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Original Article

Techno-Economic Assessment of EV Charging Infrastructure in Residential Buildings in Nonthaburi, Thailand

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Abstract - *Rapid Electric Vehicle (EV) growth in Thailand has resulted in growing demand for EV charging station infrastructure, particularly in condominium buildings with limitations in terms of parking space, common property ownership, electrical grid capacity, and condominium juristic person regulations. However, studies on the feasibility of shared EV charging stations in residential buildings remain limited when compared to public EV charging stations. Therefore, this study aims to assess the technical and economic feasibility of installing EV charging stations in residential buildings by using a building in Nonthaburi Province, Thailand as a case study and by making comparisons between three installation configurations where Configuration 1 has two 60-kW DC charging stations, Configuration 2 has one 60-kW DC charging station and two 22-kW AC charging stations, and Configuration 3 has four 22-kW AC charging stations. Analysis used economic indicators, namely, Net Present Value (NPV), Internal Rate of Return (IRR), and payback period, under conditions where the project duration is seven years, the discount rate is 5.5%, the mean electricity price is 7.25 baht/kWh, the service durations are 4, 6, and 8 hours per day, and the electricity cost is 4.50, 4.73, and 4.95 baht/kWh, resulting in 27 scenarios. According to the findings, all three configurations were found to have financial feasibility under the specified conditions. The configuration with two DC charging stations yielded the highest return in the event that the stations were in use for eight hours per day and the electricity cost was 4.50 baht/kWh, with an NPV of 3,258,975.10 baht, an IRR of 45.52%, and a payback period of 2.04 years, while the configuration with four AC charging stations was suitable for residential buildings with long parking durations because of its lower initial capital expenditure and maintenance cost. Analysis results indicated that daily service time and the difference between the electricity price and the electricity cost were the most significant factors for project cost-efficiency. This study provided practical recommendations for building managers, investors, and policymakers to select charging technologies, pricing structures, and residential building EV infrastructure development guidelines for consistency with space limitations and utilization behaviors.*

Keywords - *Electric vehicle charging station, Residential building, Techno-economic feasibility, Sensitivity analysis.*

1. Introduction

Electric Vehicles (EVs) have gained attention globally as a key alternative for greenhouse gas emission and fossil fuel reduction supported by battery technology advances, government policies, and private sector investments. In Thailand, the number of new EV registrations increased from 5,857 vehicles in 2021 to 147,121 vehicles in 2025 while the number of Hybrid Electric Vehicles (HEV) increased from 35,585 vehicles to 137,012 vehicles over the same period. This growth has made charging station infrastructure development an urgent necessity.

Due to continuous EVs demand growth, demand for sufficient charging station infrastructure is necessary, particularly in high-density residential buildings, such as condominiums where large numbers of residents are unable to install personal EV charging stations due to parking space ownership limitations, original electric grid capacity, and condominium juristic regulations. Therefore, planning of shared EV charging stations in residential buildings is an infrastructure and a structural engineering challenge. Multidimensional assessments of charging station infrastructure, including impact on the electrical grid, charging station position and capacity planning, user behavior, and financial feasibility have been conducted in previous studies. Most of the studies used NPV, IRR, and Payback Period (PB) as key indicators and found charging station utilization rates, electricity price structure, and pricing strategies to be key factors for project cost-efficiency**.** Although the infrastructure for Electric Vehicle (EV) stations has been widely studied, it's in terms of public charging stations and charging networks at gas stations. The study of charging stations in residential buildings or condominiums for electricity distribution presents an interesting research gap due to the constraints of condominiums, which include limited parking space, ownership of common property, existing electrical system capacity, and the regulations of the condominium juristic person.

Moreover, there are very few studies comparing AC, DC, and AC/DC charging models under the same financial assumptions for residential buildings in Thailand. Therefore, a techno-economic feasibility assessment is necessary to support investment decisions. This study is aimed at assessing the technical and economic feasibility of EV charging stations on three main points in a commercial building in Nonthaburi Province by integrating price quotation information, information on local electrical grid design, and financial model analysis with sensitivity analysis. The findings from this study will provide guidelines for investors, building managers, and policymakers in sustainably expanding EV infrastructure in the residential sector. Therefore, this study had the purpose of analyzing the feasibility of investments to install EV charging stations in residential buildings by using the building in Nonthaburi Province, as a case study.

This study used data on real use of charging stations installed to provide services in the building and financial modeling to assess project cost, revenue, cash flow, payback period, and returns in situations where the electricity price increased by 5% and 10%**.** Therefore, this study builds prior knowledge in three main aspects. First, this study aims to study AC charging stations in a high-density condominium building near main road, which is not a broadly studied category compared to public or fast-charging stations. Second, this study applies data on field use, making analysis of user behaviors and energy demand consistent with facts. Finally, this study analyzes the sensitivity of financial returns to variance in electricity cost and service user numbers, which are key indicators of cost-efficiency and commercial growth. The findings from this study will provide a useful guideline for building managers, juristic persons, investors, and government agencies in planning EV infrastructure to suit urban contexts and transition to an EV society in the future.

2. Theories and Related Studies

2.1. Electric Vehicles (EVs)

Electric Vehicles (EVs) are vehicles that use electric motors as a part of or the entirety of the transmission system by using energy from a battery or fuel cell rather than an internal combustion engine alone. Electric vehicles have gained attention by reducing fossil fuel consumption, air pollution, and greenhouse gas emissions in the logistics sector. In general, EVs have four categories consisting of HEVs, which use an engine with an electric motor without need to plug in and charge, PHEVs, which use both an electric engine and motor with the ability to charge externally, BEVs, which are entirely driven by an electric motor and require external charging, and FCEVs, which use hydrogen to generate electricity to drive motors. In the context of charging station development, the vehicle categories directly involved are PHEVs and BEVs out of dependence on external energy sources for charging, while HEVs do not require charging stations and FCEVs require specialized hydrogen infrastructure. EV growth, therefore, has made charging station development important for convenience, less concern about distance, and broad EV acceptance. Nevertheless, installing large numbers of charging stations may affect distribution systems in terms of peak load, voltage, and electricity quality, making parallel recognition of electrical grid readiness necessary.

2.2. EV Charging Stations

EV charging stations are key infrastructure in providing energy services for electric vehicles. In general, EV charging stations are in two main categories: DC charging stations, which supply direct current electricity directly to batteries and enable fast charging suitable for public stations or long-distance trips, and AC charging stations, which supply alternating current electricity via a converter within the vehicle. Although AC charging stations take longer, AC charging stations carry lower costs and are suitable for residences, offices, or places where vehicles are parked for a long time.

Charging can be categorized as conductive charging that uses cables to connect to vehicles and inductive charging that uses the principle of electromagnetic induction. However, conductive charging is more widely used due to technology availability, low cost, and greater support for commercial use. In high-density residential building contexts, AC charging stations are suitable due to consistency with long parking times and lower initial capital expenditure than DC charging stations. Nevertheless, when installing EV charging stations, consideration needs to also be given to old power grid capacity, peak demand, voltage, electricity quality, and transformer load.

2.3. Economic Evaluation Methods

Electric vehicle charging station installation requires detailed technical and economic analysis to support effective and cost-efficient investment decisions. This study enables clear assessment of project expenses and costs, including cost-benefit analysis, cash flow analysis, return on investment analysis, risk assessment, and comparison of existing alternatives with the following instruments:

Net Present Value (NPV) [1, 2] is a financial concept used in assessing the current value of net cash flow from any project or investment. Net present value (NPV) indicates investment cost-efficiency. A positive Net Present Value (NPV) indicates cost-efficiency while negative NPV indicates cost-inefficiency as shown in Equation 1.

$$NPV = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - C_0 \tag{1}$$

where:
NPV = net present value
n = number of periods or years
t = time period in which the cash flow occurs
C_t = net cash flow in period t
r = discount rate
C_0 = initial investment cost

Internal Rate of Return (IRR) [3, 4] is used to assess cost-efficiency of investments in the project and investment decisions. When the Internal Rate of Return (IRR) is higher than the discount rate, the project has investment cost-efficiency as shown in Equation 2.

$$0 = \sum_{t=1}^{n} \frac{C_t}{(1+IRR)^t} - C_0 \tag{2}$$

where:
IRR = internal rate of return
n = number of periods or years
t = time period in which the cash flow occurs
C_t = net cash flow in period t
C_0 = initial investment cost

Payback period is time spent paying back the investment [5]. Payback period calculations considered cash flow spent by the project to cover the initial capital expenditure and helped with assessment of time needed to pay back the project's capital as shown in Equation 3.

$$PV_t = \frac{C_t}{(1+r)^t} \tag{3}$$

where:
PV_t = present value of cash flow in period t
C_t = net cash flow in period t
r = discount rate
t = time period

Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PB) are widely used for assessing project investments. For example, Chongloi et al. [6] analyzed biomass power plant feasibility using NPV, IRR, payback period, sensitivity analysis, and minimum selling price, and found the project to have positive NPV, higher IRR than the criteria, and a break-even point dependent on product price and operating cost. Zuhri et al. [7] assessed economic feasibility of Robusta coffee cultivation in Indonesia by using R/C ratio and B/C ratio indicators to assess profitability. Nirvana et al. [8] studied the basic technical and economic feasibility of biodegradable packaging by assessing ROI, payback period, break-even point, investment structure, and operating costs. The findings from the above study indicated the project had economic capacity and supported a circular economy. Atshan [9] described the role of artificial intelligence in an economic feasibility study, emphasizing how data quality and quantity form a major foundation of financial analysis, trend estimations, and investment decision-making risk reduction. Mikayelyan et al. [10] analyzed the feasibility of rehabilitating cotton cultivation in Armenia by using NPV with sensitivity, productivity, and market price analysis and found the project to have positive NPV in many situations.

2.4. Related Studies

Research relevant to EV stations have been conducted in many areas with need for charging speed, electrical load management systems, planning of charging station installation, position, size, and capacity, including energy management and smart technologies. For example, Deilami et al. [11] proposed coordinating real-time charging in smart grids to reduce power loss and control the load, while Hassan et al. [12] studied guidelines on power user participation to reduce maximum load in residences. This study indicated how consideration should not be given only to the number of charging stations when installing charging stations in residential buildings and how assessment of electrical grid readiness and configuration must be carried out simultaneously when the number of EVs increase. In a case of EV charging station construction planning, Al-Hanahi et al. [13] summarized commercial EV infrastructure challenges, such as station adequacy, investment cost, and electrical grid limitations. Unterluggauer et al. [14] proposed planning EV charging station construction by linking transportation and power grids. In the case of Li and Jenn [15], space and time efficiency enhancement platforms were developed to estimate charging demand in each area. These studies reflected how charging station location and capacity should be relative to modes of travel, user behavior, and power grid capacity.

Furthermore, research on residential buildings and condominiums, such as Carvalhosa et al. [16], explored conventional charging methods for condominiums and indicated limitations in terms of the electricity grid, common area management, and allocation of charging station rights. This was consistent with the context of condominiums in Thailand where many residents are unable to install personal charging stations, making shared charging station development a more suitable alternative which requires thorough technical and financial assessment.

Concerning energy and price management, Liao et al. [17] proposed a charging strategy with recognition of integrated energy management and electricity purchases and sales. Simulations showed how station selection and price mechanisms were able to reduce waiting time and increase revenue. This concept indicated how service fees and charging time management affected user convenience and service provider revenue, which are key issues in assessing EV charging station feasibility in residential buildings.

In the area of long-term planning, Yang et al. [18] proposed planning adaptive EV charging station construction based on EV growth by using system dynamics and considerations of station growth or adjustments as decision-making variables. The abovementioned work emphasized how single plans may be insufficient when the number of EVs increases rapidly. In the meantime, Chen et al. [19] studied planning for construction of highway EV charging station capacity with DC cluster micro grids by using station selection behaviors and queue theory to assess charging demand.

Therefore, both studies support the idea that EV charging station construction planning should support changes in supply and infrastructure limitations. Uncertainty was another factor with effects on charging station design. Hinov et al. [20] proposed efficiency enhancement frameworks for modular fast charging stations under supply uncertainty, distributed energy, electricity price, temperature, and user arrival configuration.

Regarding use of renewable energy and smart technologies with EV charging stations, Kumar et al. [21] developed a prototype solar energy EV charging station with backup power from the grid and Rohane et al. [22] proposed a smart charging station that uses energy from the power grid with CC/CV charging control, while Gowri et al. [23] developed wireless solar energy EV charging stations and IoT for real-time system status tracking and Rizvi et al. [24] summarized challenges, strategies, and techniques for enhancing solar energy EV charging stations by focusing on connections between photovoltaic panels, energy storage systems, station design, and smart grids. The above studies demonstrated how energy cost reduction and operational efficiency enhancement are key factors for EV charging station cost-efficiency.

In the area of digital systems for locating and booking EV charging stations to fulfill operational dimensions, Anas et al. [25] developed the EV Charging Station Finder and Smart Booking System, which used mapping services, advanced booking, and emergency charging request systems, and Bhand et al. [26] developed a web application for locating EV charging stations. In addition, Ramya Sri et al. [27] proposed a real-time EV charging station finding and booking system with Google Maps and an online payment system while Kazi et al. [28] developed a cloud-based EV charging station locator and booking system which helped users to check for nearby stations, book station time, and receive warnings in advance.

This group of studies reflected how queue management and real-time status data can reduce waiting time, increase station utilization, and facilitate use of stations by users with effects on project revenue and cost-efficiency in terms of charging station investment economics. Most of the studies used NPV, IRR, payback period indicators, and sensitivity analyses to assess project cost-efficiency.

For example, George-Williams et al. [29] developed a probabilistic framework for assessing smart energy hubs that support EV charging while Bernal et al. [30] analyzed the cost-efficiency of DC fast charging infrastructure investment. In the meantime, a study conducted in Thailand by Chiradeja et al. [31, 32] used data on cost, income, electricity price, and service fee configurations to assess the financial feasibility of EV charging stations. These studies confirmed that investment decisions should consider uncertainty of supply, electricity cost, and service fees without considering only initial capital expenditure.

Relevant research indicated assessment of investments in condominium EV charging stations should integrate technical and economic factors e.g. electrical grid readiness, charging station category and capacity, real configuration of use, electricity cost, service fees, charging station utilization rates, and uncertainty of key variables and there is no economic analysis data on different AC/DC charging configurations in residential buildings under the same assumptions.

Therefore, this study used data from real project data in Thai commercial buildings with analysis of NPV, IRR, payback periods, and sensitivity analysis to determine EV charging station feasibility under operating conditions similar to the real situation.

3. Charging Station Cost and Details

3.1. Technical and Economic Feasibility Assessment

This study assessed the technical and economic feasibility of charging station installation in residential buildings by making comparisons between the following three installation configurations: (1) two 60-kW DC charging stations; (2) one 60-kW DC charging station with two 22-kW AC charging stations; and (3) four 22-kW AC charging stations. The analysis considered initial cost expenditures, annual operating costs, charging service revenue, and the impact of key variables through sensitivity assessment. The indicators used in the assessment were Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PB) with interest set at 5.5% by referencing the bank loan interest rate throughout the analysis. The selected installation location is shown in Figure 1.

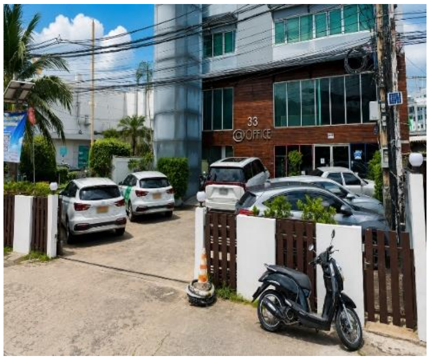

Fig. 1 Selected installation location of the proposed EV charging station

3.2. EV Charging Station Installation Cost Assessment

The project's cost assessment was based on EV charging station installation costs with coverage of the cost of charging stations, accessory equipment, labor, electrical system work, relevant construction work, leasing fees, and maintenance. Cost data was referred from real price quotations made by suppliers from collected data on design of the building in the case study as shown in Table 1 and Table 2. Initial investment cost was calculated as charger cost plus installation and equipment cost. Annual maintenance cost was treated as a recurring operating expense and deducted from annual cash flow.

Table 1. Charger cost and annual maintenance cost

Configuration	Charger Cost (THB)	Maintenance Cost (THB/year)
2 DC chargers	695,500.00	69,550.00
1 DC charger + 2 AC chargers	434,750.00	43,475.00
4 AC chargers	174,000.00	17,400.00

Table 2. Installation costs

Item	Quantity	2 DC Chargers (THB)	1 DC Charger + 2 AC Chargers (THB)	4 AC Chargers (THB)
250 kVA transformer including installation	1 set	425,000.00	425,000.00	425,000.00
Station construction work	For 4 parking	462,592.00	462,592.00	462,592.00
Charger pedestal installation	1 set	119,000.00	178,500.00	238,000.00
Parking space improvement work	For 4 parking	72,000.00	72,000.00	72,000.00
Software installation fee	1 set	20,000.00	20,000.00	20,000.00
Space rental fee	1 area	10,000.00	10,000.00	10,000.00
Installation and inspection fee	1 item	12,000.00	12,000.00	12,000.00
Additional electrical cable cost	50 meters	3,289.65	3,289.65	3,289.65
Transformer inspection fee	1 item	2,500.00	2,500.00	2,500.00
Total cost		**1,126,381.65**	**1,185,881.65**	**1,245,381.65**

3.3. Engineering Economy Analysis

Analysis of the project's financial feasibility applied engineering economy analysis principles to assess the return on investment from installing EV charging stations in different configurations.

The main indicators used in the assessment consisted of Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PB).

The project duration was set at seven years, with a discount rate of 5.5% applied throughout the analysis. Initial capital expenditure consisted of the cost of charging stations, equipment, electrical systems, construction, and installation, while maintenance cost was considered as an annual expense in the project's cash flow. The abovementioned cost division made assessment of returns more appropriate while reducing risk of redundant costs between initial expenditures and operating costs.

3.4. Sensitivity Analysis Design

Sensitivity analysis was used to assess the impact of changes in major variables on project financial cost-efficiency. The variables analyzed were charging station installation configuration, daily service time, electricity cost, and electricity price with service times at 4, 6, and 8 hours per day at a base electricity cost of 4.50 baht/kWh with consideration given to cases where the electricity cost increases by 5% and 10%, and a mean electricity price of 7.25 baht/kWh. This situation design covered service demand and energy cost fluctuations in a total of 27 situations as shown in Table 3.

Table 3. Scenario matrix for sensitivity analysis

Case Study	EV Charging Station Configuration	Operating Hours per Day	Electricity Cost (THB/kWh)	Electricity Selling Price (THB/kWh)
Case 1	2 DC chargers	4, 6, 8	4.50, 4.73, 4.95	7.25
Case 2	1 DC charger + 2 AC chargers	4, 6, 8	4.50, 4.73, 4.95	7.25
Case 3	4 AC chargers	4, 6, 8	4.50, 4.73, 4.95	7.25

3.5. Summary of Investment Feasibility

Analysis results in each situation were compared to summarized feasibility of investment by giving primary consideration to NPV, IRR, and PB values. Cases where NPV is positive, IRR is higher than the specified discount, and the payback period is suitable are financially feasible.

In addition, sensitivity analysis results were used to assess project risks under changes in electricity cost, electricity price, and service time to identify the most suitable charging station configuration for the building in the case study in terms of investment cost, revenue generation capacity, and long-term sustainability of returns.

4. Results

This study analyzed the economic feasibility of establishing EV charging stations in a condominium building by making comparisons between three system configurations where Configuration 1 had two 60-kW DC charging stations, Configuration 2 had one 60-kW DC charging station and two 22-kW AC charging stations (a mixed system), and Configuration 3 had four 22-kW AC charging stations. In financial assessment, the project duration was set at seven years, the discount rate was 5.5%, and the mean electricity service fee was 7.25 baht per kilowatt-hour (kWh). Analysis was carried out under conditions with variance in service time (4, 6, and 8 hours per day) and electricity cost (4.50, 4.73, and 4.95 baht per kWh) in a total of 27 simulations. Results in financial indicators, such as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PB), were summarized as shown in Table 4.

According to the findings, investment in all three configurations was found to have financial feasibility in every simulation. Configuration 1 (2 DC charging stations) was able to generate the highest return (NPV at 3,258,975.10 baht, IRR at 45.52%, and PB at 2.04 years) in the event with the highest load (8 hours per day) and the lowest electricity cost (4.50 baht per kWh). Due to a high overall energy distribution capacity, Configuration 1 generated higher revenue than the other configurations because of its greater energy delivery capacity. and at a significantly higher amount than other configurations.

Table 4. Financial results for sensitivity analysis

No.	Configuration	Hours/ day	Electricity cost (THB/kWh)	Selling price (THB/kWh)	NPV (THB)	IRR (%)	Payback Period (years)
1	DC 2 chargers	4	4.5	7.25	520,921.54	13.02	4.42
2	DC 2 chargers	4	4.73	7.25	296,898.98	9.89	4.89
3	DC 2 chargers	4	4.95	7.25	72,876.42	6.6	5.46
4	DC 2 chargers	6	4.5	7.25	1,889,948.32	30.2	2.79
5	DC 2 chargers	6	4.73	7.25	1,553,914.48	26.21	3.07
6	DC 2 chargers	6	4.95	7.25	1,217,880.63	22.1	3.41
7	DC 2 chargers	8	4.5	7.25	3,258,975.10	45.52	2.04
8	DC 2 chargers	8	4.73	7.25	2,810,929.97	40.63	2.23
9	DC 2 chargers	8	4.95	7.25	2,362,884.85	35.63	2.47
10	1 DC charger + 2 AC chargers	4	4.5	7.25	505,281.10	13.67	4.33
11	1 DC charger + 2 AC chargers	4	4.73	7.25	311,128.22	10.64	4.77
12	1 DC charger + 2 AC chargers	4	4.95	7.25	116,975.33	7.48	5.30
13	1 DC charger + 2 AC chargers	6	4.5	7.25	1,691,770.98	30.34	2.78
14	1 DC and 2 AC chargers	6	4.73	7.25	1,400,541.65	26.46	3.05
15	1 DC charger + 2 AC chargers	6	4.95	7.25	1,109,312.31	22.47	3.37

16	1 DC charger + 2 AC chargers	8	4.5	7.25	2,878,260.85	45.27	2.05
17	1 DC charger + 2 AC chargers	8	4.73	7.25	2,489,955.08	40.5	2.24
18	1 DC charger + 2 AC chargers	8	4.95	7.25	2,101,649.30	35.63	2.47
19	AC 4 chargers	4	4.5	7.25	489,640.66	14.49	4.23
20	AC 4 chargers	4	4.73	7.25	325,357.45	11.59	4.62
21	AC 4 chargers	4	4.95	7.25	161,074.24	8.59	5.10
22	AC 4 chargers	6	4.5	7.25	1,493,593.63	30.51	2.77
23	AC 4 chargers	6	4.73	7.25	1,247,168.81	26.78	3.02
24	AC 4 chargers	6	4.95	7.25	1,000,743.99	22.93	3.33
25	AC 4 chargers	8	4.5	7.25	2,497,546.61	44.95	2.06
26	AC 4 chargers	8	4.73	7.25	2,168,980.18	40.34	2.25
27	AC 4 chargers	8	4.95	7.25	1,840,413.75	35.62	2.47

However, in a situation with low demand for use and high electricity cost, Configuration 3 (4 AC charging stations) had the lowest financial risk from having the lowest initial capital expenditure and maintenance cost, making the configuration suitable for residential buildings where users park vehicles for a long time, while Configuration 2 (a mixed system) demonstrated high operational flexibility capable of supporting balanced urgent and long-term charging behaviors. Sensitivity analysis results indicated daily service time and electricity price were the main factors sensitive to financial returns due to direct fluctuations on the amount of electricity sold and the project's incoming cash flow. Figures 2-4 demonstrate that financial performance improved as operating hours increased. The configuration with two DC chargers produced the highest NPV because of its greater charging capacity and revenue generation potential. Compared with previous studies [33], this case study confirms that utilization, electricity cost, and service tariff strongly affect financial performance. The two-DC-charger configuration achieved the highest NPV due to greater charging capacity, while the four-AC-charger configuration showed shorter payback because of lower investment and maintenance costs.

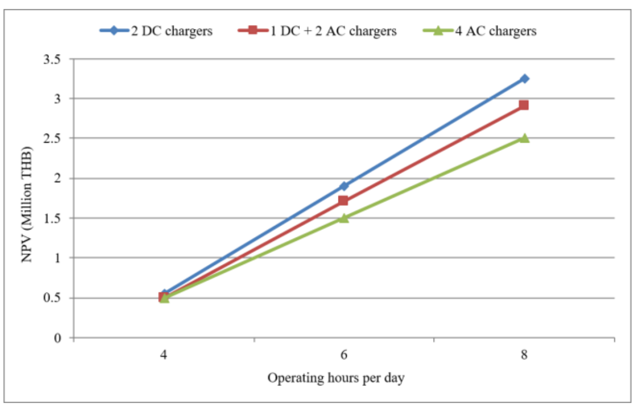

Fig. 2 NPV comparison by configuration

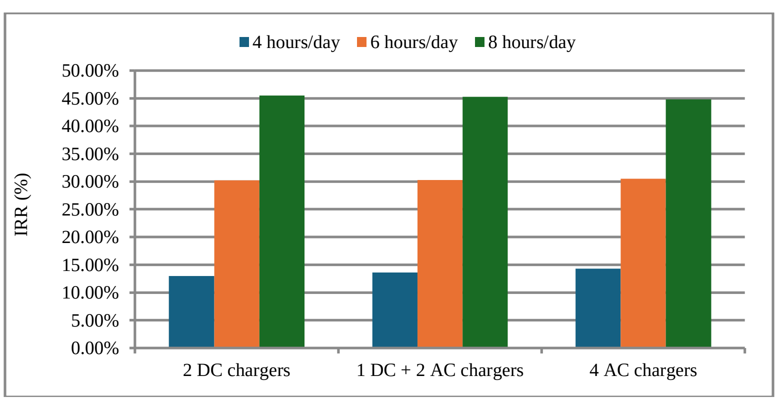

Fig. 3 IRR comparison by configuration

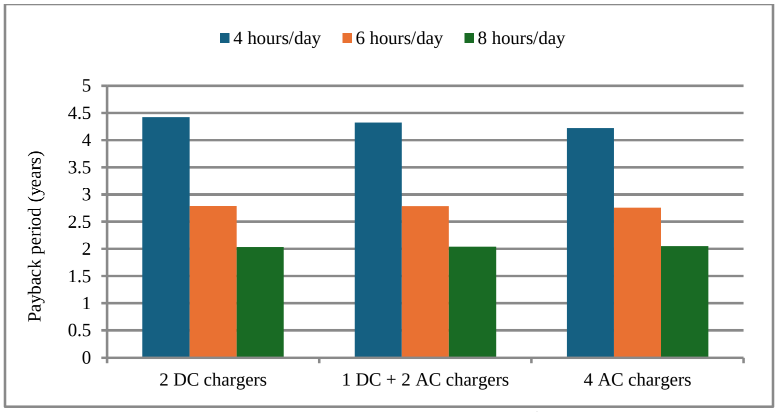

Fig. 4 Payback period comparison by configuration

5. Conclusion & Recommendations

5.1. Conclusion

This study assessed technical and economic feasibility in establishing EV charging stations within a high-density residential building by simulating alternative situations in 27 sensitivity scenarios. Evidence-based analysis concluded investment projects in all three configurations were financially cost-effective with different contextual suitability. Configuration 1 with two DC charging stations yielded the highest financial return in the event of dense and continuous service utilization, making this configuration suitable for buildings in need of parking space turnover speed. Configuration 2 with one DC charging station and two AC charging stations was most effective and flexible in parking management in support of diverse service user behaviors. Configuration 3 with four AC charging stations had a clear advantage in terms of lower initial capital expenditure, making this configuration structurally suitable for buildings where residents focus on overnight parking. Therefore, in conclusion, the critical economic variables that determine project sustainability were mean daily service time and the difference between electricity price and energy cost.

5.2. Practical and Policy Recommendations

For building managers and condominium juristic persons, an in-depth survey form should be prepared to survey electric vehicle utilization behaviors of residents and survey the building's electrical load capacity before projects begin in order to prevent technical problems. In addition, consideration should be given to setting a service fee structure consistent with real periodical energy costs (such as electricity fees based on time of use) in order to manage peak electricity demand.

In terms of policy recommendations for the government sector and agencies involved, supportive and tax incentive measures should be put in place, including low interest financing for condominium electrical infrastructure improvements and improvements to electrical safety standards and building codes to support electric vehicle growth in urban contexts.

5.3. Limitations and Guidelines for Future Research

To improve on knowledge bodies and discoveries, future studies should apply longitudinal data from real field use to reduce simulation variance along with analyzing technical impact on power quality, such as voltage drops and harmonic distortion. In addition, the scope of the study should be expanded to new business model canvases, such as smart charging/load management systems, digital booking and payment systems, including integration of Solar Photovoltaic (Solar PV) rooftop power generations systems with Battery Energy Storage Systems (BESS) to drive towards full energy and environmental sustainability.

Conflicts of Interest

The authors declare no conflict of interest.

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