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Piloting and Market Validation of Electric Vehicle (EV) Rapid Charging Station Operation in a Smarter City

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Abstract

Electric vehicles (EV) are undoubtedly becoming popular worldwide because of their huge potential in reducing fuel consumption, carbon dioxide emissions, and noise pollution. This is especially true in the Philippines, where the transportation sector accounts for about 70.7% of the nation's petroleum consumption. As such, a shift to EVs will contribute a lot to the National Climate Change Action Plan (NCCAP). In addition, a gradual shift to EVs will also make the country less vulnerable to fluctuations in oil prices in the world market. The study explored the appropriate business model for the electronic vehicle charging operation in a Smarter City.

Disciplinary: Business Management, Smart City, Transportation, Sustainability.

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1. Introduction

Cauayan City, Isabela, Philippines is the first urban local government to adopt the Smarter City concept in Region 2. The Local Government Unit of Cauayan City developed some smarter city strategies that will make processes more efficient, participative, and innovative to its people and also plans to adopt appropriate modern transportation technologies as part of the many smarter-city strategies of including smart transportation (Montalbo et al., 2011; Sazali, 2020) or the use of e trikes. Public transport utility vehicle services in Cauayan City include buses, mini-buses, jeepneys, and tricycles. Tricycles generally serve short-distance trips within the urban barangay with some trips being made to outlying barangays and nearby towns. In 2002, Cauayan City has 39 registered tricycle operator-drivers associations whose membership totals 2,585 units. To date, this number doubled up to 4,500 registered tricycles. Tricycle uses a conventional combustion engine that emits carbon monoxide which later on has a dramatic impact on air quality affecting the health of people and increases exposure to climate change risks. Recognizing the need for cleaner and more efficient vehicles, the government initially transformed the public transportation sector by adopting electric vehicles specifically electric tricycles. Given this scenario, the city government is interested to invest on e-trikes as part of its strategy to promote Smarter City-Smarter Mobility in the municipality as well as the adoption of an e-trike battery charging station for the successful implementation of the project (ADB, 2012; Schneider, 2015). One of the recent technologies for e - trike is the locally developed facility that can charge e-vehicles in less than 30 minutes instead of the usual six hours. This technology known as Rapid Electric Vehicle Charging or CharM (Charging in Minutes) is developed by the University of the Philippines – Electrical and Electronics Engineering Institute (UP-EEEI) with funding support from DOST-Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD). This technology is used in this project as a charging facility for e-trikes.

Both e-trikes and CharM are piloted in Cauayan City. This project aims to promote local technologies vis-à-vis economic growth and technological advancements and technological advancements not only in Cauayan City but also in Region 2. The development of fast-charging stations promotes the growth of e-trikes by increasing their reliability for continuous operation (Peterborough, 2016; BipiZ, 2017). Likewise, the primary objective of this research is to establish the pre-commercialization requirements of the Rapid Electric Vehicle Charging (Charging in Minutes). To achieve this goal, the following specific objectives are identified (a) to validate the type of users, frequency of use, and other market and social drivers for the commercialization of CharM in Cauayan City, Isabela, Philippines; and (b) to identify an appropriate financial and business model for CharM (Nigro & Frades, 2015).

2. Business Models Used

The project utilizes three business models, which include the following: a straightforward charging station, battery swapping system, and automated charging machines. These business models are applied to replenish the energy source of e-trikes.

Except for the battery swapping system, the two (2) models are similar to a conventional gasoline refueling station in terms of operation. The goal of fast-charging is to replenish the batteries up to at least 80% of rated capacity in less than an hour. The system comprises of an electric vehicle service equipment (EVSE), which includes the power supply and a medium for power transfer to the EV and a battery management system(BMS) which will monitor the battery parameters of the EV and communicate with the EVSE for proper charging.

2.1 Model 1: Straightforward Charging Station

This model is a fast-charging station (Borges et al., 2010, Jossi, 2016) capable of as quick as 30 minutes charging time. It is similar to a regular refueling station where the user utilizes a chademo-compliant connector to recharge the e-trike. This model involves no major behavioral adaptation on end-users of automobiles during refueling (recharging) and can reduce operating costs in relation to extra equipment (battery swapping) and operation time (reduced productivity).

2.2 Model 2: Battery Swapping System

This model is usually done in a station that replaces discharged batteries with a fully charged back-up battery. Ideally, the battery swapping will only take minutes by removing the depleted battery and installing the fully charged battery.

2.3 Model 3: Automated Charging Machine

This model is a modern convenience to e-trike users. The concept of e-money is introduced to e-trike drivers in order to use the CharM facility. The model allows users to charge the e-trike without the use of actual money. E-trike drivers can charge and access the facility 24/7 at any time of the day. E-trike drivers will adopt a self-service technology that is cost-effective in the long run.

3. Methodology

Year 1 of the project involved the installation of CharM in a strategically located area in Cauayan City, Philippines, and the purchase of e-trikes. Each model is applied and tested for four months. The most convenient, economical, and financially-viable model for e-trike users is implemented for the Yeand manufacturers of e-trikes in region 2 of the project.

During the initial phase, the university partners with interested local assemblers and manufacturers of e-trikes in the region. Local fabricators like Equipment Manufacturing Cluster in Region 2(EMC-2), ROPALI, ACT, Agricom Machineries, among others, were tapped to fabricate e-trike prototypes. This prototype undergoes stringent endurance, performance, and durability tests on actual runs prior to commercial fabrication. The university also considered the economical and environmental advantages of e-trikes to the end-users.

For the scale-up phase, the remaining 20 units of e-trikes were fabricated. Local suppliers and fabricators of e-trikes were prioritized to boost the productivity and competitiveness of the metal sector in the region and provide additional job opportunities to the people.

3.1 Financial Analysis Metrics

To evaluate the business case for each entity involved in the business models, three commonly used financial analysis metrics are used in this project, namely: return on investment (ROI), net present value (NPV), and payback period. Each of these metrics has its own advantages and when combined, will offer a rich analysis of the financial viability of e-trikes and CharM facility and the benefits that they provide to each of the stakeholders involved. The financial performance of both the e-trikes and the CharM facility is evaluated from the following distinct perspectives:

a) The e-trike drivers, when operating based on boundary system;

b) The e-trike drivers when they own the e-trikes that they are driving;

c) The Isabela State University as an operator of e-trikes;

d) The Isabela State University as the owner-operator of the CharM facility;

Each of the above perspectives was analyzed with its own cash inflows and outflows, ROI, NPV, and payback period, if feasible and deemed necessary. Table 1 shows the definitions of each of the financial metrics used, as well as the equation and their relevance in evaluating the economic advantages of e-trikes and CharM to e-trike operators and other stakeholders.

Table 1: Financial Analysis Metrics

Financial Metric	Definition	Formula	Relevance to the feasibility of the new technology
Return on Investment (ROI)	The most commonly used profitability ratio that measures the gain or loss generated on an investment relative to the amount of investments	$ROI = \frac{Net\ Profit}{Cost\ of\ Investment} \times 100$	The ROI determines the efficiency of the prospective project and the benefits that it offers to the respective entities. In most cases, a higher ROI is preferable
Net Present Value(NPV)	The total profit or loss of the new technology to the respective entities involved, net of total costs, in present value amount. It is computed by means of summing all cash inflows and outflows over the expected lifetime of the equipment and adjusting for the time value of money.	$NPV = -Co + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \ldots + \frac{C_T}{(1+r)^T}$ *where:* *Co = Initial investment* *C = Cash flow* *R = Discount Rate* *T = Time*	The NPV determines whether the respective entities will gain net profits over the expected lifetime of the project. A positive NPV suggests that the investment is profitable while a negative NPV implies a net loss.
Payback Period	The length of time required for the project to recover its initial cash outlay and generate net positive value for the respective entities involved	$Payback\ period = \frac{Initial\ Investment}{Amount\ Profit}$	The payback period helps determine whether an investment in the project generates net profits fast enough to be acceptable. Many private individuals are only interested in investing in projects that achieve payback within five years or less.

4. Results and Discussion

4.1 Market Validation

4.1.1 Target Market and its characteristics

A market validation, which consists of a series of interviews with e-trike drivers and tricycle drivers in the city was conducted to determine the characteristics of the potential target market and the issues that need to be addressed to ensure the successful commercialization of CharM in Cauayan City, Isabela, Philippines. Based on the said series of interviews, it was determined that aside from the higher cost of electric vehicles (EVs) as compared to gas-powered vehicles, the biggest barrier to the adoption of EVs among consumers is the time that it takes for EVs to recharge. As such, the availability of fast-charging stations is a crucial factor in attracting people to shift from gas-powered vehicles to EVs. Moreover, the potential target market consists of current e-trike and tricycle drivers aged 21-50 years old. These drivers usually serve short distance trips around the Poblacion area and other urban barangays with several trips to other outlying barangays and nearby towns. The tricycle drivers have a designated terminal that serves as their pick-up point. If the driver owns the tricycle, the operating time usually starts at 7 AM and ends at 5 PM. On the other hand, under the boundary system, most e-trike and tricycle drivers operate longer hours, typically from 6 AM to 6 PM.

4.1.2 CharM facility

EVs can be charged in two primary locations: at home and in public stations. Each location favors a specific level of the charger, from simple to sophisticated. At home, Level 1 chargers are usually used, which takes about six to seven hours to recharge an EV but are considered as the simplest and cheapest EV chargers. This kind of charger works well at home because it allows EV users to recharge their vehicles regularly every night. In fact, according to Jackson & Roy (2016), the two primary advantages of home charging stations are their affordability and convenience.

On the other hand, public charging stations typically use Level III "fast chargers", which take just about 30 minutes to charge vehicles but cost substantially more than the other types of chargers. However, based on the market validation, despite the substantial cost of installing fast-charging stations in public places, the availability of fast-charging stations in public places is necessary to accelerate the adoption of EVs, not just in the City of Cauayan, but also in the entire country. This is mainly because fast-charging stations, such as the CharM facility, address "range anxiety", which is commonly cited as the primary reason why many people are reluctant to purchase electric cars. Range anxiety refers to the concern on the part of EV drivers that their battery will run out of power before reaching their destination or a suitable charging station.

Moreover, while home charging might be cheap and already sufficient for most private commuters, this might not work well for service vehicle drivers, such as e-trikes because of the long-distance that they travel every day. As such, fast-charging stations are necessary to address the charging needs of these types of users. Based on a study conducted by the Tokyo Electric Power Company (TEPCO), the installation of fast-charging stations in the area of experiment alleviates "range anxiety" among EV service vehicle drivers (Botsford & Szczepanek, 2009). According to the study, after a fast-charging station was installed in the area of experiment, EV service vehicle drivers started to access the entire service area, as did the conventional service vehicles. In this case, just knowing that the EV service vehicle could be recharged during the day reassured the drivers that they would reach their destination and would not be stranded. Moreover, the study also showed that prior to the installation of the fast-charging station, EV drivers returned their vehicles at a battery State of Charge (SOC) much greater than 50 percent. After the fast charger was installed, the SOC shifted to below 50 percent. This is further evidence of the largely psychological impact provided by the fast-charging station.

Therefore, the availability of CharM facilities in Cauayan City can facilitate the rapid growth of the EV market in the municipality by minimizing vehicle downtime. As shown in the TEPCO study and validated in the interviews conducted, if the introduction of one fast charger can already have a huge impact on the psychology of a group of e-trike drivers, then the installation of several CharM charging stations in various public locations will enable the wide adoption of EVs in the city.

4.2 Business Models

Based on the experiment conducted, the most appropriate business model to utilize during the commercialization of CharM is the automated charging machine system, because it is not only the most convenient business model but also the one that offers the highest revenue potential and lowest costs. Table 2 summarizes the advantages and disadvantages associated with each of the three business models used in this project.

Table 2: Advantages and Disadvantages of the Business Models.

Business Model	Advantages	Disadvantages
Model 1: Straightforward Charging Station	· Convenience to e-trike drivers	· The additional cost to CharM operator due to the need to employ more people · Limits the operating time of the facility
Model 2: Battery Swapping System	· No need to wait to charge batteries	· The heavy-weight of the batteries requires several people to carry it · It takes about 30-45 minutes to swap batteries · Additional cost for the purchase of additional batteries
Model 3: Automated Charging System	· Convenience to both the e-trike drivers and the CharM operator · Labor cost savings · Operating time is maximized without incurring additional cost	· Additional costs associated with the provision of tap cards to e-trike drivers and short seminars on how to use the automated charging machine

4.3 Financial Analysis

The financial performance of the CharM facility is evaluated with the assumption that the automated charging machine is utilized.

4.3.1 Return of Investment (ROI)

In order to make CharM operational, the University and its partner agencies incurred the following costs as shown in Table 3.

Table 3: Initial Investment for CharM. (Note: 1USD » 48PhP)

Investment item	Costs (Philippine peso (PhP))
Manufacturing cost per charger unit	255,000.00
Power supply and electrical works	129, 682.00
Improvement of CharM housing	137, 339.00
TOTAL	**522,021.00**

In computing the financial sustainability of CharM, the following additional assumptions are used: (1) the automated charging machine model is used; the charging station is open 24 hours every day; (2) no employees are required to manage the charging station, thus no labor cost is incurred; (3) it takes 30 minutes to charge an e-trike; CharM has a lifespan of 15 years; (4)Electric cost per charge equals PhP8.91 per kilowatt-hour; and (5)the operator charges PhP15 per kilowatt-hour of charging to e-trike drivers.

If an e-trike charges a total of 5 kilowatt-hours for the 30-minute charging duration, then the university generates sales revenue of PhP75 per charge (P15 x 5).

For a day (assuming CharM is used for 8 hours), it has the potential to earn total sales of:

$$Daily\ sales = \text{Php}15\ per\ kWh\ x\ 5kWh\ x\ 16\ times\ per\ day$$

$$Daily\ \text{Sales} = \text{Php } 1{,}200$$

Therefore, the daily gross profit would be

Daily gross profit = Daily sales - Cost of electricity

Daily gross profit = PhP1,200 – PhP712

Daily gross profit = PhP488

An average of PhP488 daily sales translates to monthly sales of PhP14, 640 or annual sales of PhP175,680.

However, since the EV market in the Philippines is still in its early stage, it is assumed in this study that the fast-charging station is utilized for just a total of 3 hours a day for its first 5 years of operation; 5 hours a day for the next 5 years and 8 hours per day or 16 e-trike charging per day for the last 5 years. This translates to average daily sales of Php450 for years 1-5; P750 for years 6-10; and Php1,200 for years 11-15.

Table 4 shows the potential ROI of CharM, given the assumptions above. In Year 15, a salvage value of Php 15,000 is also included in the cash inflows.

Table 4: Return on Investment (ROI) for CharM.

Year	Cash Inflow	Cash Outflow	Net Cash Flow	Cumulative Cash Flow	Simple ROI
Year 0	0	-522,201	-522,201		
Year 1	162,000	0	162,000	-360,021	-36.50%
Year 2	162,000	0	162,000	-198,021	-37.90%
Year 3	162,000	0	162,000	-36,021	-6.90%
Year 4	162,000	0	162,000	125,979	24.10%
Year 5	162,000	0	162,000	287,979	55.20%
Year 6	270,000	0	270,000	557,979	106.90%
Year 7	270,000	0	270,000	827,979	158.60%
Year 8	270,000	0	270,000	1,097,979	210.30%
Year 9	270,000	0	270,000	1,367,979	262.10%
Year 10	270,000	0	270,000	1,637,979	313.80%
Year 11	432,000	0	432,000	2,069,979	396.50%
Year 12	432,000	0	432,000	2,501,979	479.30%
Year 13	432,000	0	432,000	2,933,979	562.00%
Year 14	432,000	0	432,000	3,365,979	644.80%
Year 15	447,000	0	447,000	3,812,979	730.40%

Despite a projection that the CharM facility will only be used for 3 hours per day during the first five years of its operation, the ROI computation above shows that it can still generate positive profits at the end of Year 4. In fact, if the charging facility reaches its estimated lifespan of 15 years, ISU can achieve an astonishing return on investment of about 730%. While the ROI might be very high, it should be noted that the time value of money is not included in the computation, which is addressed by the NPV.

4.3.2 Net Present Value (NPV)

Based on the NPV analysis, CharM is a financially viable investment on the part of the university. As shown below, the project can generate a positive NPV of more than P2 million over its projected lifespan of 15 years. Table 5 shows the NPV for CharM.

Table 5: Net Present Value(NPV) for CharM.

Year	Net Cash Flow	FV Factor	PV of Cash Flows
Year 1	162,000	0.943	152,830
Year 2	162,000	0.890	144,179
Year 3	162,000	0.840	136,018
Year 4	162,000	0.792	128,319
Year 5	162,000	0.747	121,056
Year 6	270,000	0.705	190,339
Year 7	270,000	0.665	179,565
Year 8	270,000	0.627	169,401
Year 9	270,000	0.592	159,813
Year 10	270,000	0.558	150,767
Year 11	432,000	0.527	227,572
Year 12	432,000	0.497	214,691
Year 13	432,000	0.469	202,538
Year 14	432,000	0.442	191,074
Year 15	447,000	0.417	186,517
Total PV of Cash Flows			2,554,681
Initial Investment			522,021
NPV			2,032,660

4.3.3 Payback Period

The following shows the computation of the payback period for Isabela State University as an owner-operator of CharM.

$$Payback\ Period = \frac{Initial\ Investment}{Average\ of\ annual\ profits} = \frac{Php522{,}021}{Php132{,}760} = 3.9 \text{ years.}$$

It takes about 3.9 years for the university to recover its initial investment from installing one unit of CharM charging unit.

5. Conclusion

The financial analyses conducted showed that CharM is a profitable investment in the long run. Moreover, it is concluded that the automated charging machine is the most appropriate business model to utilize during the commercialization of CharM in the City of Cauayan, Isabela, Philippines because it is not only the most convenient model but also the one that offers the highest revenue potential and lowest costs. Isabela State University should continue operating its

CharM facility, not just because of its high earning potential, but also because of the overall economic and environmental benefits that are associated with it.

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7. Availability of Data, and Material

Data can be made available by contacting the corresponding author.

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