KATHMANDU UNIVERSITY

SCHOOL OF ENGINEERING

DEPARTMENT OF GEOMATICS ENGINEERING

A PROJECT

REPORT ON

SUITABILITY ANALYSIS OF EV CHARGING STATION SITES USING AHP: A CASE STUDY OF KOSHI PROVINCE

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ABSTRACT

As a new means of transport, electric vehicles (EV) are of great significance to alleviate the energy crisis. EV charging station planning has a far-reaching significance for the development of EV industry. The transition to electric mobility is gaining momentum worldwide, necessitating the strategic deployment of Electric Vehicle (EV) charging infrastructure to support this paradigm shift. This project focuses on the crucial aspect of site selection for EV charging stations, aiming to optimize the placement of these facilities to enhance accessibility, efficiency, and sustainability. The complexity of waste management systems requires evaluating various solutions and criteria when selecting a suitable site for EV charging stations. In this study, the selection of charging station site was carried out using Geographic Information System (GIS), Multi-criteria Decision Analysis (MCDA) and Analytical Hierarchy Process (AHP) techniques. The study focused on Koshi Province in Nepal, which is experiencing rapid growth in utilization of electric vehicles. The major criterion selected for this mini project were: - Road network, Transmission grids, Substations, Existing data, and Land Use Land Cover (LULC) data. The standardization of the criteria was done by reclassification to use a common scale of measurement. The AHP pairwise comparison matrix was used to calculate the weight for each criterion. The five classes of suitability index were found: Least Suitable, Less Suitable, Moderately Suitable, Suitable and Highly Suitable of the study area which are found to include of the total study area 6.104%, 66.87%, 22.547%, 4.462% and 0.016% respectively for charging station site.

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LIST OF ABBEVRATIONS

AHP	Analytical Hierarchy Process
CR	Consistency Ratio
DEM	Digital Elevation Model
EV	Electric Vehicle
GCS	Geographic Coordinate System
GIS	Geographic Information System
KM	Kilometer
M	Meter
MCDA	Multi Criteria Decision Analysis
MCDM	Multi Criteria Decision Making
NEA	Nepal Electricity Authority
PCS	Projected Coordinate System
WGS	World Geodetic System

1. INTRODUCTION

1.1.Background

With the rapid progress of battery technology, EV gets more and more attention in recent years, and EVs have many positive effects on solving the present crisis of environment pollution and resources shortage.

At present, the development of the EV charging station is still in the demonstration and operational stage, the EV technology is increasingly developing, and the EV battery technology has improved greatly, with its unique advantages of high efficiency of charging and discharging, large output power and long service life, lithium-ion batteries are the most widely used in the electric car battery system now. However, the common charging time of EV batteries is too long (5 to 8 hours), and the mileage is limited after each charging, which is always the crux of the EV industry development. EVs are not only a kind of load, but so can serve as energy storage for power grid, except that they have strong randomness, which is associated with the moving characteristic as a means of transport. In current scenario, almost all consumed petroleum oil is imported from India which is increasing trade deficit of Nepal (Khanal). Nepal imports all petroleum products, with more than two-thirds of them used in the transportation sector. On the other hand, the total installed electricity generation capacity of Nepal is 1377.9 MW (DOED, 2021, July 29). and some import from India in dry season is fulfilling today's demand. By 2030, the clean energy generation will be 15,000 MW (SNDC, 2020). Similarly, Nepal Electricity Authority (NEA) has done Power Purchase Agreement (PPAs) for 5978.134 MW (NEA, 2020). From this we can say that Nepal will have surplus electrical energy in coming years. This surplus energy supply can be balanced by creating demand from the growing number of EVs through EV charging stations. So as the need is felt, NEA has proposed 50 charging stations across the country within a year. Thus, the more study and research is needed for the charging stations in Nepal as number of EVs are increasing day by day. In conclusion, the related literature for systemic study on the influencing factors of EV charging station planning is less, and the related literature that considering the weight of every factor is much scarcer. Range limitation is also one of the major obstacles that influencing the growth of EVs. Customer will not buy an EVs if they cannot assure that constantly available and compatible charging station is present to solve the range anxiety problem (Bonges III, 2015). This project made systemic in-depth research for the influencing factors of EV charging station planning with the application of AHP method and studied their weights and provided the theoretical basis of the planning for EV charging stations in future.

Figure 1: EV charging in a station.

1.2. Problem Statement

The use of electric vehicles is a booming business. People are highly attracted to EV due to the sudden and unknown nature of oil demand/supply chain in Nepal. According to the Department of Customs, the country imported a total of 4,050 assembled electric vehicles in the fiscal year 2022-23, which is more than double the units imported in the previous year. Nepal had imported 1,807 electric four-wheelers in 2021-22. In addition, 6,914 three wheelers were imported last fiscal year, according to the customs data. In the first four months of the current fiscal year (2023-24), Nepal imported 2,787 units of EVs, up 174 percent year-on-year, according to the customs department. (TKP, 2023).

The present number of EV charging stations in Koshi Pradesh is 10. And as the number of imports increases in an exponential manner, the establishment of extra charging stations is essential and critical.

1.3. Objectives

Primary Objective:

- To analyze and determine the suitable site for EV charging stations Koshi Province.

Secondary Objective:

- To be able to use Multi Criteria Decision Making and Analytical Hierarchy Process for decision-making.

1.4. Scope

This mini project mainly aims to locate suitable sites for EV charging stations in Koshi Province. This study incorporated a few of the major factors influencing the charging site like Road network, Power supply, LULC and Substations.

2. LITERATURE REVIEW

The electric car first debuted in the mid-nineteenth century. Electric battery-powered taxis were accessible in London streets around the end of the nineteenth century. Concerns about the difficulties associated with hydrocarbon fuel vehicles, particularly the harm caused by their emissions, fueled interest in electric automobiles around the turn of the twenty-first century (Lowry, 2007).

E-mobility has a long history in Nepal. The first ropeway was built between Kathmandu and Dhorsing in 1922, and it was later extended to Hetauda in 1964, totaling 42 kilometers. The Chinese government backed the installation of electric trolleybuses in the Kathmandu Valley in 1975. These trolleybuses ran successfully between Kathmandu and Bhaktapur for 13 kilometers until 2001, when it was forced to close due to management concerns (Acharya, 2015). It reopened in 2003 for a limited time before closing again in 2008. Electric bus technology is suited for Nepal, according to the trolleybus experience, however operations must be professionally performed. Simply entrusting the buses to a government agency may not result in effective and efficient service.

There are now roughly 700 Safa Tempos operating as public transportation in the Kathmandu Valley on 28 different routes. The Safa Tempo has been a success story since it has operated as a method of public transportation for 25 years without receiving any government subsidies. Except for a small-scale effort in which ten Safa Tempos were converted to Lithium-ion batteries, Safa Tempo technology has not advanced over the years, and their numbers have not risen in recent years. While the private sector may operate electric vehicles (EVs), it will require support when the technology is initially launched. Furthermore, the government must place a strong emphasis on research and development to ensure that technology improves and thrives throughout time ("National Action Plan for Electric Mobility,Accelerating Implementation of Nepal's Nationally Determined Contribution", 2018).

2.1. Multiple Criteria Decision Analysis

Multi-criteria decision-making (MCDM) is one of the main decision-making problems which aims to determine the best alternative by considering more than one criterion in the selection process. MCDM has manifold tools and methods that can be applied in different fields from finance to engineering design (Taherdoost & Madanchian, M., 2023). Multi-criteria decision analysis provides a set of strategies, procedures, and calculations for organizing choice issues, planning process, assessing, prioritizing from the multiple set of alternatives. Example: For the goal of selecting suitable site for EV charging station in Koshi Province; settlement, roads, LULC, elevations, and substations could be the criteria.

2.2. Analytical Hierarchy Process

The analytic hierarchy process (AHP) is a process that uses hierarchical decomposition to deal with complex information in multicriteria decision making, such as multi-criteria decision making and product evaluation. It consists of three steps:

- Developing the hierarchy of attributes germane to the selection of multiple alternatives.
- Identifying the relative importance of the attributes.
- Scoring the alternatives' relative performance on each element of the hierarchy.

(Definition of Analytical Hierarchy Process (AHP), 2023).

3. METHODOLOGY

3.1. Study Area

Koshi Province is in the eastern part of Nepal, and it situated at 27.3372°N and 87.3811°E. The elevation ranges from 8,848.86m to 58 m (PeakBagger.com, 2014).Koshi Province due to which the centralization of various facilities such as education, medical, governance, economy, and other productive activities has led to rapid population growth. According to the 2021 Nepal census, there are around five million people in the province, with a population density of 190 per square kilometre. The province covers an area of 25,905 km^2 (10,002 sq mi), about 17.5% of the country's total area.

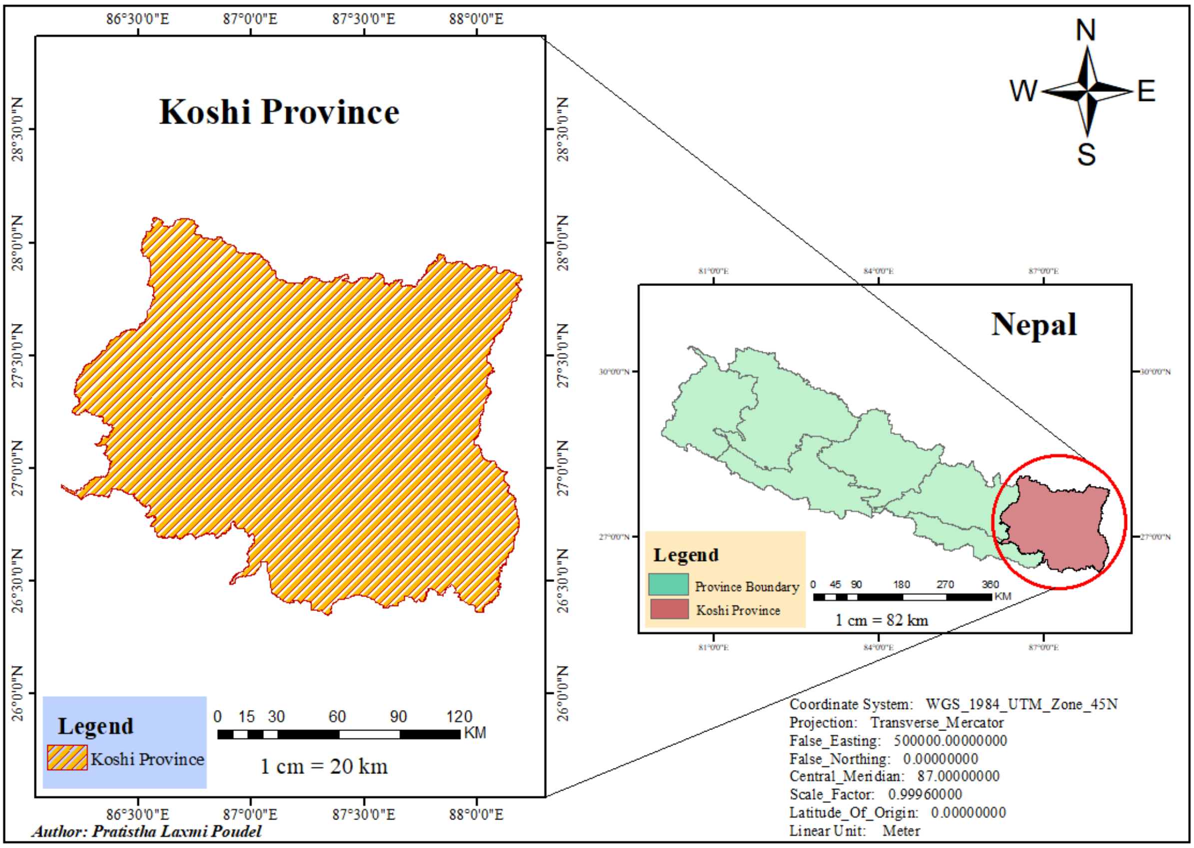

Figure 2: Study Area of Koshi Province

3.2. Materials Used

3.2.1. Data Used

Most data were provided by the supervisor and some necessary data were downloaded from the authenticated sources like Nepal Electricity Authority (NEA), etc. For uniformity all these data were converted to the same projection system as WGS 1984 UTM zone 45N.

Table 1: Data used and its type.

S.N.	Name of Data	Type of Data
1.	Road Network	Vector
2.	Power Grid	Vector
3.	Substation	Vector
4.	LULC	Raster
5.	Elevation data	Raster

3.2.2. Software Used

For the completion of the mini project, we used the ArcMap 10.8 version and an online AHP calculator to determine the weightage for each criterion on a pairwise comparison basis.

3.2.3. Workflow

The overall process involved in the AHP analysis for suitability map of EV charging station in Nepal is shown below:

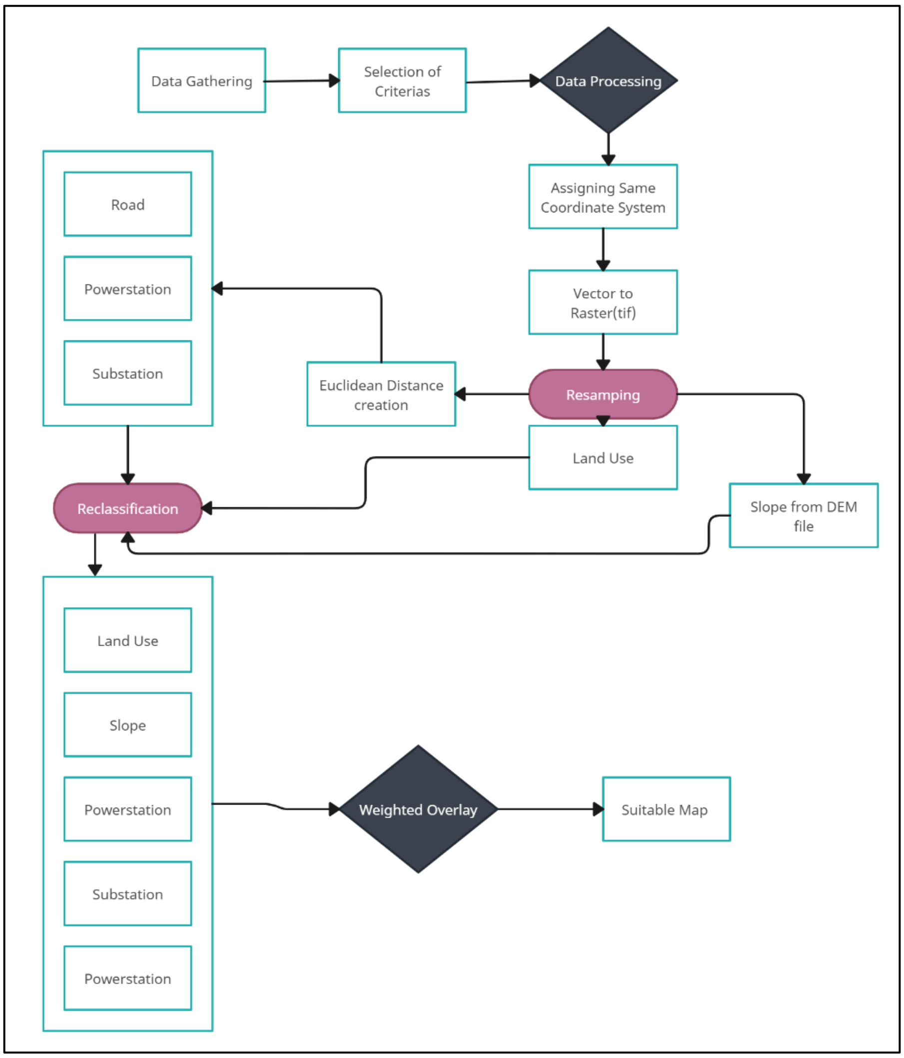

Figure 3: Methodological Workflow.

3.3. Influencing Factors

The charging station for EV can be influenced by many factors but some of the most basic and dependable factors are shown in diagram below:

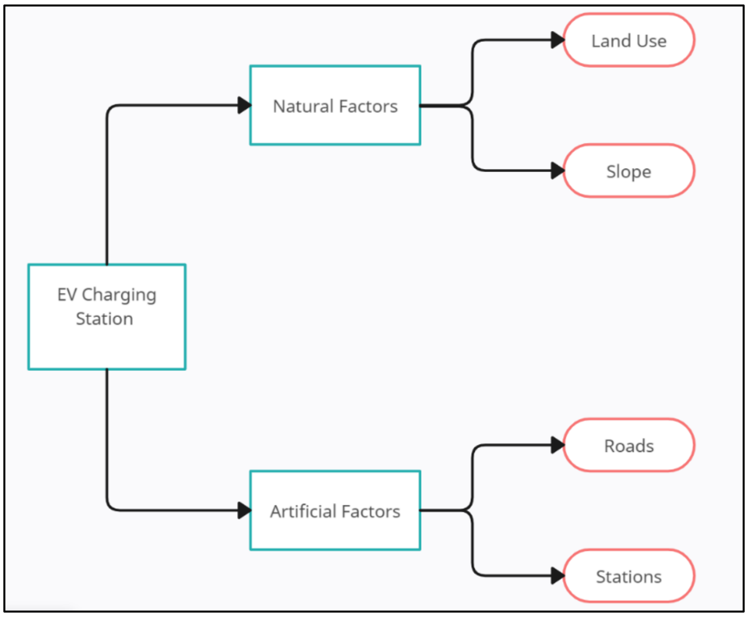

Figure 4: Influencing factors.

3.4. Criteria Selection

GIS is more than just a program. GIS technologies make working with dynamic data on spatially distributed objects more efficient. With its development, GIS has become an amazing tool capable of storing, retrieving, analyzing, and displaying vast amounts of geographic data from various sources. This is an essential factor to consider when selecting the most suitable location for charging stations (Bhandari, 2021).

The first step in this process is to decide on the selection criteria for appropriate charging locations. Consequently, standards were developed through the analysis of past site selection standards research. Many considerations were considered when selecting the ideal location, including slope, land use, road, settlement, and the data layers needed for interpretation.

3.5. Rating for suitability

A total of five classes are constructed, with number 1 being assigned to Least Suitable zones and number 5 being assigned to highly suitable zones. The article provided the majority of the data that was utilized to rate the features (Mussa, 2019). In contrast, certain numbers were presumptive based on generalizations and industry standards. Various factors are rated using the following standards.

Table 2: Assigned Ranking.

Assigned Rank	Suitability Classes
1	Least Suitable
2	Less Suitable
3	Suitable
4	Moderately Suitable
5	Highly Suitable

3.6. Classification of Criteria into Suitable Classes

The very first step in this process is to decide on the selection criteria for appropriate charging locations. Many considerations were considered when selecting the ideal location, including slope, land use, road, settlement, and the data layers needed for interpretation. Based on the data and rankings from the preceding research papers, the data layers for each criterion are reclassified using the suitability interval and ranking parameters. Every rank has a unique suitability class, with the range being 1 (Least Suitable) to 5 (Highly Suitable).

3.6.1. Road Criteria Allocation

For the easily and convenience of travelers, the charging stations were selected in such a way that they were near the main highways and other feeder roads. People could easily locate the charging stations without any additional assistance. So, the most appropriate distance from major road would be 50m and it would get highest ranking. Similar to this, as the buffer increases the ranking decreases in a similar manner.

Table 3: Suitability Rating for Road.

S.N.	Criteria	Distance (m)	Suitability	Ranking
1.	**Road**	> 600	Least Suitable	1
2.		250 - 600	Less Suitable	2
3.		150 – 250	Suitable	3
4.		50 – 150	Moderately Suitable	4
5.		< 50	Highly Suitable	5

3.6.2. Useable Land Criteria Allocation

The data from Land Use Land Cover (LULC) was provided by our instructor where the metadata consists of various additional information regarding water body, forest, riverbed, buildup area, cropland, bare soil, bare rock, grass land, other wooded areas, etc. We reclassified this information according to suitable theme and used it in a way that could create meaningful output. The ranking allocated as per the availability of useable land is shown in table below:

Table 4: Suitable Rating for Useable land.

S.N.	Criteria	Type	Suitability	Ranking
1.	Useable Land	Waterbody	Least Suitable	1
2.		Glacier	Least Suitable	1
3.		Snow	Least Suitable	1
4.		Forest	Suitable	3
5.		Riverbed	Less Suitable	2
6.		Build-up Area	Moderately Suitable	4
7.		Crop Land	Moderately Suitable	4
8.		Bare Soil	Highly Suitable	5
9.		Bare Rock	Less Suitable	2
10		Grassland	Highly Suitable	5
11.		Other wooded Land	Suitable	3

3.6.3. Power station Criteria Allocation

Due to high potential transmission grid coverage by power stations, the radius for buffer taken is comparatively greater than the sub-stations. The top ranking is for the range below 3 kilometers. The table below shows the ranking of power stations:

Table 5: Suitable Rating for Power stations.

S.N.	Criteria	Distance (km)	Suitability	Ranking
1.	Power Station	12 - 15	Least Suitable	1
2.		9 – 12	Less Suitable	2
3.		6 – 9	Suitable	3
4.		3 – 6	Moderately Suitable	4
5.		0 – 3	Highly Suitable	5

3.6.4. Sub-station Criteria Allocation

As the electric potential decreases as it reaches the sub-stations, the range of buffer also decreases in accordance with that. The ranking given to sub-stations are shown in table below:

Table 6: Suitable Rating for Sub-stations.

S.N.	Criteria	Distance (m)	Suitability	Ranking
1.	Sub-station Station	6000 - 7500	Least Suitable	1
2.		4500 – 6000	Less Suitable	2
3.		3000 – 4500	Suitable	3
4.		1500 – 3000	Moderately Suitable	4
5.		0 – 1500	Highly Suitable	5

3.6.5. Slope Criteria Allocation

The slope is an important consideration when choosing a site for charging station because as the site is plain, it will lower the cost of construction for excavation. A digital elevation model is used to generate the Slope. The region with a minimum percentage of slope (0-5%) is a highly suitable zone for the charging station site selection. We had assigned values from 1 to 5 to the slope based on worst to best site for landfill i.e., 1 as the least suitable and 5 as the highly suitable.

Table 7: Suitability Rating for Slope.

S.N.	Criteria	Percent (%)	Suitability	Ranking
1.	Slope	20 - 25	Least Suitable	1
2.		15 – 20	Less Suitable	2
3.		10 – 15	Suitable	3
4.		5 – 10	Moderately Suitable	4
5.		0 – 5	Highly Suitable	5

3.7. Calculation of Weightage using AHP for Data analysis

The weightage of each criterion is generated from the pairwise comparison technique of AHP (Analytic hierarchy process). In the pairwise comparisons method, for every pair of criteria, it should be determined which factor or criterion is more important than the other (Yousefi, 2018). By building the ratio matrix, AHP uses pair-wise comparison to assign weights to measure the relative importance of each criterion and then determines overall weights for evaluation. The comparison matrix indicates the comparative importance of the assigned criteria in a column to the criteria in a row as shown in the below table. A scale from 1 to 9, with 1 indicating that both column and row elements are equally essential.

Table 8: Graduation scale for Quantitative Comparison of Criteria.

Option	*Numerical value(s)*
Equal	1
Marginally strong	3
Strong	5
Very strong	7
Extremely strong	9
Intermediate values to reflect fuzzy inputs	2, 4, 6, 8
Reflecting dominance of second alternative compared with the first	Reciprocals

Table 9: Priority rating for pairwise comparison.

	A - wrt AHP priorities - or B?		Equal	How much more?
1	◉ Road	○ Sub Station	○ 1	○ 2 ◉ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
2	◉ Road	○ Power Station	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ◉ 6 ○ 7 ○ 8 ○ 9
3	○ Road	◉ LULC	○ 1	◉ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
4	◉ Road	○ Slope	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ◉ 9
5	◉ Sub Station	○ Power Station	○ 1	◉ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
6	○ Sub Station	◉ LULC	○ 1	◉ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
7	◉ Sub Station	○ Slope	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ◉ 6 ○ 7 ○ 8 ○ 9
8	○ Power Station	◉ LULC	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ◉ 7 ○ 8 ○ 9
9	◉ Power Station	○ Slope	○ 1	◉ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
10	◉ LULC	○ Slope	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ◉ 7 ○ 8 ○ 9
CR = 3.8% OK				

The *Consistency Ratio (CR) = 0.038* which is less than 0.1 thus, we can consider that our judgements are reasonably consistent so we may continue in decision making process using AHP.

The comparison matrix is given below as:

Table 10: Comparison matrix.

Criteria	Land Use	Road	Power station	Sub-station	Slope
Land Use	1	2	7	2	7
Road	1/2	1	6	6	9
Power station	1/7	1/6	1	1/2	2
Sub-station	1/7	1/3	2	1	6
Slope	1/7	1/9	1/2	1/6	1

Thus,

Number of comparisons = 10

Principal Eigen Value = 5.171

Eigenvector solutions = 5 iterations

Delta = 5.4E-8

Finally, using the principal eigenvector of the decision matrix, the appropriate weights are determined. The weights from the pairwise comparison matrix's primary eigenvector is displayed in the table below.

Table 11: Weightage of different criteria.

Criteria	Weight in Percent (%)	Rank
Land Use	40.6%	1
Road	33.4%	2
Sub-station	15.9%	3
Power station	6.4%	4
Slope	3.7%	5

4. RESULTS AND DISCUSSIONS

The purpose of this mini project is to improve the inadequacy and efficiency of site selection for suitable EV charging station operations and address a serious shortcoming in the identification of station sites. Several criteria are used in the suitable charging site selection procedure, namely, road, power station, sub-station, land use and slope data. The operation was performed in GIS using Multi- Criteria Evaluation, Analytic Hierarchical Process and Weighted overlay process in order to obtain the final particulars. For every layer encircling the station site, a proximity evaluation is carried out, taking slope and distance into account. It has been found that sufficient buffers are those that are 3000m distance from the power station and insufficient of about 15000m. For substation, a buffer of more than 7500 meters is considered least suitable. Roadside buffers greater than 1000 meters are likewise regarded as least suitable because they increase lengthen travel times. Bare soil, bare rock, grassland, crop land wooden land and built-up area were considered to be more sustainable while glacier, water body, snow and forest are studied to be implausible. Since fewer slopes is appropriate for the installation of EV charging station, about 5% of the gradient are deemed appropriate and more than 25% are deemed to be inappropriate.

4.1. Creating Criteria Maps

After the process of AHP suitability assessment, ranking and the weighted overlay, a final suitability map for EV charging stations was obtained which shows that about falls 6.13% under least suitable, 66.81% falls under less suitable, 22.52% moderately fall under suitable region, 4.52%fall under suitable and finally only 0.02%fall under highly suitable region.

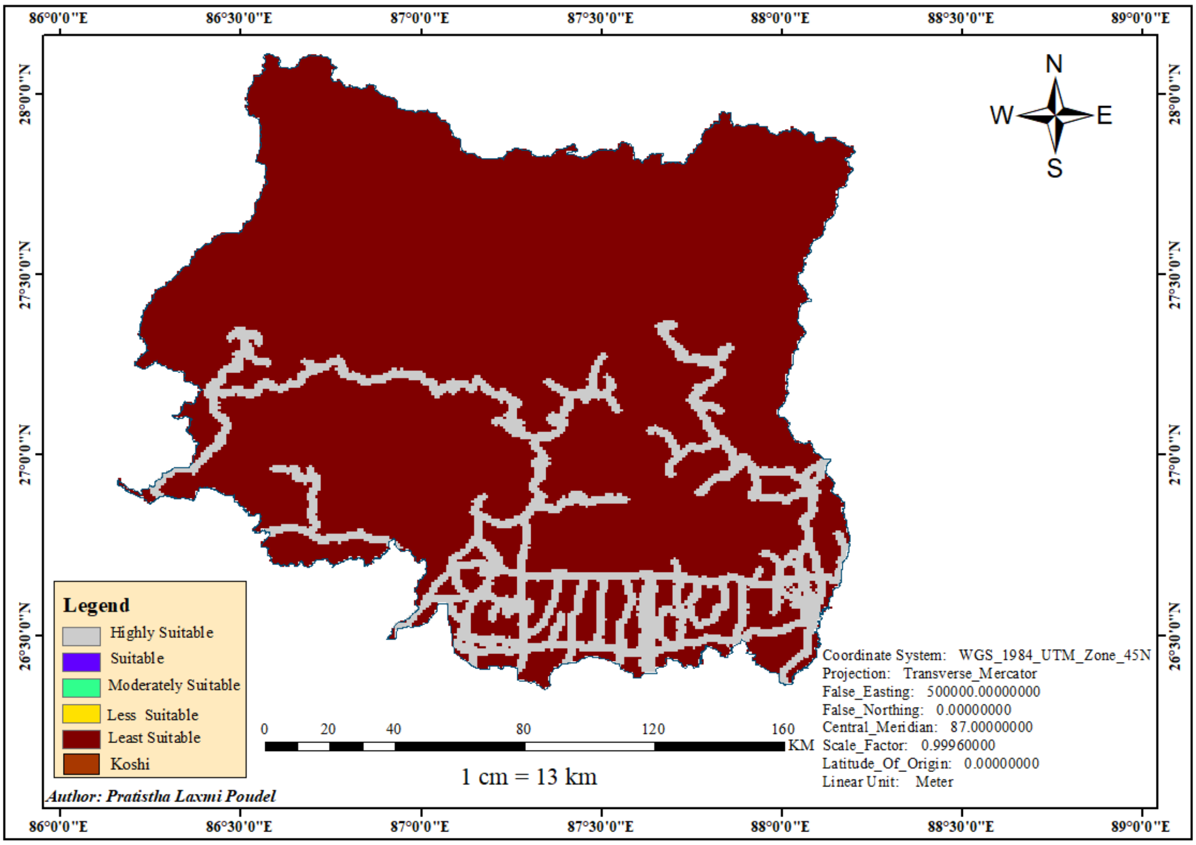

Figure 5: Road Network Suitability Map.

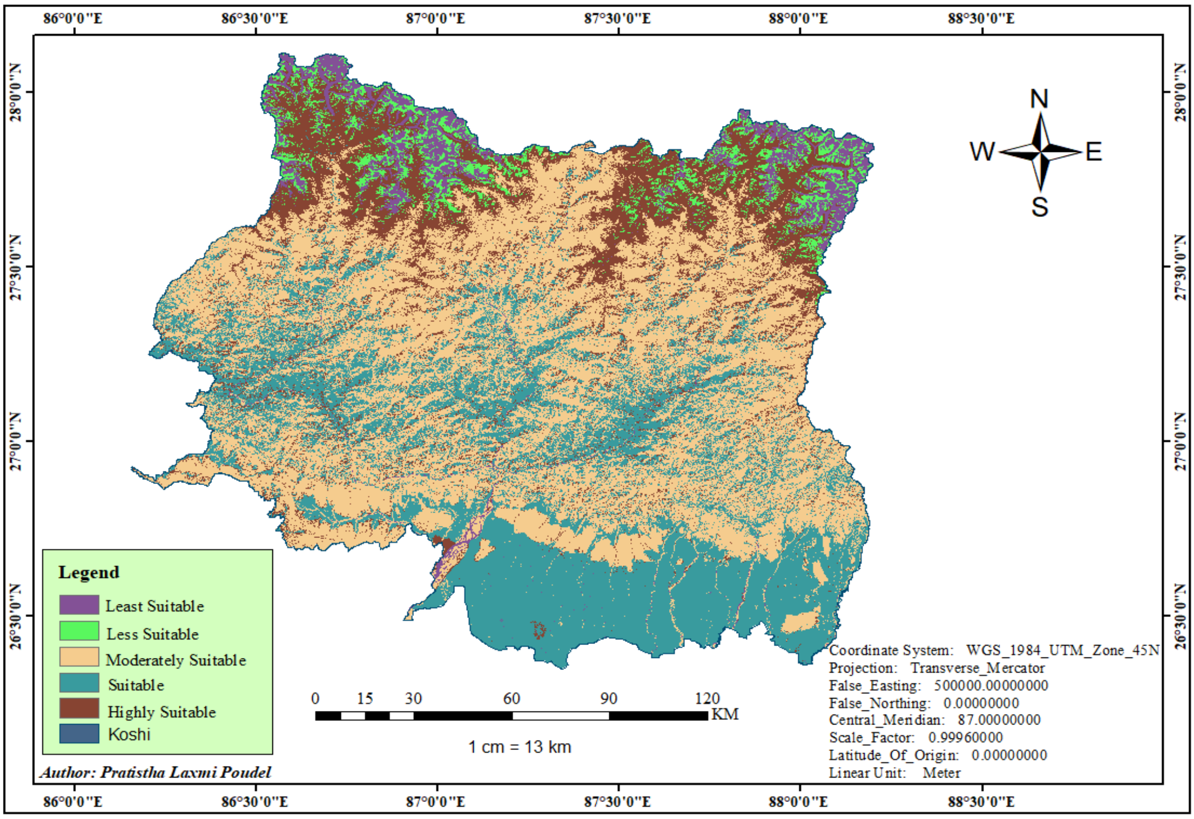

Figure 6: Land Use Suitability Map.

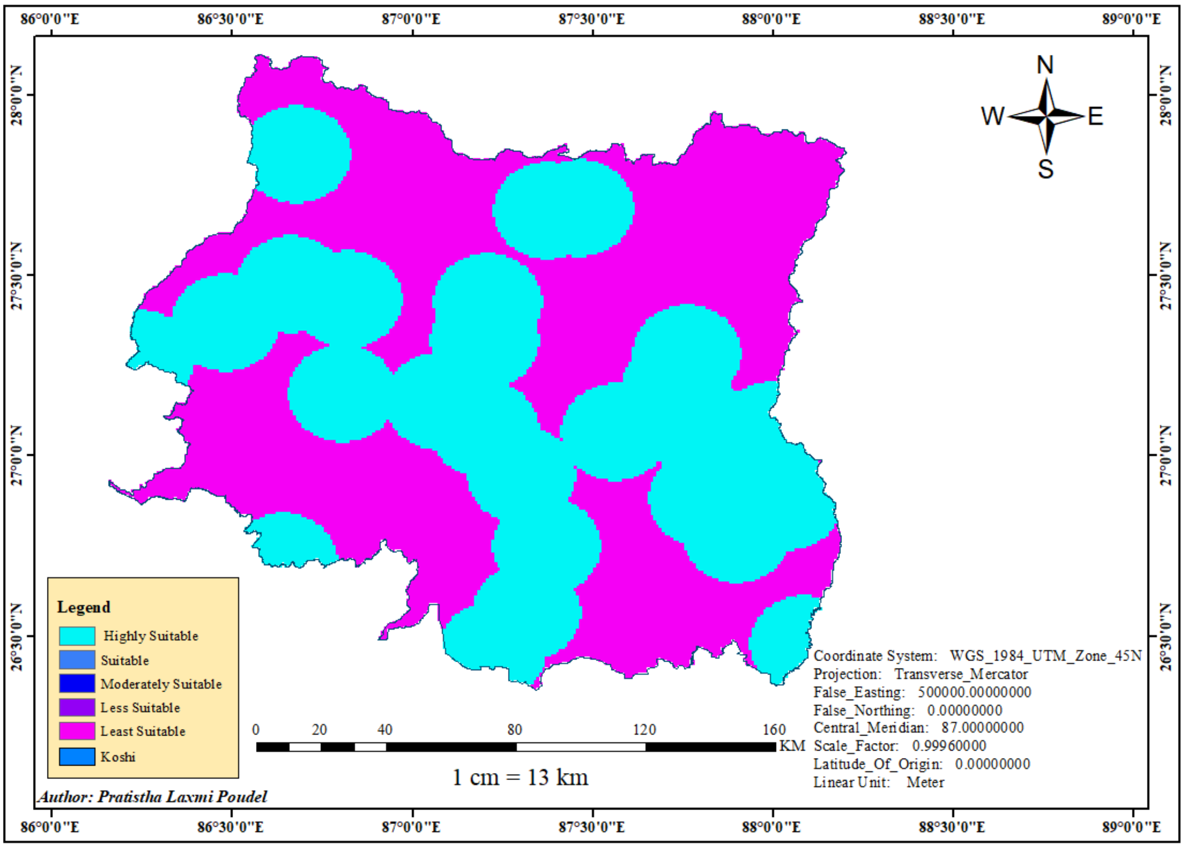

Figure 7: Power Station Suitability Map.

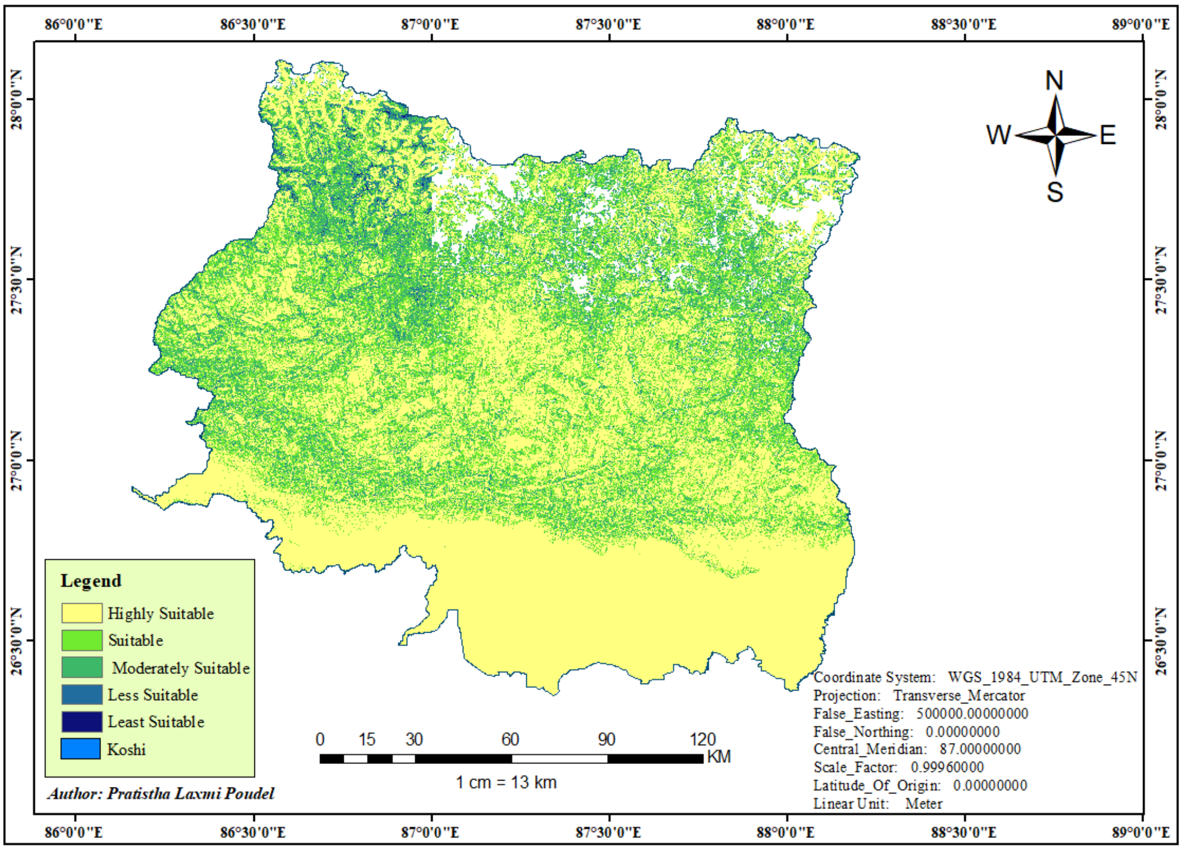

Figure 8: Slope Suitability Map.

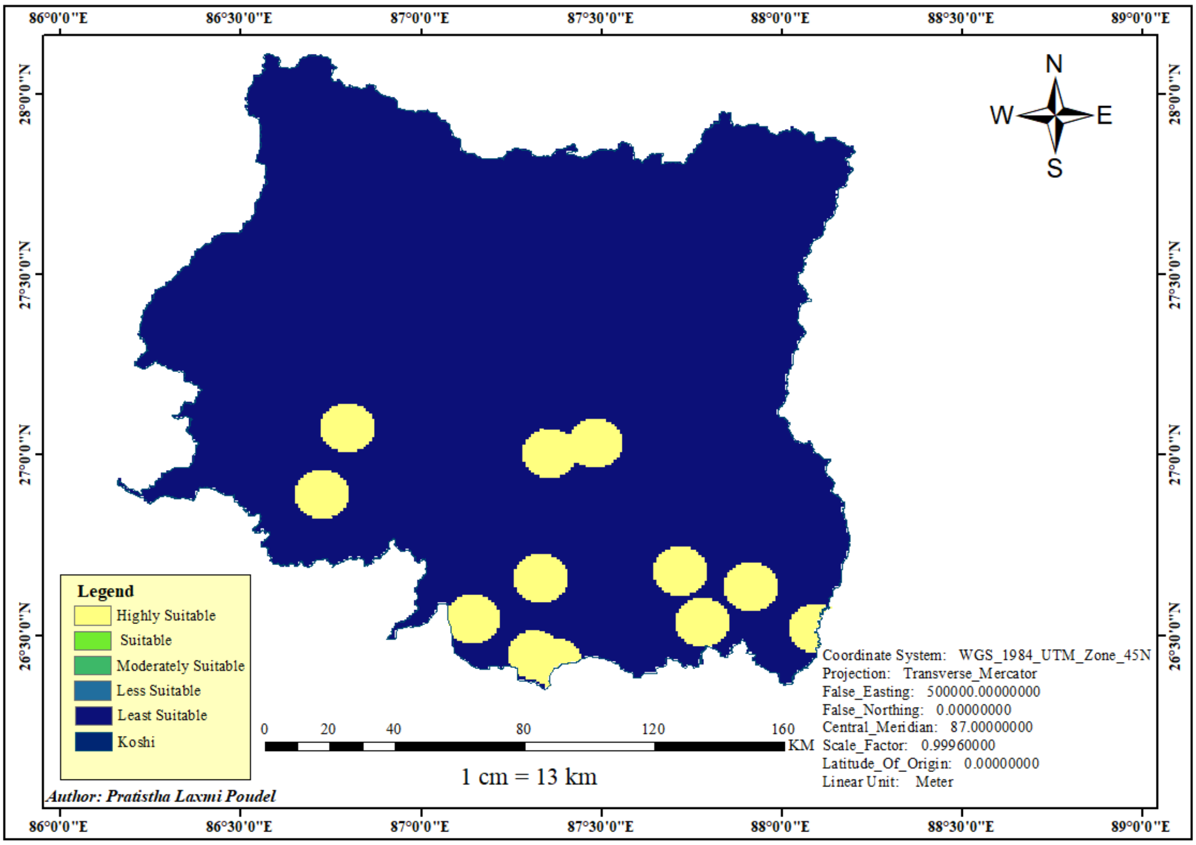

Figure 9: Sub-Station Suitability Map.

4.2. Final EV Charging Station Map after Weighted Overlay

Table 12: Area and Percentage coverage for each ranking.

Suitability Classes	Percentage of Area (%)	Area (km^2)
Least Suitable	6.104%	1494
Less Suitable	66.87%	16365
Moderately Suitable	22.547%	5518
Suitable	4.462%	1092
Highly Suitable	0.016%	4

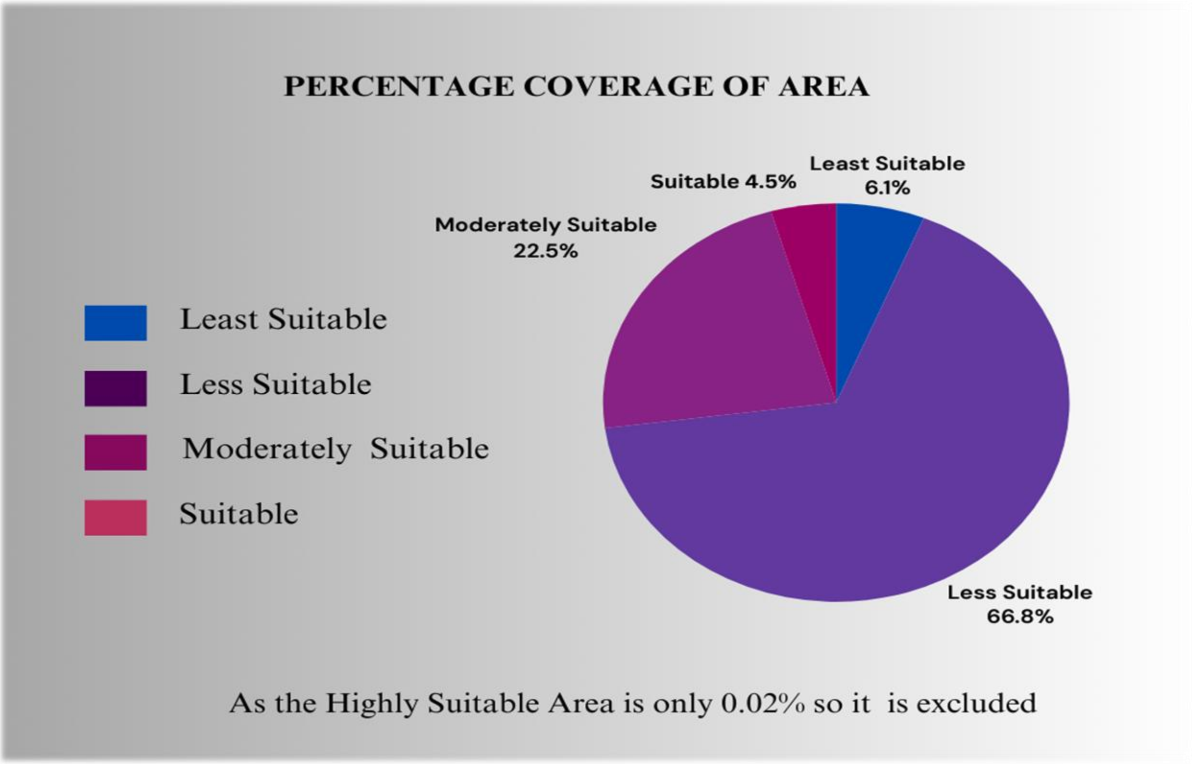

Figure 10: Pie Chart showing percentage for each ranking.

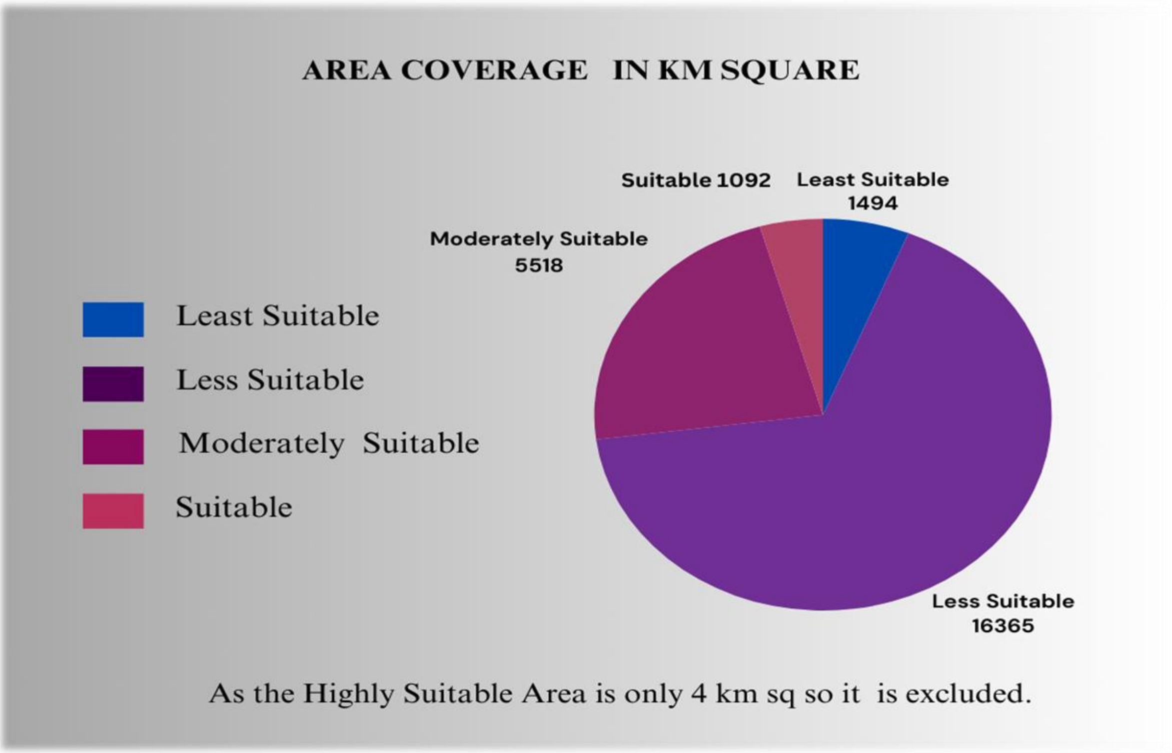

Figure 11: Pie Chart showing area covered by each ranking.

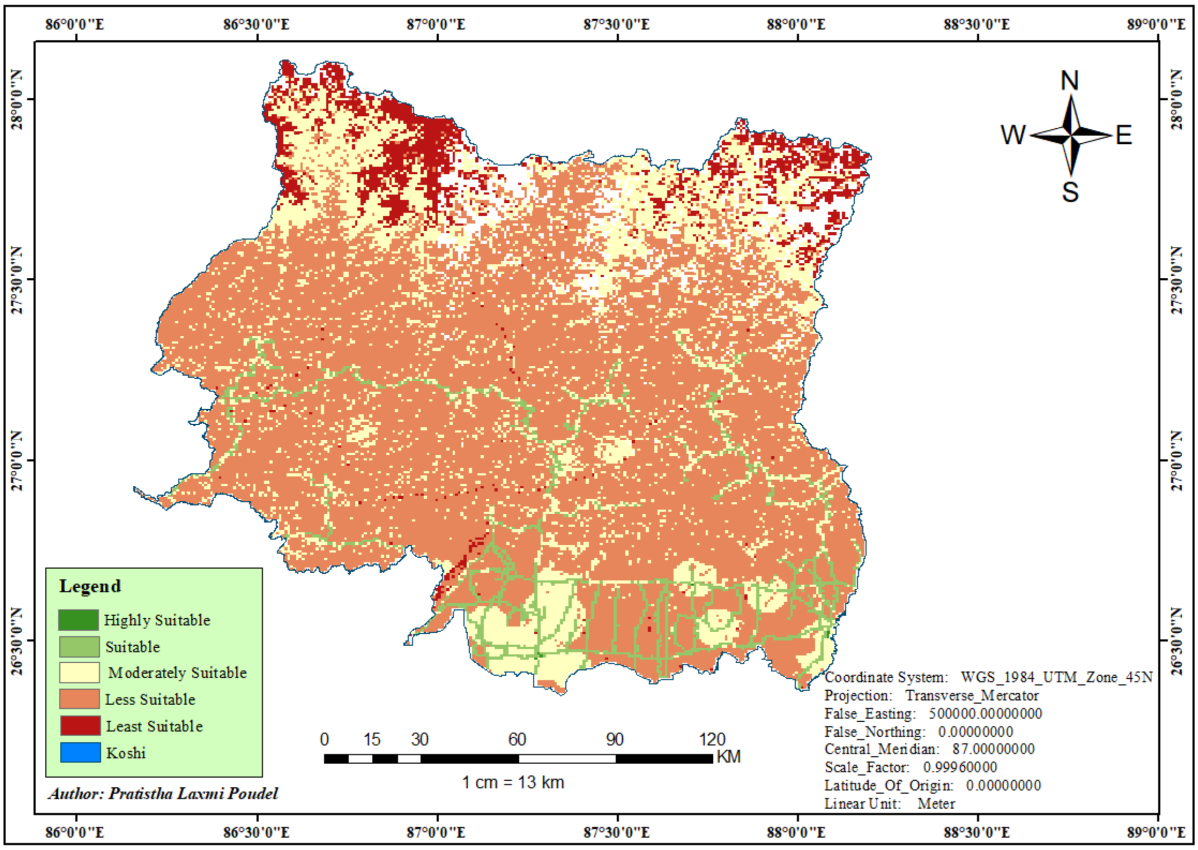

Figure 12: EV Charging Station Suitability Map.

5. LIMITATIONS

Despite all the efforts to maintain the efficiency of the project there are a few challenges due to which project have its limitations. With inadequate data it is difficult to manifest a sound integrated analysis with convenient result. And the data that were downloaded from various unauthorized platforms might be corrupted which leads to faulty output. While classifying the layers the criteria were imposed with reference to a few research papers which may be insufficient. We have used the online AHP calculator to identify the most important to least important criterion, so the reliability of its yields is questionable. Hence, the resulting map for suitability of EV charging station can be insufficient for precise and accurate detection of the exact location.

6. CONCLUSION AND FUTURE WORKS

6.1. Conclusion

The establishment of electric charging stations in, Nepal, marks Koshi Province a significant step towards promoting sustainable, eco-friendly, and economic transportation infrastructure. Due to high expenses of petroleum products the vehicles running with it will become outdated soon. So, the strategic placement of charging stations across key locations in Koshi Province not only addresses the current limitations in EV infrastructure but also lays the foundation for a more resilient and environmentally conscious transportation network. The primary goal of the project is to identify a suitable EV charging station's location. This study is based on the MCDA for selecting EV station's location which involves multiple criteria. AHP was used to calculate each criteria's relative importance. GIS was used to help construct each map layer. For the suitability analysis, several factors including LULC, roads, electric power stations, electric sub-power stations and slope were considered. The regions of Least Suitable, Less Suitable, Moderately Suitable, Suitable, and Most Suitable were created by reclassifying these criteria. Following the implementation of a weighted overlay, the regions classified as Least Suitable, Less Suitable, Moderately Suitable, Suitable, and Highly Suitable were identified.

6.2. Future Works

As the global market of EV is growing day by day, the developing countries like Nepal are keeping the development of EV in top priority for the sustainable development. To increase its growth, authorities must focus on the organization of public charging station along with the development of basic guideline. Concern authorities must concentrate on developing a trained workforce through training and other potential skill development programs in order to install, run, and maintain the EV charging station. The policy should benefit both the service provider and the user. With the increase in the number of middle-class families, budget options would ensure that EV's market share increases. Also, provision of aid can be helpful in research work of EV sector which may reduce trade deficit in import of petroleum oil. The Future surplus electric energy can be balanced by creating the demand in EV sector (Majid, 2020). Here in this report five parameters were considered to acknowledge the suitable site selection for EV charging station. Furthermore, parameters can be considered such as weather impacts, future expansion, range of EVs, battery technologies and so on in order to improve the outcome.

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