Journal of Innovations in Engineering Education
JIEE 2021, Vol. 4, Issue 2, pp 109-116.

https://doi.org/10.3126/jiee.v4i2.39712

THAPATHALI CAMPUS
Institute of Engineering
Tribhuvan University

Business model for financially sustainable electric vehicle charging station using EV charging financial analysis tool

Dilli Prasad Sapkota[a,*], Govind Raj Pokharel[a], Nawraj Bhattrai[a] and Pratap Jung Rai[a]

[a]*Department of Mechanical and Aerospace Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Lalitpur, Nepal*

ARTICLE INFO

Article history:

Received 12 Sep 2021
Received in revised form
19 Nov 2021
Accepted 01 Dec 2021

Keywords:

E-Buses
Optimization
Charging station
Linear programming method
Multi-criteria decision analysis

Abstract

Electric Vehicles (EVs) is an emerging field in transport sector. For Nepal, this is the golden opportunity to decrease petroleum oil consumption and creating another electricity demand area for future surplus electricity. There are various challenges which hinder the growth of EV adoption. Unavailability of sufficient public charging station is one of the major barriers. This gap brings a new business sector. This paper presents a business model for public charging station using EV charging financial analysis tool. The three potential partners that can collaborate in this project are owner-operator partner, private sector partners and public sector partner. Financial analysis is performed for three different scenarios. Discounted Cash Flow (DCF) method is used to calculate the financial parameters such as NPV, IRR and DPP for all partners in three different scenarios. In the first scenario, charging station along exist, without any government subsidy and indirect revenue sources. Only owner operator exists in first scenario. NPV stand at -$63,590, IRR and DPP are unavailable. Only government subsidy exists in second scenario. In this case, for owner operator and public sector partner, all three financial parameter shows infeasibility of project. For private sector partner, NPV is -$34,756, IRR and DPP are not available. Last scenario includes indirect revenue sources along with government subsidy. For owner operator, NPV stand at +$53,614, IRR is 17.7% and DPP is 6 year. Similarly, for private sector partner, NPV is positive, IRR is 10% and 7 year of DPP. For public sector, the project is in breakeven zone.

Abbreviations and acronyms

AC	: Alternating Current
CAPEX	: Capital Expenditure
CCS	: Combined Charging System
CHAdeMO	: CHArge de Move
DC	: Direct Current
DCF	: Discounted Cash Flow
DCFC	: DC Fast Charging
DPP	: Discounted Payback Period
EVs	: Electric Vehicles
IEC	: International Electrotechnical Commission
IRR	: Internal Rate of Return
LDVs	: Light Duty Vehicles
NPV	: Net Present Value
N/A	: Not Available
OPEX	: Operating Expenditure

*Corresponding author:
sapkotaasantosh66@gmail.com (D.P. Sapkota)

1. Introduction

The development of electric vehicles (EVs) has become a good opportunity for Nepal to decrease oil consumption and enhance air quality in major urban city. In current scenario, almost all consumed petroleum oil is imported from India which is increasing trade deficit of Nepal [1]. Petroleum product along cover 23% of total import by Nepal in FY 2018/1019 [2]. By 2030, the

clean energy generation will be 15,000 MW [3].This shows Nepal will have surplus electrical energy in coming years. This surplus energy supply can be balanced by creating demand from growing number of EVs through EV charging station.

Ministry of Finance have plan of encouraging electric vehicles to control the adverse effects of environment pollution on human health and promote clean and environment friendly development. A strategic plan will be formulated and implemented by 2031 AD (2088 BS) to replace the light vehicles powered by fossil fuels by electric vehicles [4]. On the other hand, Nepal Electricity Authority (NEA) is planning to establish charging station infrastructure in different part of country to increase demand of electricity [5].

To achieve these goals, the availability of charging stations in public areas is a critical need for the acceptance and widespread use of EV [6]. Infrastructure barriers (24.60%) is the major barrier among other which hindering the uptake of EVs in Nepal [7]. The other major problem for EV charging is its charging time. It depends upon the vehicle battery capacity and charging power. Based on the power output of charging equipment, four modes of charging were defined in international standard IEC 61851-1 [8]. For public charging station, mode 4 charging system, whose charging power level is more than 50kW is best option to reduce charging time of EVs. DC fast charging (DCFC) can recharge an EV in approximately 30 minutes [9]. As there is issue in range of EVs, there is need fast charging station in between long-distance travel. This incorporate the necessity of charging station in desired location. This has created a new business sector. There is various factor that affect the economic/financial status of public charging station. To attract private sector to invest in EV charging station, total revenues must be greater than the project's cost [10].

Direct and Indirect Revenue (R) > Capital Costs(C) + Operating Costs(O)+ Cost of Funds(F)

Where:

- Capital Costs are the cost of equipment and Installation
- Operating Costs are the ongoing costs to maintain
- Cost of Funds are the cost of paying interest on debt and investor returns on equity
- Direct Revenue are from sell of electricity and other direct fee
- Indirect Revenue are funds that came through sale of other products in charging station premises.

For the validation of the project, the projected financial parameters were compared with the similar business model project for its accuracy.

2. Literature review

EV charging equipment provides different power output for EV charging. Based on the power output of charging equipment, four modes of charging were defined in international standard IEC 61851-1 [8]. Namely, Mode 1, Mode 2, Mode 3 and Mode 4. Where the first three are AC and the later one is DC fast charging which can charge an EV within 30 minutes from 0% to 80%. Off-board chargers were used to charge an EV. DC fast charging stations require the installation of dedicated three-phase power supply equipment that draws significantly higher amperage than AC. This mode of charging is best for public charging station to remove anxiety range. The charging cable may be connected to the car inlet using a variety of connections. IEC 62196-2 specifies AC connections, whereas IEC 62196-3 specifies DC connectors.

EVs is a new business sector in transport field but at present scenario, EVSE business is not feasible for private sector to invest [6]. This is because of high initial cost of investment, low and uncertain future demand, and commercial charging competing with home charging. To make it feasible, Other sources of revenue, such as advertising, commodities sales, parking fees, and food services, must be explored by charging operators in addition to the charging fee [11]. In addition to the indirect revenue sources, government subsidy also helps to sustain public charging station. Therefore, a reliable business model must be built that allows charging station operator to recoup their expenditures while also offering EV consumers a charging price that is competitive with internal combustion engines vehicles [12].

3. Research Methodology

Issues identification on need of business model formulation of EV charging station, literature review, primary and secondary data collection, varying parameter and few assumption, financial tool calculation, results with financial analysis was made and finally conclusion and recommendation was made. For the inputs to the tool, indirect revenue sources was collected from field visit.

3.1. Financial tool

The EV Charging Financial Analysis Tool is a powerful Microsoft Excel based tool that is capable of analyzing different business arrangements, sophisticated public-private partnerships using various financial parameter

of electric vehicle charging projects. The tool was developed by Cadmus Group and the Centre for Climate and Energy Solutions and has been maintained by Atlas Public Policy since 2015. The tool analyzes the presented EV charging infrastructure investment from the perspective of three different potential partners, a private sector owner-operator, a private sector partner who contributes funding to project establishment, and a public sector partner who contributes funding or in other ways helps financial project deployment. Overall project's discounted cash flow was calculated to study the feasibility of the project. Output dashboard shows the financial parameters such as NPV, IRR and DPP for three different partners.

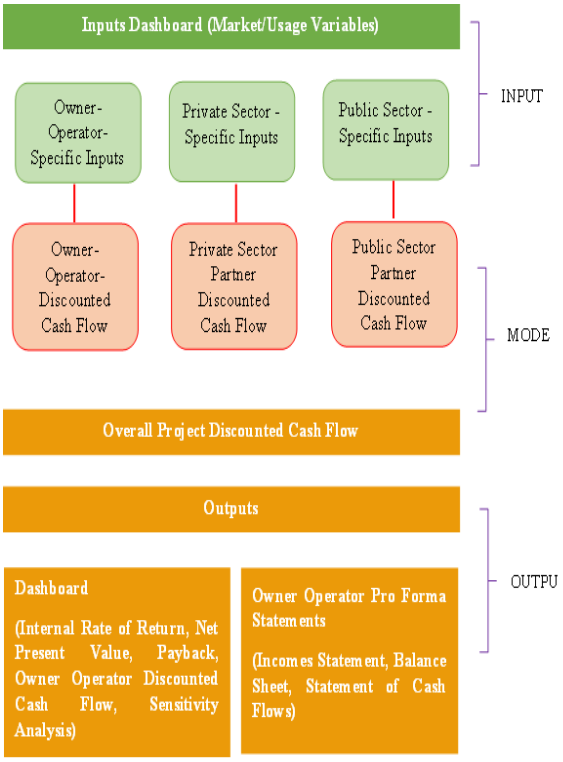

Figure 1: Structure of the EV charging financial analysis tool

3.2. Scenario development

There are various factor that affect the sustainability of public charging station. Such as government subsidy, indirect revenue sources, electricity price etc. By varying these parameters, we made three scenarios as shown in Table 1.

3.3. Data collection

Primary data collection and secondary data collection are the two methods utilized to acquire data. The primary data were collected from unstructured interview/questionnaires. The initial investment to establish the public charging station was divided into CAPEX and OPEX. To perform CAPEX, a sample charging station of 142 kW (two 60 kW DC off board and 22 kW AC on board in a single station), whose cost is $23,733 [13]. The cost of electrical equipment i.e. 200 KVA transformer and its accessories such as mounting set, steel tubular pole(11m), switchgear equipment, high tension cable, panel board, TOD meter etc. is $16,487.9 [14]. Similarly, civil structure cost such as flooring, painting is $588.23 [15]. The total number of EVs till today in the country was taken from sales manager of EV seller company. Indirect revenue sources such as revenue from hotel/resort and grocery sales were taken from existing public charging station in Riverside Spring Resort in Kurintar, Chitwan. Advertisement revenue was $5,842.5 [16].

Secondary data such as electricity tariff rate is $0.0564/kWh for 11 kV user [17]. Financial parameter like risk free rate is 3.24% [18]. Market risk premium is taken as 11.54% as country risk premium [19]. The cost of debt is considered as 5% [20]. Similarly, for private sector inputs, the weighted average cost of capital (WACC) is taken as 12% [21]. Marginal tax rate is taken as 12.5% [22].

3.4. Financial analysis

A financial analysis must perform to find the feasibility of the project. Therefore, a financial analysis was done using discounted cash flow method to find the financial parameters such as NPV, IRR and DPP.

Financial analysis is necessary to identify the profitability and investment payback. The tool uses discounted cash flow (DCF) method using free cash flow and weighted average cost of capital (WACC) for all partners associated with EV charging station system.

$$E_0 + D_0 = PV_0(WACC_t; FCF_t) \quad (1)$$

Equation 1 Equation (1) indicates that the present value of expected free cash flows (FCF) that the company will generate, discounted at the weighted average cost of debt and shareholder's equity after tax (WACC) will be equal to the value of the debt (D) plus that of the shareholder's equity (E).

WACC is given by Equation 2.

$$WACC_t = \frac{E_{t-1}Ke_t + D_{t-1}Kd_t(1-T)}{E_{t-1} + D_{t-1}} \quad (2)$$

In Equation 2, Ke is the required rate to equity, Kd is the cost of debt, and T is the effective tax rate applied to earnings. $E_{t-1} + D_{t-1}$ are market values.

Table 1: Parameters of three scenarios

Parameters	Scenario A	Scenario B	Scenario C
Service Life (Year)	10	10	10
Electricity selling Price ($)	0.0564	0.0564	0.0756
Discount rate for Owner Operator	14.78%	14.78%	14.78%
Discount rate of Private Sector	12%	12%	12%
Discount rate of Public Sector	0%	5%	5%
Equity Funded	100%	75%	75%
Debt Funded	0%	25%	25%
Annual Advertisement Revenue ($) per annum	0	0	5,842.5
Revenue from hotel/resort and grocery sales ($) per day	0	0	126

By using DCF method, we obtain financial indicators such as Payback period, internal rate of returns and net present value as in Equation 3, 4 and 5.

$$DDP = \frac{ln\left(\frac{1}{1-\frac{Ixr}{A}}\right)^{-1}}{ln(1+r)} \quad (3)$$

$$NPV = -I + \frac{F_1}{(1+r)} + ... + \frac{F_n}{(1+r)^n} \quad (4)$$

IRR is given as in Equation 5

$$NPV = -I + \frac{F_1}{(1+IRR)} + ... + \frac{F_n}{(1+IRR)^n} \quad (5)$$

Where,

DPP : Discounted Payback Period

NPV : Net Present Value

IRR : Internal Rate of Return

I : Initial Investment

A : Annual return

F : Future Values

r : Interest rate

Subtracting the present value of cash outflows from the present value of cash inflows yields net present value as shown in Equation 6.

$$NPV = PV_{inflows} - PV_{outflows} \quad (6)$$

The project should be accepted if NPV is positive (i.e. NPV >0) otherwise rejects. Similarly, IRR is the discount rate which makes NPV=0. The project will be accepted if the internal rate of return (IRR) is greater than the cost of capital otherwise rejects. Discounted Payback period is calculated using discounted cash flows of the project at given required rate of return. It gives the number of years for breakeven of project.

4. Result and discussion

4.1. Analysis of growth rate of EVs

For this research work, only light duty vehicles (LDVs) were taken for the study. Vehicle registration till 2018 were taken from DoTM. For the sake of simplicity, vehicle number from 2002 is taken, as there is only car/jeep/van were registered from 1989 to 2001. By using scatter with straight line and markers tool and adding exponential fit as trendline, the growth rate of LDVs is found to be 13.5% as shown in Figure 2.

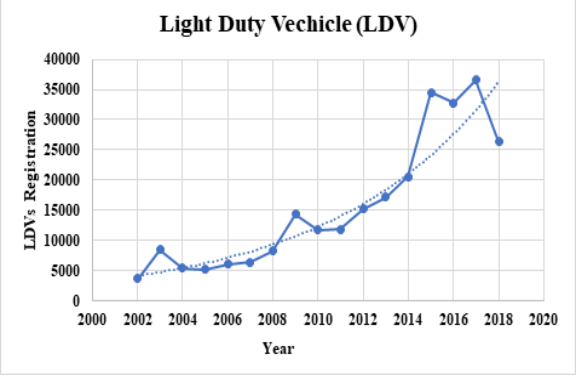

Figure 2: Registration of LDVs in Nepal

Using this data, we forecast the number of LDVs till 2031. For forecasting, we used FORECAST.ETS function in Excel tool, which return the forecasted value for a specific future date using exponential smoothing method.

4.2. Financial analysis of different scenario

Three different scenarios were made to perform the financial analysis of the project.

Table 2: Average annual growth rate of EV registration

Year	Forecasted Data	Taking 80% Vehicle	No. increment in Fossil Fuel LDV	Respective Increase in EV	EV Number for EV	% Growth
2021	36212	28970		2500		
2022	38092	30474	1504	4172	6672	167%
2023	39977	31982	1508	4183	10855	63%
2024	41776	33421	1439	3992	14847	37%
2025	43645	34916	1495	4147	18994	28%
2026	45514	36411	1495	4147	23142	22%
2027	47383	37906	1495	4147	27289	18%
2028	49232	39386	1479	4103	31392	15%
2029	51114	40891	1506	4176	35568	13%
2030	52989	42391	1500	4161	39729	12%
2031	54865	43892	1501	4163	43892	10%
		Difference	14922		41392	
			Multiplying Factor	2.77	Average	38%

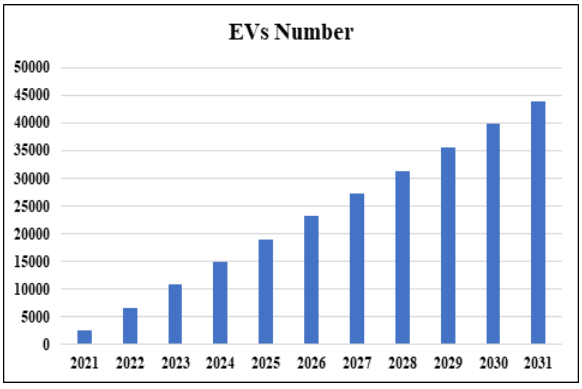

Figure 3: Projection of EV number

4.2.1. Scenario A: Base case scenario

For this scenario, only owner-operator exist i.e. there will be no involvement of private funding and government funding. The owner-operator itself is a private sector. Thus, only owner operator DCF is calculated for 10 year of service life.

Table 3: Financial performance summary (Scenario A)

Project NPV (Payback)	-$109,972
Owner-Operator NPV (Payback)	-$63,590
Private Sector Partner NPV(Payback)	-$46,382
Public Sector Partner NPV(Payback)	-N/A

In this scenario as represented in Table 3, the whole project NPV was negative. That means, public charging station cannot sustain without government subsidy and indirect revenue sources.

From the analysis, we found that NPV is negative of $63,590, IRR and discounted payback period are not available as the cash flow throughout the life time is negative.

Table 4: Financial performance details (Scenario A)

Parameters	Project	Owner-Operator
Capital Investment	$46,382	
Equity	-	$46,382
Private Debt	-	$0
Public Subsidized Debt	-	$0
NPV	-$109,972	-$63,590
IRR	N/A	N/A
DPP (Years)	N/A	N/A

4.2.2. Scenario B: With government subsidy but no indirect revenue sources

In this scenario, there will be involvement of all three partners. The portion of financial mix will be change to 75% equity and 25% debt. The 75% will be from private sector and 25% debt will be from government side. DCF is used to calculate the financial parameter. This scenario will not have any source of indirect revenue. In this scenario too, the energy cost taken same as that of scenario A i.e. $0.0564.

Table 5: Financial performance summary (Scenario B)

Project NPV (Payback)	-$99,824
Owner Operator NPV (Payback)	-$59,340
Private Sector Partner NPV(Payback)	-$34,786
Public Sector Partner NPV(Payback)	-$222

In the scenario B too, the project was infeasible for the investment. That means only public subsidy doesn't make project profitable.

For owner operator, NPV stand at -$63,590 and for private sector, NPV was -$34,786. For public sector, the project shows breakeven position which is good for government entity.

Table 6: Financial performance detail (Scenario B)

Financial Parameters	Project	Owner-Operator	Private Sector	Public Sector
Capital Investment	$46,382	-$34,786	-$11,595	
Equity	-	$34,786	-	-
Private Debt	-	$0	-	-
Public Subsidized Debt	-	$11,595	-	-
Net Present Value	-$99,824	-$59,340	- $34,786	-$222
IRR	N/A	N/A	N/A	0%
DPP	N/A	N/A	N/A	N/A

4.2.3. Scenario C: With government subsidy and indirect revenue sources

This is the most optimistic scenario for this project. Both government subsidy and indirect revenue sources such as advertisement revenue, grocery sales, revenue from hotel/resort sector were included.

Table 7: Financial performance summary (Scenario B)

Project NPV (Payback)	-$90,164(7)
Owner Operator NPV (Payback)	-$53,614(6)
Private Sector Partner NPV(Payback)	-$29,229(7)
Public Sector Partner NPV(Payback)	-$228

The whole project NPV is $90,164 which shows that the project seems feasible when there is involvement of government subsidy and indirect revenue sources.

For owner operator, NPV stand as positive of $53,614, while IRR is 17.7% and discounted payback period stand 6 year. Similarly, for private sector partner, NPV was $29,229, IRR is 10% and payback period is of 7 year. NPV for public sector partner stand negative and IRR stand 0% with no availability of discounted payback period.

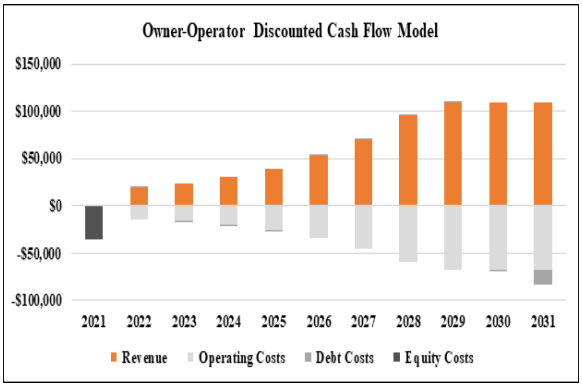

Figure 4: Owner Operator Discounted cash flow model

At initial time, there is high equity cost for owner operator i.e.75%. With the growth of electric vehicles, the revenue from indirect sources along with sales of electricity will be increased. The operating costs, debt costs and equity costs also increased with time.

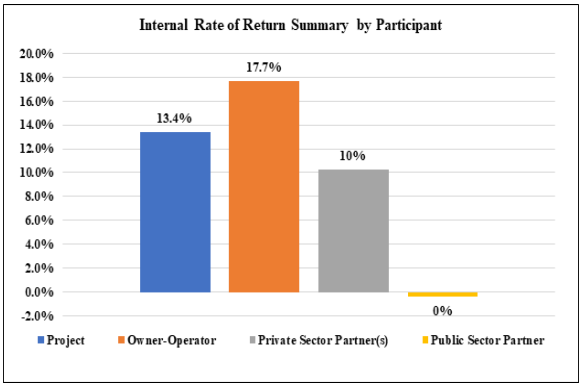

Figure 5: Internal rate of return for three different parameters.

For scenario C, the IRR shows positive aspect of the project with project's rate of return of 13.4%. Owner -Operator partner has highest rate of return than private sector and public sector. This shows the project will be feasible for them as they have WACC of 14.78%. But from private sector side, the project doesn't seem so much attractive. For the public entity, the project is good as their motive is to enhance EV sector.

4.3. Research validation

Similar type of business research done in the past were compared to the result achieved from this study in order to validate the results.

Research on cost estimates and revenue model for a public charging station (PCS) in India conclude that government subsidy is necessary in order to sustain the public charging station [15]. Two scenario which is based on margin on electricity tariff shows negative financial performance. While the case with 100% subsidy on charger cost shows the positive NPV with IRR of 16.04% and 14.97%. Similarly, report on assessing the business case for hosting electric vehicle charging stations in New York State shows that indirect revenues sources such as retail sales, advertisement near EV stations, has positive

Table 8: Financial performance details (Scenario C)

Financial Parameters	Project	Owner Operator	Private Sector	Public Sector
Capital Investment	$46,382		-$34,786	$11,595
Equity	-	$34,786	-	-
Private Debt	-	$0	-	-
Public Subsidized Debt	-	$11,595	-	-
Net Present Value	$90,164	$53,614	$29,229	-$228
IRR	13.40%	17.70%	10%	0%
DPP (Years)	7	6	7	N/A

impact on the sustainability of a public charging station. The study found that the profitability of station in between 7% to 250% based on archetype [23]. Report on business models for financially sustainable EV charging networks created three business models with the involvement of different possible partners such as government entity, local business group, owner-operator etc [10]. One time grant of $85,000 to $240,000 and loan at 5.4% interest rate is provided for three different business model. It shows the sustainability of charging station with government grant and loan at low interest rate.

The result of the above research resembles closely to the result of the study. Therefore, the results obtained from the past study and the result of the study matches with minor deviation in result.

5. Conclusion

Different polices from government has become a motivating factor for EV sector growth. But, the growth rate is much less than the government target due to lack of awareness about benefits of EV over petroleum vehicle. To meet the target set by government, the average annual growth rate of EVs should be 38%. We made three different business model scenarios to see the financial sustainability of EV charging station. The basis of different scenario formation is by varying of government subsidy, indirect revenue source and combination of both parameters. In scenario A i.e. for base case scenario, without any government subsidy and indirect revenue sources, all financial parameter came out infeasible. NPV stand at -$63,590 both IRR and discounted payback period were not available. So, this scenario showed the project is financially infeasible. For scenario B i.e. project with government subsidy but without any indirect revenue sources. Under this scenario, there are three different cases for three partners. For owner operator, all three financial parameters were infeasible. Similarly, for private sector operator, NPV is -$34,786, IRR and discounted payback period were unavailable. For public sector partner, all parameters are also infeasible. For scenario C i.e. having both government subsidy of 25% and indirect revenue sources. There are also three cases for this scenario. First one is for owner operator, where NPV is $53,614 IRR is 17.7% and discounted payback is 6 year. Similarly, for private sector partner, NPV stand at $29,229, IRR comes out 10% and payback period is of 7 year. From public sector partner side, the project seems neutral, which is good for government entity for providing quality service to general public. So, the feasible case will be inclusion of government subsidy and indirect revenue sources.

6. Acknowledgement

The Authors are thankful to staff of different EV seller company, Riverside Spring Resort, NADA Automobiles Association of Nepal, Electric Vehicle Association of Nepal (EVAN) for their kind support during data collection. The authors also thankful to all teachers and colleagues who directly or indirectly provide help, support and recommendations during this thesis work.

References

[1] Khanal S. Trade deficit impede Nepalese economic growth : an analysis from review perspective[J/OL]. International Journal of Multidisciplinary Research and Analysis, 2020, 03(10): 138-161,. http://ijmra.in/v3i10/1.php. DOI: https://www.doi.org/10.47191/ijmra/v3-i10-01.

[2] Singh K. Top Ten Items of Imports From India[R]// Nepal-India chamber of Commerce and Industry. Nepal, 2019.

[3] SNDC. Second Nationally Determined Contribution[M]. Kathmandu: Government of Nepal, 2020.

[4] Ministry of Finance. Budget Speech English[Z]. Kathmandu, 2021.

[5] Nepal Electricity Authority. A Year In Review-Fiscal Year-2019/2020[M]. Nepal: Nepal Electricity Authority, 2020.

[6] Pillai K R, Suri R, Kundu S, et al. Electric Vehicle Charging Stations Business Model for India[M]. India Smart Grid Forum, 2018.

[7] Adhikari M, Ghimire L P, Kim Y, et al. Identification and analysis of barriers against electric vehicle use[J/OL]. Sustainability (Switzerland), 2020, 12(12). DOI: https://www.doi.org/10.3390/SU12124850.

[8] IEC. IEC 61851-1 Electric vehicle conductive charging system – Part 1: General requirements[M]// Iec: 61851-1. International Electrotechnical Commission, 2017: 99.

[9] Kettles D. Electric Vehicle Charging Technology Analysis And Standards[M]// Florida Solar Energy Center. Florida, 2015.

[10] Nigro N, Frades M. Business business models for financially sustainable EV charging networks: March[M]. Washington: Center For Climate And Energy Solutions, 2015: 1-101.
[11] Zhang Q, Li H, Zhu L, et al. Factors influencing the economics of public charging infrastructures for EV – A review[J/OL]. Renewable and Sustainable Energy Reviews, 2018, 94: 500-509. DOI: https://www.doi.org/10.1016/j.rser.2018.06.022.
[12] Madina C, Zamora I, Zabala E. Methodology for assessing electric vehicle charging infrastructure business models[J/OL]. Energy Policy, 2016, 89: 284-293. DOI: https://www.doi.org/10.1016/j.enpol.2015.12.007.
[13] Nanjing Ark Tech Company Ltd. Ark 120kW DC and 22kW AC Output Electric Car Charger Stations for EV Charging in CCS CHAdeMO AC Type-2 with RFID and OCPP1.6[EB/OL]. https://www.alibaba.com/product-detail/Ark-120kW-DC-and-22kW-AC_1600092046895.html?spm=a2700.galleryofferlist.normal_offer.d_image.47503096YAfbf2.
[14] District Coordination Commitee Office. Kathmandu District Price Rate[EB/OL]. Kathmandu, Nepal, 2020. https://dccktm.gov.np/en/.
[15] Shah N. Plug In India[EB/OL]. 2019[7 Jan 2019]. https://www.pluginindia.com/blogs/cost-estimates-and-revenue-model-for-a-public-charging-station-pcs.
[16] Pixeltouch LED Display. Pixeltouch[EB/OL]. 2021. https://pixeltouch.asia/.
[17] Electricity Regulatory Commission. Full Tariff[EB/OL]. 2020. https://erc.gov.np/pages/full-tariff.
[18] NRB. Nepal Rastra Bank[EB/OL]. 2019. https://www.nrb.org.np/weighted-average-treasury-bills-rate/.
[19] Narsingh A A. Solution for estimating weighted average cost of capital, wacc, in frontier markets[J/OL]. 2018. https://anupamatya.com/estimating-cost-of-capital-wacc-in-frontier-markets/.
[20] Nepal Rastra Bank. Monetary Policy[EB/OL]. 2021. https://www.nrb.org.np/category/monetary-policy/.
[21] USAID. Nepal Private Sector Engagement Assessment, 2020[J]. USAID, 2020.
[22] Inland Revenue Department. Annual Report[EB/OL]. 2020. https://ird.gov.np/publication/category/annual-reports.
[23] DOED. Ministry of Energy Water Resources and Irrigation[EB/OL]. Govenment of Nepal,, 2021. https://www.doed.gov.np/.