Promoting Green Mobility Through Electric Motorcycles in Cambodia

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ABBREVIATIONS

AFD	Agence Française de Développement
BSEB	Bicycle Style E-bike
CGRER	Center for Global and Regional Environmental Research
CC	Cubic Centimeters
E2W	Electric Two-Wheeler
E3W	Electric Three-Wheeler
EV	Electric Vehicle
EVI	Electric Vehicles Initiative
EM	Electric Motorcycle
GDCE	General Department of Customs and Excise
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GSSD	General Secretariat for Sustainable Development
ICEM	Internal Combustion Engine Motorcycle
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IPCC	Intergovernmental Panel on Climate Change
ISC	Institute of Standards of Cambodia
ISO	International Organization for Standardization
JICA	Japan International Cooperation Agency
KHR	Khmer Riel (Cambodia's Currency)
Kph	Kilometers per hour
Kw	Kilowatt
LIB	Lithium-ion Battery
MEF	Ministry of Economy and Finance
MoE	Ministry of Environment
MoEYS	Ministry of Education, Youth and Sport
MoP	Ministry of Planning
MPWT	Ministry of Public Works and Transport
NCSD	National Council for Sustainable Development
NDC	Nationally Determined Contribution
NEV	New Energy Vehicles
NGO	Non-governmental Organization
NIS	National Institute of Statistics
NSPD	National Strategic Development Plan
PPP	Public-private partnership
RGC	Royal Government of Cambodia
SSEB	Scooter Style E-bike
TEPA	Taiwan Environnemental Protection Administration
ULAB	Used lead-acid batteries
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
VKT	Vehicle Kilometers Traveled
VIN	Vehicle Identification Number
VOC	Volatile Organic Compound

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01. Introduction

1.1 Background

Cambodia is one of the fastest-growing economies in Southeast Asia, with an average annual GDP growth rate of 7.7% between 1995 and 2018 (see Figure 2) (RGC, 2019; World Bank, 2019). The country has an estimated population of 15.3 million people and it is projected to reach 17 million by 2023 (MoP, 2015; RGC, 2016; NIS, 2019). Cambodia is comprised of the central plains of the Mekong River and Tonle Sap Basin and mountains and highland areas (Figure 1). Phnom Penh, the capital, and most populous city in Cambodia, has an estimated population of more than 2 million people and it is projected to grow to 3 million people by 2035. Phnom Penh is densely populated, with 3,400 persons per square kilometer (km2) and an area of 678.46 km2, covering 0.37% of the total area of the country.

Rapid economic development, improved income, population growth, and rising rates of urbanization have contributed to a high demand for vehicle ownership in Cambodia. This demand is forecasted to increase as the economy continues to grow at an average annual rate of 7.0% (RGC, 2019). Imported fossil fuel vehicles dominate the market in Cambodia, and only a small fraction of vehicles are electric. Phnom Penh alone represented over half of all vehicle registrations in Cambodia last year. As a result, urban areas are suffering from traffic congestion, poor air quality, and municipal transport infrastructure is unable to keep up with demand.

Figure 1. Map of Cambodia

Greenhouse Gas (GHG) emissions and air pollution caused by fossil fuel vehicles impact public health and hamper the government's vision to transform Phnom Penh into a sustainable and green city. The deployment of electric motorcycles (EM) could contribute to achieving the government's vision by reducing GHG emissions and air pollution in Cambodian cities. It could also pave the way for wider electrification in the transport sector.

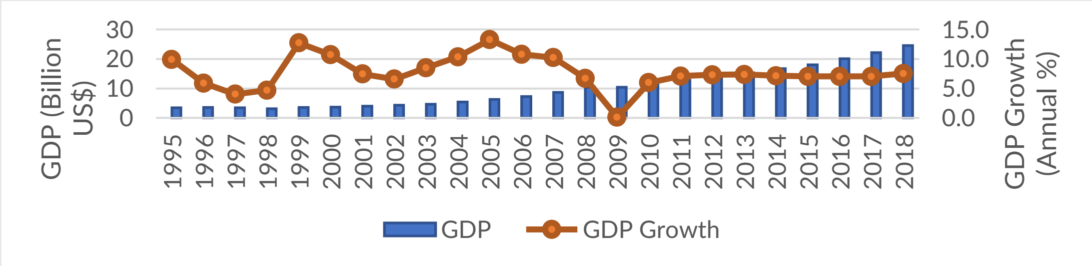

Figure 2. Cambodia's GDP and GDP Growth, 1995-2018 (World Bank, 2019)

1.2 Objectives

The overall objective of this study is to develop an investment project proposal that can facilitate the deployment of electric motorcycles (EM) in Cambodia and contribute to the reduction of GHG emissions in the transport sector. The key objectives are as follows:

- Undertake a market and technical assessment of EMs, reviewing existing EM companies in the market and their business models.
- Undertake an assessment of the education and public awareness-raising needs to understand public perceptions towards EMs and identify potential awareness-raising strategies.
- Conduct a comparative assessment of the economic, environmental, and social benefits of EMs and ICEMs.
- Undertake a policy and regulatory gap analysis to provide policy recommendations for the deployment of EMs.

1.3 Methodology

Three research methods were utilized to collect data over six months, from January to June 2020.

1.3.1 Desk Review

A desk review of secondary data was conducted to understand global market trends and the technical specifications of EMs in the Cambodian market. Scientific journals provided an overview of the economic, environmental, and social benefits of using electric two-wheelers (E2Ws), depicting regional and global cases. Case studies from countries in the region, including China, Taiwan, India, and Viet Nam, provided useful insights into the policy and regulatory measures used to stimulate the deployment of EMs. The following local studies were also drawn on widely:

- Electric Motorcycle Assessment in Phnom Penh (MoE, 2019)
- An Assessment of Regulatory and Fiscal Policies for Road Transport Vehicles in Cambodia (Clean Air Asia, 2019)
- Development of Standards for the Uptake of E2Ws and electric three-wheelers (E3Ws) in Cambodia

1.3.2 Interviews

Interviews were conducted with key stakeholders in the transport sector, see Table 1.

Table 1. Interview participants

Entity	Topics discussed
Government Agencies	
The Ministry of Public Works and Transport (MPWT)	Plans for the transportation sector in Cambodia, EM registration procedures, and data on the number of vehicles.
The Ministry of Environment (MoE) - Department of Environmental Education	Suggestions and recommendations for public awareness-raising strategies for EMs.
The Ministry of Environment (MoE) - Department of Hazardous Substance Management	Export fees and procedures of used lithium-ion batteries (LIB).
The General Department of Custom and Excise	ICEM and EM import taxes and the export tax of used lithium-ion batteries (LIB).
Private Companies	
Voltra Motors	Technical aspects of EMs, plans for the company, and details of their business model.
Oyika	Technical aspects of EMs, expansion plans, and battery swapping business models.
Star8	Technical aspects of EMs and plans for the company.
Honda	The price of motorcycles and how the public can access loans.
Suzuki	The price of motorcycles and how the public can access loans.
Yamaha	The price of motorcycles and how the public can access loans.
Meal Temple (food delivery company)	The use of EMs in the commercial sector.
Financial Institutions	
ACLEDA Bank	The provision of loans for ICEMs and EMs.
PRASAC Microfinance Institution	The provision of loans for ICEMs and EMs.
AEON Specialized Bank	The provision of loans for ICEMs and EMs.

1.3.3 Survey

A survey was conducted to understand the travel behavior of EM and ICEM users in Cambodia, as well as public perceptions of EMs. The survey questions can be found in Appendix 1. The survey was conducted online between 1st June to 17th June 2020 in accordance with COVID-19 restrictions.

1.3.4 Scope and Limitations of the Study

The analysis of this study was limited to an assessment of brand new ICEMs and EMs, it did not include second-hand motorcycles. Brand new ICEMs with a small engine capacity (< 100cc) are not available in the Cambodian market, they are all second-hand. As a result, this study only included brand new ICEMs with an engine capacity ≥ 100cc.

The market and technical analysis presented in this study is also limited to the availability of information provided by the EM companies. Detailed information was obtained from three of the five EM companies operating in the Cambodian market (Voltra Motors, Oyika, and Star8). However, further information was obtained from the website of a fourth EM company, Thada.

02. Situational Analysis

2.1 Cambodia's Transport Sector

The transport sector plays a significant role in promoting economic development and mobility in Cambodia. The Royal Government of Cambodia's (RGC) Rectangular Strategy IV aims to improve transport connectivity and build efficient logistic systems to enhance economic competitiveness and diversification (RGC, 2018). Cambodia's Industrial Development Policy (2015-2025) requires significant improvement of the transport network, especially along the industrial corridor (RGC, 2015). Through the National Strategic Development Plan (NSDP) 2014-2018, the RGC and its development partners planned a sector expenditure program of US$910.40 million to improve the economy through better transport infrastructure (RGC, 2014). The RGC had allocated a large budget for transport infrastructure improvement and construction: US$123.75 million in 2014, US$183.75 million in 2015, US$223.04 million in 2016, US$216.70 million in 2017, and US$158.07 million in 2018 (MPWT, 2019).

Cambodia's economy is driven by four main sectors: agriculture, tourism, manufacturing (mainly garment exports), and construction. The agricultural sector requires road transport for moving and exporting agricultural products, while the tourism sector requires road and water transport to tourist destinations. The industrial sector and the construction sector are also reliant on road and water transport to deliver raw materials and export finished products. The recent large-scale investment in roads, railways, ports, and waterways aims to facilitate the mobility of goods and people across the country.

2.2 Vehicle Stock

The number of registered vehicles has been increasing in line with the per capita income (see Figure 3). Motorcycle registration has increased by 10% per year since 2005, and in 2018, motorcycles represented around 87% of all vehicle registrations. From 1990 to 2018, approximately four million motorcycles, 422,631 cars, and 261,885 minibuses, buses, pick-up trucks, and trucks have been registered. As shown in Figure 4, motorcycles play a significant role in road transport (vehicle registration data can be found in Appendix B).

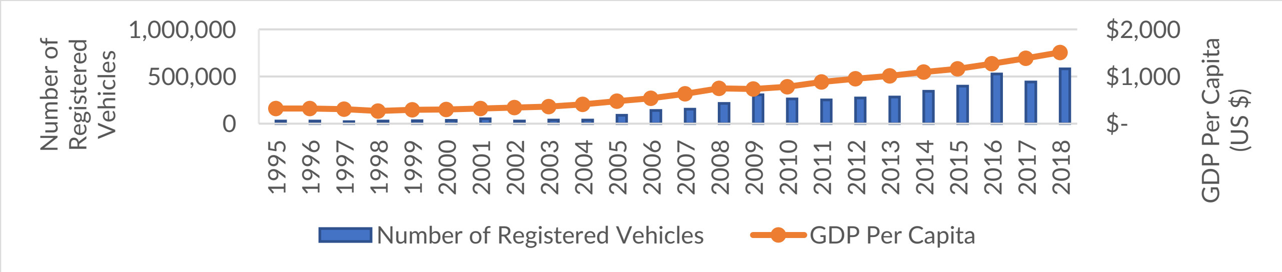

Figure 3. GDP per capita and number of registered vehicles in Cambodia, 1995-2018

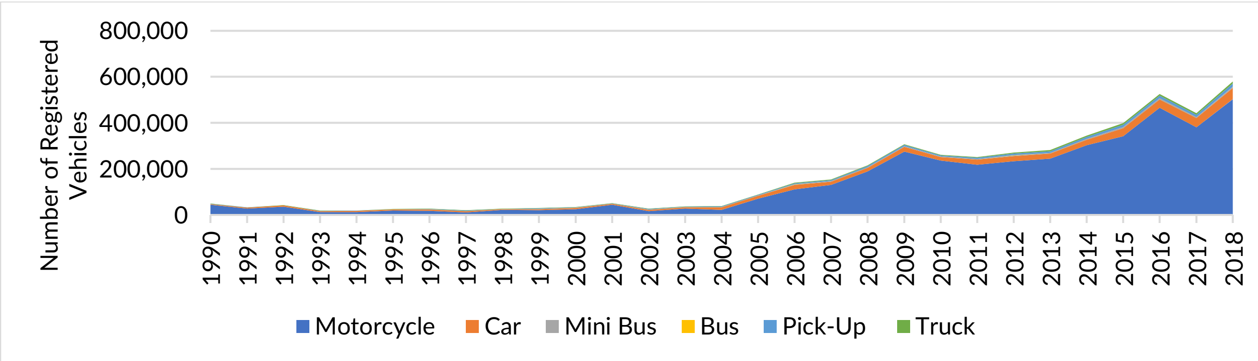

Figure 4. Registered vehicles in Cambodia by type, 1990-2018

2.3 Energy Consumption and Externalities of the Transport Sector

Cambodia is a low emitter of GHG emissions but is highly vulnerable to the effects of climate change. In 2000, per-capita GHG emissions were approximately 0.23 tCO2e. However, this figure is expected to rise to about 1.10 tCO2e by 2030 and 5.49 tCO2e by 2050. GHG emissions from the transport sector are rising in line with the increasing number of vehicles. The transport sector is the largest contributor to Cambodia's CO2 emissions, and it is projected to have the greatest increase and share of GHG emissions in 2050 at 10,816 GgCO2e, followed by energy industries, manufacturing, and commercial and residential sectors (see Figure 5) (GSSD, 2015).

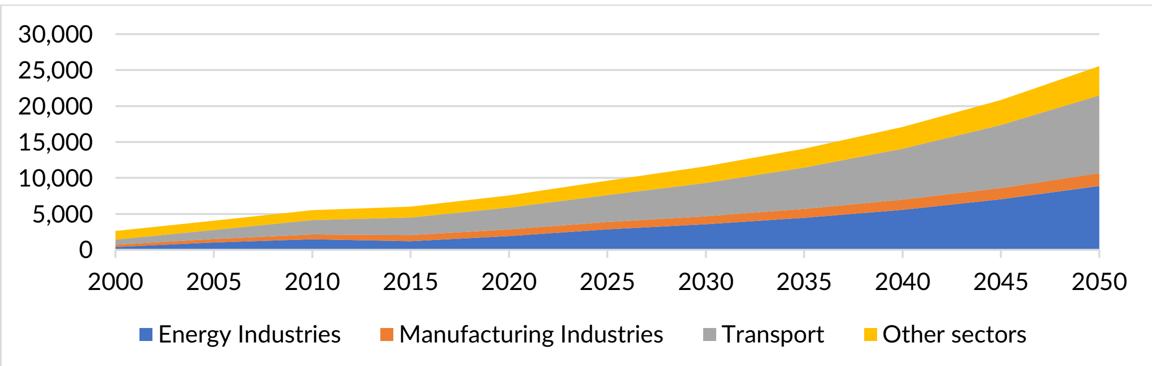

Figure 5. Total emissions by sectors in GgCO2-eq, 2000-2050 (GSSD, 2015)

The MoE conducted a study to estimate the CO2 emissions in the transport sector using the Long-range Energy Alternatives Planning (LEAP) model. The results revealed that motorcycles, cars, pick-ups, and trucks are significant sources of CO2 emissions. Trucks account for the largest share of CO2 emissions, followed by pick-ups, cars, and motorcycles (Table 2) (MoE, 2010). Over the past two decades, Cambodia has constructed large-scale infrastructure projects and improved logistic systems, leading to increased movement of goods around the country and contributing to CO2 emissions.

Table 2. The CO2 emissions projections of vehicles (Gg CO2eq) (MoE, 2010)

Vehicle	Year										
	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Motorcycle	117	203	356	433	527	642	781	950	1155	1406	1710
Car	146	267	424	516	627	763	929	1130	1374	1672	2035
Pick-Up	173	303	455	554	674	819	997	1213	1476	1796	2185
Minibus	55	105	168	204	248	302	368	447	544	662	806
Bus	27	47	77	93	114	138	168	205	249	303	369
Truck 2 axel	183	314	506	648	829	1062	1359	1739	2226	2849	3646
Truck 4 axel and trail	8	11	18	22	27	33	40	48	59	72	87
Truck 5 axel	11	12	16	19	23	28	34	42	51	62	75

2.3.1 Air Pollution

The growing number of imported, second-hand vehicles and increasing motorization in Cambodia contribute to air pollution. The transport emissions from old and inefficient vehicles, that are not equipped with pollutant mitigation technology, damage air quality in urban areas. No vehicle age limit is imposed on imported second-hand vehicles in Cambodia, and most are at least 10 years old. Despite this, the air quality in Cambodia is not currently a threat to public health according to government data (Cambodia Air Quality Monitoring Project, 2016).

Cambodia conducted two emission inventories under Cambodia's First National Communication in 1994 and Cambodia's Second National Communication in 2000 to the United Nations Framework Convention on Climate Change (UNFCCC). Table 3 shows the emission inventories in 1994 and 2000 from the transport sector (MoE, 2002; GSSD, 2015). The inventories included Non-CO2 air pollutant emissions (CO, NOx, NMVOCs) but did not include PM2.5 and PM10. As shown in the table, the emission levels of these air pollutants decreased from 1994 to 2000. In 2006, the Center for Global and Regional Environmental Research (CGRER) also released data on the emission of air pollutants in Cambodia's transport sector (Table 3). The results highlighted increased emissions of air pollutants from the transport sector, in comparison to the inventories in 1994 and 2000.

Table 3. Non-CO2 air pollution emissions from the transport sector in 1994, 2000, and 2006 in Cambodia (CGRER, 2006; MoE, 2002; 2015)

Pollutant	1994 (Gg yr^{-1})	2000 (Gg yr^{-1})	2006 (Gg yr^{-1})
NO_x	7.55	7.17	14.3
CO	52.54	36.45	74.2
NMVOCs [1]	9.93	6.91	50.3
SO_2	x	x	6.1
PM10	x	x	0.5
PM2.5	x	x	0.5
Black carbon	x	x	0.1
Organic carbon	x	x	0.2

2.4 Cambodia's NDC

The RGC submitted the Nationally Determined Contribution (NDC) to the UNFCCC in 2015 and has since submitted an update in 2020 indicating a target to reduce GHG emissions against the business-as-usual (BAU) level by 47.7% by 2030. Although no specific target is set to lower emissions from the

[1] Non-methane volatile organic compounds

transport sector, the NDC identifies some key transport mitigation actions, including promoting mass public transport, improving operation and maintenance of vehicles through inspections, and upgrading technology for electric mobility.

2.5 Cambodia's Transport Plans

The Phnom Penh Urban Transport Master Plan (PPUTMP) is a comprehensive and integrated transport sector master plan with the target year of 2035 (Figure 6). PPUTMP concludes with a shortlist of project recommendations, pre-feasibility studies for priority projects, and financial and economic analysis of the priority projects. Recommendations include a shift to public transport (a combination of rail, bus rapid transit (BRT), and public buses), completion of the radial-ring trunk road network, an upgrade of traffic management (including modern traffic management system, parking systems, and high-quality pedestrian environments), and institutional capacity building (JICA, 2014).

Phnom Penh City Bus launched in 2014 to facilitate public transport, ease traffic congestion, and reduce road accidents. Initially running on three lines, it has gradually expanded over several years, and as of 2019, 13 lines are in operation throughout the city. To further reduce traffic congestion, Phnom Penh launched a taxi boat and in 2018, an airport shuttle train was introduced in Phnom Penh.

Alternative public transport options are being explored by various donors and investors. Agence Française de Développement (AFD) has assessed the feasibility of an urban tram system and Japan International Corporation Agency (JICA) conducted a feasibility study for a proposed elevated Automated Guideway Transit (AGT) or "sky train" linking Phnom Penh International Airport to the city center, which would cost an estimated US$800 million to build. Additionally, the Department of Urban Transport of the MPWT is conducting a feasibility study on introducing electric public buses in the Siem Reap Province. This would be the first project to deploy electric buses in Cambodia.

2.6. The Current Status of Low Carbon Vehicles in Cambodia

Cambodia has not yet developed a low carbon vehicle policy or strategy, although one study proposed a low carbon development plan for Cambodia towards 2050 (Mao et al., 2015). According to this study, Cambodia has the potential to promote low carbon transport such as buses, eco-driving, and EVs. Low carbon vehicles in Cambodia currently include hybrid cars, electric cars, and EMs, but the number of these vehicles on the streets is unknown. In Cambodia, hybrid cars are all secondhand and at least 10-years old. The Cambodian Angkor EV, a Cambodian made electric car, was launched in 2013. However, locally produced vehicles have not proved to be popular. Companies that import electric cars to the Cambodian market include LevDeo and Blue Mobility. Table 4 summarizes the existing options for EVs in Cambodia.

Table 4. EVs in the Cambodian market (EnergyLab, 2019)

Electric Vehicles (EVs)	Brands
E-passenger Cars	LevDeo Blue Mobility Angkor Car
EMs	Thada Oyika Voltra Motors Star8

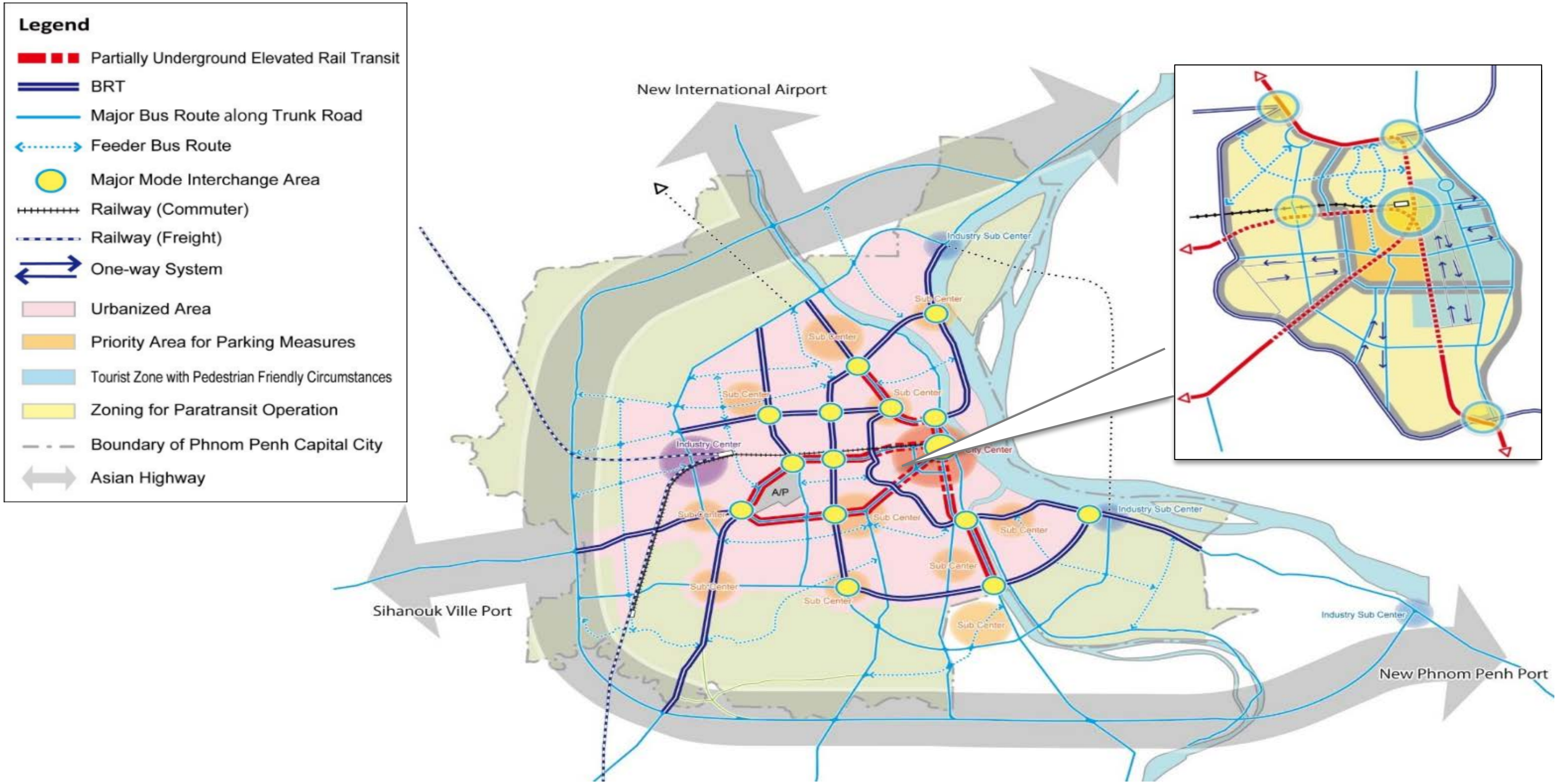

Figure 6. Phnom Penh Urban Transport Master Plan towards 2035 (JICA, 2014)

03. A Market and Technical Assessment

3.1 Global EM trends

Transport contributes almost one-quarter (23%) of current global energy-related GHG emissions and is growing faster than any other energy end-use sector. GHG emissions from transport are anticipated to rise from today's levels by nearly 20% by 2030 and close to 50% by 2050 unless major action is undertaken (UN Climate Change Conference, 2015). The Paris Declaration on Electro-Mobility and Climate Change and Call to Action, announced at COP21, expresses the ambition to achieve 400 million E2Ws on the road by 2030 (UN Climate Change Conference, 2015). Furthermore, to achieve net zero emissions globally by 2050, the International Energy Agency (IEA) suggest that more than half of all cars would need to be electric by 2030 (IEA, 2020b).

Climate action, among other factors (see box 1), is causing a modal shift in the transport sector. In 2019, more than 2 million electric cars were sold and there is an estimated stock of 350 million E2Ws and E3Ws, which equates to 25% of all two and three wheelers in circulation globally (IEA, 2020a). As the technology of E2Ws advances, the market for them increases. The EM market could also witness further growth due to rising demand in developing countries such as India and Thailand (Market Research Future, 2019). In the Asia Pacific Region, EMs are often best suited to the transport infrastructure and public demand. Definitions of EMs in different regions vary based on the top speed (see Table 5).

Despite of the growth in the electric mobility market, public concerns regarding EM performance constraints, high upfront costs, and the presence of low-quality products on the market persist. A lack of awareness about EMs could slow the potential market growth in the near and medium-term.

Table 5. EM definition by region, based on top speed (Pika Research)

Region	EMs
North America	Top speed > 45 kph; Motor size > 3 kw
Latin America	Top speed > 45 kph
Western Europe	Top speed > 45 kph
Eastern Europe	Top speed > 45 kph
Asia Pacific	Top speed > 50 kph

Box 1. Factors increasing EM market growth.

The market growth of EMs globally is the result of several factors, including:

- Considerable investments in charging infrastructure.
- Surging interest from large scale manufacturers.
- Reduced battery costs.
- Concerns over environmental issues such as climate change and health impacts from air pollution.
- The incorporation of regenerative braking.
- Economical maintenance costs.
- Elevated mechanical efficiency.
- Low noise levels.

3.1.1 The Asia and Pacific Region (APAC) Market

The EV market in the Asia and Pacific Region (APAC) is showing progress. China leads the way in EVs in the region and globally: 47% of the 7.2 million EVs on the road in 2019 were in China (IEA, 2020a). China also recorded the highest volume of sales of e-scooters and EMs in the region in 2017 and is expected to continue its leading position in the market in the coming years, primarily because of government policies such as a strict ban on the ownership of ICEMs in certain cities and support in the form of subsidies. While in India, the second largest EV market in the region, the E2W market is expected to grow by 25% between 2021 and 2026 (Research and Markets, 2020). A burgeoning population, increasing traffic congestion, declining prices of EMs, a supply of cheap power, and mounting environmental concerns add to the market strength in the region.

Based on battery type, the APAC EM market is segmented into two categories: lead-acid and LIB. The lead-acid category recorded the highest volume of sales in the market, with a contribution of more than 80% in 2017. However, the LIB category is predicted to grow at a faster rate during the forecast period (2013-2025), owing to their lightweight and longer lifespan. The APAC EM market is also segmented based on charging technology: plug-in or battery. The plug-in category denotes a type of battery that is attached to an EM, while the battery category refers to a removable battery. The plug-in category has dominated the market, with more than a 95% share of sales in the regional market in 2017 and is expected to continue to lead the market. This can be attributed to its ease of operation when compared to the battery category, and to the poor and inadequate battery swapping infrastructure in the developing economies of the region (Market Research Future, 2019).

3.2 Cambodia's EM Market

EM's are part of an emerging EV market in Cambodia, and while there are no available estimates for the number of EMs in the country, it is thought to be behind that of neighboring countries. In Thailand, there were 5,020 registered EMs in 2019 and in Viet Nam, the number of e-bikes and EMs reached approximately 370,000 units as of 2015 (Truong and Hung, 2015).

3.2.1 Voltra Motors

Voltra Motors has released two models of EMs: the OFF-ROAD and MATRIX models. MATRIX is the latest model and has a longer range compared to the OFF-ROAD model. Both are equipped with LIBs, as indicated in Tables 6 and 7.

Table 6. Voltra OFF-ROAD model technical specifications

Figure 7. Voltra OFF-ROAD model

Voltra OFF-ROAD Technical Characteristics	
Model	OFF-ROAD
Motor	500W Brushless DC motor
Charging time	4 hours
Max speed	38 km/h
Dimension (L*W*H)	1690 × 620 × 1050 mm
Removable battery option	48V12AH Li-Ion battery
Charging voltage	AC 220V
Brake front/rear	Disc/Expand
Drive range	50 km
Tires	Fr. & Rr. 18"×2.5

Table 7. Voltra MATRIX model technical specifications

Figure 8. Voltra MATRIX mode

Voltra MATRIX Technical Characteristics	
Model	MATRIX
Motor	1500W Brushless DC
Charging time	5,5 hours
Max speed	55-60 km/h
Dimension (L*W*H)	1690 × 620 × 1050 mm
Removable battery option	60V28AH Li-Ion battery
Charging voltage	AC 220V
Brake front/rear	Disc
Drive range	80 km
Tires	Fr. & Rr. 10"×3

3.2.2 Oyika

Oyika has only released one EM model. The Oyika Ego can travel up to 80 km per full charge, and the battery is charged through a swapping station (see Table 8).

Table 8. Oyika Ego model technical specifications

Figure 9. Oyika Ego model

Oyika Ego Technical Characteristics	
Motor	800W
Maximum speed	50 km/h
Drive range	Up to 80 km
Battery	60V 20 Ah Lithium Ion
Charging time	Through swap stations
Tires	10 inches tubeless
Wheelbase	1330 mm
Measurements	1660 mm x 710 mm x 1070 mm
Brakes	Front Disc/Rear Drum

3.2.3 Star8

Star8 is a relatively large company selling a range of EMs equipped with both lead-acid batteries and LIBs. Technical specifications of the Pegasus model are shown in the following table (see Table 9).

Figure 10. Star8 EM Pegasus model

Table 9. Technical specifications of the Pegasus model

Star8 Pegasus Technical Characteristics	
Model	Pegasus
Motor	2500W
Charging time	5-8 hours
Max speed	70 km/h
Battery	72v20Ah Lead-acid
Drive range	50 km

3.2.4 Thada

Thada's website only provided technical specifications of the Thada-OX, but not the Thada-Monster model: a more superior model in terms of battery capacity and driving range. Table 10 shows the detailed specifications of the Thada-OX model.

Figure 11. Thada-OX model

Table 10. Technical specifications of the Thada-OX

Thada-OX Technical Characteristics	
Model	Thada-OX
Motor	1200W
Maximum speed	Up to 50 km/h
Drive range	Up to 60 km
Battery	Lithium Ion
Dimension	1.8L × 0.7W × 1.0H
Brakes	Full Hydraulic Disc

3.2.5 The Lifecycle of EMs

Findings from interviews conducted with Voltra Motors and Oyika indicated that EMs can have a lifecycle of up to 10 years[2]. The battery is one of the most important components of an EM. A LIB's lifecycle can last up to three years, while a lead-acid battery can last for only one year. The lifecycle of the LIB attached to both models of Voltra Motors is 1,000 cycles in four years. The battery in Oyika's Ego model has 800 to 1000 recharge cycles before the battery starts to reduce its performance.

At the end of a battery's lifecycle, it requires recycling. Appropriate battery recycling facilities are critical to lowering the cost of EMs and increasing the market's competitiveness. The challenges of disposing and recycling battery waste are discussed in detail later in this report (see section 5.3.3 Battery Waste). Some companies have already shown a willingness to recycle EM batteries. Voltra Motors is willing to export used batteries to China for recycling, only if export fees on used batteries are exempt, and Oyika intends to sell used batteries to an Indonesian company to be used for an energy storing system.

[2] Lifecycle here refers to the time from when an EM is purchased, to when it is discarded or unusable.

3.2.6 Suppliers and Business Models

At present, four EM companies operate in Cambodia: Thada, Oyika, Voltra Motors, and Star8[3]. Table 11 summarizes the existing suppliers of EMs in the Cambodian market and their business ideas and models.

Table 11. EM company business models in the Cambodian market

Company	Business Model	Outlet Location	Product Origin	Business Plan
Voltra Motors	Manufacturer & Dealer	Phnom Penh	Cambodia	By the end of 2020, the company aims to produce all plastic parts locally, and within the second quarter of 2020, they plan to export to Europe.
Oyika	Manufacturer & Dealer	Phnom Penh	China	They retail to private customers and operate a bike-sharing system for public use. They aim to increase battery swapping stations (11 stations as of January 2020) and increase the number of EMs on the road in Phnom Penh by around 500 to 1000.
Star8	Dealer	Phnom Penh	China, Hong Kong, the Philippines	They retail various models of EMs, in contrast to the other companies who only advertise a few models.
Thada	Dealer	Phnom Penh	Malaysia	They are planning to provide an EM taxi service in Phnom Penh.

3.2.7 Driving License, Registration, and Insurance

According to the 2017 law on Road Traffic, ICEMs with an engine capacity of 125cc or below do not require a driving license. However, owners of brand new ICEMs are required to register their motorcycle's technical specifications to the MPWT database to obtain a registration card. The registration card is necessary for resale purposes and insurance. The 2017 law on Road Traffic also states EMs with a motor capacity of less than 11 kW do not require a driving license. Our findings show that EMs with a motor capacity larger than 11 kW do not currently exist on the Cambodian market.

3.3 The Pricing Structure of ICEMs and EMs

3.3.1 Capital Costs

Prices of EMs in the Cambodian market, as of January 2020, range from US$890 (Star8-ST-01) to US$1,450 (Star8-M3) (Figure 12). For ICEMs, prices range from US$1,200 to US$4,000 as of January 2020 (Figure 14). On average, an EM costs around US$1,000, which is relatively low in comparison to an ICEM, which costs US$2,000 on average.

The price of EMs commonly depends on battery capacity. In the case of Voltra Motors, a 40V12AH LIB battery capacity (OFF-ROAD Model) costs around US$900, while a 60V28AH LIB battery capacity (MATRIX Model) costs almost US$1,400. Larger LIB battery capacity means an increased distance range for EMs. In the case of Oyika, the purchase cost of an EM includes free battery swapping for two years at Oyika's battery swapping station. In comparison, the price of an EM equipped with a lead-acid battery is lower. The benefits of LIBs include nearly 100% efficiency, compared to the 85% efficiency of most lead-acid batteries. LIBs also have less of an impact on the environment than lead-acid batteries (see section 5.3.3 Battery Waste).

[3] In this study, only three companies (Voltra Motors, Oyika, and Star8) were willing to provide detailed information about their business models. Information about Thada could only be obtained from online sources.

The cost of ICEMs depends on engine capacity, model year, and brand. New models and large engine capacities yield higher prices. A 2020 model ICEM with a 100cc energy capacity would cost US$1,200, whereas the same model with a 125cc engine capacity would cost US$2,000. Brand new ICEMs, with an engine capacity smaller than 100cc, are not on sale in the Cambodian market. As indicated in Figure 14, the smallest engine capacity of an ICEM starts from 100cc.

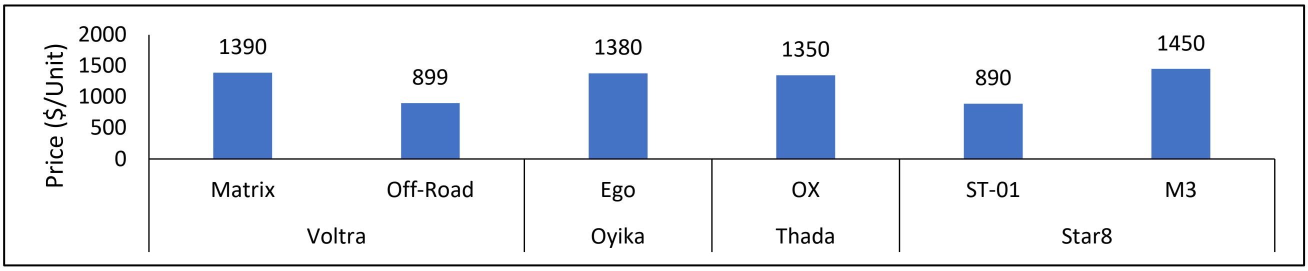

Figure 12. Price ranges of EMs in the Cambodian market as of January 2020

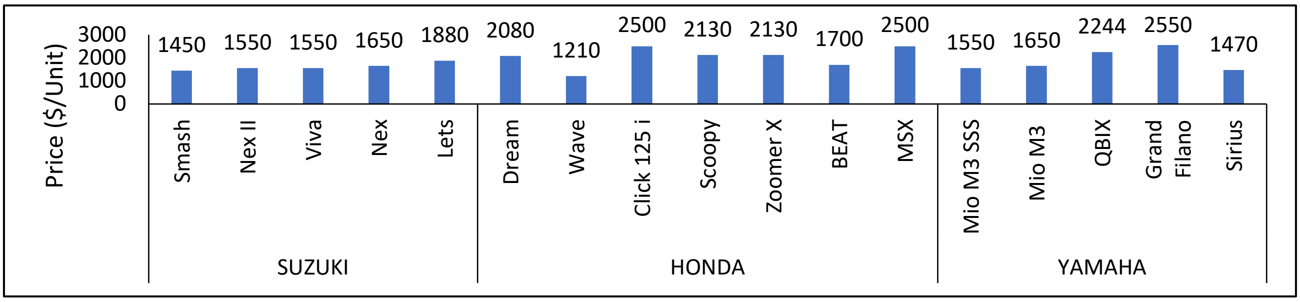

Figure 13. Price ranges of ICEMs in the Cambodian market as of January 2020

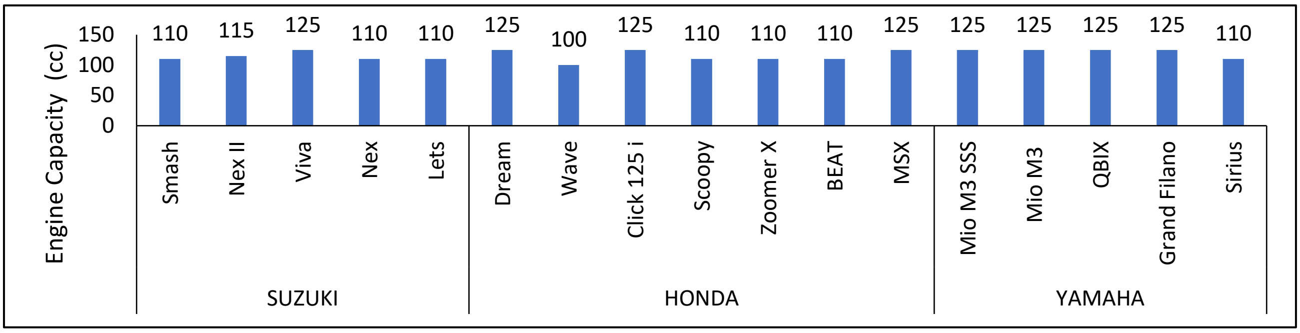

Figure 14. Engine capacity in Cubic Centimeters (cc) of ICE motorcycles

3.3.2 Operating Costs

According to a study conducted by the MoE in 2019, EMs consume about 2.30 ±0.45 kWh per 100 km or 0.023 ± 0.004 kWh per VKT. Therefore, the cost per 100 km traveled for an EM is around KHR 1,600 ± 300. This number is relatively low if compared with ICEMs (for 100 km), which cost approximately KHR 17,600 ± 9,600 for an engine capacity smaller than 100cc and KHR 18,800 ±10,800 for an engine capacity ranging from 100 to 125cc. However, this can vary between users, depending on the traffic flow and the user's preference.

The same study investigated the expenses of ICEMs and EMs over 10-years. The results revealed that ICEM owners are required to spend around US$254 per year, or US$2,540 for 10-years, on operating costs. On the contrary, over 10-years, the operational cost of an EM will be around US$1,181 (assuming the battery life lasts for two years and the price of a battery is US$150); however, if the battery lasts for five years, the cost can decrease to only US$721 (MoE, 2019). Therefore, over 10-years, consumers can save up to US$1,359 (if the battery life lasts for two years) and US$1,890 (if the battery life lasts for five years) if they switch from using ICEMs to EMs.

Voltra Motors and Oyika promote this financial saving as a key benefit of EMs, both of which have an EM with a range of 50 km per full charge. For Voltra Motors, the cost of one full charge is only KHR 750 (US$0.18) and for Oyika, driving 50km requires US$1 to swap the battery at a swapping station. The lifetime operating costs of the EMs from these two companies are likely to be similar in the long term because Oyika also provides two years of free battery swapping at their swapping stations, but Voltra Motors does not provide such incentives.

3.3.3 Tax

Three types of tax are applied to EMs and ICEMs in Cambodia:

1) **Import Tax:** currently, the import tax on EMs and ICEMs (≤50cc) is 32.83% and 39.15% for ICEMs (50cc to 150cc) (GDCE, 2017).
2) **Road Tax:** all motorcycles are exempt from paying road tax (MEF, 2018).
3) **Value Added Tax (VAT):** VAT is 10% for all imported goods, including EMs and ICEMs, according to the General Department of Customs and Excise (GDCE).

3.3.4 Financing Options

This study had limited access to information, through interviews with company representatives, regarding financing options to purchase EMs. EM companies, including Voltra Motors, Oyika, and Thada, have only recently begun operating in Cambodia. As a result, they have not formed strong partnerships with financial institutions in the country. Oyika gives customers a choice to either pay directly to the company or negotiate with financial institutions for a loan. While other companies, such as Voltra Motors, are still in negotiation with local banks (Table 12).

Table 12. Financing options for purchasing EMs

Company	Model	Financing Options		
		Installment payment option	Financing Institution	Interest rate%
Voltra	MATRIX	No	ACLEDA*; AEON*	N/A
	OFF-Road	No	ACLEDA*; AEON*	N/A
Oyika	Oyika Ego	USD 79/month for 2 years	Phillip Bank	No
Thada	Thada-OX	No	N/A	N/A
Star8	ST-01	No	N/A	N/A
	M3	No	N/A	N/A

* The company is still negotiating with these financial institutions.

Customers purchasing an ICEM, rather than an EM, have a greater chance of obtaining loans from financial institutions. Most local banks do not have experience in providing loans for purchasing EMs. Banks usually focus on market trends of a product when providing loans, and the ICE motorcycle market is currently stronger than the EM market. The re-sell market is the main factor affecting this. The re-selling of ICEMs is low risk, while the market for re-selling EMs does not currently exist. Three Microfinance Institutions provide loans to ICEMs, the conditions of the loans they provide are shown in Table 13.

Table 13. Financial institutions conditions for loans for ICEMs

Financial Institution	Max loan (US$)	Interest Rate	Max loan without collateral (US$)	Loan amount (% of ICEM)	Duration	Ages applicable	Required documents
ACLEDA Bank Plc	US$100,000	Starts at 12.5% per year	US$2,500	70% or 100% [4]	Up to 5 years	18-60	ID card and employee payment slip (if employed)
PRASAC Microfinance Institution [5]	US$2,000 [6]	Starts at 16.2% per year	US$2,500	100%	Up to 3 years		ID card and employee payment slip (if employed)
AEON Specialized Bank (CAMBODIA) Plc [7]	Any amount of the motorcycle cost.	1.69% to 1.9% per month (1.5% per month for a Honda Dream)		100%	3 to 4 years	18-65	ID card and family book

3.4 Consumer Perceptions of EMs

According to Honda Cambodia, N.C.X., Co., Ltd., the company first introduced ICEMs to the Cambodian market in 1992. It is believed that Honda was the first company to bring modern designs of motorcycles to the country, but it is unknown when other companies, such as Yamaha and Suzuki, entered the market as there are no official records. ICEM companies have had a firmly rooted place in the Cambodian market that dates back long before EM companies emerged. The Cambodian public is, therefore, well accustomed to ICEMs but more unfamiliar with EMs. As a result, they tend to hold negative perceptions of EMs. The following are some common negative perceptions of EMs based on the study conducted by the MoE (2019) and interviews with EM companies conducted in the current study:

- **Limited Design**

Consumers are restricted by limited purchase options. The EMs currently available in Cambodia are also not considered stylish enough to entice customers, whereas ICEM companies such as Honda, Yamaha, and Suzuki release new designs annually.

- **Price**

When purchasing a motorcycle, consumers tend to focus on the initial purchase price and rarely consider the lifetime cost of a product, which includes the operating and maintenance costs that aggregate over time. Despite the financial savings that an EM can offer (see 3.3 The Pricing Structure of ICEMs and EMs), consumers continue to view EMs as expensive due to their perceived low quality and reliability.

- **Quality**

[4] The loan amount can be up to 70% of the cost of the motorcycle if there is no property provided as collateral and the customer buys a third-party insurance. The loan amount can be up to 100% of the cost of the motorcycle if a property is provided as collateral.

[5] PRASAC has US$140 million in loans outstanding for ICEMs

[6] Minimum US$500

[7] AEON has US$70 million in loans outstanding for ICEMs

EMs are new to the Cambodian market, consequently, consumer trust in the technology is low in comparison to ICEMs. A common perception of EMs is that they are not durable and cannot drive for long distances. Consumers also question the battery quality, how fast it recharges, and how long it lasts. Due to the large penetration of high-quality Japanese ICEMs, Cambodian consumers tend to have a high level of trust in Japanese motorcycles.

- **Resale Market**

The resale market is important to support consumer demand for new motorcycle models. New ICEMs models are released every year and many consumers sell their existing motorcycle to upgrade to a newer design. EMs are not accepted on the resale market, leaving consumers hesitant to purchase them.

- **Charging Stations**

Although companies, such as Oyika, are increasing charging infrastructure around Phnom Penh, such as battery swapping stations, there are currently no charging stations in the country. EMs can only drive on average 50 to 60 km per full charge and drivers must return home or to a shop with a power supply to re-charge. Concerned they will not be able to charge their EM, consumers commonly have range anxiety.

- **Maintenance**

EM companies provide maintenance services to their customers. However, each EM company operating in Cambodia has only one showroom in Phnom Penh for displaying their products, running their business, and providing maintenance services. If an EM breaks down, the user is required to travel to the company showroom to get it repaired. This is an inconvenience for consumers who can, on the other hand, access ICEM maintenance and repairs at every street corner in Phnom Penh. The difficulty of servicing EMs makes them less appealing to the masses.

3.5 Marketing Strategy

The ICEM market outperforms the EM market in Cambodia, and advertisements are likely to be a factor in this. ICEM companies such as Honda, Yamaha, and Suzuki have large marketing budgets, hiring top celebrities to advertise their products on TV and social media platforms, while EM companies mostly rely on Facebook to market their products.

Social media has become a key platform for companies to advertise their products. Facebook has transformed itself into an influential platform that provides users with a completely new online shopping experience. Voltra Motors, Oyika, Star8, and Thada all have a Facebook business page to retail and promote their products and it is utilized as their main communication strategy to reach younger populations of Cambodia who are prominent on the platform. In addition, these companies market their products to specific groups such as young white-collar workers and students aged between 20 and 40 years old. By dividing potential customers into groups or segments, it is easier to personalize a marketing campaign and to make efficient use of time, money, and resources (Pahurkar and Metha, 2017). Utilizing this strategy to target a specific market segmentation on Facebook (or other social media platforms), could help the EM market to expand.

3.6 Summary

The market and technical assessment indicated that EMs have a low adoption rate and only capture a small share of market segments in Cambodia. It has also revealed common consumer perceptions of EMs, such as the unfavorable design and perceived high prices in comparison to ICEMs. Access to maintenance was also found to be a barrier that prevents consumers from purchasing EMs. EM companies are still new to Cambodia and their marketing strategies have not been fully developed as they rely heavily on Facebook to promote their products. The lack of public awareness about the benefits and quality of EMs in Cambodian is key factor preventing market growth.

04. Education and Communication Needs Assessment

4.1 Awareness of EMs

The theory of diffusion of innovations describes how new technologies become accepted (Roger, 2010). A measure of exposure can serve as a prerequisite and proxy measure for future vehicle purchases. Based on this theory, the level of exposure to new technology is one of the most significant awareness-raising activities to promote the acceptance of new technology such as EMs. The survey conducted by the MoE (2019) on *Electric Motorcycle Assessment in Phnom Penh* revealed that only 34% of respondents could sufficiently explain what an EM is and expressed willingness to use one in the future. In addition to limited awareness, the study also highlighted the negative perceptions held by the public. Negative perceptions of the quality and performance of EMs were identified as the main challenges that prevent the adoption of this emerging technology in Cambodia. This suggests that raising awareness on the quality, performance, economic, and environmental benefits of EMs is significant to kick-start the market.

During an interview with a representative from Star8, they suggested that the majority of the Cambodian population are not well informed about EMs and their benefits. Representatives from Oyika also claimed that the main difficulty of promoting EMs is to educate users about the benefits and reliability. Oyika stated that 16 out of 17 people who had driven their EMs were satisfied with the product and would purchase an EM and introduce them to their peers in the future.

4.1.1 Survey results

An online survey was conducted from 1st to 17th June 2020 and received 266 respondents. Most respondents were students/university students (65%), followed by teachers/professors (9%) (Figure 15). About 71% of respondents were aged between 18 and 24 years (Figure 16).

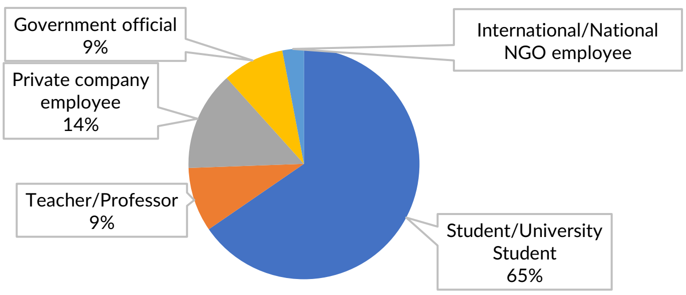

Figure 15. Professions of survey respondents

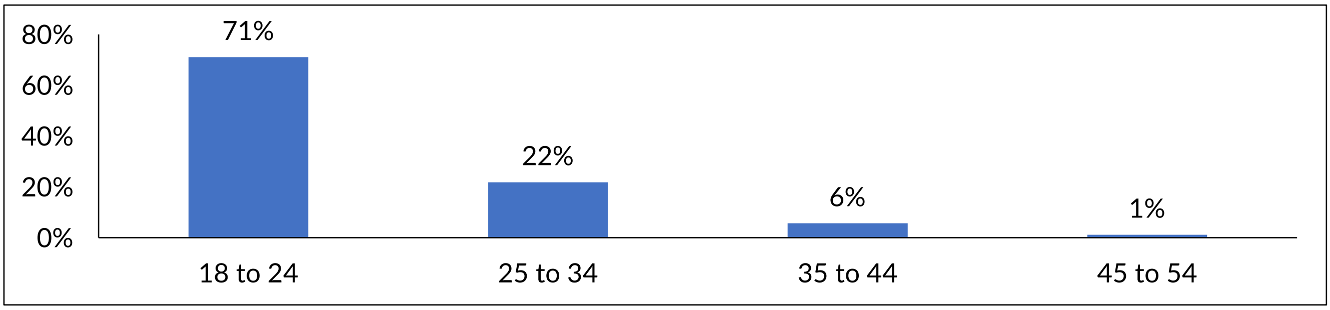

Figure 16. Age distributions of the survey respondents

The survey results revealed that more than 83% of the respondents are aware of EMs. The results also suggest that university students are well informed about EMs because they are the most active users of social media. These factors mean that they are likely to be EM users in the future, as indicated in the MoE (2019) study. Furthermore, our survey demonstrated that 43% of respondents think that EMs are better than ICEMs, and around 36% think that EMs are as good as ICEMs (Figure 17). This suggests that the acceptance rate of this new technology is high.

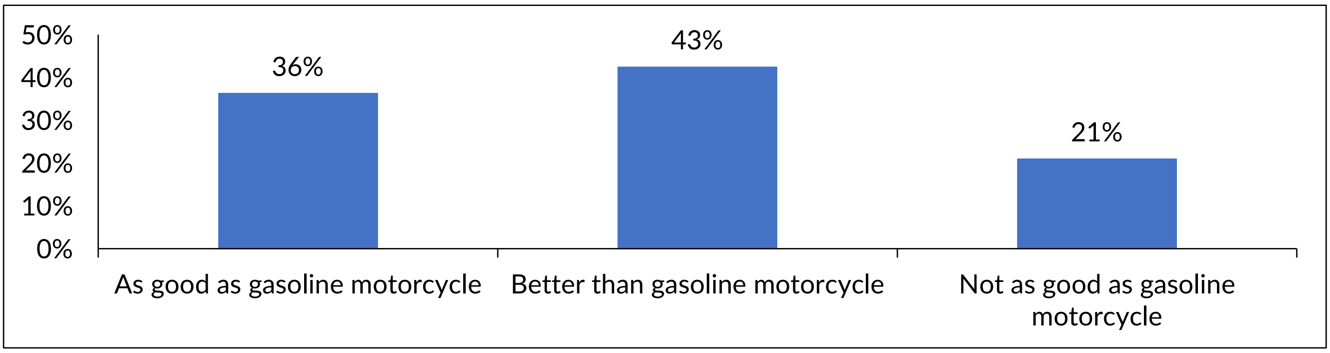

Figure 17. Survey responses to "What do you think about EMs vs. ICEMs?"

In addition, 83% of respondents expressed their willingness to purchase an EM in the future. Color, design, speed, and range were found to be the most influential factors in the respondent's decision to purchase an EM. The survey also revealed that the environmental benefits of EMs are the least influential factors, (see Table 14). Based on the results, it is reasonable to conclude that high school and university students pay more attention to the design and technical features of EMs than to other factors, such as economic and environmental benefits. Therefore, awareness-raising campaigns should highlight the 'cool' aspects of EMs and companies should take this into account to ensure the viability of their business in the Cambodia market.

Table 14. Influential factors when purchasing an EM, ranking from high (5) to low (1)

Influencing factors	Ranking
Color, design, speed, and range	5
Subsidies/incentives when purchasing	4
Easy to drive	3
Economic benefits	2
Environmental benefits	1

High ↑ Low

The findings from the online survey and the MoE (2019) study differed considerably on the public awareness of EMs. Our findings revealed that 83% of the respondents are aware of EMs, compared to only 34% in the MoE (2019) study. However, this could be the consequence of variations in the demographic of respondents: more students responded to the current study (65% compared to 28%).

Although most of the respondents in our study indicated that they are aware of EMs and expressed willingness to purchase one in the future, they have less physical exposure to this new technology. Combining results from our study and the MoE (2019) study, we have identified two main issues that could be addressed through awareness-raising strategies:

1) Limited information on the quality, performance, and benefits of EMs; and
2) Limited exposure to EMs.

Appropriate strategies and actions are required to tackle these gaps and stimulate the adoption and acceptance rate of EMs.

4.2 Target Groups for Awareness-raising Strategies

The below groups have been identified as the key target audiences for an EM awareness-raising campaign. These target groups are largely aged between 18 to 24 years old, and most are students at high school or university. This age group is typically the most active population in Cambodia, and they are often open to change and new technologies. For example, a viral video on reducing plastic waste, posted on Facebook, has successfully encouraged the young population to change their lifestyle by using eco-bags instead of plastic bags when shopping. There is a high adoption rate for new technologies in Cambodia, especially in Phnom Penh, and the youth[8], who make up 65% of the Cambodia population, are the driving force in embracing and spreading new technologies.

4.2.1 Students

Findings show that the group most likely to use EMs are students and individuals with an income less than US$350/month (MoE, 2019). A discussion with the Director of the Department of Environmental Education of the MoE also confirmed that students would be the most promising target group for conducting an awareness-raising campaign due to travel demand. After high school, students tend to move to Phnom Penh to pursue their studies at university and thus require transport to commute to their university campus.

4.2.2 Eco-conscious Groups

This group mainly comprises university students, environmental youth networks, civil society groups, and NGOs. They have concerns about environmental issues in Cambodia such as plastic waste, climate change, and natural resource depletion. They often organize local events including community waste collections along the riverside and campaigns to reduce plastic waste. Environmentally friendly technology, such as EMs, would appeal to this group if the right messages and strategies are delivered.

4.2.3 Young Professionals

The majority of respondents to the online survey are aged between 18 and 24 and could be labeled as 'young professionals' as they have just obtained their first or second job. This group may have a sufficient budget to purchase EMs.

[8] Youth here refers to the population under 30 years old.

4.3 Key Messages

Based on our findings, the following key messages have been developed to convey the benefits and experience of using EMs:

4.3.1 Driving an electric motorcycle is cool.

As indicated in table 13, color, design, speed, and range are highly influential factors on consumers looking to buy a motorcycle, ranking above the economic and environmental benefits. It is therefore important to convey the desirable aesthetics of EMs and market them in a way that makes them seem cool and fun to the target demographic.

4.3.2 Choosing an electric motorcycle is choosing to protect the environment.

Although environmental factors ranked lowly on the study of influential factors (see Table 14), climate change is increasingly a hot topic and public awareness is growing. Technologies that help to mitigate emissions, such as EMs, will appeal to a demographic that want to reduce their environmental footprint. Therefore, messages around EMs should emphasis their environmental benefits.

4.3.3 Electric Motorcycles are affordable and efficient. Make the switch today!

A common misconception about EMs is that they are expensive and unreliable. This key message aims to appeal to audiences that want to save money while also highlighting the advances made in EM technologies that allow for large battery capacity and a long-life cycle. Through this message, it is important to emphasize that making the switch from ICEM to EM will have positive, rather than negative, impacts on the users' everyday life.

4.4 Awareness-raising Strategies

4.4.1 EM Showcase

In Cambodia, people do not have many opportunities to experience electric vehicles. As well as promoting the economic and environmental benefits of EMs, a showcase would increase people's physical exposure to this emerging technology by giving them the chance to test drive models. An example of a similar event is the Urban Mobility Showcase, organized by EnergyLab in Phnom Penh in 2019. The Urban Mobility Showcase attracted around 200 participants and demonstrated the fun and excitement of EMs to the public. The disadvantages of implementing this strategy, however, include cost allocations and time requirements.

4.4.2 Social Media Marketing

Social media marketing could be an effective tool to promote EMs to the Cambodian public. Facebook provides a platform to reach a large portion of the population: in 2018, there were an estimated 7 million Facebook users in Cambodia (Telecommunication Regulator of Cambodia, 2019). Social media influencers and celebrities could also feature in the marketing of EMs as their popularity will generate interest in this emerging technology and make it look çool and trendy, especially to a younger audience.

4.4.3 Integrating EMs into Government Fleets

Integrating EMs into governmental or institutional daily operations would also increase public exposure. Government institutions regularly send documents or letters to ministries, and there is an opportunity to integrate EMs for this purpose. The potential barriers to implementing this barrier are, mobilizing financial resources to purchase EMs and the willingness of the government to adopt this new technology.

4.4.4 Incorporating Sustainable Transport into the School Curriculum

This is a long-term and indirect method to increase the knowledge and understanding of high school students on sustainable modes of transport such as EMs. The MoE, the MoEYS, and the NCSD have developed a *Climate Change Textbook for Upper Secondary School* in Cambodia, which has been published and used across upper secondary schools in Cambodia (CDD, 2018). To complement this textbook, information on sustainable transport could also be integrated into the school curriculum. However, this strategy is time and cost-intensive in comparison to the previous strategies.

4.4.5 Integrating an EM Campaign into the Eco-Schools Biannual Award Ceremony

The MoE and the MoEYS have developed a *National Guideline on Eco-schools in Cambodia* (2016). The Cambodian Eco-school Awards are held biannually nationwide to select the best schools that align with the environmentally friendly criteria set out in the *National Guideline on Eco-schools*. Eco-schools include primary and secondary school levels that recognize the values of environmental sustainability. Integrating an EM campaign into the Eco-school Awards would utilize the award ceremony platform to increase the exposure of high school students to EMs. This idea was also suggested by the Director of Environmental Education of the MoE. During the campaign, students could test-drive EMs and learn about the new technology. However, it would have a limited reach as the award ceremony is held at a school with only a few hundred students in attendance. Aligning the timing of the campaign and the award ceremony may also be difficult as it is only held every two years.

4.4.6 Prioritized Strategies

The strategies listed above include both short and long-term ways of increasing public awareness about the benefits of EMs. The strategies also aim to increase the public's physical exposure to EMs so that they can gain experience with this new technology. Table 15 shows the awareness-raising strategies in order of priority.

Table 15. Priority of awareness-raising strategies

No.	Strategy	Short-term (< 1 year)	Long-term (3-5 years)	Benefits	Priority
1	EM Showcase	√			High
2	Eco-school Biannual Award Ceremony	√			
3	Social Media Marketing	√			
4	Integrating EMs into Government Fleets		√		
5	Incorporating Sustainable Transport into the School Curriculum		√		Low

Key:
Both physical exposure & awareness raising:
Only awareness raising:

4.5 Summary

The assessment of education and communication needs has highlighted two major bottlenecks that prevent the growth of EMs in the Cambodia market: limited information about EMs and a lack of exposure to EMs. To address these issues, five awareness-raising strategies were proposed (see Box 2).

Among these five prioritized strategies, the EM showcase is the most suitable as it would not only increase public understanding of EMs but also allow the public to gain hands-on experience using EMs. Furthermore, the showcase would reach large audiences as it would be held in a public space. The current study has also identified the target audiences best suited to receive information about EM's: students, eco-conscious groups, and young professionals.

Box 2. Awareness raising strategies.

1. An EM showcase.
2. Integrating an EM campaign into the biannual eco-school award ceremony.
3. Social media marketing.
4. Integrating EMs into government fleets.
5. Incorporating sustainable transport into the school curriculum.

05. Economic, Environmental, and Social Assessment

A recent study found that CO2 emissions from EMs are around five times lower than from ICEMs (MoE, 2019). Alongside environmental benefits, the same study revealed that making a 100 km trip with an EM, rather than an ICEM, would save the user around US$1.60[9]. The study, which piloted 12 EMs from Terra Motor Corporation between April and December 2018, highlighted the economic and environmental merits of EMs but the results were limited as only one brand of EM was piloted over a short period. In the following section, a comparative analysis of ICEMs and EMs will be conducted to further assess the economic, environmental, and social challenges and benefits of electrifying mobility.

5.1 Driving Behaviors

5.1.1 ICEM Users

In the current study, the online survey received 266 responses from ICEM users. More than half of these respondents were male and aged between 18 and 24. The majority of respondents were students pursuing their undergraduate studies at university and earned an income of less than US$190 per month (see Appendix C).

The daily driving distance of 44% of the survey respondents was only 7.5 km, and about 37% of them drive around 15 km per day (Figure 18). The current study indicates that the daily average Vehicle Kilometers Traveled (VKT) for ICEM users is 14 km.[10] Driving speed, fuel consumption, and fuel expense are important variables to be examined in this section. The average driving speed of the majority of respondents is 30 to 40 km per hour, which is the speed limit in urban areas of Cambodia. Since the average daily driving distance is only 14 km, the average daily fuel consumption for ICEMs is 0.5 liters. This would cost about 1,500 to 1,800 Riels per day, according to the price of gasoline as of July 2020 (3,000 to 3,500 Riels per liter or US$0.7 to US$0.8).

The average daily VKT found in the current study (14 km) and the previous study (18 to 19 km) by the MoE (2019) differed slightly. This is probably due to the differences in sampling methods and geographical coverage. The MoE (2019) study set specific locations (supermarkets, petrol stations, and public spaces) to conduct physical interviews with the 703 users of ICEMs. Therefore, the geographical coverage was larger than in the current study that delivered the survey online without considering geographical coverage. The two studies revealed similar results on other aspects, including average traveling speed, average fuel consumption, and expense.

[9] The study found that making a 100 km trip using an EM cost about 1600 ± 300 Riel (around US$0.4), whereas an ICEM would cost 17,600 ± 9,600 Riel (around US$2) (MoE, 2019).
[10] Vehicle Kilometers Traveled (VKT) is a measurement of the total kilometers traveled by a vehicle over a certain period.

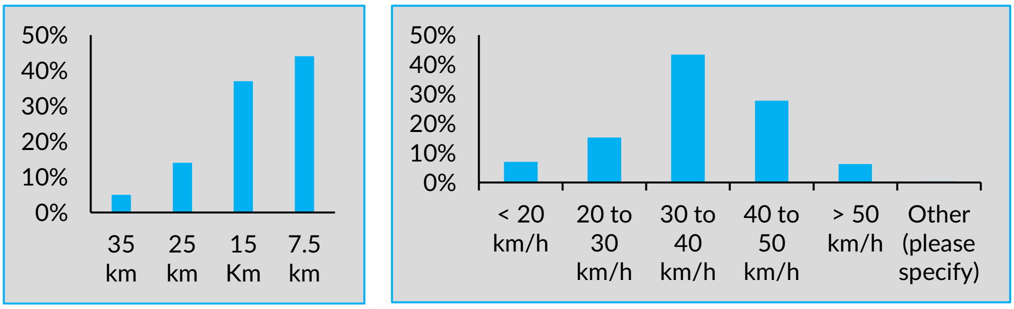

Figure 18. The daily average VKT (left) and the average driving speed (right)

5.1.2 EM Users

In the current study, 17 EM users responded to the online survey, the majority of which had driven or purchased an EM from Voltra Motors. Eight respondents indicated that they use the Voltra OFF-ROAD model, seven use the Voltra Matrix model, and two use the Thada OX model. The daily driving distance of the majority of EM users is 7.5 km (44%), and about 24% of them drive only 15 km per day (Figure 19). Combining the daily travel distance of the 17 users, the daily average VKT for EM users is about 16 km (close to 14 km average VKT found for ICEM users). As stated previously, Voltra OFF-ROAD, Voltra Matrix, and Thada-OX have a range of 50 km, 80 km, and 60 km, respectively per full charge.

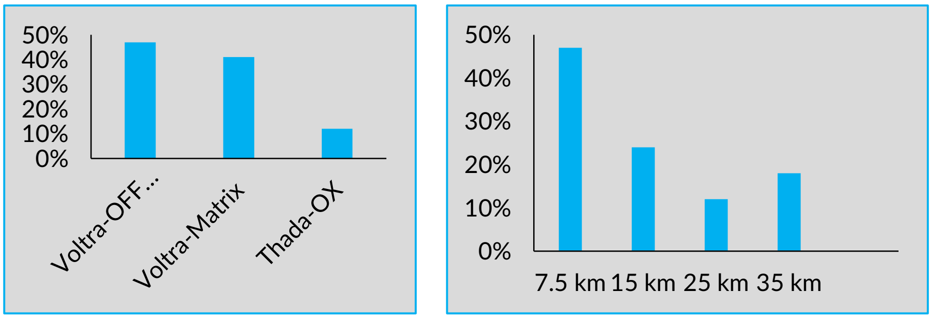

Figure 19. EM models in the survey (left) and the daily driving distance (right)

Two types of EM batteries were identified in the online survey: lithium-ion (LIB) and lead-acid battery. The majority of respondents drive LIB EMs (94%). Only a small portion drive lead-acid battery EMs. On average, both types of batteries take about four hours to fully charge and most of the respondents charge one time per day (Figure 20).

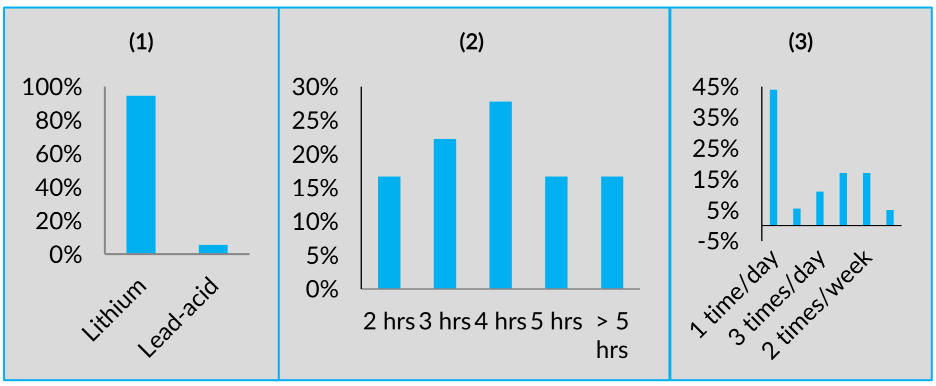

Figure 20. Types of battery (1), average time to fully charge the battery (2), and frequency of charging per day/week (3)

5.1.3 The Cost of Charging an EM Battery

To estimate the cost of recharging an EM battery, the battery capacity and the cost of electricity need to be identified. The survey indicates that the battery capacity of the Voltra OFF-ROAD model is 48V12AH and 60V28AH for the Voltra Matrix and Thada-OX models. The electricity cost for household consumption in Cambodia, as of July 2020, is 610 Riels (or US$0.15) per kWh. Table 16 shows an estimation of the recharging cost for EM batteries based on different battery capacities.[11]

As previously stated, the daily average VKT for EM users is 16 km per day. On average, one full charge of an EM can travel up to 50 km and costs 400 Riels. If one full charge can travel up to two days, then making trips using EMs would cost around 200 Riels per day. Traveling for 100 km using EMs would cost only 800 Riels. The results from this study are compatible with the previous study by the MoE (2019) which found that it would cost around 300 to 1600 Riels to travel 100 km by EM. Other factors such as driving behavior and traffic congestion will impact the range of EM.

Table 16. Cost to recharge an EM battery for one time based on different capacities.

Models	Battery capacity Voltage (V)	Charging Capacity (AH)	Energetic Capacity (Wh)	Consumption for 1 charge (kWh)	Cost for 1 charge
Voltra-OFF ROAD	48	12	576	0.58	400 Riels (US$0.09)
Voltra-Matrix or Thada-OX	60	28	1680	1.68	1000 Riels (US$0.25)

5.2 An Economic Assessment of ICEMs Vs. EMs

5.2.1 Operating Costs

To illustrate the economic benefits of driving an EM, the operating costs for driving 100 km with and EM and an ICEM will be compared. The comparison will be made between a Voltra OFF-ROAD model (50 km range) and Voltra Matrix (80 km range) model, and 100 cc and 125 cc engine capacity ICEMs. An EM only consumes electricity for its operation, but an ICEM consumes fuel to operate. The average daily VKT of EM and ICEM users, as indicated in the survey, is roughly the same: 14 to 16 km. The expense of electricity for an EM for 100 km is around 800 Riels for Voltra OFF-ROAD and 1,300 Riels for Voltra Matrix, which is considerably lower than an ICEM at 9,000 to 10,500 Riels, considering the current prices of fuel[12]. Based on this, the cost of driving an EM for 100 km is about eight to 10 times lower than driving an ICEM for the same distance. The result is comparable to the MoE (2019) study which found that the operating cost of an EM for 100 km is about 10 times lower than an ICEM (Table 17).

Table 17. A comparison of the operating cost of EMs and ICEMs

Indicators	EM	ICEM
Motor Power/Engine Capacity	500 to 1600 W	100 to 125cc
VKT	16 km	14 km
Range (km/charge)	50 to 80 km	None
Electricity consumption (kWh/ 100 Km)	0.58 to 1.68	None
Fuel consumption (L/km)	None	0.03
Total expense on operating cost (Riels/$) /100 km	800 to 1300 Riels (0.2 to US$0.32)	9,000 to 10,500 Riels (2.2 to US$2.57)

[11] To calculate the cost of recharging the battery, the following steps were applied: 1) Multiply the voltage (V) and the charging capacity (Ah) of the battery. This equation provides the energetic capacity of the battery (Wh): 2) Multiply the result obtained by equation 1 in kWh with the price of electricity per kWh.

[12] The majority of the survey respondents drive a Honda Dream 125 cc which has a range of 30 to 35 km per liter of fuel.

5.2.2 Maintenance Costs

An EM does not require regular maintenance costs such as changing engine oil. Based on the survey's result, 56% of the respondents have not had their EM repaired as most EMs in use in Cambodia are new (most were purchased in 2019 and 2020). The other 44% of respondents repaired their EMs under the warranty period, which is free of charge. Although regular maintenance costs are small, the cost of battery replacement is significant. An LIB can last for about three years according to the interviews conducted with EM companies, and the replacement cost of an LIB is about US$195. Therefore, the annual cost of battery replacement is approximately US$65. If the cost of an LIB decreases in the future, this annual yearly maintenance cost will be reduced. Although EMs do not require regular maintenance, access to maintenance poses a challenge as users have to return the EM to the company shop in Phnom Penh. One EM company is seeking cooperation with a vocational training school to offer training in EM maintenance; however, it is yet to develop.

For ICEMs, the current study will consider two important maintenance costs: engine oil and the cost of repairs. According to the survey, on average, ICEM users change the engine oil six times per year. The average cost of changing engine oil is US$5, therefore the average cost of changing the engine oil per year is around US$30. On average, ICEM users have their motorcycles repaired five times per year and each time the average cost is approximately US$10. In total, the annual average cost of repairing an ICEM is around US$50 (Table 18). The analysis showed that the average annual maintenance cost of EMs is slightly lower than ICEMs.

Table 18. A comparison of maintenance costs of EMs and ICEMs

Types of Maintenance Cost (Yearly)	EM	ICEM
Battery replacement	57 to US$65	None
Engine oil	None	US$30
Repairing cost	None	US$50
Total maintenance cost	57 to US$65	US$80

5.2.3 Total Ownership Cost

The total ownership cost is the combination of different cost components that occurred in a given time. The cost components here refer to the price of an EM or an ICEM, the operating cost, and the maintenance cost. The current study will compare the total ownership cost of an EM, with a LIB with a three-year lifespan, and a 125cc ICEM over 10 years.

The technical and market assessment of EMs and ICEMs indicated that the average price of an EM is US$1,000, while the average price of an ICEM is US$2,000 (125cc with a 4-stroke engine). The operating cost of an EM is about US$18 per year, and as mentioned in Table 19, the yearly maintenance cost is US$65. Over 10 years, the total ownership cost of an EM is US$1,830 (plus the average price of an EM). The operating cost of an ICEM is about US$134 per year, and the yearly maintenance cost is US$80. Over 10 years, the total ownership cost is US$4,140 (plus the price of an ICEM). Therefore, driving an EM, rather than an ICEM, could save users around US$2,000 over 10 years.

Table 19. A comparison of the total ownership cost of EMs ICEMs

Cost components in 10 years (US$)	EM	ICEM
Operating cost	180	1,340
Maintenance cost	650	800
Price of vehicle (average)	1,000	2,000
Total ownership cost (excluding the price of vehicle)	**830**	**2,140**
Total ownership cost (including the price of vehicle)	**1,830**	**4,140**

5.2.4 Personal and Commercial Use Suitability

The economic assessment of EMs has mostly focused on personal use as the daily average VKT and the battery range of EMs (50 to 80 km) is not suited for commercial use: according to a local food delivery company, the daily average VKT for a delivery company is around 200 km per day. EMs have, however, previously been used for business operations by Meal Temple, a food delivery company, in Cambodia although they faced challenges and were forced to return to using ICEMs (see Box 3).

One EM company has been developing and deploying battery swapping stations in the Cambodian market to overcome the issue of low battery range. The battery swapping stations will be installed at mini marts so that users of the company's EMs can swap the battery by using an application in their phones to scan a QR code. The swapping will be done in under 60 seconds for US$1 per swap and the range of the fully charged battery will be around 50 km. Considering the cost of swapping (US$1) and the average daily VKT for a delivery business (200 km), it would cost the business only US$4 per day for their operations using an EM, which is lower than the daily operating costs of using an ICEM (US$6 considering the price of gasoline as of July 2020).

The business use suitability is however limited as only a small number of swapping stations are in operation (currently 11 stations in Phnom Penh). Swapping stations or the development of fast-charging batteries are needed so that businesses can operate sustainably. Consequently, the current technical specifications of EMs make them more suitable for personal use.

Box 3. Meal temple EM fleet case study

Meal Temple purchased 10 EMs from XSOON in July 2018; all imported from China and equipped with LIB 60v 30AH battery capacity, costing US$1,000 each. Initially, the driving range was exceeding 100 km per full charge and the charging time was from six to eight hours. However, in the first three months, the batteries melted down due to intensive use totaling approximately 110 km per day. XSOON replaced the LIB batteries, but they lasted only six months. Meal Temple has returned to ICEMs to ensure its competitiveness in the food delivery businesses. For commercial businesses, including ride-sharing companies, the range, speed, and weight limitations of EMs are also a constraint. The commercial use of EMs has experienced challenges and as a result, trust in this new technology is low in comparison to ICEMs.

5.3 An Environmental Assessment of ICEMs Vs. EMs

5.3.1 GHG Emissions

EMs emit zero tailpipe emissions at their point of use, their overall energy efficiency is higher, and their emissions per kilometer are lower than ICEMs (Weinert et al., 2007). In this section, the GHG emissions from both EMs and ICEMs will be estimated[13]. To estimate the GHG emissions, two parameters, the emission factors and the activity data, need to be identified. The emission factors are default values that have been identified from previous research. For EMs, the grid emission factor based on electricity consumption, as reported by IGES and MoE (2016), for Cambodia will be applied. For ICEMs, the emission factor is based on a study by Cherry and Jones (2009) and Meszler (2007) (Table 20). The activity data for EMs, taken from the online survey, is the total electricity consumption, while the activity data for ICEMs is the average VKT.

[13] GHG emissions consist of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), however, the current study will limit the estimation to the only CO2, as CH4 and N2O are minuscule in quantity.

Table 20. Emission factors for EMs and ICEMs

Types of vehicle	GHG emission factors CO_2	References
EMs	0.3839 (kg/kWh)	IGES &MoE (2016)
ICEMs (4 stroke)	77 (g/km)	Cherry & Jones (2009) Meszler (2007)

As shown in Table 17, the average electricity consumption of an EM is around 0.30 kWh in one day. The total electricity consumption of an EM in one year is 110 kWh. Therefore, the CO2 emissions from driving an EM are approximately 42 kg in one year. As previously established, the daily average VKT for the ICE motorcycle users is 14 km per day, and the total traveling distance in one year is 5,114 km. In one year, the CO2 emissions from driving an ICEM would be around 394 Kg. Based on these figures, the CO2 emissions in one year from an EM are about nine times lower than an ICEM. In 100 km, an EM emits only 719 g of CO2, compared to an ICEM which emits 7700g of CO2 (Figure 21).

Results from the current study, however, differ from the previous study by the MoE (2019). The current study applied the average National Grid Emission Factor (0.3839 kg/kWh) (IGES &MoE, 2016), while the previous study applied Kompong Cham Province Grid Emission Factor (0.72 kg/kWh) (IGES &MoE, 2016), which is higher than the national average. As a result, the MoE study found that emissions from EMs are only five times lower than the emissions from ICEMs.

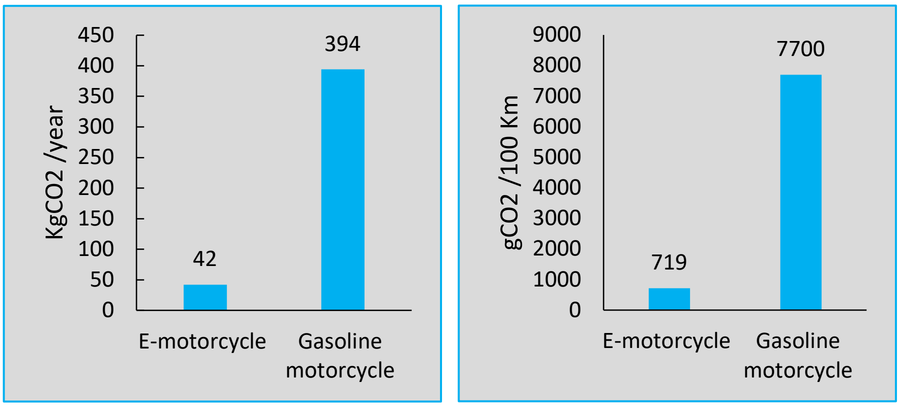

Figure 21. CO2 emissions of an EM and ICEM in KgCO2/year and gCO2/100 Km

5.3.2 Air Pollution

Although EMs do not produce direct emissions or pollution during the use phase, it is difficult to conclude the emissions emitted during the production phase. The assessment of emissions or pollution from EMs during the production phase is out of the scope of the current assessment due to limited availability of data [14] and time restrictions. Therefore, the current study assumed that the tailpipe emissions or pollution from EMs are equal to zero. The indirect emissions of EMs through electricity consumption are shown in Figure 21.

Emissions from ICEMs have detrimental effects on the environment and public health. As technology has improved, ICEMs have not seen the same progress in reducing emissions as other vehicles. ICEMs emit less CO2, NOx, SO2, and PM10 per person-mile traveled than most cars, but more VOC and CO if there is no catalytic converter present (Fagnant et al., 2013). ICEMs with smaller engines produce fewer emissions, but those with larger engines perform worse than most other vehicles (Fagnant et al., 2013).

[14] The availability of data is limited as all the existing EMs in the Cambodian market are imported. Data on the amount of raw material or energy used to produce EMs is, therefore, recorded in different countries.

There is little information related to empirically measured ICEM emission rates in the developing world. However, a recent report outlined the current state of worldwide motorcycle emission rates, as shown in Table 21 (Meszler, 2007).

Table 21. ICEM emission rates (g/km) (Meszler, 2007)

Engine type	CO	VOC	NO_x	SO_2	PM
2 stroke	18	16.75	0.05	0	0.5
4 stroke	12.5	2.25	0.15	0	0.1

Table 24, adopted from Bekker (2018), compares the environmental sustainability of E2Ws against other modes of transport across four factors: space efficiency, air pollution, CO2 emissions/energy use, and noise [15]. E2W's receive a higher rating for sustainability across most factors compared to cars and ICEMs and receive a higher sustainability rating than public transport for air pollution, CO2 emissions/energy use, and noise.

Table 22. Environmental and sustainability impacts of urban transport modes

Mode	Typical trip distance (km)	Space efficiency	Air pollution	CO_2 emissions/ Energy use	Noise
E2W	1-15	++	+++	+++	+++
Motorcycle	1-15	++	+	+	0
PT +NMT	1-20$^+$	+++	++	++	++
Car	1-20$^+$	0	+	0	+

Note: *PT-Public transport; NMT-Non-motorized transport; lowest rating: 0; low rating: +; medium rating: ++; high rating: +++ (Bakker, 2018)*

5.3.3 Battery Waste

The solid lead waste of E2Ws is considerably higher than ICEMs. These lead emissions are 5–10 grams/100 km, due to the production, distribution, and recycling of used lead-acid batteries (ULAB) (Weiss et al, 2015; Liu et al., 2017). In China, 95% of the total lead emissions are released at the end-of-life stage, due to an inadequate recycling process of ULAB. In Cambodia, while data does not exist, there is no formal collection and recycling system, and ULAB are likely recycled in informal settings, creating environmental pollution and harm to human health (MOE, 2019b). Up to 85% of the total global consumption of lead is for the production of lead-acid batteries (WHO, 2017). Even without E2Ws, the use of lead-acid batteries is already widespread in Cambodia, such as in cars, and issues associated with ULAB already exist.

According to one study, 60% of the lead-acid content is recyclable. If there was a 100% collection rate of ULAB for recyclability, 98% of the total toxicity impact could be avoided (Kerdlap & Gheewala, 2016). In the United States, about 99% of ULAB are recycled, and recycling is also working well in Europe and Japan. However, lead exposure can still take place during the mining and processing of the lead, as well as the recycling stage. Most of the imported EMs in the market have lead-acid batteries, and without proper regulations, the country will face critical challenges in dealing with lead contamination.

There are alternatives to lead-acid battery, such as LIB and nickel-metal hydride batteries, which weigh half as much and have higher battery life. However, these are four times more expensive for the same energy provided by lead-acid batteries (Weiss et al., 2015). End of life LIBs are more environmentally friendly because lithium is not a toxic heavy metal like lead. According to one of the interviewed EM companies, LIBs can be recycled in China. However, the recycling process is much more complex and expensive, and is not currently widespread. In addition, the mining lithium creates environmental issues.

[15] For illustration purposes only as the transport modes cover different trip distances and impacts may differ considerably depending on local circumstances, particularly transport planning and environmental standards.

5.4 A Social Assessment of ICEMs Vs. EMs

5.4.1 Public Health

Emissions from the increasing number of ICEMs in Cambodia pose a threat to air quality and public health, especially in urban areas such as Phnom Penh. Although data from the MoE's real-air quality monitoring station indicates that there is currently no major health risk from air pollution, this will be likely to change if vehicle use and congestion continue to increase (Cambodia Air Quality Monitoring Project, 2016).[16] Low-income groups are more likely to be exposed to air pollution than high and middle-income groups due to traffic congestion as they often live in the outskirts of a city and face longer commutes into the city for work. Research shows that the health impact of particulate matter on a per person-km basis of E2Ws is lower than other modes of transport (Ji et al., 2011). A further health benefit of electrifying motorcycles is the reduction in noise pollution as EMs are quiet in comparison to ICEMs (Sheng et al., 2016). The electrification of motorcycles could therefore help to cut harmful emissions and reduce the exposure to air and noise pollution faced by low-income groups and vulnerable communities.

5.5 Summary

The economic, environmental, and social assessment of EMs and ICEMs has shown that there are significant benefits to adopting EMs. EM's have shown to be more economical than ICEMs as the total ownership cost of an EM (including the price of an EM, the operating and maintenance costs) over 10 years is two times lower than an ICEM. Environmental benefits include the mitigation of air and noise pollution and the subsequent public health benefits. EMs produce nine times less CO2 emissions than ICEMs in one year. However, the battery waste of EMs poses an environmental risk without sophisticated recycling facilities and regulations to govern the disposal of this waste.

[16] Data from the MoE's real-time air quality monitoring station in a central area of Phnom Penh, Tonle Bassac, indicated an average airborne particle level of 10.24 µg/m3 compared to the PM2.5 standard of 30 µg/m3 within 24 hours from June 3 to June 9, 2018 (Cambodia Air Quality Monitoring Project, 2016). This data may not be representative of pollution levels across the city.

06. Policy and Regulatory Gap Analysis

6.1 Lessons from Other Countries

Local, regional, and national government policies play a major role in the adoption of EVs. Countries have employed different approaches to promote EV adoption, which has resulted in policies favoring promotion or containment. Case studies and lessons learned about electric two-wheelers (E2W) are presented below, with a focus on the China (e-bike), Taiwan (Republic of China) (e-scooter), India (EVs and E2Ws), and Viet Nam (EMs and e-scooters). Table 23 shows the definitions of different E2Ws, including e-bikes, e-scooters, and EMs.

Table 23. Definitions of different E2Ws (European Commission, 2013)

E2W Type	Description	Maximum speed	Maximum electric motor continuous rated power
E-bikes	Pedal-assisted two-wheelers	⩽25 km h−5	⩽0.25 kW
E-mopeds & small e-scooters	Mid-size electric two-wheelers without pedal assistance	⩽45 km h−5	>0.25–4 kW
EMs and large e-scooters	Large E2Ws	>45 km h−i	>4 kW

6.1.1 China

It is estimated that about 150 million e-bikes are in use in China, and about 30 million are sold annually (Jamerson &Benjamin, 2013). Before the late 1990s, there were attempts to commercialize e-bikes and scooters. Those attempts all failed. However, the e-bike market in China took off in the 1990s, facilitated by local regulator practices in the form of ICEM bans and looser enforcement of e-bike standards (Weinert et al., 2007; 2009). The national government has a few key policies that have facilitated the development of the e-bike market, the "1999 National E-bike Standards", the 2004 "Road Transportation Safety Law", and the economic incentives for New Energy Vehicles (NEVs).

<u>The 1999 National E-bike Standards</u>

In 1999, National E-bike Standards were set to establish performance limits for e-bikes with respect to speed, weight, and power. One crucial specification in the standards stipulated that as long as the bike had functional pedals, it could be classified as an e-bike, which allowed Scooter Style E-bikes (SSEBs) to be classified under the same rules and regulations as Bicycle Style E-bikes (BSEBs). This opened the doors of what would become a huge, important market for SSEBs. Manufacturers capitalized on this loophole in the standard by making SSEBs with pedals that barely functioned and that could be easily removed after purchase. They realized that the scooter style could directly compete with the incumbent technology of gasoline and LPG scooters as, with exception of the powertrain, all other features were equal. Many prefer this style over BSEB because it is easier to carry cargo and passengers, they are more comfortable (larger seat, lower center of gravity), and they create more opportunities for unique, fashionable styling. In Shanghai, it is estimated that >70% of e-bikes are SSEB. This is a common trend in Southern cities, though, in Northern cities, BSEB is more popular because batteries run down quicker in cold weather, requiring users to pedal often.

The following specifications must be met, or the vehicle cannot be licensed (Table 24). The other specifications such as weight, width, motor power, pedal capability result in a monetary fine for the OEM (Original Equipment Manufacturers) if not met, and they are then "recommended".

Table 24. Mandatory Technical Specifications of E-bikes in the 1999 National E-bike Standards

E-bike Technical Specifications	
Speed limit	< 20 km/h
The brake distance	Dry: 4m; Wet: 15m
Frame vibration	Quiver test > 70,000 cycles without damage

<u>The National Road Transport Safety Law</u>

In 2004, the National Road Transportation Safety Law classified any e-bike equipped with pedals, including SSEBs, as a non-motorized vehicle, granting e-bikes access to bike lanes and eliminating requirements for e-bike operator licenses, vehicle registration, and the use of helmets. This law, combined with the proliferation of bans on fuel-burning two-wheelers, strong pricing competition, lenient enforcement of performance regulations, drove the national adoption of e-bikes (Ling et al., 2015; Weinert et al., 2007; 2008).

6.1.2 Taiwan

The Taiwanese government's effort to promote e-scooters provides an interesting contrast to the experience in mainland China. The Taiwan Environmental Protection Administration (TEPA) started to promote and subsidize e-scooters in 1998. It spent millions of dollars (NT $1.8 billion or US$64 million) subsidizing e-scooters but without any restrictions on the use of gasoline-fueled scooters (Lee and Pan, 2003). The subsidies included tax reductions for e-scooter manufacturers, subsidies for research and development, promotional activities, charging facilities, and rebates for consumers amounting to nearly half of the scooter retail prices. With all these subsidies, the cost of e-scooters was comparable to their gasoline counterparts. Nevertheless, sales of e-scooters remained very low (Tang and Liao, 2004). Riders still considered EM performance as inferior to ICEMs. In addition, no restrictions were issued for ICEMs.

Learning from the unsuccessful experiences in promoting e-scooters during the last decade, the Industrial Development Bureau of Taiwan drew up a subsidization program to reach the goal of one hundred thousand e-scooters 'on-road' in the four years from 2009, including the subsidy for consumers, the reward for manufacturers, and the subsidy for constructing charging facilities. Conditions for the subsidization policy for the e-scooters were set to ensure products are high-quality and can satisfy the requirement of consumers (see Box. 4).

Box 4. Conditions for the e-scooter subsidization policy

- Vehicle type approved by MOTC (Ministry of Transportation and Communications).
- Adopt a detachable lithium-ion battery (LIB) pack.
- The nominal voltage of the battery pack is 48V.
- Information on battery management system (BMS) including temperature, voltage, residual capacity, abnormal signal, recharging cycles, and battery identification should be recorded and can be read out.
- Meet the criteria of performance and safety.
- Issue business operations plan to approve: (1) Projected sales quantity (2) Detailed vehicle performance; (3) Detailed battery specification (including nominal voltage and BMS information); (4) Warranty conditions; (5) Promotion plan and sales channel; (6) After service.
- Quality compliance: (1) Regularly scheduled inspection (2) Scheduled inspections if a customer complains.

Gogoro

This promotion program in 2009 was meant to convert traditional motorcycle manufacturers to fabricate low pollution products and to drive the local LIB industry into the power battery business segment. However, only from 2015, after spending tens of millions of Taiwan Dollars in subsidies without much effect, did a notable increase in EM registrations commence with the market entry of EM manufacturer Gogoro (Yang, 2010; Tang & Liao, 2004; Chiu & Tzeng, 1999). As of May 2019, the company has sold 160,000 scooters. The success of Gogoro is due to a few main factors: the design, government support, and the battery swapping business model.

Gogoro markets their e-scooters to look cool and comfortable to ride. Taiwan's Ministry of Economic Affairs supported Gogoro over other e-scooter brands to build Taiwan's 1,300 swapping stations. Battery swapping sites are placed every 500 meters in urban Taiwan, usually in obvious roadside locations. The stations are placed every two to five kilometers in other parts of the island. The central government pays half the cost of building the swapping stations and offers publicly accessible land.

6.1.3 India

India's roadmap for vehicle electrification, outlined in the National Electric Mobility Mission Plan (NEMMP) 2020 launched in 2013, highlights the country's vision to boost the adoption and manufacturing of EVs. Over the years, India's approach to EV deployment has evolved. The current EV policy framework is a mix of incentive-based policies accompanied by regulatory reforms, and public-private partnerships to encourage EV adoption, expand charging infrastructure and support domestic EVs, and supply equipment manufacturing capacity and battery manufacturing. Energy security and clean air considerations have also prompted the adoption of stricter performance and efficiency standards for the overall vehicle fleet and led to new policies focusing on the development and market adoption of electric and hybrid vehicles.

Electric Two-wheeler Policies

Based on the Indian government's support for EV adoption, there was a significant increase in the sales of E2Ws from 54,800 units in 2018 to 126,000 units in 2019 (Wadhwa, 2019). According to an IEA report, there were 600,000 E2Ws in 2019 (IEA, 2019). The government has tried to find a way to move directly from fossil fuel two-wheelers toward EVs due to the fact that approximately 20% of the CO2 emissions and 30% of particulate emissions in India are estimated to be caused by motorized two-wheelers (Viswanathan and Sripad, 2019). The government was able to provide a subsidy to 88 models of E2Ws by introducing the first phase of the Faster Adoption and Manufacturing of Hybrid & Electric

Vehicles (FAME I) scheme. As of April 2019, the government has introduced the FAME II scheme which required strict speed, range, and energy efficiency leading to discontinuation of their subsidy to most of the LIB-driven models (CRISIL, 2019). The government provided incentives in FAME II relate to the types of vehicles such as electric buses, two/three-wheelers, PHEV, and HEV cars: the largest share of the incentives are reserved for buses (41%), followed by three-wheelers (29%) and two-wheelers (23%). Despite the government's strong support, there was a big fall in the sales of E2Ws by about 94% because most E2Ws are not eligible for incentives under the FAME II scheme.

Charging Infrastructure Policies

The Indian government announced the change of the title of the Bureau of Energy Efficiency to the Central Nodal Agency for expanding the charging infrastructure network in India in 2019 (Government of India, 2019). With the institutional reform as a beginning, the government has tried to establish a clear EV charging governance framework and improve the previous guidelines and standards for charging infrastructure for EVs. The guidelines set out targets for the installation of at least one publicly accessible charger within a 3x3 km grid in cities, and one charging station every 25 km on both sides of highways and include information on the specifications of the Electric Vehicle Supply Equipment (EVSE) and related aspects of charger deployment (IEA, 2020). The government of India has already taken action aligned with this guideline to try and reduce the rising dependence on fossil-fueled vehicles by mobilizing approximately INR 10 billion (US$130 million) for deploying networks of charging stations under FAME II and deploying 498 publicly accessible chargers in government offices along with 68 publicly accessible chargers across the country.

6.1.4 Viet Nam

Rapid growth in transport activities since the late 1990s is jeopardizing the achievement of climate targets in Viet Nam. The transport sector accounted for 18% of total CO2 emissions in 2014. Under the BAU scenario, it is estimated that until 2030 carbon emissions from transport would rise sharply to nearly 90 Mt CO2e (WB, 2019). To tackle climate change and achieve their Nationally Determined Contribution (NDC), the government of Viet Nam has set out its policies for sustainable transport. However, there is no specific EV policy or incentives in Viet Nam. Without the government's strong EV initiative, it is difficult to find EMs on the roads of major cities in Viet Nam, particularly in Ha Noi.

The metropolitan population of Ha Noi is around 7.5 million with an urban population of around 3.5 million. According to ADB's household surveys in 2014, there are about 250,000 cars and approximately 4.6 million motorcycles on the roads, around 16% of which are E2Ws. In Ha Noi, Gasoline motorcycles are four-stroke and follow Euro 2 or Euro 3 standards with an engine displacement of 110 cc. Average urban fuel consumption is around 2.5 liters per 100 km, and the average annual mileage is 4,100 km (WB, 2014). Good quality gasoline motorcycles cost US$700–$1,400, while e-scooters are available at a lower price. The e-scooter market peaked in 2016 and then started to decline due to customer issues on quality such as power, speed, and driving range. Batteries also need to be replaced around everyone to two years, and they are lead-acid units that have a high potential environmental impact. E-scooters are used primarily by students as they do not require a license, and they have a low purchase cost.

6.2 Policy Gaps and Recommendations

Limited government policies and regulations on EMs have presented a significant challenge to the uptake of this new technology. The following section explores the existing policies and regulations in Cambodia and proposes policy and regulation recommendations that will promote the adoption of EMs in Cambodia.

6.2.1 Charging Infrastructure

Currently, the Cambodian government has no specific policies or incentives to promote investment in EV charging infrastructures, such as battery swapping or plug-in charging stations. Charging infrastructure is an important component that reduces the range of anxiety for EV users, a study by Krupa et al. (2014) found that intention to purchase an EV is affected by the availability of charging stations.

Recommendation 1: Increase charging infrastructure through incentives

Installation of battery swapping stations or plug-in charging infrastructure at supermarkets (Figure 22), entertainment spaces, universities, or government institutions, where people tend to spend a lot of time, could be an effective strategy. In Cambodia, although the government may not have the capacity to invest in charging infrastructure, they could formulate a policy or strategy to facilitate investment from the private sector or international donors. In Taiwan, for example, local enterprises can apply for subsidies to open a battery station, with grants per unit totaling US$10,140 or 49% of installation costs. Building permits for commercial buildings or parking lots could also be linked to EV charging stations. The Green Building Guidelines, which are currently underway by GSSD, could include the provision of charging infrastructure for new building permits. In addition, the government could facilitate investment in battery stations by reducing the import tax on battery stations and thus reducing the cost of installation.

Figure 22. EV Charging Station at a parking lot in a mall in Phnom Penh

6.2.2 Registration

The formal registration of EMs is critical to their adoption in the Cambodian market, despite this, EM users are not given preferential treatment as they pay the same US$10 registration fee as ICEM users (MPWT & MEF, 2019). EMs can be registered at the MPWT, as stated in Sub-decree No.73 on the Registration and Plate Number of Vehicles dated 3rd June 2019 (RGC, 2019). However, according to the interview held with a representative from the MPWT, few EMs have been registered at the MPWT and often they cannot be registered because they do not have import tax papers. Obtaining the import tax papers can be a challenge for consumers because EMs are put in shipping containers with other items, and often only one tax paper is issued for a shipping container, not for the individual items. To obtain the tax paper, the owner of the shipping container must declare the EM at the time of import.

Without registration, users are often unable to buy insurance, which also leaves them unable to access loans from financial institutions. According to Voltra Motors and Oyika, however, some insurance companies only require an EM Vehicle Identification Number (VIN) and motor number (a tax paper and plate number is not required) to issue insurance. Based on information from Oyika, only two insurance companies are currently willing to issue insurance for EMs with just a VIN and motor number. Furthermore, without the formal registration of EMs at the MPWT, the resale market does not function.

Recommendation 2: Streamline the import tax and registration process

To decrease the confusion surrounding the EM registration process, including obtaining import tax papers, the MPWT could reinforce the law that stipulates that owners of shipping containers are responsible for the declaration of all individual items at the time of import, including EMs. Increasing registration would allow MPWT to track the number of EMs on the roads in a database, which could also prove to be a useful resource for the effective implementation of policies and strategies. To achieve this, MPWT would need to work closely with the General Department of Customs and Excise (GDCE) to issue tax papers for EMs at the time of importation. EMs that have already been imported without tax papers could also be given the opportunity to register for a plate number at MPWT. To further encourage registration, the government could waive the registration fee for EMs.

6.2.3 Financial Incentives

Currently, there are no financial incentive policies or strategies for consumers seeking to purchase an EM, such as subsidies and tax exemptions. In Taiwan, the average total subsidy is NT$18,000 (around US$620) and can even reach as much as NT$33,000 (around US$1,150). In the context of Cambodia, however, it is a challenge for the government to provide subsidies for EMs as the country's primary source of revenue in 2019 came from imports of vehicles (including ICEMs) and machinery. These imports also account for about 50% of the total revenue of GDCE. Financial incentives such as tax reduction, exemption, or subsidies to promote the adoption of EMs would likely reduce the importation of ICEMs, thus reducing tax revenues.

Although the current average price of an EM (US$1,000) is lower than an ICEM (US$2,000), EMs are considered expensive by consumers as the design, quality, and resale market is considered no match for ICEMs. The US$1,000 price tag is almost comparable to a Honda Wave 100cc, which is one of the best-selling ICEM models on the market. According to the GDCE, the current import tax on the LIB or lead-acid battery is 48.5%, which is high and significantly affects the price of EMs. The current import tax for EMs and ICEMs (≤50cc) is 32.83% and 39.15% for ICEMs (≥50cc) (see Table 25), but if import taxes on EMs and batteries were to be reduced, the adoption rate of EMs in the Cambodian market would likely increase.

Access to loans for purchasing EMs is also a challenge as most of the financial institutions in Cambodia only provide outstanding loans for the purchase of ICEMs, not EMs. According to the financial institutions interviewed in this study, many of them do not have experience in providing loans for EMs, and their partnerships with EM companies are not well constructed. As a result, financial institutions still perceive providing loans to purchase EMs as high risk.

A policy to promote cleaner vehicles is, however, currently in discussion. In 2019, the National Council for Sustainable Development (NCSD) established an inter-ministerial working group to develop a vehicle tax policy aimed at establishing the vehicle tax for imported vehicles and promoting cleaner vehicles. With this policy, tax rates between low carbon and internal combustion vehicles will be differentiated. This working group is currently developing a report on the suggested adjustment for the vehicle tax rate in Cambodia (MoE, 2020).

Table 25. Tax and tariff rates for ICEMs and EMs in Cambodia (GDCE, 2017)

Engine Size (cc)	Duty Rate (%)	Special Tariff Rate (%)	VAT Rate (%)	Total
Below 50	15	5	10	32.83%
50 to 125	15	10	10	39.15%
Electric Motorcycle	15	5	10	32.83%

Recommendation 3: Reduce the import tax for EMs

The MEF could reduce Duty Rate and Special Tariff Rate (Table 25) to make the total import tax of EMs lower than ICEMs. This reduction in import tax would further reduce the cost of EMs and could increase their share in the market. Purely electric family and passenger cars already saw import duty reduced from 30 to 10 per cent, in early 2021.Similar fiscal incentives for EVs were recommended in the study conducted by Clean Air Asia on an Assessment of Regulatory and Fiscal Policies for Road Transport Vehicles in Cambodia and the study conducted by the MoE in 2019. EDC could also consider preferential electricity tariffs for charging and battery swapping stations.

6.2.4 Disposal of Battery Waste

Cambodia does not currently have an established system to collect and recycle batteries and it lacks regulatory controls and oversight of the informal and unregistered recycling facilities. Establishing recycling facilities, however, is complex and expensive. The management of battery waste poses a great concern as the disposal of batteries to landfills or informal recycling may increase in the future and without sophisticated recycling facilities it will eventually lead to environmental pollution. Most of the imported EMs in the market have lead-acid batteries, and without proper regulations, the country will face challenges in dealing with lead contamination. While LIB's are less damaging to the environment than lead-acid batteries, recycling them is often more complicated and expensive. Battery waste, however, is not only an issue caused by EVs: battery waste also comes from cars and many other appliances. It is therefore necessary for battery waste to be dealt with regardless of EV adoption.

Sub-decree No. 16 on E-waste Management outlines how e-waste is managed, it states that any company wishing to export or import e-waste needs to ask for permission from the MoE (RGC, 2016). The Sub-decree does not explicitly mention LIB or ULAB in the e-waste categories, but batteries are classified as hazardous waste, which is under the jurisdiction of the MoE. According to the Sub-decree of Solid Waste Management (1999), importing hazardous waste is strictly prohibited. Export is not prohibited but strictly regulated to avoid waste dumping in other countries. Batteries can be exported for recycling if the required procedures are followed.

According to a representative from the GDCE, there is no export tax for exporting used LIBs for recycling to other countries. However, export requirements are imposed by the MoE and include a service fee and a letter of permission. The cost of exporting batteries for recycling can still be high (due to paperwork, export fees, storage, and transport). According to the Inter-ministerial Prakas between the MEF and the MoE, the permission letter to export hazardous waste is issued by the MoE based on the export quantity. Although the national policy on the import and export of hazardous waste is in place, the control of battery waste disposals is still limited.

Table 26. Service fees to export hazardous waste

Quantity of Hazardous Waste	Service Fees (in Riel and US$)
> 500 tons	1,000,000 (or US$250)
100-500 tons	800,000 (US$200)
< 100 tons	500,000 (US$125)

Recommendation 4: Reduce battery waste export fees

The government could formulate a policy to encourage the recycling of used LIB or ULAB through the reduction in export fees imposed by the MoE. This would encourage more EM companies to recycle their batteries and thus reduce the environmental impact in Cambodia.

Recommendation 5: Develop guidelines for the battery disposal and recycling sector

To protect public health and the environment, the government could do a stock take of the current situation and propose improvements, such as formalizing the sector and developing and implementing guidelines on the collection, storage, and recycling of battery waste in Cambodia.

Recommendation 6: Establish battery take back schemes

To avoid the accumulation of waste which cannot be recycled locally, take back schemes and Extended Producer Responsibility (EPR) schemes could be put in place to ensure batteries are channeled back to production or recycling centers. Business models for battery repurposing in less demanding applications, such as home energy storage, could also be investigated. Voltra Motors, a local EM company, is as example of this as they are committed to recycling all LIBs by exporting them to China. Another company, Oyika, is willing to sell its LIB to an Indonesian company for energy storage purposes.

6.2.5 National Standards

A study conducted by Clean Air Asia in 2019 on the Development of Standards on the uptake of E2Ws and E3Ws in Cambodia indicated that there are no national standards for EVs in Cambodia. The lack of national standards is a loophole for low-quality EMs flowing into the Cambodian market and could hinder plans to promote low-carbon vehicles. National minimum standards could help to ensure that only high-quality EMs penetrate the market, thus helping to build trust among consumers. National minimum standards could also prevent damage to the environment caused by low-quality imported batteries. Making high-quality LIB the standard battery, rather than lead-acid batteries, could lessen the environmental impact of EMs as the longer life of LIB's decreases the amount of waste generated.

The Institute of Standards of Cambodia, in cooperation with the UNDP and Clean Air Asia, set up a Working Group under the Technical Committee of Automotive Product (TC8). The members of this working group include representatives from related government ministries, the private sector, and non-governmental organizations. The aim is to establish standards for E2Ws and E3Ws in Cambodia and propose a work plan for the adoption and implementation of the standards. The standards under consideration include battery quality, safety, testing requirements, and more. However, testing centers in Cambodia do not have the capacity to test the quality and safety of EVs, without such capacity, compliance with standards remains difficult to ensure, especially if EMs begin to be produced locally.

Recommendation 7: Establish an EV Association

An association of EV companies and relevant parties operating in Cambodia could provide a platform to share their views and concerns. A unified association of EV companies could help the government to address complex issues and form national standards for EMs in an efficient manner.

Recommendation 8: Establish minimum standards policy for EMs

As shown in the case of China and Taiwan, a national policy on the standard of EMs is necessary to boost the adoption rate. In these two countries, national policies were established to set standards for EM manufacturers. In Taiwan, the standard-setting was a response to complaints by consumers about EM glitches such as the range and battery life. For Cambodia, a national policy on the minimum standards of EMs could be established to define the technical specifications required for EM manufacturers and importers. Setting a policy on the minimum standards of EMs could prevent low-quality vehicles from penetrating the market and will therefore build consumer trust. Capacity of testing centers needs to be driven up accordingly.

6.2.6 Government Fleet Integration

Every year several government institutions purchase a large number of new ICEMs for their daily operations. These motorcycles are often given to specific officials to facilitate their work for a limited period. According to the data from MPWT, the top 14 government institutions have purchased up to 8,637 ICEMs from 2017 to April 2020.

Recommendation 9: Integrate EMs into Government fleets

The Cambodian government could pave the way for electric mobility by making it mandatory for government institutions to purchase EMs in the following fiscal years. This presents an opportunity for the government to be a green model for private institutions (which also deploy large fleets of ICEMs) and neighboring nations to follow. Electrifying government fleets could also contribute to savings of the national budget expenditure on gasoline.

6.4 Summary

This assessment has revealed that the existing policies and regulations in Cambodia are limited in promoting the uptake of EMs. Policies and strategies to promote the development of e-bikes and e-scooters, which have been applied by China and Taiwan, such as financial incentives and national standards on EMs, are not in place in Cambodia. Without such policies or strategies, the adoption of EMs is unlikely to be successful.

The case studies of countries in the region highlight the need for careful policy design and implementation and shows that cash injections alone do not guarantee the desired effect. The case of China has shown that policy measures, such as the National E-bike Standard and the National Transport Safety Law, play a significant role in promoting the development of e-bikes. For the case of Taiwan, both financial subsidies and government support of battery swapping infrastructure were required to stimulate the growth of e-scooter sales. For India, the combination of incentive-based policies and regulatory reforms helped spur the growth of EVs. Without specific EV policies and incentives, the development of EVs in Vietnam peaked in 2016 and then declined due to quality issues.

The proposed policy recommendations and strategies to promote the adoption of EMs are outlined in Box 5. Among these policies, prioritizing financial incentives and national standards may be the most efficient way to increase the adoption of EMs. Financial incentives would further lower the price of EMs, thus benefiting lower and middle-income groups. Crucially, national standards could prevent low-quality EMs from penetrating the market and help to build trust with consumers. Although these policies are necessary for addressing the challenges and gaps of EM adoption, other measures such as banning the use of ICEMs could also be beneficial. The model in China showed that the stick and carrot approach is more effective and efficient than a single approach.

Box 5. Policy recommendations

- Increase charging infrastructure through incentives.
- Streamline the import tax and registration process.
- Reduce the import tax for EMs.
- Reduce battery waste export fees.
- Develop guidelines for the battery disposal and recycling sector.
- Establish battery take back schemes.
- Establish an EV association.
- Establish minimum standards policy for EMs.
- Integrate EMs into Government fleets.

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APPENDIX A: Online Survey

Questions for Gasoline Motorcycles Users

1. **What type of motorcycle do you have?**
   - Gasoline motorcycle
   - Electric motorcycle
2. **What is the engine capacity of your gasoline motorcycle?**
   - 50 cc
   - 100 cc
   - 110 cc
   - 125 cc
   - above 125 cc
3. **What is your gender?**
   - Female
   - Male
4. **What is your age?**
   - 18 to 24
   - 25 to 34
   - 35 to 44
   - 45 to 54
   - 55 to 64
   - 65 to 74
   - 75 or above
5. **What is your marital status?**
   - Single
   - Married
   - Divorce
6. **What is your education level?**
   - Primary school
   - Secondary school
   - High school
   - Undergraduate school
   - Graduate school
   - other (Please specify)
7. **Which of the following best describes your current occupation?**
   - Student/University student
   - Teacher/Professor
   - Private company employee
   - Government official
   - International/National NGOs employee
   - Other (Please specify)
8. **What is your monthly income?**
   - ≤190$
   - 191-350$
   - 351-700$
   - 701-1200$
   - 1201-2000$
   - > 2000$
9. **What is your current address?**
   - Phnom Penh
   - Other (Please specify)
10. **What is the brand of your gasoline motorcycle?**
    - Honda
    - Suzuki
    - Yamaha
    - Other (Please specify)
11. **What is the model of your Honda gasoline motorcycle?**
    - Wave
    - Scoopy
    - Today
    - Click 125i
    - Zoomer X
    - Beat
    - MSX
    - other (Please specify)
12. **What is the model of your Suzuki gasoline motorcycle?**
    - Smash
    - Nex
    - Viva
    - Lets
    - Other (Please specify)
13. **What is the model of your Yamaha gasoline motorcycle?**
    - Mio M3 SSS
    - Mio M3
    - AEROX
    - QBIX
    - Grand Filano
    - Sirius

- [ ] Airblade
- [ ] Other (Please specify)

14. What was the condition of your gasoline motorcycle when you purchased it?
- [ ] New
- [ ] Secondhand

15. What are your daily trip destinations?
- [ ] Home
- [ ] Office
- [ ] School/University
- [ ] Restaurant
- [ ] Market
- [ ] Other (Please specify)

16. On average, what distance do you travel per day?
- [ ] 5 to 10 km
- [ ] 10 to 20 km
- [ ] 20 to 30 km
- [ ] 30 to 40 km
- [ ] other (Please specify)

17. What is your average traveling speed? (Km/h)
- [ ] < 20 km/h
- [ ] 20 to 30 km/h
- [ ] 30 to 40 km/h
- [ ] 40 to 50 km/h
- [ ] >50 km/h
- [ ] other (Please specify)

18. How many liters of fuel does your motorcycle consume in one week?

19. How often do you change your engine oil per year?
- [ ] 2 times
- [ ] 3 times
- [ ] 4 times
- [ ] 5 times
- [ ] 6 times
- [ ] 7 times
- [ ] 8 times
- [ ] 9 times
- [ ] 10 times
- [ ] > 10 times

20. How often do you repair your motorcycle in one year?

21. On average, how much do you spend on the repair each time? (in USD)
- [ ] < 5 USD
- [ ] 5 to 10 USD
- [ ] 10 to 20 USD
- [ ] > 20 USD
- [ ] Other (Please specify)

22. On average, how much time do you spend in traffic congestion daily?
- [ ] < 20 minutes
- [ ] 20 to 40 minutes
- [ ] 40 minutes to 1 hour
- [ ] > 1 hour
- [ ] other (Please specify)

23. Have you heard about electric motorcycles?
- [ ] Yes
- [ ] No

24. What do you think about electric motorcycles in comparison to gasoline motorcycles?
- [ ] As good as gasoline motorcycle
- [ ] Better than gasoline motorcycle
- [ ] not as good as gasoline motorcycle

25. Would you buy an electric motorcycle in the future?
- [ ] Yes
- [ ] No

26. If YES, what factors would influence your decision? 1 (low) to 5 (high)
- Color, design, speed, range
- Environmental benefits
- Economic benefits
- Subsidies/incentives when purchasing
- Easy to drive

Questions for EMs Users

1. What type of motorcycle do you have?
- [ ] Gasoline motorcycle
- [ ] Electric motorcycle

2. What is your gender?
- [ ] Female
- [ ] Male

3. What is your age?
- [ ] 18 to 24
- [ ] 55 to 64

- [ ] 25 to 34
- [ ] 35 to 44
- [ ] 45 to 54
- [ ] 65 to 74
- [ ] 75 or above

4. **What is your marital status?**
- [ ] Single
- [ ] Married
- [ ] Divorce

5. **What is your education level?**
- [ ] Primary school
- [ ] Secondary school
- [ ] High school
- [ ] Undergraduate school
- [ ] Graduate school
- [ ] other (Please specify)

6. **Which of the following best describes your current occupation?**
- [ ] Student/University student
- [ ] Teacher/Professor
- [ ] Private company employee
- [ ] Government official
- [ ] International/National NGOs employee
- [ ] other (Please specify)

7. **What is your monthly income?**
- [ ] ≤190$
- [ ] 191-350$
- [ ] 351-700$
- [ ] 701-1200$
- [ ] 1201-2000$
- [ ] > 2000$

8. What is your current address?
- [ ] Phnom Penh
- [ ] Other (Please specify)

9. What is the brand and model of your electric motorcycle?
- [ ] Voltra-OFF ROAD
- [ ] Voltra-Matrix
- [ ] Oyika-ego
- [ ] Thada-OX
- [ ] Star8-Pegasus
- [ ] Other (Please specify)

10. What payment method did you use to purchase your electric motorcycle?
- [ ] Down payment
- [ ] Payment in full price

11. What was the price of your electric motorcycle? (in USD)

12. In what year did you purchase your electric motorcycle? (For example, in 2019)

13. Did you receive any financial incentives/subsidies/discounts from the company?
- [ ] Yes
- [ ] No

14. If YES, please explain.

15. Is your electric motorcycle imported or locally produced?
- [ ] Import
- [ ] Locally produced or assembled
- [ ] Other (Please specify)

16. Where was your electric motorcycle imported from?
- [ ] China
- [ ] Japan
- [ ] Singapore
- [ ] Malaysia
- [ ] Other (Please specify)

17. What type of battery does your electric motorcycle have?
- [ ] Lithium
- [ ] Lead-acid

18. What is the battery capacity?
- [ ] 48V12AH
- [ ] 60V28AH
- [ ] 60V20AH
- [ ] 72V20AH
- [ ] other (Please specify)

19. How many hours does it take to recharge your battery fully?
- [ ] 2 hours
- [ ] 3 hours
- [ ] 4 hours
- [ ] 5 hours
- [ ] > 5 hours
- [ ] other (Please specify)

20. How often do you usually recharge your battery?

- 1 time per day
- 2 times per day
- 3 times per day
- 4 times per day
- 1 time per week
- 2 times per week
- 3 times per week
- other (Please specify)

21. Where do you usually charge your battery?

- Home
- Office
- Swapping stations
- Other (Please specify)

22. What are your daily trip destinations?

- Home
- Office
- School/University
- Restaurant
- Market
- Other (Please specify)

23. How far could you drive with a full battery, when the battery was new? (in km)

24. How far could you drive with a full battery after one year of use? (in km)

25. How long did your first battery last?

- Still using the first battery
- Between 3 to 6 months
- Between 6 months to 1 year
- Between 1 year to 2 years
- More than 2 years

26. On average, what distance do you travel per day?

- 5 to 10 km
- 10 to 20 km
- 20 to 30 km
- 30 to 40 km
- other (Please specify)

27. How often have you replaced your battery since purchasing the vehicle?

- I have not replaced it yet
- 1 time
- 2 times
- 3 times
- 4 times
- Other (Please specify)

28. What was the price of the battery replacement?

- < $100
- $100 to $200
- $200 to $300
- Othe (Please specify)

29. What is the top speed of your electric motorcycle?

- 50 km/h
- 60 km/h
- Other (Please specify)

30. Have you had your electric motorcycle repaired?

- Yes
- No

31. If YES, how much have you spent on reparation costs in total?

32. If YES, where did you get it repaired?

- at the company
- at the repair shop

33. Why did you choose an electric motorcycle over a gasoline motorcycle?

- Financial incentives/subsidies/discounts
- The design
- Savings
- environmentally friendly
- Other (Please specify)

34. What factors worry you after purchasing an electric motorcycle?

- Battery quality
- Not durable
- Resale market
- Other (Please specify)

APPENDIX B: Registered Vehicle Data

Table 27. Registered vehicles in Cambodia by type, 1990-2018

Year	Motorcycle	Car	Minibus	Bus	Pick-Up	Truck
1990	43,733	3,427	221	105	533	1,431
1991	27,432	4,319	218	105	570	1,183
1992	36,443	4,548	305	42	727	651
1993	12,544	3,576	310	102	1,336	1,255
1994	12,818	4,634	182	146	1,027	827
1995	19,080	4,898	384	153	986	1,231
1996	18,422	4,893	890	107	1,450	1,646
1997	10,794	5,303	795	65	1,931	1,993
1998	21,756	3,377	485	51	1,138	900
1999	20,147	5,221	1,112	56	2,672	943
2000	24,796	5,363	986	39	2,190	855
2001	43,690	4,493	593	71	1,624	649
2002	16,956	5,418	903	182	2,346	1,305
2003	27,891	5,335	1,028	107	1,804	1,175
2004	22,664	10,275	1,205	202	2,376	1,462
2005	70,523	12,807	1,749	178	2,763	1,197
2006	111,457	18,694	2,486	349	4,364	2,284
2007	130,106	14,453	2,284	401	4,197	3,143
2008	188,915	15,902	2,338	231	4,808	3,288
2009	275,471	20,435	2,514	324	5,065	3,241
2010	236,614	15,563	2,510	224	3,815	2,243
2011	218,217	21,813	2,894	404	5,513	2,888
2012	233,497	22,209	3,356	502	6,882	4,709
2013	244,971	21,153	3,032	327	7,528	5,126
2014	303,180	23,793	3,327	391	8,073	5,485
2015	342,076	34,886	4,610	535	10,184	6,211
2016	464,970	37,480	4,610	528	10,961	7,215
2017	381,400	39,503	4,328	639	9,803	6,127
2018	502,701	48,860	5,180	901	13,383	8,871

APPENDIX C: Survey respondents: ICEM User Profile

Table 28. Profile of the survey respondents who use ICEMs

Respondent Profile		Percentage (%)
1. Sex	Male Female	51 49
2. Age	18-24 24-34 35-44 45-54 55-64 65-74 75 or older	71 22 6 1 0 0 0
3. Education Level	Primary school Secondary school High school Undergraduate school Graduate school Others	0 0 2 58 36 4
4. Current Occupation	Student/University students Teachers/Professors Private company employees Government Officials International/National NGO employees	65 9 14 9 3
5. Monthly Income (US$)	≤$190 191-$350 351-$700 701-$1200 1201-$2000 >$2000	55 16 16 9 3 1
6. Motorcycle Brands	Honda Suzuki Yamaha	87 11 2
7. Motorcycle Engine Capacity	Above 125cc 125cc 110cc 100cc 50cc	6 51 26 12 5

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