per 1 kw-h of charge (with air-conditioning) for a fully loaded bus (Max. Capacity) on a flat gradient. The suggested total state of charge (SoC) for this bus operation is recommended as 80% by the manufacturer (minimum SoC of 20%, maximum SoC of 100%)[1].

The charger provided by PMI along with the bus has a rating of 200kw-h with a stated efficiency of 90%[1]. However due to harsh climatic conditions prevailing in the region, it is prudent to assume an additional 5% discount on the efficiency of the charger and the SoC of the battery. Basis this it is estimated that the bus has a range of 121.5km and after utilising this range the battery can be fully re-charged within 36 minutes if the rate of charge can be maintained at different levels of battery SoC.

PMI Foton Regio

Luobinsen 200KW DC charger

Figure 2: PMI Electric bus and Charger used in Leh

Although the current buses are primarily city buses, PMI Photon claims that the buses have been tested across a variety of terrains and ranges in the region, and a range of 120km can be guaranteed basis these tests. However, it is unknown at what loading capacity is this range promised.

[1] These values have been provided by the technical team at PMI Foton based on request by the project team and presented in Annexure.

3 Non-Urban Routes for E-Bus operational planning

More than 85% of stage carriage bus operations in India is on non-urban routes. Additionally non-urban bus services have on an average higher vehicle utilization than urban services (CIRT, 2018). Therefore, non-urban operations offer higher potential of reduction in local pollution in the short term and greenhouse gas (GHG) emissions in the long term (with reducing grid emission factor[2]). Additionally, non-urban services offer a higher total cost of ownership (TCO) saving with electrification than for urban operations (Vijaykumar, Kumar, Mulukutla, & Agarwal, 2021)[3], and thus they have a higher profitability potential for operators.

Thus, electrification of non-urban routes promises higher societal and financial benefits. E-bus route specific operation planning and defining the charging strategy plays a key role in reaping these benefits. However, little knowledge and experience is available on operational planning of non-urban services. The current study focussed on undertaking electric bus pilots in Ladakh and deploying the learnings from these pilots to develop operational plans for select routes. A separate report includes findings and learnings from the pilots. This report focusses on the application of these learning to develop an operational plan for identified routes.

This section of the document presents the routes selected for e-bus operational planning along with its selection criteria. As a first step taken towards developing the E-bus operational plan, a total of 17 non-urban routes were identified based on the interactions with the public and private operators of the region. Out of these 15 were proposed by LA as well SIDCO while 2 routes were shortlisted based on discussions with Ladakh Bus Operators Cooperative (LBOC)[4]. *Table 1* presents the details of 17 shortlisted routes.

Table 1: Routes for non-urban E-bus operations

Route No.	Route Name	Average Occupancy	Total trips catered in a day	Vehicle Utilization (Avg Km covered/day w.r.t Routes)	Route Length in km
1	Leh-Kargil	53%	1	230.2	230.2
2	Leh-Nyoma	50%	1	160	182
3	Leh-Dahbeema	55%	1	189	189.1
4	Leh-Nubra	85%	1	150	150
5	Leh-Surbhuchan	55%	2	120	124
6	Leh-Dhomkhar	25%	2	120	126
7	Leh- Hanu	60%	1	150	163
8	Leh-Lamayuru	50%	2	120	129
9	Leh-Temisgam	30%	2	90	97
10	Leh-Skitmang	closed	2	120	125

[2] Grid emission factor represents the per kw GHG emissions from the electricity production process.
[3] Total cost of operations (TCO) is even lower for electric buses than for Diesel buses when the daily drive distance (DDD) is higher. Non-urban services are characterized by higher DDD than urban services
[4] Currently Ladakh Bus Operators Cooperative (LBOC) operates non-urban bus routes with a fleet of 89 buses (ranging from 10.5m to11m buses).

Route No.	Route Name	Average Occupancy	Total trips catered in a day	Vehicle Utilization (Avg Km covered/day w.r.t Routes)	Route Length in km
11	Leh-Hemis	20%	2	75	81
12	Leh-Shara	40%	2	50	67
13	Leh- Chumathang	30%	2	120	140
14	Leh- Chiktan	40%	1	180	184
15	Leh-Phokar	30%	1	201	202
16	Leh-Alchi	86%	2	268	67
17	Leh-Pangong	86%	1	160	160

Out of these 17 routes, the priority routes with the optimal electrification potential were identified and evaluated based on the following listed parameters.

1. Route Occupancy – To determine the demand on the route
2. Total vehicle km operated in a day – To determine the operational performance.
3. Overlapping route – To determine the possibility of sharing charging infrastructure en-route.
4. Length of the route – To determine the need for charging infrastructure enroute or at destination.

The data collected for these 17 routes suggests that Ladakh does not witness very high daily passenger trips on non-urban routes by buses and the overall demand for bus trips per route is not very high. This is mainly because of remoteness of destinations and difficult terrain. These non-urban routes usually have one service (trips) per day. Therefore, one of the criteria for route election for electrification was occupancy (as proxy of demand).

The selection process was based on a matrix of criteria, based on indicators listed above. Out of the 17, the low occupancy routes with less than 50% of occupancy were ruled out. Thus, for remaining 9 routes, a rating was done against each criterion and an overall ranking for route selection derived.

The scale of the measure against the parameters varied between very high (ordinal scale value 5) to very low (ordinal scale value 1). This matrix is presented in *Table 2*.

Table 2: Route Evaluation Matrix

Route No.	Route Name	Average Occupancy	Points on Ordinal scale	Vehicle Utilization (Avg Km covered/day w.r.t Routes)	Points on Ordinal scale	Route Length in km	Points on Ordinal scale	Overlapping Segments	Points on Ordinal scale	Total	Remarks	Rank
1	**Leh-Kargil**[5]	53%	3	200	5	230.2	5	3	5	**18**	High range, Strategic and National Importance. Additionally overlapping with routes 3,7,8	**1**
2	**Leh-Nyoma**	50%	2	160	4	182	4	1	3	**13**	Minimum Demand and Overlapping with route 9	**4**
3	**Leh-Dahbeema**	55%	3	189	4	189.1	4	3	5	**16**	High range, Moderate Demand and Overlapping with routes 1,7,8	**3**
4	**Leh-Nubra**[6]	85%	5	150	3	150	3	0	0	11	High range, High demand	**7**
5	Leh-Surbhuchan	55%	3	120	3	124	3	0	0	9	Moderate range and demand	9
6	Leh- Hanu	60%	3	150	3	163	4	0	0	10	High demand and High range	8
7	Leh-Lamayuru	50%	2	120	3	129	3	3	5	**13***	Minimum demand & overlapping with routes 1,3,8	6
8	**Leh-Alchi**	86%	5	268	5	67	2	3	5	**17**	High Ridership and Overlapping with routes 1,3,7	**2**
9	**Leh-Pangong**	86%	5	160	4	160	4	1	3	**16**	High Tourist and local demand and overlapping with route 2	**5**

[5] Geographically Leh Lamayuru route falls over Leh Kargil route hence not considered to be a separate Route

[6] Thus, Leh- Nubra route, which ranked 7 as per evaluation was promoted as 6th selected route for operational planning.

Total of six non- urban routes were identified for operational planning based on the higher demand (*Table 3*).

Table 3: Six priority routes for operational planning

Route No.	Route Name	Average Occupancy	Total trips catered in a day	Vehicle Utilization (Avg Km covered/day w.r.t Routes)	Route Length in km
1	Leh-Kargil	53%	1	230.2	230.2
2	Leh-Nyoma	50%	1	160	182
3	Leh-Dahbeema	55%	1	189	189.1
4	Leh-Nubra	85%	1	150	150
5	Leh-Alchi	86%	2	268	67
6	Leh-Pangong	86%	1	160	160

The selected, existing non-urban routes have rest stops which are for a duration of between 10-20 minutes.*Table 4* presents the existing characteristics of these routes, including origin, destination, and mid-block stops.

Table 4: Route Characteristics

Route No.	Origin	Destination	Route Length in Km	Stop 1	At Distance from Origin in Km	Stop 2	At Distance from last stop in Km
1	Leh	Kargil	230.2	Khalsi	96.2	Wakha	86
2	Leh	Alchi	67	Nimmo	35.2	No stop	-
3	Leh	Nyoma	182	Upshi	48.1	Chumathang	91.7
4	Leh	Dahbeema	189.1	Nimmo	35.2	Khalsi	61
5	Leh	Nubra	161.3	Khardung	73.2	No stop	-
6	Leh	Pangong	160	Karu	34	Tagste	85

Figure 3 presents a map with all routes and their existing mid-block stops.

Figure 3 Selected routes and their existing midblock stops

4 Operational Planning

The planning for electric bus operations on the selected routes was undertaken based on the following inputs/specifications:

- **Observed/recorded route characteristics** – This includes route length, number, and location of mib/block rest stopovers, distance between the stopovers and the duration of stop-over or layover time
- **Vehicle as well charger characteristics** – This includes battery size, seating capacity, minimum SoC, maximum SoC, charger rating, charger efficiency, etc.
- **Findings as well data generated from pilot operations** – This included rate of charge (at constant current and constant voltage state), per passenger/kg energy consumption[7] and discharge rate in the given context, in relation to gradient, load, etc.

The technical inputs and specifications derived from these sources and used in the operational planning of routes in Ladakh have been presented in *Table 5*.

Table 5: Technical Inputs

S.no.	Parameters	Values	Units
1	Energy consumption per km at 16% occupancy (without A/C)	0.61	Kw-h/Km
2	Total Additional energy consumption for full load (without AC)	0.23	Km/Kw-h
3	Additional energy consumption per passenger (over empty bus)	0.0087	Kw-h/passenger
4	Additional energy consumption per kg (over empty bus)	0.00014	Kw-h/kg
5	Total energy consumption for an empty bus (without AC)	0.57	Km/Kw-h
6	Max SoC	99	%
7	Min. SoC	20	%
8	Discount on available charge on account of contingency/ weather conditions	5	%
9	Charger rating	200	Kw-h
10	Charger efficiency	75	%
11	Discount on charger efficiency on account of contingency	0	%
12	Total battery capacity	150	kw-h
13	Average battery capacity over life	90	%
14	Boarding alighting time excluding charging time	10	min
15	Constant current phase up to SoC level	83	%
16	% Of SoC charge per hour	100.00%	
17	Additional parasitic load for AC	0.125	Kw-h/km
18	Average passenger weight	64	kg
19	Maximum passenger occupancy	32	No's

[7] Derived based on variance of discharge characteristics between two trips of similar route characteristics, one at 16% occupancy and the other at 70% occupancy.

20	Maximum charge rate in constant current phase	150	Kw-h/h

The methodology for deriving operational requirement and developing the operational plan is as following:

1. For worst case planning a full load of 32 passengers8 with AC was considered.
2. Existing rest stops, their layover time, and the distance between them (referred to as a journey leg) was mapped.
3. The recorded altitude of each of these stops and the distance between the was used to determine the average gradient for each leg of the journey.
4. Maximum battery capacity, maximum usable SoC (SoC after full charge – i.e., maximum of 99% minus the minimum SoC of 20%) was used to determine the total energy available for each journey leg.
5. The energy consumption rate per km for the given gradient, with AC and full load was estimated, to determine the maximum range available for the bus to cover each leg.
6. Where the range was less than the current length of the leg, a new stopover/ rest stop is proposed with a charging facility. In case the range is much more than a (existing or revised) journey leg, then a new/alternate rest stop is proposed with a charger location.
7. All rest stops are proposed at locations with existing settlements, where grid-based power source is available for the charger and where passenger amenities can be provided.
8. The layover time at each rest stop is estimated as total charging time plus boarding/alighting time (10 minutes).
9. The layover time is calculated for each rest stop. It is optimised to minimise the layover time and yet achieve the range required till next stop. This is based on known maximum constant charging rate in constant current phase and variable rate in constant voltage phase (above 83%) (Figure 4).
10. This method is used to develop the operational plan (location of stops and chargers, number of chargers and layover time) on each route both for onward and return journey.

[8] Most permits for non-urban routes are conditional to maximum of 100% occupancy (zero standing).

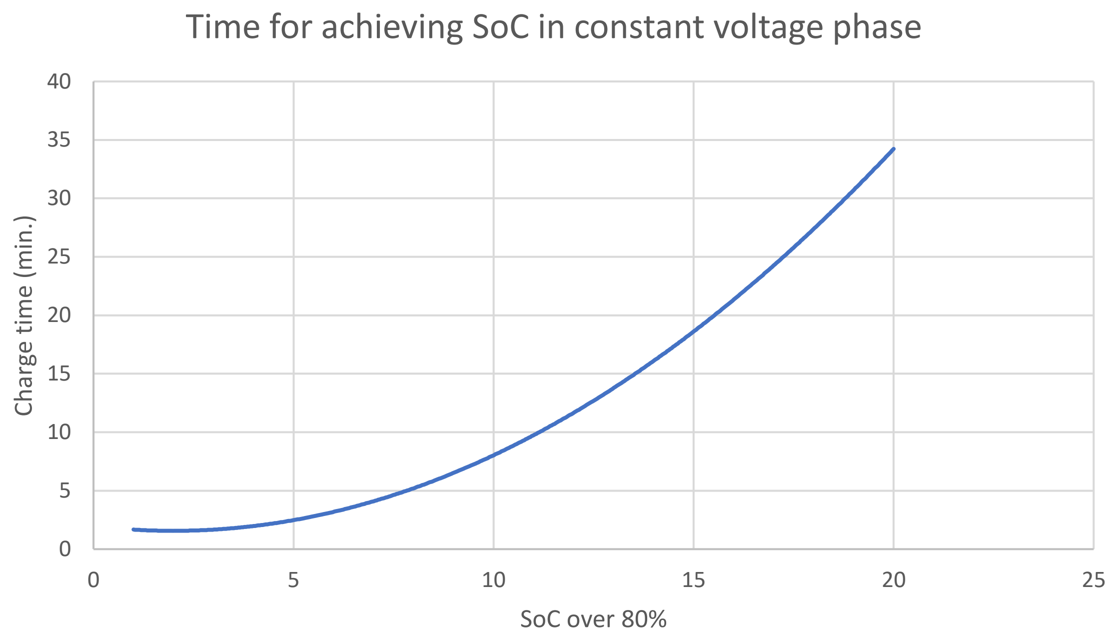

Figure 4: Time to achieve SoC level over 80% SoC in constant voltage phase

Figure 5 presents the graph on relationship between gradient and expected change in percentage of SoC, derived from findings of the plot study. The formula for the slope of this line used to estimate the rate of discharge based on gradient (with 16% occupancy). The impact of loading as derived by analysing the variance of SoC with 16% and 70% occupancy (1 sample each). To factor this in a value for additional occupancy of 84% (from 16%) equivalent to 0.234 Kw-h per km was added to the energy consumption on a given gradient with 16% occupancy.

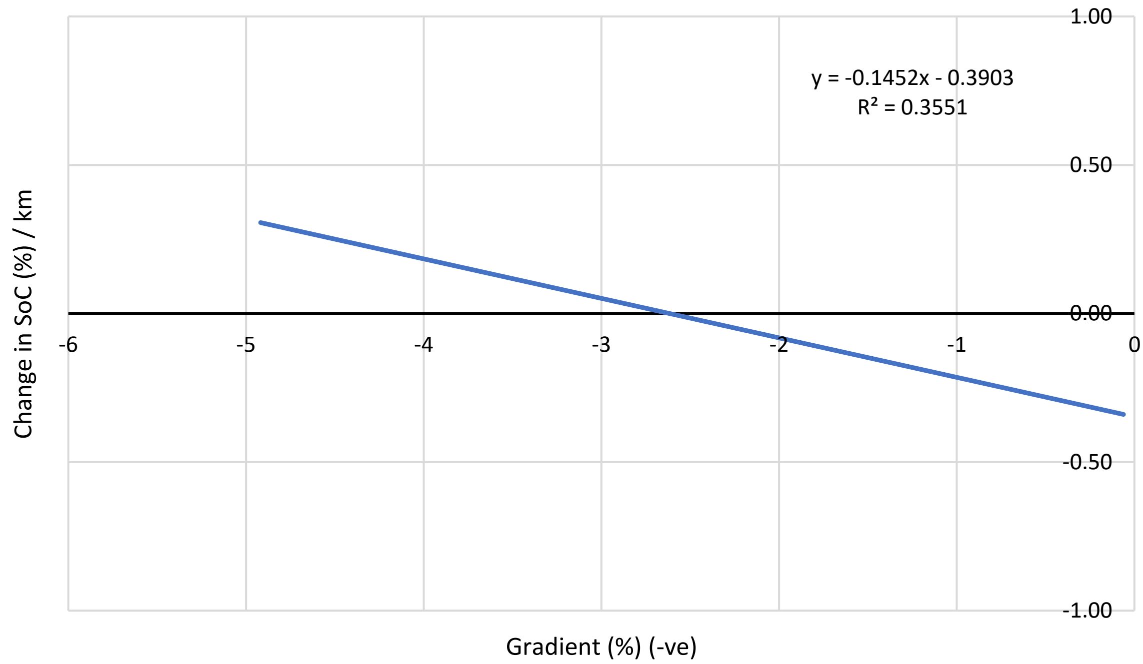

Figure 5: Relationship between gradient and percentage change of SoC from that on flat terrain

It is assumed that ten minutes from the total stop-over time shall be dedicated for boarding/alighting with no charging possible during this time. So, total layover time is estimated by adding 10 minutes to the minimum required charging time. Basis this a charging schedule at each stop-over with the total range available till next stop-over/destination, Soc when arriving at a stop, SoC level when leaving from a stop (after scheduled charging/layover time), total range available after charging, etc. has been estimated. This gives an assessment of the changes required in the timetable/schedules to accommodate e-bus charging requirements. This operational plan has been presented for each of the six selected routes below.

4.1 Leh – Kargil

Leh to Kargil Route is 230.2 km in length and is one of the most prominent routes in terms of connecting the two major towns of Ladakh UT. Also being a part of Leh – Srinagar highway the route holds national as well tourist importance. The route is suggested to be provided with enroute charging at Khalsi and Wakha. The operational plan for this route is developed in 3 journey legs for a one-way trip based on available SoC after reaching the enroute charging locations. The route is planned for full load (Occupancy) with operational AC throughout. Figure 6 presents the route plan with proposed charging locations.

Figure 6: Operational Route Plan – Leh to Kargil

The operational planning for this route is presented in *Table 6.*

Table 6: Leh – Kargil Operational Plan

Route 1	**Leh**	**To**	**Kargil**	**Route Length**		**230.2**	**kms**	**Enroute Charging 1 at**		**Khalsi**	**Enroute Charging 2 at**		**Wakha**
Onward Trip	From	Alt. (m)	To	Alt. (m)	Gradient to next destination (%)	Mileage on full load with AC till next stop (km/Kw-w)	Distance from Origin/ last stopover (Km)	Distance to destination/ next stop over point (Km)	Available SoC on arriving (Mins)	Planned layover time (Mins)	Charging time available (Mins)	Available SoC on Departure	Range available after charge (Km)
First Leg Journey	Leh	3419	Khalsi	2987	-0.45	1.16	0	96.2	0.99	1020	1010	0.99	124.20
Second Leg Journey	Khalsi	2987	Wakha	3497	0.59	0.90	96.2	86	0.44	40	30	0.91	85.82
Third Leg Journey	Wakha	3497	Kargil	2676	-1.71	1.83	86	48	0.29	20	10	0.45	62.61
Return Trip													
First Leg Journey	Kargil	2676	Wakha	3497	1.71	0.72	0	48	0.28	1020	1010	0.99	76.6
Second Leg Journey	Wakha	3497	Khalsi	2987	-0.59	1.22	48	86	0.54	35	25	0.92	118.2
Third Leg Journey	Khalsi	2987	Leh	3419	0.44	0.93	86	96.2	0.45	50	40	0.98	97.8

4.2 Leh – Alchi

Leh - Alchi Route is 67 km in length. This route is planned for full load (Occupancy) with operational AC throughout. The route does not need any enroute charging facility and thus the operational plan for this route is developed in single journey leg for a one-way trip based on available SoC after reaching from the origin to destination. Figure 7 presents the route plan.

Figure 7: Operational Route Plan – Leh to Alchi

The operational planning for this route is presented in *Table 7*.

Table 7: Leh – Alchi Operational Plan

Route 2	**Leh**	**To**	**Alchi**	**Route Length**		**67**	**kms**		**Enroute Charging**				**N/A**
Onward Trip	From	Alt. (m)	To	Alt. (m)	Gradient to next destination (%)	Mileage on full load with AC till next stop (km/Kw-w)	Distance from Origin/ last stopover (Km)	Distance to destination/ next stop over point (Km)	Available SoC on arriving (Mins)	Planned layover time (Mins)	Charging time available (Mins)	Available SoC on Departure	Range available after charge (Km)
First Leg Journey	Leh	3419	Alchi	3100	-0.48	1.17	0	67	0.99	495	485	0.99	125.2
Return Trip													
First Leg Journey	Alchi	3100	Leh	3419	0.48	0.92	67	0	0.61	20	10	0.78	71.51

4.3 Leh – Nyoma

Leh - Nyoma Route is 182 km in length. The route is suggested to be provided with enroute charging at Upshi and Chumathang. The operational plan for this route is developed in 3 journey legs for a one-way trip based on available SoC after reaching the enroute charging locations. The route is planned for full load (Occupancy) with operational AC throughout. Figure 8 presents the route plan with proposed charging locations.

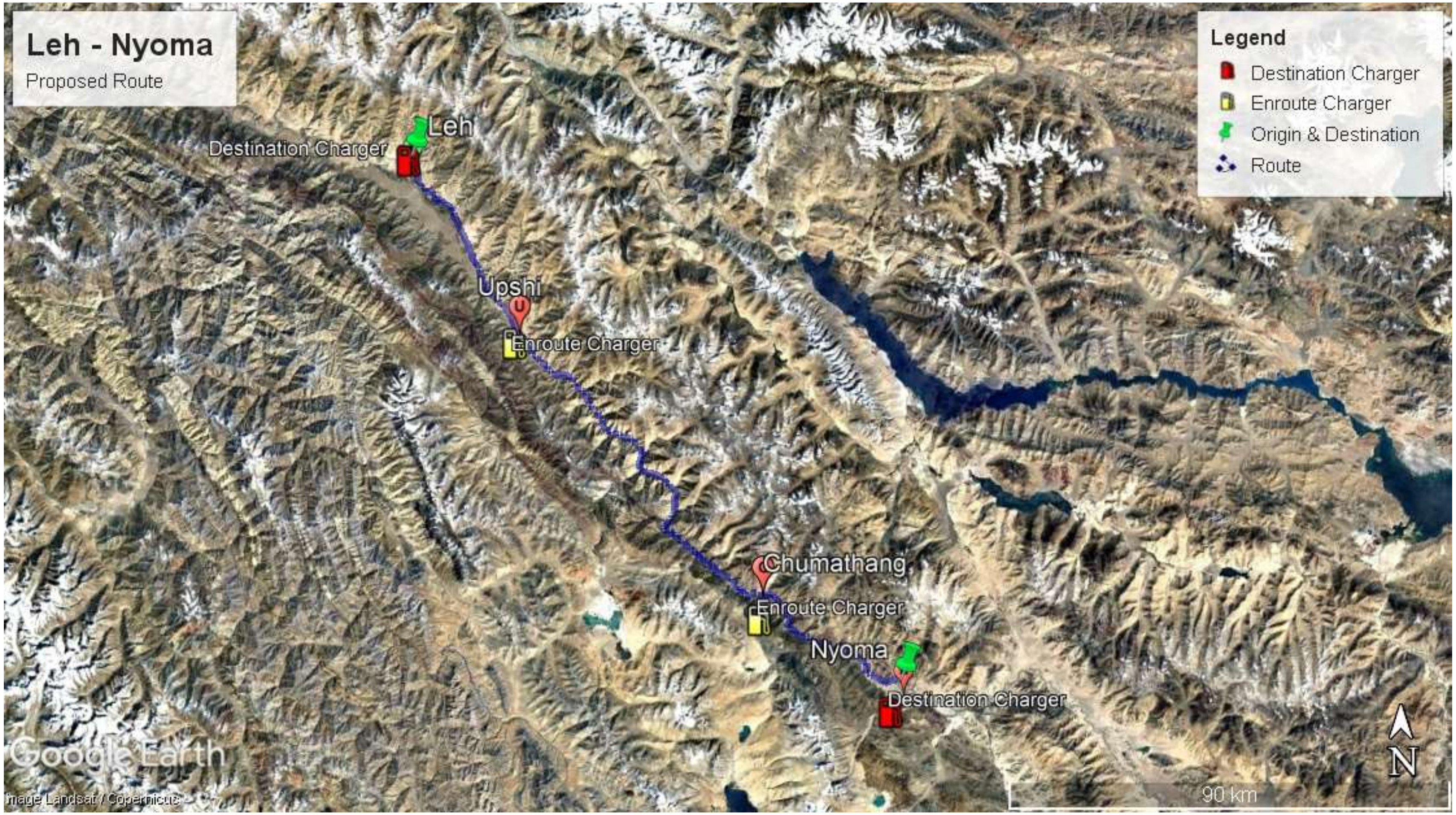

Figure 8: Operational Route Plan – Leh to Nyoma

The operational planning for this route is presented in *Table 8*.

Table 8: Leh – Nyoma Operational Plan

Route 3	**Leh**	**To**	**Nyoma**	**Route Length**		**182**	**kms**	**Enroute Charging at**		**Upshi**	**Enroute Charging at**		**Chuma-thang**
Onward Trip	From	Alt. (m)	To	Alt. (m)	Gradient to next destination (%)	Mileage on full load with AC till next stop (km/Kw-w)	Distance from Origin/ last stopover (Km)	Distance to destination/ next stop over point (Km)	Available SoC on arriving (Mins)	Planned layover time (Mins)	Charging time available (Mins)	Available SoC on Departure	Range available after charge (Km)
First Leg Journey	Leh	3419	Upshi	3398	-0.04	1.04	0.00	48.10	0.99	495.00	485.00	0.99	111.21
Second Leg Journey	Upshi	3398	Chumathang	3950	0.60	0.89	48.10	91.70	0.68	35.00	25.00	0.98	93.66
Third Leg Journey	Chuma-thang	3950	Nyoma	4180	0.55	0.91	91.70	42.20	0.29	35.00	25.00	0.71	62.19
Return Trip													
First Leg Journey	Nyoma	4180	Chumathang	3950	-0.55	1.20	0.00	42.20	0.40	35.00	25.00	0.81	99.40
Second Leg Journey	Chuma-thang	3950	Upshi	3398	-0.60	1.22	42.20	91.70	0.58	25.00	15.00	0.83	103.59
Third Leg Journey	Upshi	3398	Leh	3419	0.04	1.02	91.70	48.10	0.33	25.00	15.00	0.58	52.05

4.4 Leh – Dahbheema

Leh - Dahbheema Route is 189 km in length. Despite having a longer route length, it is suggested to be provided with one enroute charging at Khalsi. This because the gradient moves consistently lower from origin to destination i.e., 3419 meters (at Leh) to 2700 meters at Dahbheema. Thus, the operational plan for this route is developed in 2 journey legs for a one-way trip based on available SoC after reaching the enroute charging location. The route is planned for full load (Occupancy) with operational AC throughout. Figure 9 presents the route plan with proposed charging locations.

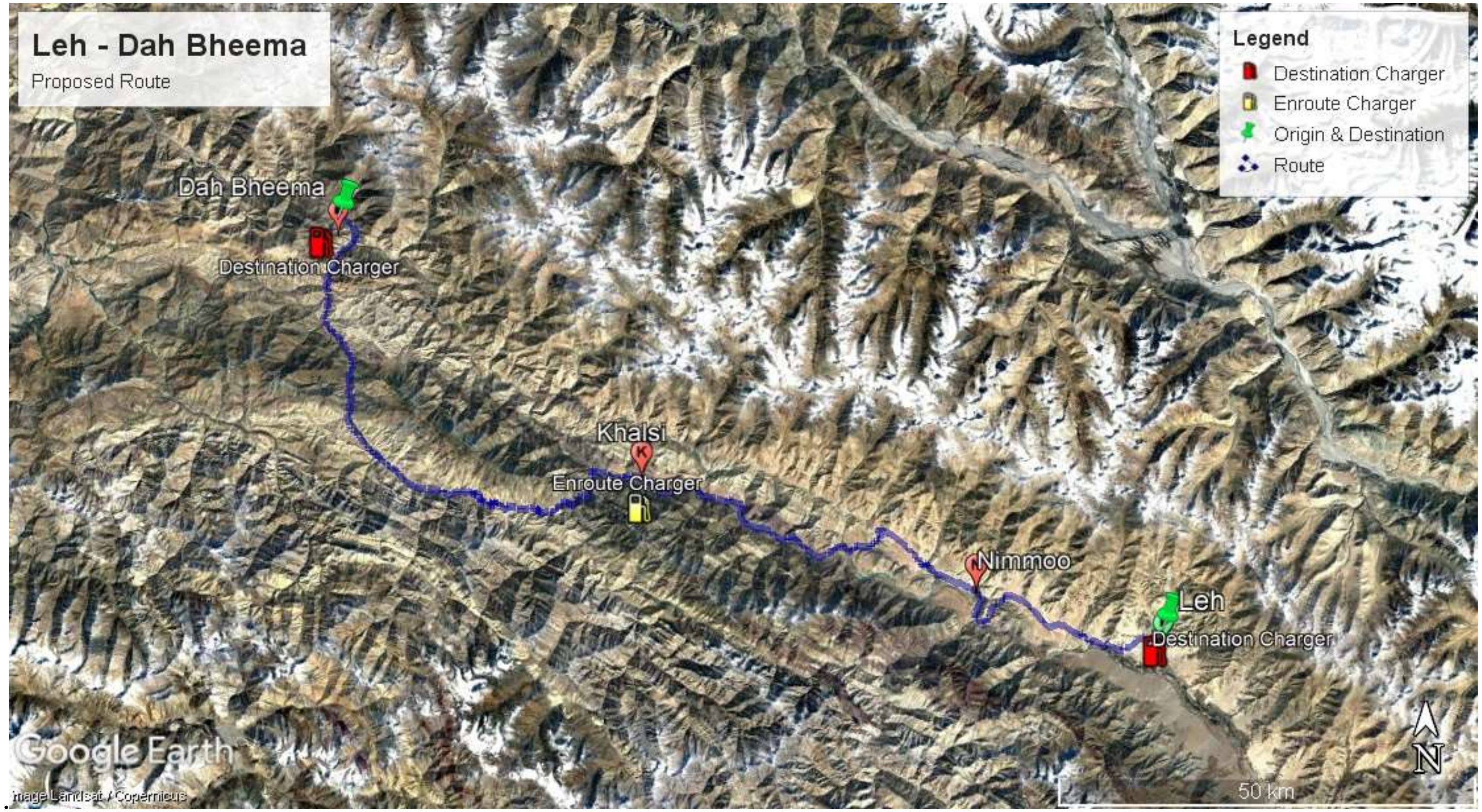

Figure 9: Operational Route Plan – Leh to Dahbheema

The operational planning for this route is presented in *Table 9*.

Table 9: Leh – Dahbheema Operational Plan

Route 4	**Leh**	**To**	**Dah-Bheema**	**Route Length**		**189**	**kms**	**Enroute Charging at**			**Khalsi**		
Onward Trip	From	Alt. (m)	To	Alt. (m)	Gradient to next destination (%)	Mileage on full load with AC till next stop (km/Kw-w)	Distance from Origin/ last stopover (Km)	Distance to destination/ next stop over point (Km)	Available SoC on arriving (Mins)	Planned layover time (Mins)	Charging time available (Mins)	Available SoC on Departure	Range available after charge (Km)
First Leg Journey	Leh	3419	Khalsi	2987	-0.45	1.16	0.00	96.20	0.99	495.00	485.00	0.99	124.20
Second Leg Journey	Khalsi	2987	Dah-Bheema	2700	-0.31	1.12	96.20	92.90	0.44	35.00	25.00	0.86	100.22
Return Trip													
First Leg Journey	Dah-Bheema	2700	Khalsi	2987	0.31	0.96	0.00	92.90	0.31	60.00	50.00	0.99	101.82
Second Leg Journey	Khalsi	2987	Leh	3419	0.45	0.93	92.90	96.20	0.34	55.00	45.00	0.97	96.61

4.5 Leh – Nubra

Leh – Nubra, route is 150 km in length. One enroute charging at Northpullu is suggested to be provided for this route. The operational plan for this route is developed in 2 journey legs for a one-way trip based on available SoC after reaching the enroute charging location. For this route the operational plan is designed considering ,50% load (Occupancy) with no AC subjected to the steep gradient observed between Nubra (3048 meters to Northpullu (4815 meters). Figure 10 presents the route plan with proposed charging locations.

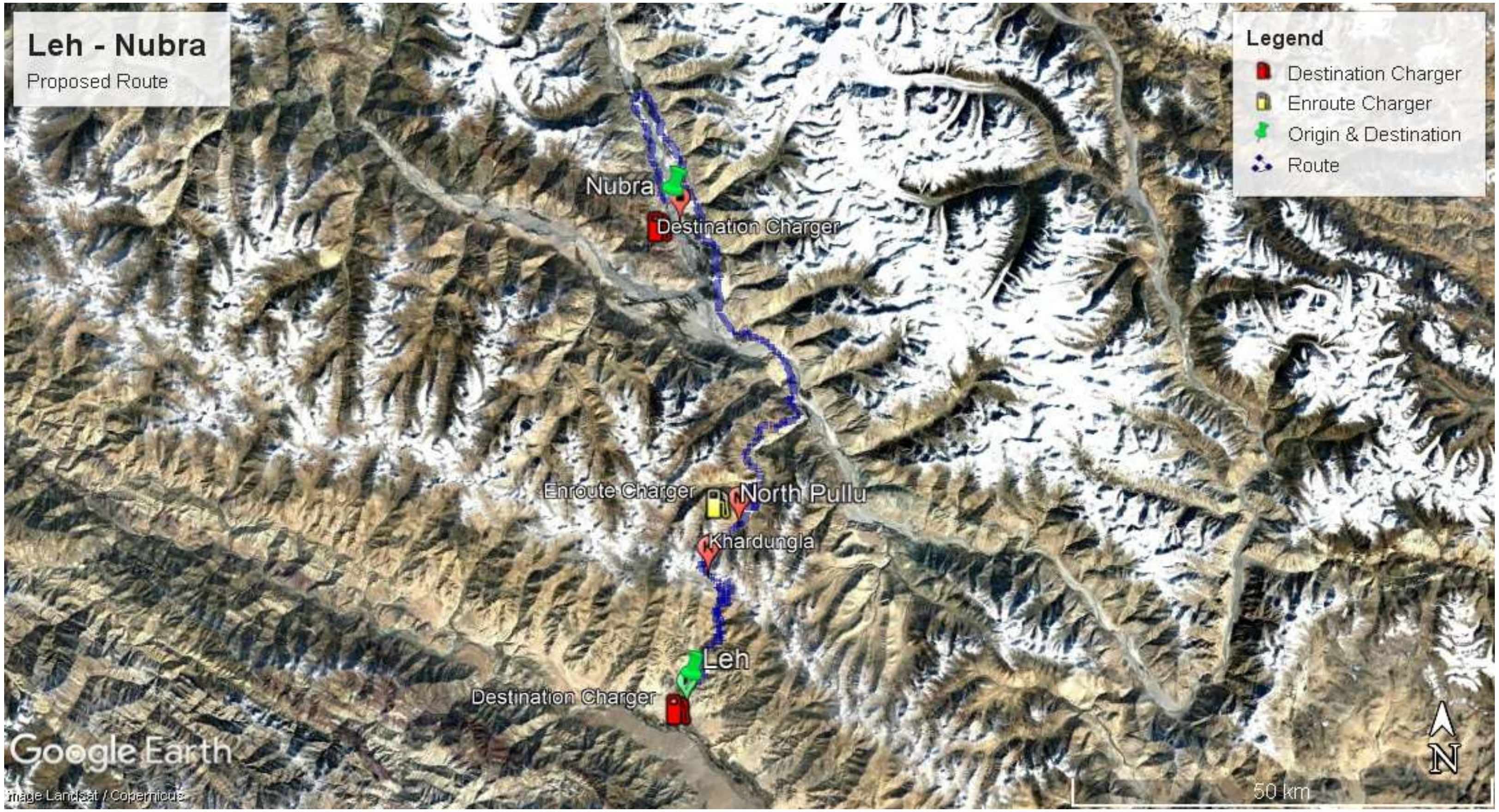

Figure 10: Operational Route Plan – Leh to Nubra

The operational planning for this route is presented in *Table 10*.

Table 10: Leh – Nubra, Operational Plan

Route 5	**Leh**	**To**	**Nubra**		**Route Length**	**150**	**kms**	**Enroute Charging at**			**Northpullu**		
Onward Trip	From	Alt. (m)	To	Alt. (m)	Gradient to next destination (%)	Mileage on full load with AC till next stop (km/Kw-w)	Distance from Origin/ last stopover (Km)	Distance to destination/ next stop over point (Km)	Available SoC on arriving (Mins)	Planned layover time (Mins)	Charging time available (Mins)	Available SoC on Departure	Range available after charge (Km)
First Leg Journey	Leh	3419	Northpullu	4815	2.59	0.62	0.00	54.00	0.99	555.00	545.0	0.99	66.26
Second Leg Journey	Northpullu	4815	Nubra	3048	-1.84	1.94	54.00	96.00	0.41	20.00	10.00	0.58	99.02
Return Trip													
First Leg Journey	Nubra	3048	Northpullu	4815	1.84	0.84	96.00	96.00	0.25	65.00	55.00	0.99	90.65
Second Leg Journey	Northpullu	4815	Leh	3419	-2.59	3.03	96.00	54.00	0.24	25.00	15.00	0.49	117.52

4.6 Leh – Pangong

Leh – Pangong, route is 160 km in length. One enroute charging at Tangste is suggested to be provided for this route. The operational plan for this route is developed in 2 journey legs for a one-way trip based on available SoC after reaching the enroute charging location. The route is planned for full load (Occupancy), however due to steep gradient ranging from 3419 meters (Leh) to 3942 meters (Tangste) to 4225 meters (Pangong), AC is recommended to be turned- off in the first leg of the trip. Figure 11 presents the route plan with proposed charging locations.

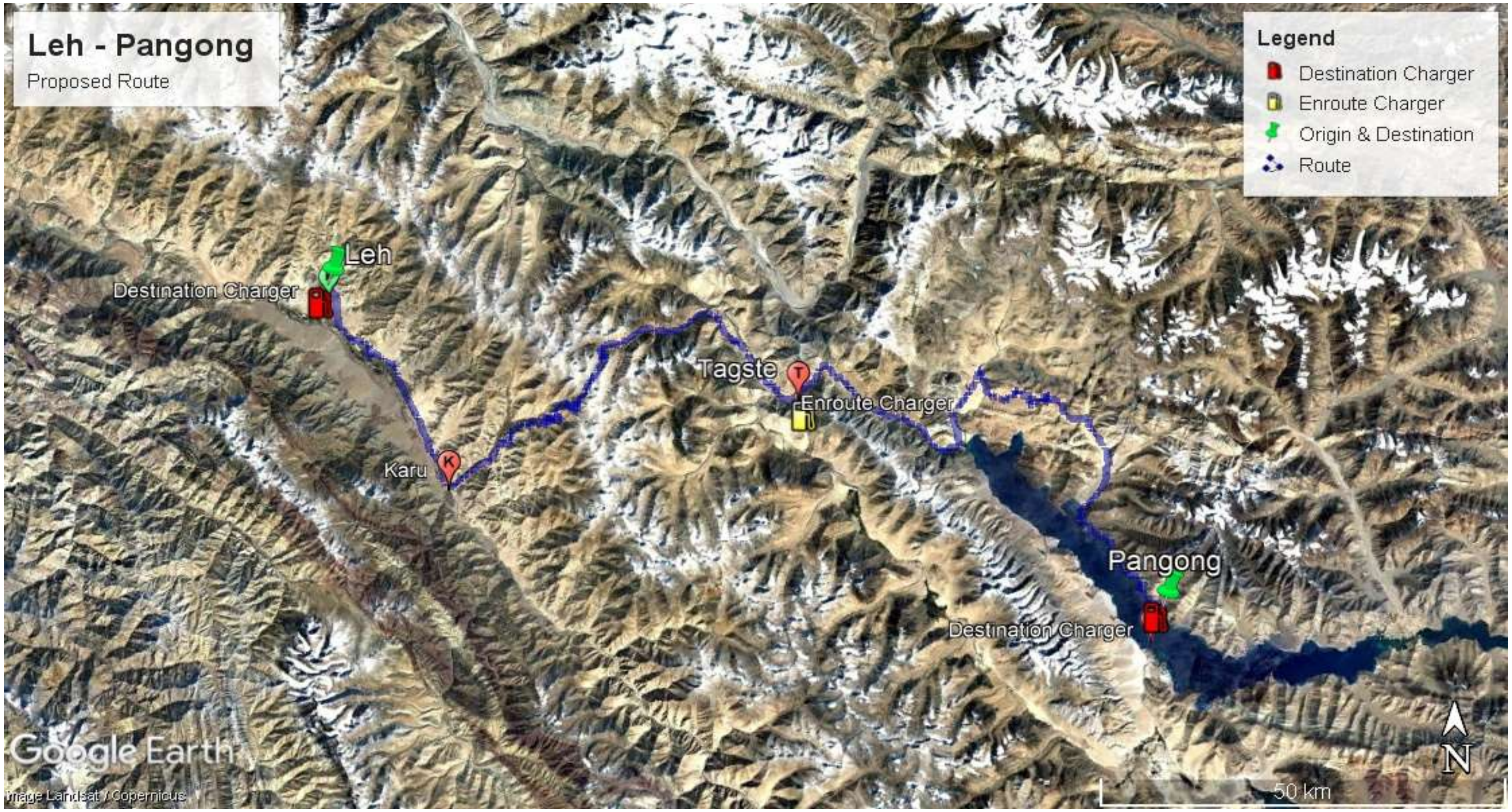

Figure 11: Operational Route Plan – Leh to Pangong

The operational planning for this route is presented in *Table 11*.

Table 11: Leh – Pangong, Operational Plan

Route 6	**Leh**	**To**	**Pangong**	**Route Length**		**160**	**kms**	**Enroute Charging at**				**Tangste**	
Onward Trip	From	Alt. (m)	To	Alt. (m)	Gradient to next destination (%)	Mileage on full load with AC till next stop (km/Kw-w)	Distance from Origin/ last stopover (Km)	Distance to destination / next stop over point (Km)	Available SoC on arriving (Mins)	Planned layover time (Mins)	Charging time available (Mins)	Available SoC on Departure	Range available after charge (Km)
First Leg Journey	Leh	3419	Tangste	3942	0.44	1.05	0.00	119.00	0.99	555.0	545.0	0.99	111.84
Second Leg Journey	Tangste	3942	Pangong	4225	0.69	0.88	119.00	41.00	0.23	30.00	20.00	0.57	43.41
Return Trip													
First Leg Journey	Pangong	4225	Tangste	3942	-0.69	1.25	0.00	41.00	0.26	65.00	55.00	1.00	134.55
Second Leg Journey	Tangste	3942	Leh	3419	-0.44	1.16	41.00	119.00	0.78	30.00	20.00	0.98	122.29

5 Charging Station Requirement and Design

The current operational plan does not account for a large fleet of electric buses, and hence for the selected priority routes, the plan proposes a minimum requirement of total 15 chargers (2 origin chargers plus 7 enroute chargers and 6 destination chargers. Leh being the common origin to all the routes is proposed with an active plus 1 standby charger. However, it is advisable that minimum 2 chargers should be provided at all destination and enroute chargers, to ensure a standby charger in case of a breakdown. The routes Leh- Kargil and Leh-Nyoma, 2 enroute charging locations are proposed whereas Leh -Alchi route require only one charger each at origin and destination. *Table 12* presents the proposed number of chargers for the priority routes.

Table 12: Proposed Chargers

S No.	Route Name	Charger Origin	At	Enroute charger	At	Enroute charger	At	Charger Destination	At	Charger required per route
1	Leh-Kargil			1	Khalsi	1	Wakha	1	Kargil	5
2	Leh-Nyoma			1	Upshi	1	Chuma-thang	1	Nyoma	5
3	Leh-Dahbeema	2 (1 + 1 Stand by charger)	Leh	1	Khalsi	-	-	1	Dah-Bheema	4
4	Leh-Nubra			1	Northpullu	-	-	1	Nubra	4
5	Leh-Alchi			-	-	-	-	1	Alchi	3
6	Leh-Pangong			1	Tangste			1	Pangong	4
Total Chargers required for the priority routes		2		5		2		6		**15**

Figure 12 presents a map with all six routes and the proposed charging stopovers.

Figure 12: Routes with proposed charging stations

Each charging location for a bus can also be used to provide charging locations for two or more motor cars, to accelerate recovery of investments made. For the purpose, the proposed charging station with 200 KW bus chargers can be planned with 140 to 150 SqM parking space which will accommodate 1-2 number of DC fast chargers[9] for charging e-buses and electric 4 and 2 wheelers. Figure 13 presents a schematic layout of a charging station.

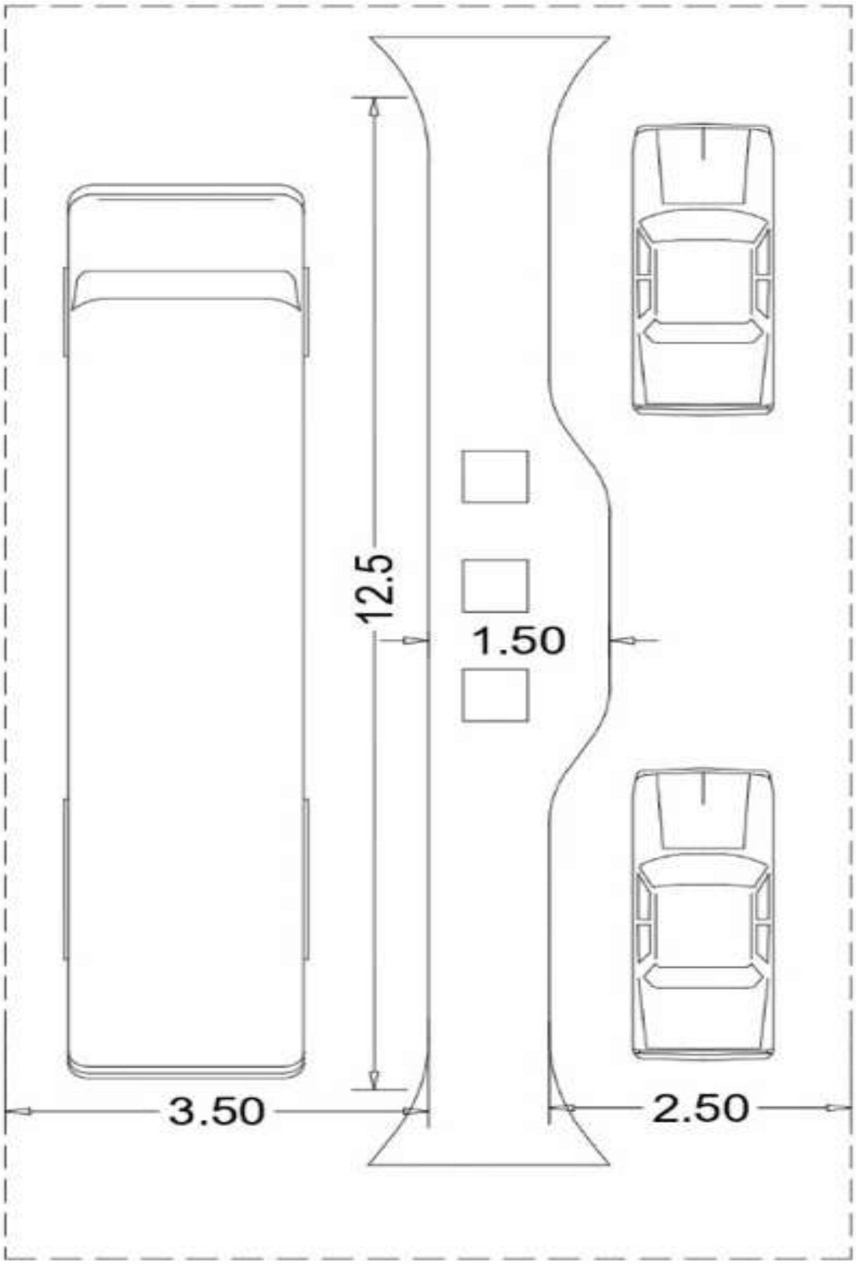

Figure 13: Schematic layout for the charging station

[9] The per day demand for 2 or 4-wheeler charging varying between 70 KW-h to150 KW-h – maximum charger power rating is 60kw-h

Bibliography

CIRT. (2018). *STATE TRANSPORT UNDERTAKINGS PROFILE AND PERFORMANCE.* PUNE: CENTRAL INSTITUTE OF ROAD TRANSPORT. Retrieved from http://www.cirtindia.com/

Vijaykumar, A., Kumar, P., Mulukutla, P., & Agarwal, O. (2021). *Procurement of Electric Buses: Insights from Total Cost of Operations(TCO) Analysis.* Bengaluru.

Annexure

Bus Specification – PMI Foton

BUS SPECIFICATION FORM

By OEM – PMI Foton

S. no	Parameters	Model 1	Model 2	Model 3	Unit
1	Bus model name & specs	**Regio Model** M3 category, Standard Type-I and Type-II Bus (HVAC type “Heating, ventilation, and air conditioning)	LITO Model	Urban Model	Rs. /Kw-h
2	Bus dimensions	**8.5 meters**, 8500-9400MM with wheel base up to 5000 MM and Seating Capacity 25+driver+Wheelchair (foldable Seat)	**7 Meters**, 6972mm +/-10mm Wheelbase up to 3250mm and seating capacity 21+D	**12 Meters**, 11980+/-20mm, Wheelbase up to 6320mm And seating capacity 33+D+W	m
3	Curb weight of bus (without passengers) including battery	12.5 with Passengers And approx. **8.5 Tonnes** without passengers	6.4 tonnes without passengers	13.4 tonnes with passenger	Kg
4	Battery size	**150 Kw h**	102 Kw h	200 Kw h	Kw-h
5	Battery Chemistry	**MNC,** Advanced Chemistry Battery/(Li-on Battery) or Better. Advanced Li – ion	**MNC,** Advanced Chemistry Battery/(Li-on Battery) or Better. Advanced Li – ion	**MNC,** Advanced Chemistry Battery/(Li-on Battery) or Better. Advanced Li – ion	

S. no	Parameters	Model 1	Model 2	Model 3	Unit
6	Minimum (recommended) state of charge (SoC)	20	20	20	%
7	Maximum (recommended) state of charge (SoC)	100	100	100	%
8	Charger type (offered)	DC	DC	DC	AC/DC
9	Cost of charger unit (excluding installation)	15 Lakhs	15 Lakhs	15 lakhs	Rs.
10	Charger rating (capacity)	180 kw- h	180kw h	180kw h	kw-h
11	Charger efficiency	99	99	99	%
12	Average energy density of battery	140 wh/kg	NA	143 wh/kg	Kg/Kw-h
13	End of life capacity of battery	80%(Tentative) as real time data is not available	80%(Tentative) as real time data is not available	80%(Tentative) as real time data is not available	Kw-h or %
14	Recommended battery capacity at end of life	80	80	80	%
15	Current Battery cost per kw/h	20000/kw-h	20000/kw-h	20000/kw-h	Rs. /Kw-h
16	Expected battery cost for replacement batteries (per Kw-h) (in 5 years)	20000/kw-h	20000/kw-h	20000/kw-h	Rs. /Kw-h
17	Residual value of battery (at end of life) in terms of current percentage of battery cost	Real time data not available	Real time data not available	Real time data not available	%
18	Maximum capacity, standing + seated	30 + 14	21+10	33+15	(No. + No.)

S. no	Parameters	Model 1	Model 2	Model 3	Unit
19	Availability of luggage storage (for non-urban trips)	Can be customised **2cu.m of space**	Can be customised **2cu.m of space**	Can be customised **2cu.m of space**	Y/N
20	Expected mileage (Power consumption) with AC (max capacity)	1.2 Km/Kw-h	0.4	1.2	Kw-h/km
21	Expected mileage (Power consumption) without AC (max capacity)	1.4km/Kw-h	0.6	1.6	Kw-h/km
22	Service Centre Availability (in select geography)	Y	Y	Y	Y/N
23	Availability of maintenance staff (in select geography)	Y	Y	Y	Y/N
24	Applicable warranties on bus	24 months for Body	24 months for Body	24 months for Body	Months
25	Applicable warranty on battery	60	60	60	Months
26	Temperature range for battery performance specs	25-30	25-30	25-30	Deg c. – Deg. C.
27	No of charging cycles (with given min. & max. SoC)	5000 cycles	5000	5000	No.
28	Features for non-urban operations - AV/Reclining seats/Luggage space/etc.	NA	NA	NA	Rs/km
29	Is customization option (external colours, seat upholstery, seating configuration, A/V	Y	Y	Y	Y/N

S. no	Parameters	Model 1	Model 2	Model 3	Unit
	systems, lights, etc.) offered to customers				
30	Ex Showroom Cost of bus	**0.94**	**0.77**	**1.35**	**Rs/crores**
31	On road Price of the bus	NA	NA	NA	Rs/crores
32	Cost of AC bus (excluding battery for electric bus) & excluding GST	65,70,000	58,10,000	95,24,000	Rs
33	Cost of AC Bus with Battery	**0.99**	**0.82**	**1.40**	**Rs/crores**
34	Cost of Non-AC bus (excluding battery for electric bus) & excluding GST	60,95,000	53,90,000	90,50,000	Rs
35	Cost of Non-AC Bus with Battery	**0.94**	**0.77**	**1.35**	**Rs/crores**