TRANSfer III Project:

Development on Public Transport Electrification in Bangkok, Thailand

Final Report

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

IKI INTERNATIONAL CLIMATE INITIATIVE

สนข สำนักงานนโยบายและแผนการขนส่งและจราจร

The Creagy

TRANSfer III Project

Development on Public Transport Electrification in Bangkok, Thailand

Final Report

Project Name:	TRANSfer III Project
Assignment title:	Support for the Development on Public Transport Electrification
Project No:	16.9019.7-006.00
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Country:	Thailand
Submitted to:	GIZ Office Bangkok for TRANSfer III Project
Submitted on:	31 August 2021
Prepared by:	The Creagy Company Limited

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Project Background

Transport is the highest energy-consuming sector in 40% of all countries worldwide and causes about a quarter of energy-related CO2 emissions. To limit global warming to two degrees, an extensive transformation and decarbonisation of transport is necessary. The TRANSfer project's objective is to increase the efforts of developing countries and emerging economies for climate-friendly transport. The project acts as a mitigation action preparation facility and thus, specifically supports the implementation of the Nationally Determined Contributions (NDC) of the Paris Agreement. The project supports several countries (including Peru, Colombia, the Philippines, Thailand, Indonesia) in developing greenhouse gas mitigation measures in transport.

The TRANSfer project is implemented by GIZ and funded by the International Climate Initiative (IKI) of the German Federal Ministry for Economic Affairs and Climate Action (BMWK) and operates on three levels.

Mobilise

Facilitating the MobiliseYourCity Partnership

The goal of the multi-stakeholder partnership MobiliseYourCity, which is currently being supported by France, Germany, and the European Commission, is that 100 cities and 20 national governments commit to ambitious climate action targets for urban transport and take appropriate measures.

Prepare

Preparation of Mitigation Measures

Standardised support packages (toolkits) are developed and used for the preparation of selected mitigation measures. As a result, measures can be prepared more efficiently, until they are ready for implementation and eligible for (climate) financing. Accumulated over 10 years, the targeted measures aim for a total reduction potential of 60 $MtCO_2$.

Stimulate

Knowledge products, Training, and Dialogue

Based on these experiences, TRANSfer is sharing and disseminating best practises. This is achieved through the development of knowledge products, the organisation of events and training, and the contribution to an increasing level of ambition. Personal exchange of experience and dialogue is promoted at events, including the annual Transport and Climate Change Week in Berlin, the United Nations Climate Change Conference (COP) or the International Transport Forum.

Meet us at www.changing-transport.org

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Abbreviations

ASEAN	The Association of Southeast Asian Nations
BAU	Business as usual
BEV	Battery Electric Vehicle
BMR	Bangkok Metropolitan Region
BMTA	Bangkok Mass Transit Authority
BMU	The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BOI	Board of Investment of Thailand
BSS	Battery Swapping Station
CAPEX	Capital expenditure
CLTCB	Central Land Transport Control Board
CO_2	Carbon dioxide
COP	United Nations Climate Change Conference
DCF	Discount cash flow
DLT	Department of Land Transport
EV	Electric vehicle
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
HEV	Hybrid Electric Vehicle
IEA	International Energy Agency
IKI	International Climate Initiative
IRR	Internal rate of return
LCV	Light commercial vehicles
LT-LEDS	Long-term Low Emissions and Development Strategy
NDC	Nationally Determined Contributions
NEP	National Energy Plan
NEPC	National Energy Policy Council
NEV	New energy vehicle
NGV	Natural Gas for Vehicles
NPV	Net present value

MEA	Metropolitan Electricity Authority
$MtCO_2$	Metric tonne of carbon dioxide
OPEX	Operating expense
OTP	Office of Transport and Traffic Policy and Planning
PEA	Provincial Electricity Authority
PHEV	Plug-In Hybrid Electric Vehicle
SPV	Special Purpose Vehicle
TCO	Total cost of ownership
tCO_2	Tonne of carbon dioxide
TCMP	Thailand Clean Mobility Programme
THB	Thai Baht
USD	US Dollar
ZEV	Zero-emission vehi

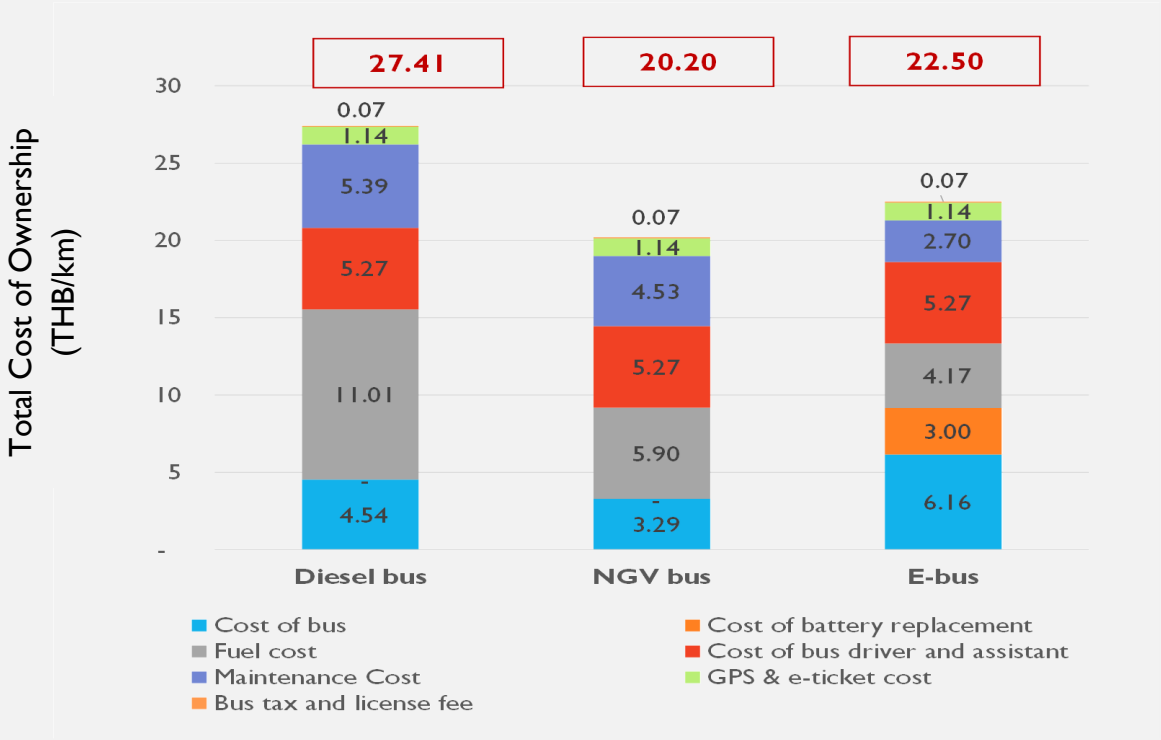
บทสรุปผู้บริหาร

โครงการศึกษามาตรการทางการเงินเพื่อส่งเสริมยานยนต์ไฟฟ้าสำหรับระบบขนส่งสาธารณะในกรุงเทพมหานคร

ภายใต้โครงการสนับสนุนการพัฒนามาตรการลดการปล่อยก๊าซเรือนกระจกที่มีความท้าทายของภาคการขนส่ง (TRANSfer III)

สรุปผลการศึกษา

รถเมล์



- ต้นทุนการเดินรถเมล์ไฟฟ้า (Total cost of ownership: TCO) ของรถไฟฟ้าต่อระยะทางการเดินรถ คือ 22.50 บาท/กม. ต่ำกว่า TCO ของรถเมล์ดีเซลซึ่งอยู่ที่ 27.41 บาท/กม. หรือประมาณ 22%
- ค่าใช้จ่ายในการลงทุน (Capex) ของรถเมล์ดีเซลอยู่ที่ 4.9 ล้านบาท/คัน ซึ่งต่ำกว่ารถเมล์ไฟฟ้าประมาณ 2 เท่า อย่างไรก็ดี ค่าใช้จ่ายการดำเนินงาน (OPEX) ของรถเมล์ดีเซลสูงกว่ารถเมล์ไฟฟ้าถึง 40% ถึงแม้ว่ารถเมล์ไฟฟ้าจะมีค่าใช้จ่ายจากการเปลี่ยนแบตเตอรี่เพิ่มเติมขึ้นมา แต่ต้นทุนค่าเชื้อเพลิงของรถเมล์ไฟฟ้าต่ำกว่าของรถเมล์ดีเซลถึงเกือบ 3 เท่า
- รถเมล์ NGV มี TCO เท่ากับ 22.10 บาท/กม. ต่ำกว่ารถเมล์ไฟฟ้าประมาณ 10% อย่างไรก็ดี หากราคา NGV สูงกว่าประมาณ 20 บาท/กิโลกรัม และไม่มีการสนับสนุนราคา NGV จากภาครัฐ TCO ของรถเมล์ไฟฟ้าจะเทียบเท่าหรือต่ำกว่ารถเมล์ NGV

สรุปผลการศึกษา

- จากการศึกษา พบว่าการสนับสนุนทางการเงินยังคงเป็นสิ่งจำเป็นสำหรับการเปลี่ยนรถเมล์ดีเซลเป็นรถเมล์ไฟฟ้า เพื่อให้ผู้ประกอบการสามารถดำเนินการได้อย่างมีกำไร รวมถึงไม่ส่งกระทบต่อราคาค่าโดยสารและผู้ใช้บริการ การลงทุนและผลตอบแทนของการเปลี่ยนเป็นรถเมล์ไฟฟ้าสามารถประเมินได้ ดังนี้

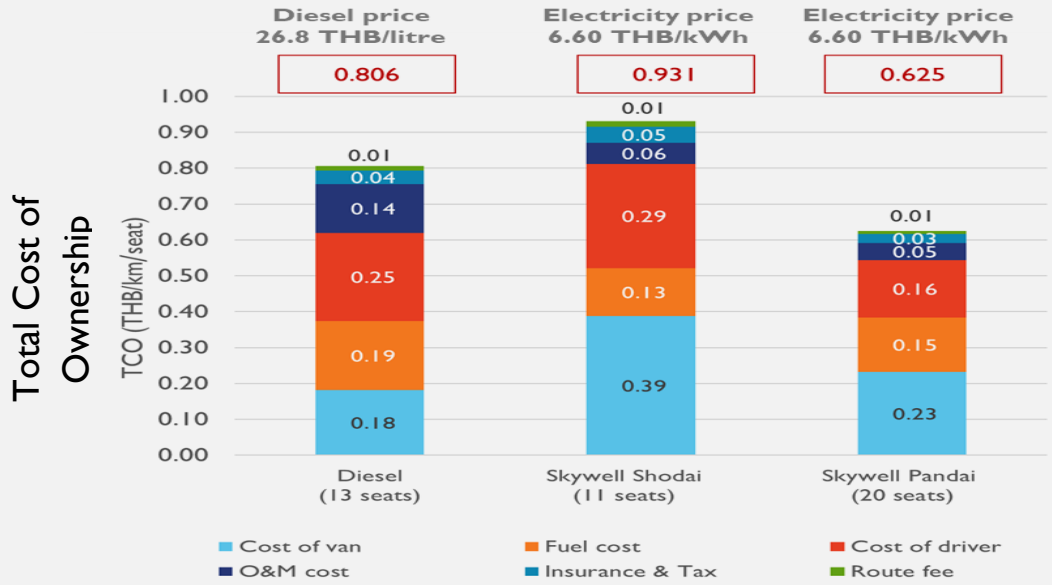
	จำนวนรถเมล์ที่เปลี่ยนเป็นรถเมล์ไฟฟ้า (คัน)		
	1	500	3,200*
เงินลงทุนซื้อรถเมล์ไฟฟ้า (ล้านบาท)	9	4,450	23,700
จำนวนหัวชาร์จ (จุด)	1	313	1,993
เงินลงทุนหัวชาร์จ (ล้านบาท)	2.7	650	3,000
เงินลงทุนทั้งหมด (ล้านบาท)	11.7	5,100	26,700
เงินสนับสนุนที่ต้องการ (ล้านบาท)	2.4 - 4	1,300 - 2,000	3,300 – 5,600
ปริมาณน้ำมันที่ประหยัดได้ (ลิตร/ปี)	46,000	23,000,000	147,200,000
มูลค่าของน้ำมันที่ประหยัดได้ (ล้านบาท/ปี)**	1.61	805	5,152
กรณีเปลี่ยนรถเมล์ดีเซลเป็นรถเมล์ไฟฟ้า ลดการปล่อยก๊าซเรือนกระจก (ตัน CO_2 /ปี)	86	43,000	275,200
กรณีเปลี่ยนรถเมล์ NGV เป็นรถเมล์ไฟฟ้า ลดการปล่อยก๊าซเรือนกระจก (ตัน CO_2 /ปี)	57	28,750	184,000
จำนวนผู้ได้ประโยชน์จากรถเมล์ไฟฟ้า (ล้านเที่ยว-ผู้โดยสาร)	2.28	1,140	7,296

* ขสมก. กำลังอยู่ในระหว่างทบทวนแผนฟื้นฟูกิจการฯ (ฉบับปรับปรุงใหม่) โดยปรับแผนการจัดหารถโดยสาร ให้เป็นรถเมล์ไฟฟ้าทั้งหมด รวม 3,200 คัน (https://thainews.prd.go.th/th/news/detail/TCATG220825154840041)

** ราคาน้ำมัน 35 บาทต่อลิตร

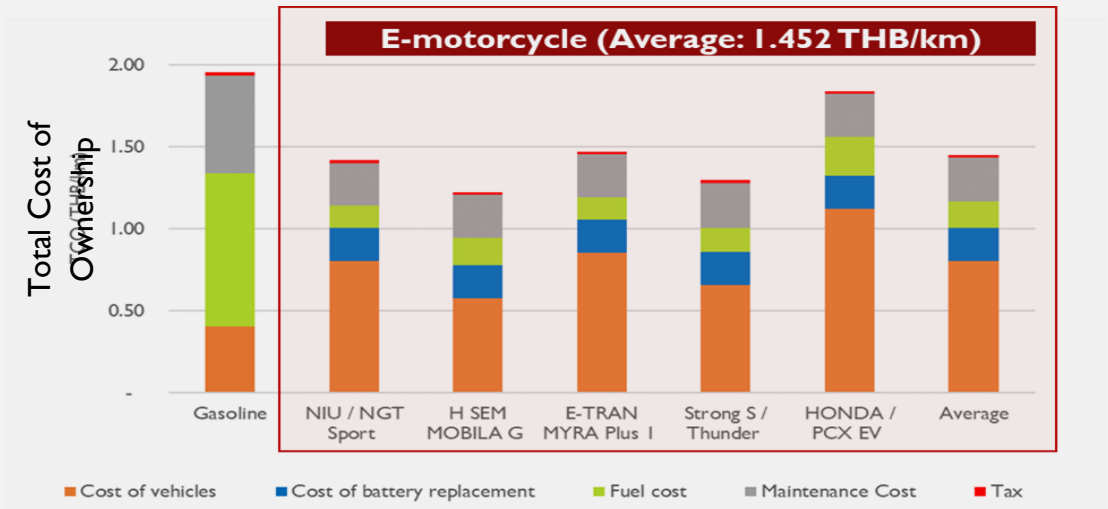
รถตู้

- ขณะนี้ รถตู้ไฟฟ้าในตลาดยังมีจำกัดและไม่หลากหลายนัก ดังนั้น จึงไม่สามารถเทียบกับรถตู้โดยสารขนาด 13 ที่นั่งที่ใช้อย่างแพร่หลายในปัจจุบันโดยตรงได้ รถตู้ไฟฟ้าที่สามารถพบได้ในตลาดเป็นรุ่น 11 ที่นั่ง และ 20 ที่นั่ง
- เมื่อเทียบกับต้นทุนการเดินรถต่อที่นั่งผู้โดยสารของรถตู้ดีเซล 13 ที่นั่ง (0.806 บาท/กม./ที่นั่ง) ต้นทุนการเดินรถตู้ไฟฟ้า 20 ที่นั่ง (0.625 บาท/กม./ที่นั่ง) ถือว่าสามารถแข่งขันได้ อย่างไรก็ตาม ต้นทุนการเดินรถตู้ไฟฟ้า 11 ที่นั่ง (0.931 บาท/กม./ที่นั่ง) ยังคงสูงกว่ารถตู้ดีเซล 13 ที่นั่ง



สรุปผลการศึกษา

รถจักรยานยนต์รับจ้างสาธารณะ



- มูลค่าปัจจุบันสุทธิของเงินลงทุนแรกเริ่มและค่าใช้จ่ายการเดินรถจักรยานยนต์ที่ใช้น้ำมันเบนซินตลอดอายุการใช้งาน 6 ปี อยู่ที่ 264,046 บาท ในขณะที่มูลค่าปัจจุบันสุทธิของรถจักรยานยนต์ไฟฟ้าจะอยู่ที่ประมาณ 196,078 บาท โดยเฉลี่ย หรือคิดเป็น 74% ของรถจักรยานยนต์ที่ใช้น้ำมันเบนซิน
- ต้นทุนการเดินรถจักรยานยนต์ไฟฟ้าอยู่ที่ประมาณ 1.452 บาท/กม. ซึ่งต่ำกว่ารถจักรยานยนต์ที่ใช้น้ำมันเบนซิน (1.956 บาท/กม.) ประมาณ 25% สรุปได้ว่า ต้นทุนการเดินรถจักรยานยนต์ไฟฟ้าสามารถแข่งขันกับรถจักรยานยนต์ที่ใช้น้ำมันเบนซินได้

	จำนวนรถจักรยานยนต์ที่เปลี่ยนเป็นรถจักรยานยนต์ไฟฟ้า (คัน)		
	10,000	85,000*	650,000**
เงินลงทุนซื้อรถจักรยานยนต์ไฟฟ้า (ล้านบาท)	503	4,276	26,432
จำนวนแบตเตอรี่ (ลูก)	15,000	127,500	975,000
จำนวนสถานีเปลี่ยนแบตเตอรี่ (สถานี)	750	6,375	48,750
เงินลงทุนสถานีเปลี่ยนแบตเตอรี่ (ล้านบาท)	960	6,077	44,189
เงินลงทุนทั้งหมด (ล้านบาท)	1,463	10,353	70,621
เงินสนับสนุนที่ต้องการ (ล้านบาท)	288	1,215	4,419
ปริมาณน้ำมันที่ประหยัดได้ (ลิตร/ปี)	7,650,000	65,025,000	497,250,000
มูลค่าของน้ำมันที่ประหยัดได้ (ล้านบาท/ปี)***	268	2,276	17,404
ลดการปล่อยก๊าซเรือนกระจก (ตัน CO_2 /ปี)	12,032	102,272	782,080

* เทียบเท่าจำนวนผู้ขับรถจักรยานยนต์รับจ้างสาธารณะที่ลงทะเบียนกับกรมการขนส่งทางบกในกรุงเทพมหานคร ปี 2021

** เทียบเท่าจำนวนรถจักรยานยนต์ไฟฟ้าตามเป้าหมายของแผน 30@30

*** ราคาน้ำมัน 35 บาทต่อลิตร

จากการทบทวนข้อมูล การสำรวจภาคสนาม การสัมภาษณ์ผู้มีส่วนได้ส่วนเสีย การจัดประชุมกับผู้ที่เกี่ยวข้องและการประเมินทางเทคนิคและการเงิน พบว่า ระบบขนส่งสาธารณะ 2 รูปแบบที่พร้อมสำหรับการส่งเสริมยานยนต์ไฟฟ้า ได้แก่ **รถเมล์โดยสารสาธารณะและรถจักรยานยนต์รับจ้าง** ขณะที่รถตู้โดยสารสาธารณะจำเป็นต้องได้รับการปฏิรูปเส้นทางและกฎระเบียบก่อนการส่งเสริมยานยนต์ไฟฟ้า

ตามที่ประเทศไทยได้ยื่นข้อเสนอการมีส่วนร่วมของประเทศในการลดก๊าซเรือนกระจก และการดำเนินงานด้านการเปลี่ยนแปลงสภาพภูมิอากาศภายหลังปี ค.ศ. 2020 (พ.ศ. 2563) หรือ Nationally Determined Contribution (NDC) โดยกำหนดเป้าหมายการลดก๊าซเรือนกระจกครอบคลุมทุกสาขาเศรษฐกิจที่ร้อยละ 20 - 25 จากกรณีปกติ ในปี ค.ศ. 2030 (พ.ศ. 2573) ทั้งนี้ การส่งเสริมยานยนต์ไฟฟ้าในระบบขนส่งสาธารณะ ถือเป็นมาตรการสำคัญมาตรการหนึ่งที่จะมีส่วนช่วยให้ประเทศไทยสามารถบรรลุเป้าหมายการลดก๊าซเรือนกระจกตามที่กำหนดไว้ได้

องค์กรความร่วมมือระหว่างประเทศของเยอรมัน (GIZ) ซึ่งได้ดำเนินโครงการสนับสนุนการพัฒนามาตรการลดการปล่อยก๊าซเรือนกระจกที่มีความท้าทายของภาคการขนส่ง หรือ TRANSfer III ซึ่งมีวัตถุประสงค์เพื่อสนับสนุนประเทศที่กำลังพัฒนาหรือประเทศที่เศรษฐกิจกำลังขยายตัว ให้สามารถพัฒนาระบบขนส่งที่เป็นมิตรต่อสภาพภูมิอากาศ โดยในประเทศไทย GIZ ได้ร่วมมือกับสำนักงานนโยบายและแผนการขนส่งและจราจร (สนข.) ในการดำเนินโครงการศึกษามาตรการทางการเงินเพื่อส่งเสริมยานยนต์ไฟฟ้าสำหรับระบบขนส่งสาธารณะ เพื่อกำหนดและพัฒนาแนวทางเชิงธุรกิจและการเงินที่จะช่วยสนับสนุนการขยายตัวของการลงทุนยานยนต์ไฟฟ้าในระบบขนส่งสาธารณะของประเทศไทยอย่างมีประสิทธิผล

รายงานฉบับนี้ มุ่งเน้นการศึกษาระบบขนส่งสาธารณะทางบก 3 รูปแบบ ได้แก่ รถประจำทาง (รถเมล์) รถตู้ และรถจักรยานยนต์รับจ้างสาธารณะ โดยมีขอบเขตการศึกษา คือ เขตพื้นที่กรุงเทพมหานครและปริมณฑล เนื่องจากระบบการขนส่งทางบกในพื้นที่ดังกล่าวถือว่าได้รับการพัฒนามากที่สุดและมีปริมาณการปล่อยก๊าซเรือนกระจกมากกว่าเมื่อเปรียบเทียบกับพื้นที่อื่น ๆ

ในการสนับสนุนยานยนต์ไฟฟ้าในระบบขนส่งสาธารณะในประเทศไทยให้ประสบความสำเร็จ จำเป็นต้องมีแนวทางการส่งเสริมที่หลากหลาย รูปแบบทางธุรกิจที่สามารถนำไปใช้ได้จริง และแผนด้านการเงินที่ชัดเจน โดยกิจกรรมหลักที่ต้องดำเนินการเพื่อให้บรรลุเป้าหมาย ได้แก่ 1) การทบทวนสถานการณ์ของขนส่งสาธารณะในปัจจุบัน 2) การวิเคราะห์ความต้องการและความท้าทายด้านการเงินและด้านเทคนิค 3) การพัฒนาแผนและกลไกทางการเงินที่เหมาะสม และ 4) สร้างความร่วมมือจากผู้มีส่วนได้ส่วนเสีย ทั้งนี้ ผลการศึกษาประกอบไปด้วย 5 ส่วน ได้แก่

ผลลัพธ์ที่ 1: ความเข้าใจที่มากขึ้นในเรื่องนโยบาย แผนงาน และสถานการณ์ของยานยนต์ไฟฟ้าในระบบขนส่งสาธารณะในปัจจุบัน รวมถึงกลไกทางการเงิน ช่องว่างและความต้องการสำหรับบริบทของประเทศไทย

ผลลัพธ์ที่ 2: การประเมินความต้องการด้านเทคนิคและการเงินสำหรับการพัฒนายานยนต์ไฟฟ้าในระบบขนส่งสาธารณะของทั้ง 3 รูปแบบ รวมถึง ค่าใช้จ่ายในการลงทุน (Capital Expenditures: CAPEX), ค่าใช้จ่ายในการดำเนินงาน (Operational Expenditures: OPEX), ต้นทุนการใช้งาน (Total cost of ownership: TCO) สำหรับการขนส่งสาธารณะรูปแบบต่าง ๆ

ผลลัพธ์ที่ 3: การศึกษาทางเลือกด้านเทคโนโลยีและต้นทุนที่จำเป็นสำหรับการพัฒนายานยนต์ไฟฟ้าในระบบขนส่งสาธารณะและโครงสร้างพื้นฐานสำหรับการอัดประจุไฟฟ้า รวมถึงการประเมิน อุปสรรคที่สำคัญต่อการพัฒนายานยนต์ไฟฟ้าในระบบขนส่งสาธารณะ

ผลลัพธ์ที่ 4: การจัดทำข้อเสนอเชิงนโยบายเพื่อจัดการกับความท้าทายและส่งเสริมให้เกิดการลงทุนจากภาครัฐและเอกชนในการพัฒนายานยนต์ไฟฟ้าในระบบขนส่งสาธารณะ

ผลลัพธ์ที่ 5: การจัดทำ (ร่าง) แผนทางการเงินเพื่อส่งเสริมการลงทุนจากภาครัฐและเอกชนในการพัฒนายานยนต์ไฟฟ้าในระบบขนส่งสาธารณะ อาทิ ทางเลือกด้านการเงิน เงื่อนไข และข้อกำหนดในการดำเนินการ เป็นต้น

ผลการศึกษาจากรายงานฉบับนี้ สามารถสรุปได้ดังนี้

1. แนวโน้มของยานยนต์ไฟฟ้าในระบบขนส่งสาธารณะและเครื่องมือทางการเงินในระดับโลกและระดับภูมิภาค

ยอดขายยานยนต์ไฟฟ้า (Electric Vehicle: EV) ขยายตัวเพิ่มสูงขึ้นอย่างมากในช่วงสิบปีที่ผ่านมาและยังคงเพิ่มสูงขึ้นอย่างมากในปี พ.ศ. 2565 จากการวิเคราะห์ของ BloombergNEF ภายใต้สถานการณ์จำลองการเปลี่ยนผ่านทางเศรษฐกิจ (Economic Transition Scenario) ซึ่งมีสมมติฐานสำคัญคือการเปลี่ยนแปลงเป็นไปตามแนวโน้มด้านเทคโนโลยี เศรษฐกิจและกลไกของตลาด โดยไม่มีนโยบายใหม่ ๆ เข้ามาช่วยส่งเสริม พบว่า รถเมล์ไฟฟ้า รถจักรยานยนต์และรถ 3 ล้อมีแนวโน้มขยายตัวสูง โดยคาดการณ์ว่าสัดส่วนของยอดขายรถเมล์ไฟฟ้าคิดเป็นร้อยละ 63 ของยอดขายทั้งหมด ส่วนรถจักรยานยนต์และรถ 3 ล้อคิดเป็นร้อยละ 49 ของยอดขายทั้งหมด ภายใน พ.ศ. 2573 ในขณะที่สถานการณ์จำลองการใช้ยานยนต์ประเภทไร้การปล่อยก๊าซเรือนกระจก (Zero-Emission Vehicle: ZEV) ทั้ง 100% พบว่า เป้าหมายการใช้ยานยนต์ไฟฟ้าทั้ง 100% จะสามารถบรรลุได้ในปี พ.ศ. 2593 หากมีการกำหนดมาตรการสนับสนุนอย่างเหมาะสม

ตลาดยานยนต์ไฟฟ้าทั่วโลกมีการพัฒนาแบบกระจัดกระจาย โดยตลาดในประเทศจีนและยุโรปมีการพัฒนาอย่างมาก และประเทศนอร์เวย์ที่มีตลาดเล็กกว่า แต่การใช้ EV ยังคงค่อนข้างต่ำในกลุ่มประเทศเศรษฐกิจเกิดใหม่ อย่างไรก็ตาม คาดว่าแนวโน้มการใช้ยานยนต์ไฟฟ้าจะเพิ่มสูงขึ้นในกลุ่มประเทศเศรษฐกิจเกิดใหม่ เนื่องจากตลาดรถเมล์ไฟฟ้า รถจักรยานยนต์ไฟฟ้าและรถ 3 ล้อไฟฟ้าในประเทศจีนเริ่มอิ่มตัว

เสาหลักสามประการที่มีส่วนสนับสนุนการรับมือของยานยนต์ไฟฟ้าจากผลกระทบภายนอกของการระบาดใหญ่ของ COVID-19 ได้แก่ 1) กฎระเบียบที่เอื้ออำนวย 2) มาตรการจูงใจเพิ่มเติมเพื่อรักษาระดับยอดขาย EV จากภาวะเศรษฐกิจตกต่ำ และ 3) การขยายตัวของโมเดลรถ EV ควบคู่ไปกับต้นทุนแบตเตอรี่ที่ลดลงอย่างต่อเนื่อง

ประสบการณ์ของจีนแสดงให้เห็นว่ากรอบนโยบายจากบนลงล่างที่แข็งแกร่งควบคู่ไปกับการดำเนินการจากล่างขึ้นบนในระดับเทศบาลนั้นมีประสิทธิภาพในการพัฒนาตลาด EV ให้ประสบความสำเร็จมากที่สุดในโลก ทั้งนี้ **นโยบายที่สำคัญมากคือ นโยบายการส่งเสริม EV ในระดับท้องถิ่นซึ่งมุ่งมั่นที่จะลดการใช้รถยนต์ส่วนตัวและให้ความสำคัญกับการส่งเสริมยานยนต์ไฟฟ้าในระบบขนส่งสาธารณะ** รัฐบาลได้นำมาตรการและนโยบายที่หลากหลายมาใช้กับ EV ซึ่งประสบความสำเร็จเป็นอย่างมาก เช่น ข้อกำหนดปริมาณการปล่อยก๊าซเรือนกระจกจากยานพาหนะ มาตรการจูงใจทางการเงิน มาตรฐานของอุปกรณ์อัดประจุไฟฟ้าสำหรับ EV การจัดการจราจรและที่จอดรถที่เอื้อต่อผู้ใช้ EV เป็นต้น

ในภูมิภาคอาเซียน อินโดนีเซียถือเป็นคู่แข่งสำคัญในการผลิตยานยนต์ไฟฟ้าของประเทศไทย เนื่องจากมีความได้เปรียบในด้านปริมาณนิกเกิลสำรองซึ่งเป็นวัตถุดิบหลักสำหรับแบตเตอรี่ ในขณะเดียวกัน สิงคโปร์กำลังขยายการใช้ EV ให้มากขึ้นผ่านมาตรการจูงใจเพื่อกระตุ้นความต้องการใช้ EV

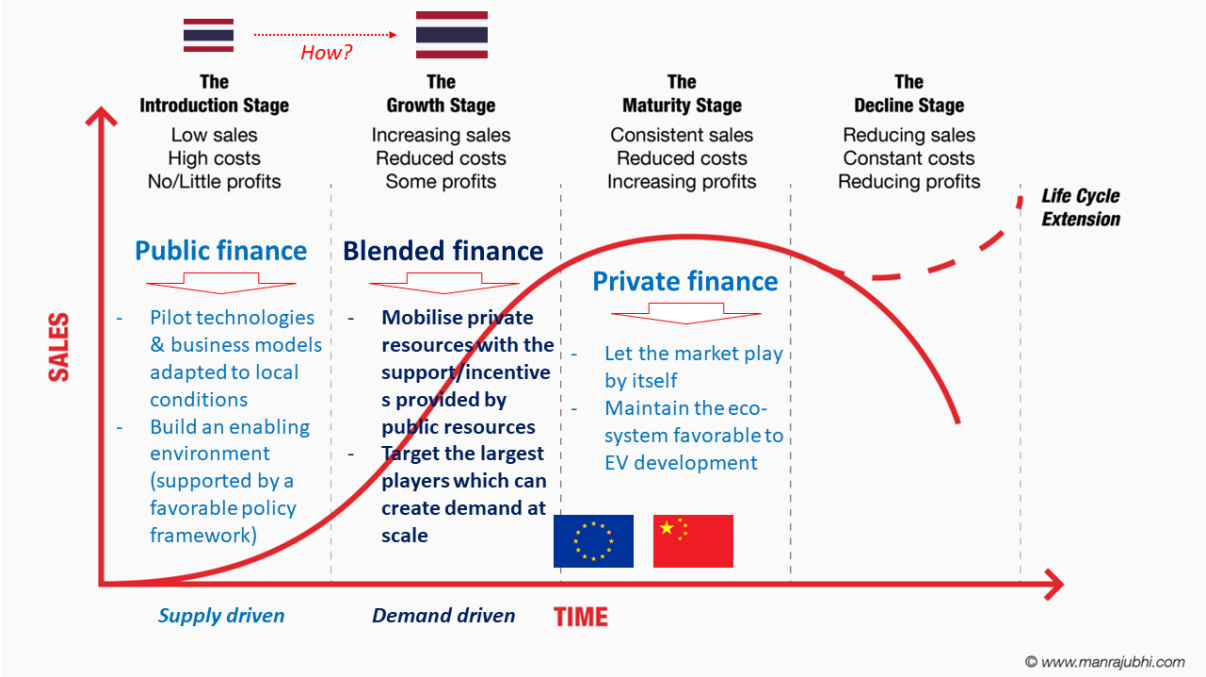
ในส่วนของเครื่องมือทางการเงินในการสนับสนุน EV จะมีทั้งในรูปแบบของภาครัฐและเอกชน โดยในประเทศอินเดียและฮ่องกง รัฐบาลได้ให้เงินอุดหนุนเพื่อกระตุ้นการปฏิรูปโครงสร้างที่จะสร้างผลประโยชน์ระยะยาวให้กับภาคส่วนทั้งหมด รวมทั้งสนับสนุนการวิจัยและพัฒนา โดยเฉพาะเทคโนโลยี EV ที่มีประสิทธิภาพโดยการปรับให้เข้ากับสภาพท้องถิ่น สำหรับประเทศสหราชอาณาจักร พบว่า นักลงทุนเอกชนหลากหลายรูปแบบเป็นผู้ลงทุนเพื่อให้เกิดการใช้ EV อาทิ สถาบันการเงินที่เสนอการปล่อยสินเชื่อที่เป็นมิตรต่อสิ่งแวดล้อมและการเช่าซื้อ ไปจนถึงผู้ให้บริการผลิตภัณฑ์/บริการด้านพลังงาน ซึ่งเน้นรูปแบบการให้บริการเพื่อแบ่งเบาภาระทางการเงินและกระจายความเสี่ยงให้กับผู้ให้บริการเดินรถสาธารณะ

สำหรับประเทศจีนและประเทศชิลี จะมีการผสมผสานเครื่องมือทางการเงินทั้งจากภาครัฐและภาคเอกชน โดยเห็นว่าการสนับสนุนจากรัฐหรือเอกชนเพียงอย่างเดียว อาจไม่เพียงพอต่อการขยายการใช้งาน EV ได้จริง ในกรณีของประเทศจีน ภาระการลงทุนจะลดลงโดยการเปลี่ยนการสนับสนุนค่าใช้จ่ายในการลงทุน (CAPEX) เป็นรูปแบบค่าใช้จ่ายในการดำเนินงาน (OPEX) ผ่านการเช่าซื้อ ในขณะเดียวกัน เงินอุดหนุนจากรัฐบาลยังช่วยลดต้นทุนการเดินรถเมล์ไฟฟ้าได้อีกด้วย ในกรณีของประเทศชิลี โมเดลธุรกิจที่แยกกลุ่มเจ้าของรถและกลุ่มผู้ดำเนินการออกจากกัน ทำให้ผู้ประกอบการเดินรถสามารถให้บริการโดยใช้รถเมล์ได้มากกว่า 400 คัน เนื่องจากผู้ให้บริการด้านพลังงานแบ่งเบาภาระทางการเงินและความเสี่ยงในการลงทุน นอกจากนั้นแล้วยังมีการค้ำประกันจากรัฐบาลเพื่อช่วยเสริมสร้างกลไกการลดความเสี่ยง

ในส่วนของการเข้าถึงกองทุนสภาพภูมิอากาศระหว่างประเทศยังคงเป็นเรื่องท้าทาย ดังนั้น จึงจำเป็นต้องจัดการกับความท้าทายหลายประการเพื่อกำหนดข้อเสนอก่อนที่ประเทศไทยจะสามารถเข้าถึงแหล่งเงินสนับสนุนเหล่านั้นได้สำเร็จ และเนื่องจากประเทศไทยกำลังเคลื่อนจากขั้นตอนแรกไปสู่ขั้นตอนการพัฒนาของตลาดยานยนต์ไฟฟ้าตามวงจร 4 ขั้นตอน การเงินแบบผสมผสานซึ่งระดมเงินทุนจากภาคเอกชนและได้รับการสนับสนุนจากเงินทุน

ของภาครัฐเป็นแนวทางที่เหมาะสมที่สุดในการจัดหาเงินทุนจำนวนมากที่จำเป็นเพื่อขยายตลาด ในระหว่างนี้ กลยุทธ์ในการพัฒนาตลาด EV ควรเปลี่ยนจากการกระตุ้นความต้องการการผลิตเป็นการกระตุ้นความต้องการยานยนต์ไฟฟ้าให้เพิ่มมากขึ้น

รูป 1: 4 ขั้นตอนในวงจรการพัฒนาตลาดยานยนต์ไฟฟ้า



2. กรอบนโยบายและโครงสร้างเชิงสถาบันของประเทศไทย และแนวโน้มตลาดรถยนต์ไฟฟ้าที่เกี่ยวข้องกับการขับเคลื่อนด้วยไฟฟ้า

ในประเทศไทย การส่งเสริมยานยนต์ไฟฟ้าได้รับแรงกระตุ้นจากนโยบายการพัฒนาเศรษฐกิจและการเปลี่ยนแปลงสภาพภูมิอากาศ เนื่องจากอุตสาหกรรมยานยนต์เป็นหนึ่งในภาคเศรษฐกิจที่สำคัญที่สุดของประเทศ การส่งเสริมการผลิตยานยนต์ไฟฟ้าจึงเป็นกลยุทธ์หลักในการเพิ่มความสามารถในการแข่งขันของเศรษฐกิจไทย ในอีกทางหนึ่ง การนำ EV มาใช้ควบคู่ไปกับการเปลี่ยนผ่านทางพลังงานคาดว่าจะลดการปล่อยก๊าซเรือนกระจกจากการขนส่งทางถนน ส่งผลให้มีส่วนช่วยในการบรรลุเป้าหมาย NDC ของประเทศ

ในขณะที่แผนการดำเนินงานตามแผน NDC ในมิติด้านการขนส่งได้ระบุมาตรการหลายอย่างที่เกี่ยวข้องกับการขับเคลื่อนด้วยยานยนต์ไฟฟ้าในระบบขนส่งสาธารณะ มาตรการเหล่านั้นมุ่งเป้าไปที่ยานยนต์สาธารณะที่องค์การขนส่งมวลชนกรุงเทพ (ขสมก.) เป็นเจ้าของ ในขณะที่ยังไม่มีการระบุมาตรการสนับสนุนหรือแหล่งเงินทุนเพื่อสนับสนุนที่ชัดเจนสำหรับยานยนต์สาธารณะที่ภาคเอกชนเป็นเจ้าของ อาทิ รถตู้ รถแท็กซี่ รถสองแถว รถจักรยานยนต์รับจ้าง

แผนการส่งเสริมยานยนต์ไฟฟ้าของประเทศไทยที่สำคัญที่สุด ได้แก่ แผนที่นำทาง EV (EV Roadmap) และเป้าหมาย ZEV 30@30 ซึ่งตั้งเป้าที่จะบรรลุเป้าหมายที่จะส่งเสริมการผลิตยานยนต์ไฟฟ้าให้ได้อย่างน้อย 30% ของการผลิตยานยนต์ในประเทศทั้งหมดภายในปี พ.ศ. 2573 ซึ่งจะยกระดับการส่งเสริมการผลิตยานยนต์ไฟฟ้าเพิ่มขึ้นเป็น 100% ในปี พ.ศ. 2578 โดยรัฐบาลได้มีมาตรการส่งเสริมทั้งทางด้านผลิตและการใช้ ในด้านการผลิต แพ็คเกจส่งเสริม EV ที่เสนอโดยคณะกรรมการส่งเสริมการลงทุน (BOI) เป็นการสนับสนุนการพัฒนา EV ที่ครอบคลุมมากที่สุดในประเทศไทย ซึ่งส่วนใหญ่ประกอบด้วยแรงจูงใจทางการเงินแก่ผู้ผลิตที่เข้าเกณฑ์ เช่น ผู้ผลิตรถยนต์ ชิ้นส่วนรถยนต์ สถานีชาร์จและสิ่งอำนวยความสะดวก เป็นต้น ส่วนด้านการใช้งานยานยนต์ไฟฟ้า พบว่า มีมาตรการเงินอุดหนุนสำหรับการซื้อรถยนต์ไฟฟ้า รวมถึงการลดภาษีสรรพสามิตรถยนต์และภาษีทะเบียนรถที่แตกต่างกัน โดยรัฐบาลไทยยังตั้งเป้างบสาธารณะ 20% สำหรับเพื่อใช้ในการจัดซื้อ BEV เป็นต้น ในขณะเดียวกัน พบว่า มีการสนับสนุนหลายประการสำหรับการพัฒนาโครงสร้างพื้นฐานสำหรับการชาร์จไฟฟ้า การกำหนดมาตรฐานของระบบ EV และการจัดการเมื่อแบตเตอรี่ EV หมดอายุการใช้งาน

มาตรการเหล่านี้ช่วยกระตุ้นให้เกิดการขยายตัวในการใช้ EV ของประเทศไทย โดยการจดทะเบียนของรถยนต์ EV ใหม่เพิ่มขึ้น ตั้งแต่ปี พ.ศ. 2560 อย่างไรก็ตาม โครงสร้างพื้นฐานสำหรับการชาร์จมีการขยายตัวค่อนข้างช้า ซึ่งสะท้อนให้เห็นถึงภาวะที่ไม่สอดคล้องกัน เนื่องจากการขยายตัวของเครื่องชาร์จจะเป็นไปได้ก็ต่อเมื่อ EV ถูกนำมาใช้กันอย่างแพร่หลาย ในขณะเดียวกัน การเติบโตของจำนวนการใช้ EV ส่วนใหญ่เป็นรถยนต์นั่งส่วนบุคคลและรถจักรยานยนต์ แต่สำหรับรถโดยสารสาธารณะพบว่ามีเพียงส่วนน้อยเท่านั้นที่เป็นรถยนต์ไฟฟ้า

3. แนวทางการส่งเสริมยานยนต์ไฟฟ้าสำหรับรถเมล์

1.1 โครงสร้างตลาดของรถโดยสารประจำทาง (รถเมล์)

1) การเดินทางโดยรถเมล์คิดเป็น 80% ของการเดินทางทั้งหมดในระบบขนส่งสาธารณะ อย่างไรก็ตาม เนื่องจากรถโดยสารที่มีสภาพเก่าและบริการมีคุณภาพไม่ได้มาตรฐาน ผู้โดยสารรถประจำทางส่วนใหญ่จึงเป็นผู้มีรายได้น้อยที่มีข้อจำกัดในการเปลี่ยนไปใช้การขนส่งประเภทอื่น
2) ในเดือนสิงหาคม พ.ศ. 2564 มีรถเมล์จำนวน 3,786 คัน ครอบคลุม 180 เส้นทางที่ให้บริการผู้โดยสารในเขตกรุงเทพมหานครและปริมณฑล (BMR) ทั้งนี้ รถเมล์ส่วนใหญ่มีสภาพทรุดโทรมและไม่มีเครื่องปรับอากาศ ซึ่งนอกจากจะทำให้เกิดความไม่สะดวกกับผู้โดยสารแล้ว ยังทำให้ต้นทุนการดำเนินงานของผู้ให้บริการสูงขึ้นด้วย
3) ผู้ประกอบการรถโดยสารในปี พ.ศ. 2564 สามารถ แบ่งออกเป็น 3 กลุ่ม ได้แก่ (1) องค์การขนส่งมวลชนกรุงเทพ (ขสมก.) ซึ่งเป็นรัฐวิสาหกิจ และผู้ประกอบการรถโดยสารรายใหญ่ มีรถเมล์ให้บริการ 2,966 คัน คิดเป็นประมาณ 78.3% ของรถโดยสารทั้งหมดใน กทม. (2) บริษัทเอกชนที่ได้รับอนุญาตช่วงจาก ขสมก. จำนวน 196 คัน (5.2%) และ (3) บริษัทเอกชนที่ได้รับใบอนุญาตโดยตรงจากกรมการขนส่งทางบกจำนวน 624 คัน (16.5%) อนึ่ง ช่วงต้นปี

พ.ศ. 2565 กรมการขนส่งทางบกได้เปิดประมูลเส้นทางรถโดยสารซึ่งอาจจะทำให้ข้อมูลนี้เปลี่ยนแปลงได้ อย่างไรก็ตาม ยังไม่มีข้อมูลที่เปิดเผยอย่างเป็นทางการว่าจำนวนรถของผู้ประกอบการแต่ละประเภทเปลี่ยนแปลงอย่างไร

4) ในอดีต ขสมก. เป็นทั้งหน่วยงานกำกับดูแลและผู้ดำเนินการที่มีอำนาจในการให้ใบอนุญาตช่วงการเดินรถแก่ผู้ประกอบการเอกชน ผู้ประกอบการจึงมี 2 กลุ่ม ได้แก่ ขสมก. และบริษัทที่ได้รับอนุญาตช่วงการเดินรถ แต่ที่ผ่านมามีปัญหาในการควบคุมคุณภาพและการบริการที่ไม่ได้มาตรฐาน ดังนั้น ในปี พ.ศ. 2559 คณะรัฐมนตรีได้มีมติให้กรมการขนส่งทางบกทำหน้าที่เป็นหน่วยงานกำกับดูแล และ ขสมก. เป็นผู้ประกอบการรถโดยสาร โดยมีเป้าหมายเพื่อส่งเสริมการแข่งขันที่เป็นธรรมสำหรับผู้ประกอบการที่ได้รับใบอนุญาตทุกราย ตลอดจนส่งเสริมคุณภาพการบริการที่ดีขึ้น การปฏิรูปนี้ยังอยู่ระหว่างการดำเนินการ ดังนั้น บริษัทเอกชนบางแห่งที่ได้รับใบอนุญาตช่วงต่อ ขสมก. จึงยังคงมีอยู่ แต่ในระยะยาวบริษัทเอกชนทั้งหมดต้องได้รับใบอนุญาตโดยตรงจากกรมการขนส่งทางบก ทำให้ในอนาคตผู้ประกอบการจะแบ่งออกเป็น 2 กลุ่ม ได้แก่ (1) ขสมก. เป็นรัฐวิสาหกิจและ (2) บริษัทเอกชนที่มีใบอนุญาต

5) กฎระเบียบใหม่ตามมติคณะรัฐมนตรีในปี พ.ศ. 2559 จะมีผลบังคับในด้านคุณภาพของรถโดยสารที่ให้บริการและมาตรฐานการบริการ โดยประมาณร้อยละ 70 ของรถโดยสารที่ให้บริการทั้งหมดต้องเป็นรถใหม่หรืออายุน้อยกว่า 2 ปี และอีกร้อยละ 30 ที่เหลือต้องเป็นรถที่มีอายุน้อยกว่า 25 ปี

6) อัตราค่าโดยสารรถประจำทางถูกควบคุมโดยรัฐบาลและอยู่ในระดับไม่สูงนัก เพื่อให้แน่ใจว่าเป็นราคาที่ผู้เดินทางทุกคนสามารถจ่ายได้โดยเฉพาะผู้ที่มีรายได้น้อย เนื่องจากค่าโดยสารเป็นแหล่งรายได้หลักสำหรับผู้ประกอบการเดินรถ ค่าโดยสารรถประจำทางที่ไม่สูงทำให้ผู้ประกอบการต้องลดต้นทุนของตน จึงทำให้คุณภาพการบริการของผู้โดยสารลดลง อัตราค่าโดยสารรถประจำทางในปัจจุบันจัดว่าอยู่ในระดับที่ประชาชนสามารถจ่ายได้ ตามดัชนีการขนส่งในเมืองอย่างยั่งยืน (ESCAP, 2017) นั่นหมายความว่า ราคาค่าโดยสารยังสามารถปรับสูงขึ้นได้เพื่อให้มั่นใจว่ารายได้ของผู้ประกอบการเดินรถสามารถครอบคลุมค่าใช้จ่ายในการดำเนินงานทั้งหมดได้ รวมถึงเป็นราคาที่สามารถทำให้ผู้ประกอบการเดินรถสามารถลงทุนในการปรับปรุงคุณภาพและบริการรถโดยสารได้อีกด้วย

1.2 สถานะทางการเงินและรูปแบบธุรกิจของผู้ให้บริการรถโดยสารประจำทาง

1) จากการประเมินสถานภาพทางการเงินในปัจจุบันของผู้ประกอบการรถโดยสารประจำทาง แสดงให้เห็นว่าผู้ประกอบการในปัจจุบันมีศักยภาพทางการเงินที่จำกัด โดยส่วนใหญ่มีผลประกอบการที่ขาดทุน ซึ่งเป็นหลักฐานว่าค่าโดยสารในปัจจุบันไม่สามารถครอบคลุมค่าใช้จ่ายในการดำเนินงานของผู้ประกอบการได้ ส่งผลให้ความสามารถในการลงทุนเพื่อปรับปรุงคุณภาพรถโดยสารและการบริการมีจำกัด อย่างไรก็ตาม มียังมีนักลงทุนรายใหม่ 2 รายจากภาคการผลิตรถยนต์ไฟฟ้าและแบตเตอรี่ ได้ลงทุนในธุรกิจให้บริการรถโดยสารสาธารณะโดยตั้งเป้าว่าจะใช้รถเมล์ไฟฟ้าทั้งหมดในการให้บริการ

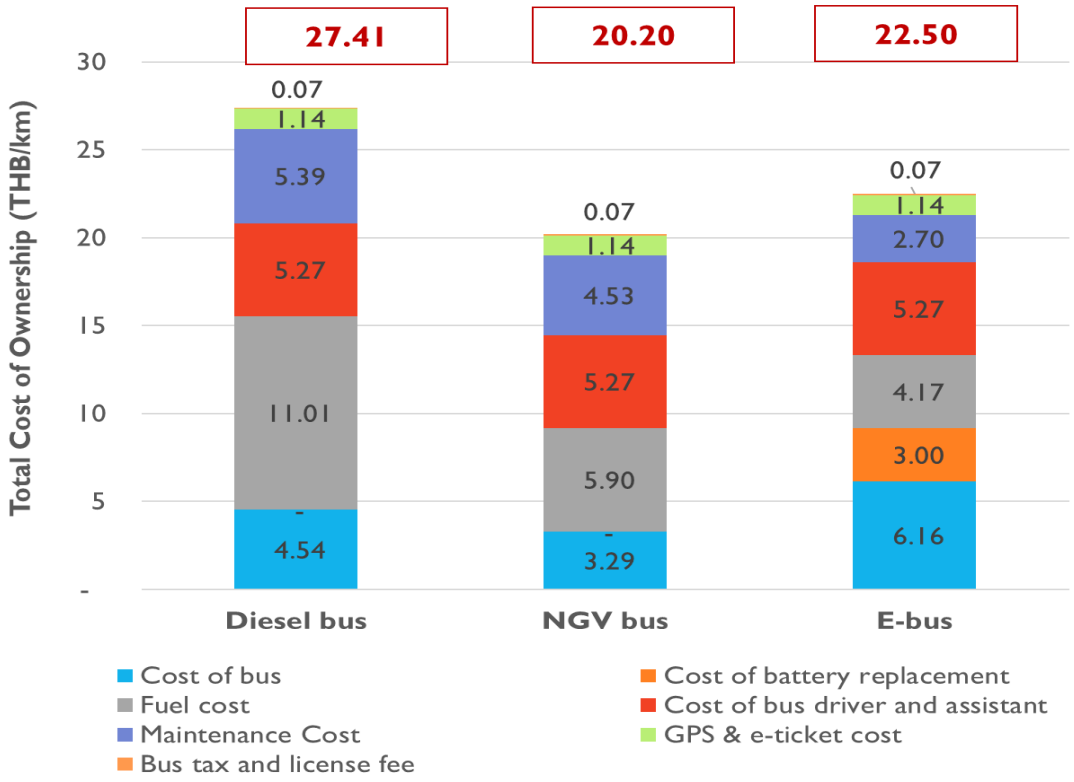
2) เมื่อพิจารณาถึงโมเดลธุรกิจในปัจจุบัน กลุ่มผู้ประกอบการเดินรถทั้ง 3 กลุ่มทำหน้าที่เป็นเจ้าของรถโดยสารให้บริการเดินรถ และบำรุงรักษารถยนต์ของตนเอง โดยในปี พ.ศ. 2554 ขสมก. ได้รับอนุญาตให้เช่ารถโดยสารได้ 117 คัน ภายใต้สัญญาจ้าง ซึ่งผู้ได้รับใบอนุญาตต้องให้บริการเดินรถโดยสารประจำทางและดำเนินบำรุงรักษารถยนต์ด้วย โดยต้นทุนการดำเนินงานที่เกิดขึ้นแก่ผู้ประกอบการเดินรถจะครอบคลุมทั้งค่าน้ำมัน ค่าจ้างและ

ผลประโยชน์พนักงาน และค่าใช้จ่ายอื่นๆ เช่น ค่าตั๋ว ค่าใบอนุญาต ฯลฯ ในขณะที่รายได้ของผู้ประกอบการเดินรถส่วนใหญ่มาจากค่าโดยสารรถประจำทางเพียงทางเดียว ในขณะที่ ขสมก. ยังได้รับเงินอุดหนุนจากรัฐบาลบางส่วน

1.3 การประเมินความต้องการด้านการเงินและด้านเทคนิคของรถเมล์ไฟฟ้าและการดำเนินการโครงสร้างพื้นฐานสำหรับการชาร์จรถเมล์ไฟฟ้าในประเทศไทย

1) ค่าใช้จ่ายในการลงทุน (CAPEX) ของรถเมล์ดีเซลอยู่ที่ 4,900,000 บาท และค่าใช้จ่ายในการลงทุนของรถเมล์ NGV อยู่ที่ 3,600,000 บาท ซึ่งต่ำกว่ารถเมล์ดีเซลร้อยละ 17 ในขณะที่ค่าใช้จ่ายในการลงทุนของรถเมล์ไฟฟ้ารวมค่าเปลี่ยนแบตเตอรี่ในปีที่ 7 อยู่ที่ 9,000,660 บาท สูงกว่ารถเมล์ดีเซล 102% ในส่วนของค่าใช้จ่ายการดำเนินงาน (OPEX) ทั้งหมดของรถเมล์ดีเซลนั้น มีมูลค่าสูงที่สุดที่ 2,619,500 บาท ในขณะที่รถเมล์ NGV และรถเมล์ไฟฟ้า คิดเป็นมูลค่า 1,964,625 บาท และ 1,519,310 บาท คิดเป็นร้อยละ 75 และร้อยละ 58 ของค่าใช้จ่ายการดำเนินงานรถเมล์ดีเซล ตามลำดับ
2) ต้นทุนการเดินรถเมล์ไฟฟ้า อยู่ที่ประมาณ 22.50 บาท/กม. ซึ่งต่ำกว่ารถเมล์ดีเซล (27.41 บาท/กม.) ประมาณร้อยละ 22 แต่สูงกว่ารถเมล์ NGV (20.20 บาท/กม.) ประมาณร้อยละ 10 สรุปได้ว่า ต้นทุนการเดินรถเมล์ไฟฟ้าจัดว่าสามารถแข่งขันได้กับต้นทุนการเดินรถเมล์ดีเซล แต่มียังไม่สามารถแข่งขันได้เมื่อเทียบกับรถเมล์ NGV ทั้งนี้เนื่องจากราคา NGV มีความผันผวนค่อนข้างมาก โดยในช่วงต้นปี พ.ศ. 2565 ราคา NGV ที่หากภาครัฐไม่มีมาตรการเงินอุดหนุนจะสูงถึง 20 - 22 บาท/กิโลกรัม ทำให้ต้นทุนการเดินรถ NGV เทียบเท่ากับต้นทุนการเดินรถเมล์ไฟฟ้า อย่างไรก็ตาม เมื่อพิจารณาเฉพาะราคารถเมล์ พบว่า ราคารถเมล์ไฟฟ้าสูงกว่าทั้งรถเมล์ดีเซลและรถเมล์ NGV
3) ต้นทุนการเดินรถเมล์ทุกประเภทเปลี่ยนแปลงมากที่สุดตามระยะทางต่อปี เนื่องจากค่าใช้จ่ายการดำเนินงานระหว่างปีที่ 1 ถึงปีที่ 15 ของรถเมล์ดีเซลและรถเมล์ NGV สูงมาก หรือ มูลค่าปัจจุบันสุทธิ (NPV) คิดเป็นเกือบร้อยละ 80 ของต้นทุนทั้งหมด พารามิเตอร์ที่ส่งผลกระทบรองลงมา ได้แก่ อัตราคิดลด (discount rate) ราคารถเมล์ ค่าเชื้อเพลิง ค่าบำรุงรักษา และอัตราเงินเฟ้อ ตามลำดับ สำหรับรถเมล์ไฟฟ้า พารามิเตอร์ที่มีผลกระทบต่อต้นทุนการเดินรถ โดยเรียงลำดับจากมากไปน้อย ได้แก่ ระยะทางต่อปี ราคารถเมล์ อัตราคิดลด ต้นทุนในการเปลี่ยนแบตเตอรี่ ค่าบำรุงรักษาต้นทุนเชื้อเพลิง และอัตราเงินเฟ้อ ตามลำดับ

รูป 2: ต้นทุนการเดินรถเมล์ดีเซล รถเมล์ NGV และรถเมล์ไฟฟ้า (หน่วย: บาท/กิโลเมตร)



1.4 ข้อเสนอโมเดลธุรกิจและกลไกทางการเงินสำหรับรถเมล์โดยสารสาธารณะไฟฟ้าในประเทศไทย

1) รูปแบบการเช่าดำเนินการ (Operating lease model) และรูปแบบการดำเนินการแบบครบวงจรตั้งแต่ต้นทางจนถึงปลายทาง (Integrated end-to-end financing model) ถือเป็นรูปแบบธุรกิจที่มีศักยภาพในการจัดการอุปสรรค โดยเฉพาะยานยนต์ไฟฟ้าที่มีราคาสูง ความสามารถทางการเงินที่จำกัดของผู้ประกอบการเดินรถในการลงทุนรถโดยสารใหม่ และการขาดรู้ความเข้าใจในการบำรุงรักษาและซ่อมแซมรถเมล์ไฟฟ้า

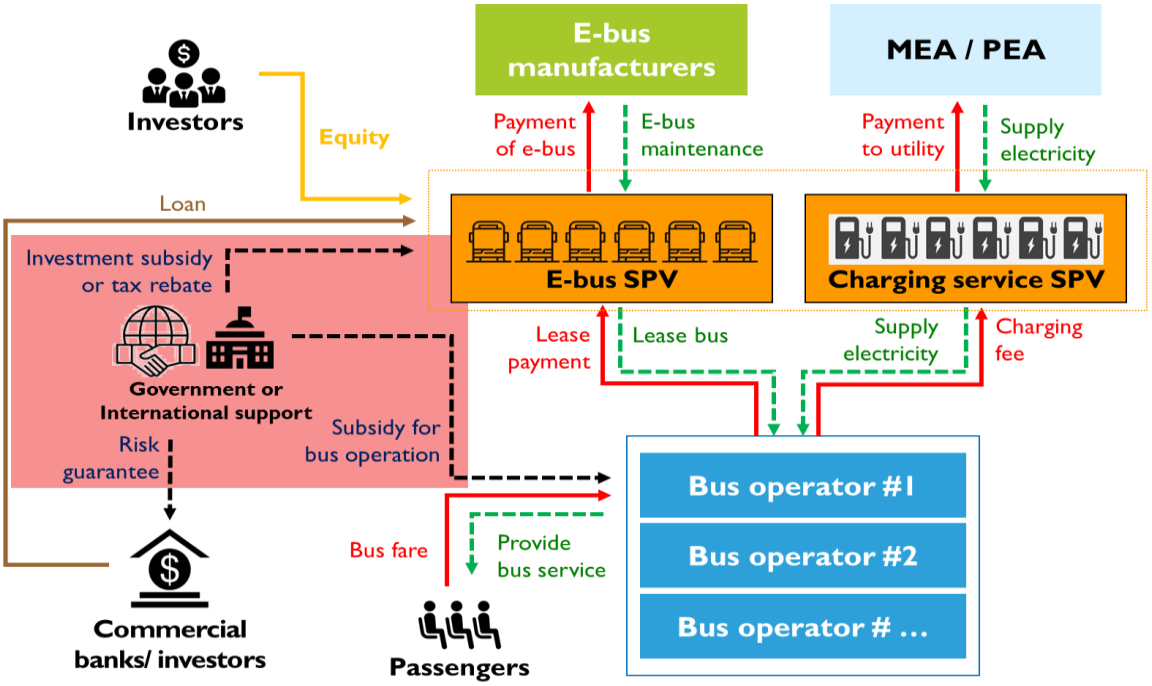
2) แบบจำลองกระแสเงินสดส่วนลด (Discounted cash flow) เป็นวิธีที่ใช้ในการประเมินความเป็นไปได้ โดยมีกรอบในการประเมินคือกำหนดมีอัตราผลตอบแทนภายใน (IRR) สำหรับการลงทุนที่ร้อยละ 10 เพื่อจูงใจนักลงทุน อย่างไรก็ตาม เนื่องจากค่าโดยสารเป็นแหล่งรายได้หลักสำหรับผู้ประกอบการเดินรถ โดยเมื่อพิจารณาระดับค่าโดยสารในปัจจุบันพบว่า เป็นระดับราคาที่ไม่สามารถทำให้รถเมล์ไฟฟ้ามีความคุ้มค่าการลงทุนและไม่สามารถที่จะเปลี่ยนเป็นรถเมล์ไฟฟ้าได้ ดังนั้น จึงจำเป็นต้องมีการสนับสนุนทางการเงินเพิ่มเติมทั้งจากรัฐบาลหรือแหล่งเงินทุนจากต่างประเทศประมาณ 1,303 – 1,983 ล้านบาท สำหรับการเดินรถโดยสารสาธารณะไฟฟ้า จำนวน 500 คัน ทั้งนี้ ขึ้นอยู่กับรูปแบบธุรกิจที่เลือกและตัวเลือกทางการเงินที่มีให้

3) เมื่อเปรียบเทียบกับโครงการเงินอุดหนุนที่มีอยู่สำหรับรถยนต์ไฟฟ้าส่วนบุคคลต่อการเดินทางตลอดอายุ 15 ปี (3.11 - 3.33 บาท/เที่ยว) การสนับสนุนที่จำเป็นสำหรับการใช้รถโดยสารสาธารณะไฟฟ้านั้นจะต้องการเงินอุดหนุนน้อยกว่า (สูงสุด 2.32 บาท/ผู้โดยสาร-เที่ยว) ทั้งนี้ ด้วยงบประมาณการสนับสนุนสำหรับรถเมล์ไฟฟ้า 500 คัน จะเทียบเท่าการสนับสนุนรถยนต์ไฟฟ้าส่วนบุคคลประมาณ 18,600 – 28,300 คัน โดยผู้ได้รับผลประโยชน์จากการอุดหนุนรถยนต์ไฟฟ้าส่วนบุคคลอยู่ที่ประมาณ 510 - 776 ล้านผู้โดยสาร-เที่ยว ขณะที่จำนวนผู้รับผลประโยชน์จากรถโดยสารสาธารณะไฟฟ้า จำนวน 500 คัน คือ 1,140 ล้านผู้โดยสาร-เที่ยว หรือคิดเป็นประมาณ 1.47 – 2.24 เท่าของในกรณีรถยนต์ไฟฟ้าส่วนบุคคล

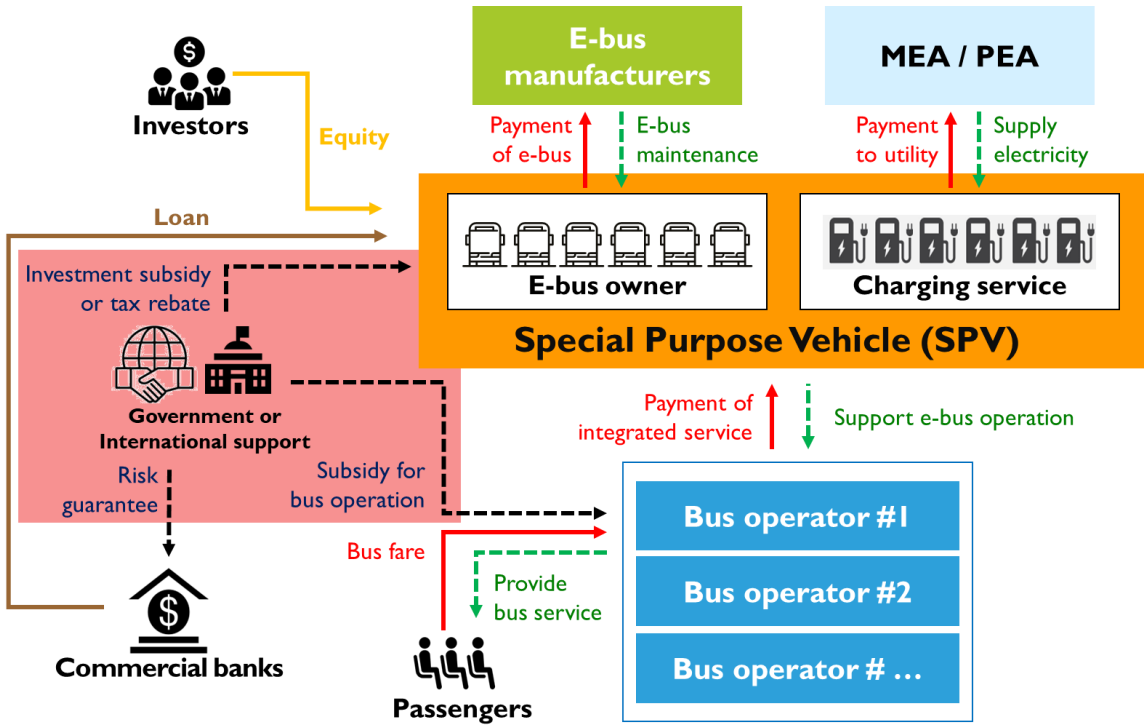
4) จากการวิเคราะห์พบว่า ปริมาณการปล่อยก๊าซเรือนกระจกที่ลดได้จากการใช้รถโดยสารสาธารณะไฟฟ้า จำนวน 500 คัน อยู่ที่ประมาณ 43,091 tCO_2/ปี ซึ่งเมื่อพิจารณางบประมาณที่ต้องใช้ในการส่งเสริมรถโดยสารสาธารณะไฟฟ้าต่อปริมาณการปล่อยก๊าซเรือนกระจกที่ลดได้ จะมีค่าน้อยกว่า 160 USD/tCO_2 ซึ่งรัฐบาลสามารถใช้อัตราการสนับสนุนต่อปริมาณการลดการปล่อยก๊าซเรือนกระจกโดยประมาณนี้ เป็นข้อมูลอ้างอิงเพื่อเปรียบเทียบกับอัตราการสนับสนุนต่อปริมาณการลดการปล่อยก๊าซเรือนกระจกของมาตรการ NDC อื่น ๆ ในการจัดลำดับความสำคัญของการสนับสนุนด้วยเงินจากทางภาครัฐ

5) ถึงแม้ว่าต้นทุนการเดินรถเมล์ไฟฟ้าจะต่ำกว่าต้นทุนการเดินรถเมล์ดีเซล แต่ยังมีปัญหาอุปสรรคทั้งทางการเงินและเทคนิคที่ส่งผลกระทบต่อการส่งเสริมการใช้รถเมล์ไฟฟ้าในระบบขนส่งสาธารณะ อาทิ มูลค่าการลงทุนที่สูง ข้อจำกัดในการเข้าถึงแหล่งทุน ศักยภาพที่จำกัดของบุคลากรในการบำรุงรักษายานยนต์ไฟฟ้า ซึ่งปัญหาอุปสรรคเหล่านี้ได้อธิบายไว้ในรายงานฉบับสมบูรณ์

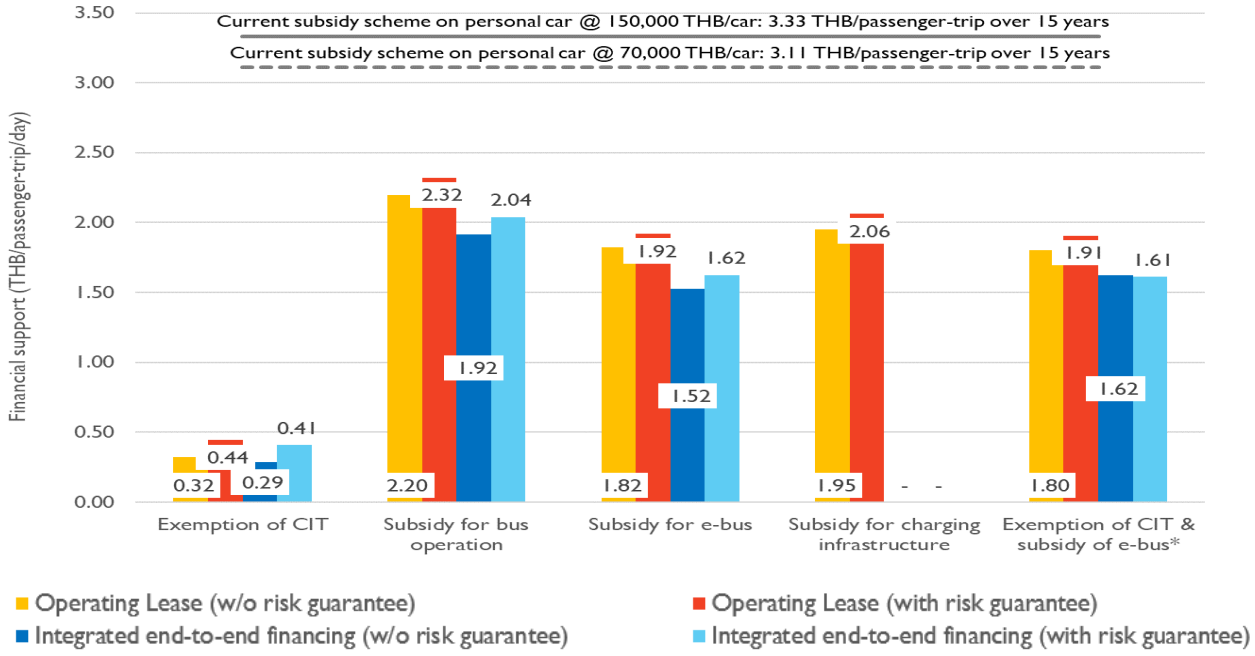
รูป 3: รูปแบบการเช่าดำเนินการ (Operating lease model)



รูป 4: รูปแบบการดำเนินการแบบครบวงจรตั้งแต่ต้นทางจนถึงปลายทาง (Integrated end-to-end financing model)



รูป 5: เปรียบเทียบเงินสนับสนุนรถเมล์ไฟฟ้าที่เสนอกับเงินอุดหนุนสำหรับรถยนต์ไฟฟ้าส่วนบุคคลที่มีอยู่ในปัจจุบัน



1.5 Roadmap ของการดำเนินการกลไกทางการเงินสำหรับรถเมล์โดยสารสาธารณะไฟฟ้าในประเทศไทย

1) โมเดลธุรกิจที่เสนอรวมถึงทางเลือกทางการเงินที่หลากหลายสามารถขจัดอุปสรรคทางการเงินได้ โดยเฉพาะอย่างยิ่งสำหรับผู้ประกอบการเดินรถโดยสาร เช่น มูลค่าการลงทุนเริ่มแรกของรถไฟฟ้าที่สูง ความสามารถทางการเงินที่จำกัด และการขาดทักษะความชำนาญในการบำรุงรักษาและซ่อมแซมรถเมล์ไฟฟ้า อย่างไรก็ตาม ยังมีอุปสรรคบางประการ เช่น เส้นทางการเดินรถ คุณภาพการให้บริการ ขาดระบบสารสนเทศที่ทำให้ผู้โดยสารสามารถวางแผนการเดินทางได้ ดังนั้น จำเป็นต้องศึกษาและดำเนินนโยบายเพิ่มเติมเพื่อช่วยให้ก้าวข้ามอุปสรรคดังกล่าว
2) ในรายงานฉบับสมบูรณ์ ได้มีการจัดทำแผนที่นำทางเพื่อดำเนินการกลไกทางการเงินสำหรับรถโดยสารสาธารณะไฟฟ้าในประเทศไทย โดยแบ่งออกเป็นสามขั้นตอน ได้แก่ ระยะเตรียมการ ระยะนำร่อง และระยะดำเนินการเต็มรูปแบบ

1.6 ข้อเสนอแนะการส่งเสริมยานยนต์ไฟฟ้าในรถเมล์โดยสารสาธารณะ

1) การยกระดับบริการรถโดยสารสาธารณะเพื่อให้เป็นทางเลือกของทุกคนควรเป็นวาระแห่งชาติเพื่อลดปัญหาการจราจรติดขัดและมลพิษทางอากาศ เพื่อปรับปรุงคุณภาพชีวิตของประชาชนในประเทศไทย โดยในการยกระดับบริการรถโดยสารสาธารณะจำเป็นต้องมีการเปลี่ยนรถโดยสารใหม่ การปรับปรุงมาตรฐานการบริการ และการปรับอัตราค่าโดยสารอย่างเป็นธรรม
2) การส่งเสริมยานยนต์ไฟฟ้าสำหรับรถโดยสารสาธารณะเป็นแนวทางหนึ่งที่ช่วยยกระดับบริการรถโดยสารสาธารณะในประเทศไทย โดยสามารถดำเนินการตามโมเดลธุรกิจและการสนับสนุนทางการเงินที่ได้อธิบายไว้ในรายงานฉบับสมบูรณ์
3) ถึงแม้ว่าข้อเสนอแนะมาตรการทางการเงินที่ได้อธิบายไว้ในรายงานฉบับนี้จะช่วยสนับสนุนให้ผู้ประกอบการสามารถให้บริการรถโดยสารสาธารณะที่ทันสมัยไปอีก 15 ปีตามอายุการใช้งานของรถเมล์ไฟฟ้า แต่การพัฒนา

ระบบขนส่งสาธารณะในระยะยาวเพื่อแก้ไขปัญหาเส้นทางที่ทับซ้อนกันและปรับปรุงคุณภาพการบริการ โดยเฉพาะอย่างยิ่ง การใช้โมเดลใหม่ในการบริหารจัดการผู้ประกอบการเดินรถโดยสารมีความสำคัญต่อความยั่งยืนของบริการรถโดยสารสาธารณะในระยะยาว

4. แนวทางการส่งเสริมยานยนต์ไฟฟ้าสำหรับรถตู้โดยสารสาธารณะ

1.7 โครงสร้างตลาดของรถตู้โดยสารสาธารณะ

1) การเดินทางรถตู้โดยสารสาธารณะคิดเป็นร้อยละ 4 ของการเดินทางทั้งหมดในระบบขนส่งสาธารณะ หรือ 142.4 ล้านคน/เที่ยว/ปี โดยในปี พ.ศ. 2562 จำนวนผู้โดยสารรถตู้โดยสารสาธารณะลดลงจากปี พ.ศ. 2561 ประมาณร้อยละ 30 สาเหตุมาจากจำนวนรถตู้ที่ลดลง (ร้อยละ 18) และความทับซ้อนกันระหว่างเส้นทางรถไฟฟ้าสายใหม่กับเส้นทางรถตู้ที่มีอยู่ จึงทำให้ผู้โดยสารบางส่วนเปลี่ยนไปใช้บริการรถไฟฟ้าบีทีเอส
2) ตามสถิติของกรมการขนส่งทางบก พบว่า ในปี พ.ศ. 2562 มีรถตู้โดยสารสาธารณะประจำทาง จำนวน 13,049 คัน ที่จดทะเบียนทั่วประเทศ ในขณะที่ ขสมก. รายงานว่ามีรถตู้โดยสารสาธารณะ 3,705 คัน ให้บริการครอบคลุม 147 เส้นทาง ในพื้นที่กรุงเทพและปริมณฑล แต่แนวโน้มของรถตู้โดยสารสาธารณะลดลงตั้งแต่ปี พ.ศ. 2558 เนื่องจากกฎระเบียบใหม่กำหนดอายุรถตู้โดยสารสาธารณะและการหมดอายุของใบอนุญาตภาย ในปี พ.ศ. 2565 ซึ่งรถตู้โดยสารสาธารณะส่วนใหญ่เป็นรถตู้ดีเซล เนื่องจากมีต้นทุนการลงทุนในช่วงแรกที่ถูกกว่าเมื่อเทียบกับรถตู้ NGV
3) รัฐบาลได้บังคับใช้ระเบียบเกี่ยวกับรถตู้โดยสารสาธารณะตามพระราชบัญญัติการขนส่งทางบก ตั้งแต่ปี พ.ศ. 2542 เพื่อกำหนดมาตรฐานการบริการด้านความปลอดภัยของผู้โดยสารและขจัดการแข่งขันระหว่างรถตู้และรถโดยสารสาธารณะ รถตู้โดยสารสาธารณะถูกควบคุมโดยคณะกรรมการนโยบายการขนส่งทางบก ซึ่งมีบทบาทเป็นผู้ควบคุมดูแลและควบคุมการทำงานของรถตู้ประจำทางและกำหนดมาตรฐานการบริการของรถตู้โดยสารสาธารณะ ในขณะที่ ขสมก.เป็นผู้ดำเนินการเพียงรายเดียวที่ได้รับใบอนุญาตให้ดำเนินการรถตู้โดยสารสาธารณะ และได้รับอนุญาตให้ทำสัญญาช่วงกับผู้ประกอบการเอกชน
4) ในปี พ.ศ. 2562 คณะรัฐมนตรีมีมติโนยบายปฏิรูประบบขนส่งมวลชนทางบก โดยแผนปฏิรูปรถตู้โดยสารสาธารณะ ซึ่งครอบคลุมถึงการวางแผนเส้นทางเดินรถและการทดแทนรถตู้ด้วยรถไมโครบัสขนาด 20 ที่นั่ง กำลังอยู่ระหว่างการพัฒนา ทั้งนี้ ได้มอบหมายให้กรมการขนส่งทางบกเป็นหน่วยงานกำกับดูแลกำหนดมาตรฐานการบริการและอนุญาตให้ผู้ประกอบการเดินรถตู้โดยสารสาธารณะ
5) ณ วันที่ 30 กันยายน พ.ศ. 2562 รถตู้โดยสารสาธารณะภายใต้ใบอนุญาต ขสมก. ได้ให้บริการครอบคลุม 147 เส้นทางในพื้นที่กรุงเทพและปริมณฑล ระยะทางของเส้นทางเหล่านี้อยู่ระหว่าง 8 - 67 กม.
6) ค่าโดยสารรถตู้โดยสารสาธารณะขึ้นอยู่กับระยะทางของเส้นทางเป็นหลัก โดยมีอัตราขั้นต่ำ 15 บาท/เที่ยว และอัตราค่าโดยสารรถตู้โดยสารในพื้นที่กรุงเทพและปริมณฑล อยู่ระหว่าง 15 - 62 บาท/เที่ยว

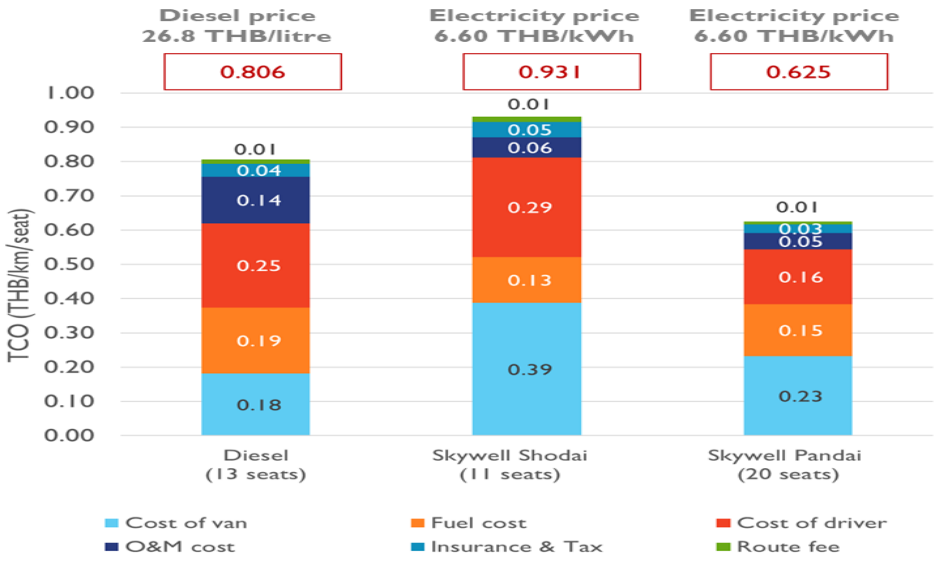
1.8 สถานะทางการเงินและรูปแบบธุรกิจของผู้ประกอบการรถตู้โดยสารสาธารณะในปัจจุบัน

1) ผู้ประกอบการรถตู้โดยสารสาธารณะส่วนใหญ่เป็นผู้ประกอบการเอกชนรายย่อยที่รับเหมาช่วงกับ ขสมก. และให้บริการประชาชนในพื้นที่กรุงเทพและปริมณฑล รายได้สุทธิของผู้ประกอบการรถตู้ อยู่ที่ประมาณ 25,000 - 35,000 บาท/เดือน ค่าดำเนินการประมาณ 62,775 บาท/เดือน ครอบคลุมค่าน้ำมัน ค่ารถตู้ ค่าบำรุงรักษา ค่าประกันภัย ภาษี ค่าเส้นทาง และค่าจอดรถ
2) รูปแบบธุรกิจที่มีอยู่ของผู้ประกอบการรถตู้โดยสารสาธารณะสามารถอธิบายได้ ดังนี้ ผู้ประกอบการรถตู้เป็นผู้รับเหมาช่วงของ ขสมก. ทำหน้าที่ให้บริการผู้โดยสาร รายได้มาจากการเก็บค่าโดยสารโดยไม่ได้รับการสนับสนุนจากรัฐบาล ผู้ประกอบการต้องชำระค่าธรรมเนียมเส้นทางให้ ขสมก. และให้บริการตามมาตรฐานที่กรมการขนส่งทางบกกำหนด ผู้ผลิตรถตู้และบริษัทน้ำมันเป็นผู้ให้บริการหลักสำหรับผู้ประกอบการรถตู้ ในขณะที่ธนาคารพาณิชย์เป็นผู้ให้เงินกู้สำหรับค่ารถตู้เพื่อให้ผู้ประกอบการสามารถชำระเงินคืนเป็นรายเดือนได้

1.9 การประเมินความต้องการด้านการเงินและด้านเทคนิคของรถตู้ไฟฟ้าและการดำเนินการโครงสร้างพื้นฐานสำหรับการชาร์จรถตู้ไฟฟ้าในประเทศไทย

1) ค่าใช้จ่ายการลงทุน (CAPEX) ของรถตู้ดีเซล 13 ที่นั่ง อยู่ที่ประมาณ 1.27 ล้านบาท ในขณะที่ค่าใช้จ่ายการลงทุนของรถตู้ไฟฟ้า 11 ที่นั่ง และรถตู้ไฟฟ้า 20 ที่นั่ง อยู่ที่ประมาณ 2.3 ล้านบาท และ 2.5 ล้านบาท ตามลำดับ
2) มูลค่าปัจจุบันสุทธิของค่าใช้จ่ายการดำเนินงาน (OPEX) ของรถตู้ดีเซล 13 ที่นั่ง ตลอดอายุการใช้งาน 10 ปี อยู่ที่ 4,391,460 บาท รถตู้ไฟฟ้า 11 ที่นั่ง และรถตู้ไฟฟ้า 20 ที่นั่ง ประมาณ 3,227,712 บาท และ 4,247,190 บาท คิดเป็นร้อยละ 74 และ 97 ของมูลค่าปัจจุบันสุทธิของรถตู้ดีเซล 13 ที่นั่ง
3) เมื่อเทียบกับต้นทุนการเดินรถต่อที่นั่งผู้โดยสารของรถตู้ดีเซล 13 ที่นั่ง (0.806 บาท/กม./ที่นั่ง) ต้นทุนการเดินรถตู้ไฟฟ้า 20 ที่นั่ง (0.625 บาท/กม./ที่นั่ง) ถือว่าสามารถแข่งขันได้ อย่างไรก็ตาม ต้นทุนการเป็นเดินรถตู้ไฟฟ้า 11 ที่นั่ง (0.931 บาท/กม./ที่นั่ง) ยังคงสูงกว่ารถตู้ดีเซล 13 ที่นั่ง
4) ระยะทางการเดินรถเป็นปัจจัยที่ส่งผลกระทบมากที่สุดต่อต้นทุนการเดินรถตู้ทุกประเภท โดยเฉพาะอย่างยิ่งของรถตู้ไฟฟ้า 11 ที่นั่ง (ร้อยละ 9.5) อัตราส่วนลดส่งผลกระทบต่อต้นทุนการเดินรถตู้ดีเซลเป็นลำดับที่ 2 เนื่องจากสัดส่วนค่าใช้จ่ายการดำเนินงาน (OPEX) อยู่ในระดับสูง สำหรับรถตู้ไฟฟ้า ค่าใช้จ่ายในการลงทุนรถตู้ส่งผลกระทบต่อต้นทุนการเดินรถตู้เป็นลำดับที่ 2 เนื่องจากสัดส่วนค่าใช้จ่ายในการลงทุนรถตู้ไฟฟ้าคิดเป็น 41.6% ของต้นทุนการเดินรถทั้งหมด
5) ถึงแม้ว่าต้นทุนการเดินรถตู้ไฟฟ้าแบบ 20 ที่นั่ง จะต่ำกว่าต้นทุนการเดินรถตู้ดีเซล แต่ยังมีปัญหาอุปสรรคทั้งทางการเงินและเทคนิคที่ส่งผลกระทบต่อการส่งเสริมการใช้รถตู้ไฟฟ้าในระบบขนส่งสาธารณะ อาทิ มูลค่าการลงทุนที่สูง ข้อจำกัดในการเข้าถึงแหล่งทุน ศักยภาพที่จำกัดของบุคลากรในการบำรุงรักษายานยนต์ไฟฟ้า ซึ่งปัญหาอุปสรรคเหล่านี้ได้อธิบายไว้ในรายงานฉบับสมบูรณ์

รูป 6: ต้นทุนการเดินรถตู้ดีเซล และรถตู้ไฟฟ้าขนาด 11 ที่นั่งและ 20 ที่นั่ง (หน่วย: บาท/กิโลเมตร/ที่นั่ง)

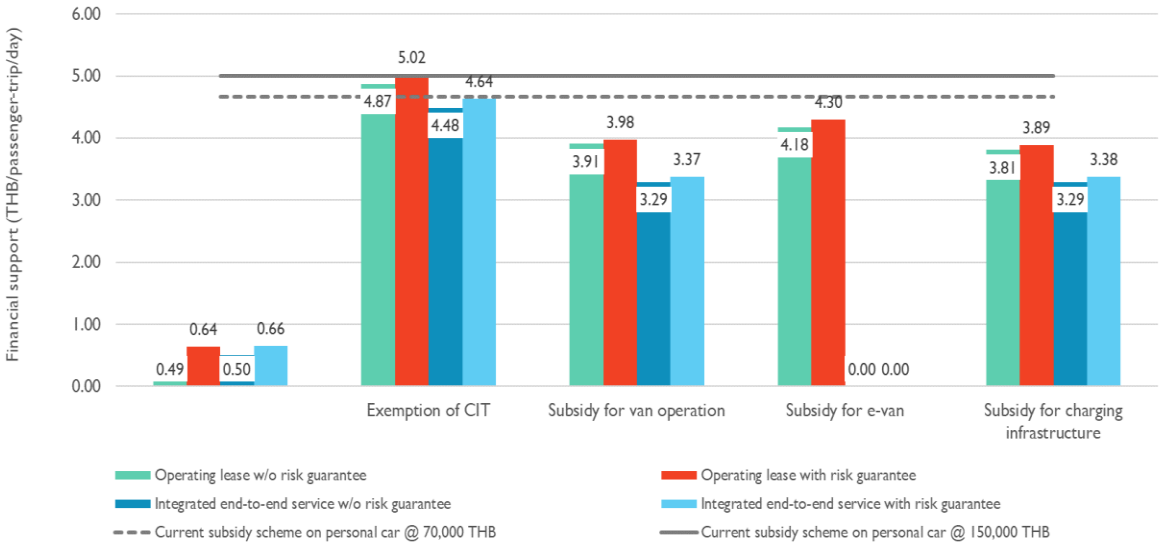


1.10 ข้อเสนอโมเดลธุรกิจและกลไกทางการเงินสำหรับรถตู้โดยสารสาธารณะไฟฟ้าในประเทศไทย

1) รูปแบบการเช่าดำเนินการ (Operating lease model) และรูปแบบการดำเนินการแบบครบวงจรตั้งแต่ต้นทางจนถึงปลายทาง (Integrated end-to-end financing model) ถือเป็นรูปแบบธุรกิจที่มีศักยภาพในการจัดการอุปสรรคที่มีอยู่ของการส่งเสริมรถตู้โดยสารสาธารณะไฟฟ้าในประเทศไทย ซึ่งส่วนใหญ่จะเกี่ยวกับมูลค่าการลงทุนเริ่มแรกที่สูง ความสามารถทางการเงินที่จำกัดในการลงทุนรถโดยสารใหม่ การขาดความสามารถในการบำรุงรักษาและซ่อมแซมรถตู้ไฟฟ้า
2) แบบจำลองกระแสเงินสดส่วนลด (Discounted cash flow) เป็นวิธีที่ใช้ในการประเมินความเป็นไปได้ โดยมีกรอบในการประเมินคือกำหนดมีอัตราผลตอบแทนภายใน (IRR) สำหรับการลงทุนที่ร้อยละ 10 เพื่อจูงใจนักลงทุน อย่างไรก็ตาม จากการประเมินพบว่า มูลค่าปัจจุบันสุทธิของผู้ให้บริการรถตู้นั้นเป็นค่าลบ ดังนั้น จึงจำเป็นต้องมีการสนับสนุนทางการเงินเพิ่มเติม โดยพบว่า ต้องการเงินสนับสนุน จำนวน 269 - 399 ล้านบาท สำหรับการปรับเปลี่ยนเป็นรถตู้โดยสารสาธารณะไฟฟ้า จำนวน 203 คัน ขึ้นอยู่กับรูปแบบธุรกิจและมาตรการสนับสนุนทางการเงิน
3) เมื่อเทียบการให้เงินสนับสนุนสำหรับรถยนต์ไฟฟ้าส่วนบุคคลต่อการเดินทางตลอดอายุ 10 ปี (4.67 – 5.00 บาท/เที่ยว) การใช้เงินเพื่อสนับสนุนสำหรับรถตู้โดยสารสาธารณะไฟฟ้านั้นมีมูลค่ามากกว่า (5.26 – 8.04 บาท/ผู้โดยสาร- การเดินทาง) นอกจากนี้ จำนวนผู้รับผลประโยชน์ตลอดอายุการใช้งาน 10 ปีของรถตู้ไฟฟ้าส่วนบุคคลเท่ากับ 53.84 – 88.09 ล้านผู้โดยสาร-เที่ยว ขณะที่รถตู้โดยสารสาธารณะไฟฟ้ามีผู้โดยสารเพียง 51.16 ล้านผู้โดยสาร-เที่ยวเท่านั้น ดังนั้นการสนับสนุนทางการเงินของรถตู้โดยสารสาธารณะไฟฟ้าภายใต้การวิเคราะห์นี้จึงยังไม่สามารถแข่งขันได้กับรถยนต์ส่วนบุคคล
4) การประเมินเพิ่มเติมแสดงให้เห็นว่าอัตราการสนับสนุนต่อปริมาณการลดก๊าซเรือนกระจกของรถตู้โดยสารสาธารณะไฟฟ้า จำนวน 203 คัน ภายใต้สถานการณ์การสนับสนุนทางการเงินรูปแบบต่างๆ อยู่ที่ประมาณ 589 -

899 USD/tCO_2 ซึ่งถือว่าสูงมาก ซึ่งหากเปรียบเทียบอัตราการสนับสนุนต่อปริมาณการลดก๊าซเรือนกระจกของรถเมล์ไฟฟ้า จำนวน 500 คัน (ประมาณ 160 USD/tCO_2) อัตราการสนับสนุนรถตู้ไฟฟ้าสาธารณะสูงกว่า 3.7 - 5.6 เท่า ซึ่งแสดงให้เห็นว่าการส่งเสริมรถตู้โดยสารสาธารณะควรถูกจัดลำดับหลังจากรถเมล์ไฟฟ้า

รูป 7: เปรียบเทียบเงินสนับสนุนรถตู้ไฟฟ้าที่เสนอกับเงินอุดหนุนสำหรับรถยนต์ไฟฟ้าส่วนบุคคลที่มีอยู่ในปัจจุบัน



1.11 ข้อเสนอแนะการส่งเสริมยานยนต์ไฟฟ้าในรถตู้โดยสารสาธารณะ

1) ผลการวิเคราะห์ทางการเงิน ชี้ให้เห็นว่า การสนับสนุนทางการเงินของรถตู้โดยสารสาธารณะไฟฟ้ายังไม่สามารถแข่งขันได้ ซึ่งอาจเป็นผลมาจากค่าโดยสารรถตู้ที่มีการควบคุม ตลอดจนเส้นทางบริการที่ทับซ้อนกันระหว่างของการขนส่งรูปแบบอื่น ๆ ในกรุงเทพ
2) จากการทบทวนข้อมูลที่ผ่านมา พบว่า การให้บริการรถตู้โดยสารสาธารณะในประเทศไทยกำลังอยู่ภายใต้การปฏิรูป โดยมีการวางแผนเส้นทางใหม่เพื่อจัดการกับปัญหาเส้นทางที่ทับซ้อนกันและจะดำเนินการเปลี่ยนรถตู้เป็นไมโครบัสขนาด 20 ที่นั่งแทน **ดังนั้น การขจัดอุปสรรคด้านกฎระเบียบจึงเป็นเรื่องเร่งด่วนที่สุดสำหรับรถตู้โดยสารสาธารณะ เมื่อมีการปฏิรูปเส้นทางและข้อกำหนดของรถตู้เรียบร้อยแล้ว มาตรการทางการเงินที่เหมาะสมจะช่วยส่งเสริมให้เกิดการลงทุนยานยนต์ไฟฟ้าในรถตู้โดยสารสาธารณะ**

5. แนวทางการส่งเสริมยานยนต์ไฟฟ้าสำหรับรถจักรยานยนต์รับจ้างสาธารณะ

1.12 โครงสร้างตลาดของรถจักรยานยนต์รับจ้างสาธารณะ

1) รถจักรยานยนต์รับจ้างสาธารณะถือเป็นส่วนสำคัญที่เชื่อมต่อชุมชนในพื้นที่ชอยเข้ากับระบบขนส่งสายหลัก นอกจากนั้นแล้ว ยังเป็นทางเลือกของระบบขนส่งสาธารณะสำหรับผู้สัญจรไปมาในช่วงที่การจราจรติดขัดของคนกรุงเทพฯ ในช่วงเวลาเร่งด่วน
2) ในปี พ.ศ. 2563 มีจุดบริการรถจักรยานยนต์รับจ้าง จำนวน 5,564 แห่ง โดยมีผู้ขับขี่รถจักรยานยนต์รับจ้างสาธารณะทั่วกรุงเทพและปริมณฑล จำนวน 84,889 คน โดยรถจักรยานยนต์รับจ้างส่วนใหญ่ที่จดทะเบียนกับ

กรมการขนส่งทางบกใช้แก๊สโซฮอล์ 95 และเบนซินเป็นเชื้อเพลิงหลัก ในขณะที่มีรถจักรยานยนต์รับจ้างเพียง 50 คันเท่านั้นที่เป็นรถจักรยานยนต์ไฟฟ้า

3) ข้อบังคับว่าด้วยการให้บริการรถจักรยานยนต์รับจ้างตามกฎหมายว่าด้วยยานยนต์ (พ.ศ. 2547) บังคับใช้ตั้งแต่วันที่ 11 พฤษภาคม พ.ศ. 2548 ให้สิทธิ์รัฐบาลในการควบคุมมาตรฐานความปลอดภัยและพฤติกรรมของผู้ขับขี่
4) หน่วยงานกำกับดูแลหลัก 3 หน่วยงานหลักที่เกี่ยวข้องกับบริการรถจักรยานยนต์รับจ้าง ได้แก่ กรมการขนส่งทางบก กรุงเทพมหานคร และสำนักงานตำรวจแห่งชาติ
5) คณะกรรมการควบคุมการขนส่งทางบกกลาง ซึ่งมีปลัดกระทรวงคมนาคมเป็นประธาน เป็นผู้กำหนดแนวทางการกำหนดอัตราค่าบริการรถจักรยานยนต์รับจ้าง โดยค่าบริการเริ่มต้นที่ 25 บาท สำหรับ 2 กม.แรก และคิดตามระยะทาง อย่างไรก็ตาม หากระยะทางเกิน 15 กิโลเมตร ผู้โดยสารและผู้ประกอบการอาจเจรจาตกลงค่าโดยสารกันได้

1.13 สถานะทางการเงินและรูปแบบธุรกิจของผู้ประกอบการรถจักรยานยนต์รับจ้างในปัจจุบัน

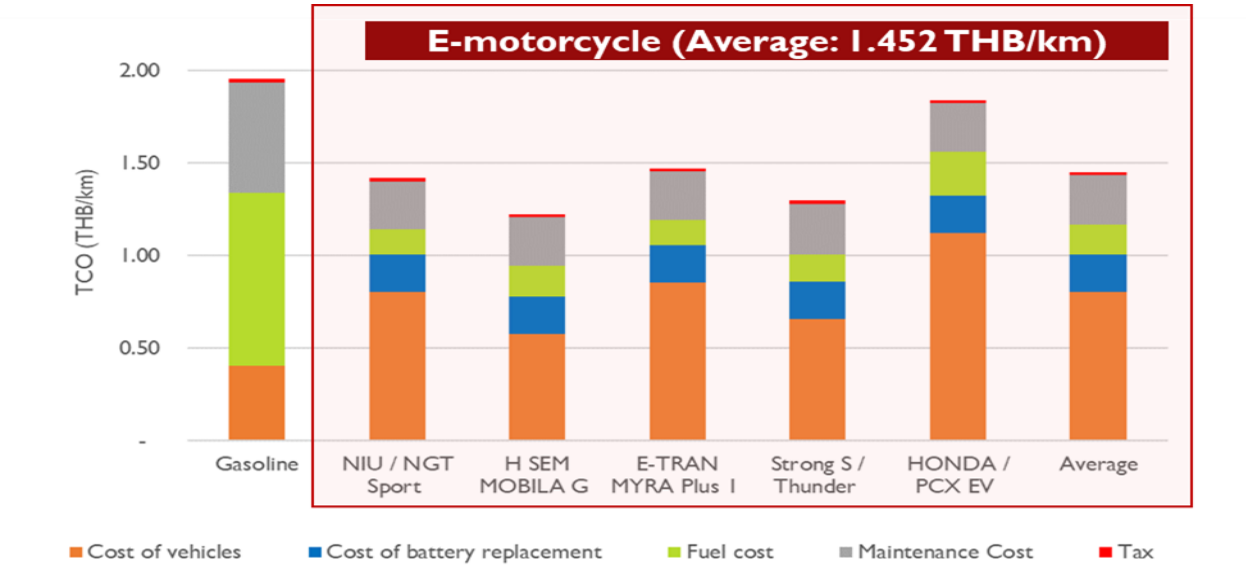
1) ผู้ประกอบการหรือคนขับรถจักรยานยนต์รับจ้างในประเทศไทยจัดเป็นแรงงานอิสระที่มีรายได้ไม่มั่นคง จากการสำรวจ พบว่า รายได้ของผู้ประกอบการรถจักรยานยนต์รับจ้าง อยู่ระหว่าง 300 – 1,000 บาท/วัน หรือโดยเฉลี่ย 620 บาท/วัน ค่าดำเนินการของรถจักรยานยนต์รับจ้าง อยู่ระหว่าง 4,800 – 7,750 บาท/เดือน หรือโดยเฉลี่ย 6,275 บาท/เดือน ซึ่งประกอบด้วย (1) ต้นทุนการเช่าซื้อรถจักรยานยนต์ (2) ค่าน้ำมัน และ (3) ค่าใช้จ่ายอื่นๆ รวมทั้งค่าบำรุงรักษา ค่าประกันภัยและภาษี
2) ผู้ประกอบการรถจักรยานยนต์รับจ้างแต่ละรายเป็นเจ้าของยานพาหนะโดยซื้อขายตรงกับผู้ขายรถจักรยานยนต์ ซึ่งขอสินเชื่อจากธนาคารพาณิชย์หรือบริษัทลีสซิ่งเพื่อผ่อนชำระเป็นงวด ในขณะที่รายได้มาจากค่าบริการ ซึ่งคนขับจะเป็นสมาชิกของกลุ่มผู้ประกอบการรถจักรยานยนต์ท้องถิ่นหรือที่เรียกว่า **วิน** โดยแต่ละวินจะทำงานภายในพื้นที่บริการของตนเองเพื่อป้องกันความขัดแย้งระหว่างวินอื่น ๆ ในการรับผู้โดยสาร ผู้ประกอบการมอเตอร์ไซค์รับจ้างต้องต่อคิวที่วินเพื่อรอรับผู้โดยสาร

1.14 การประเมินความต้องการด้านการเงินและด้านเทคนิคของรถจักรยานยนต์รับจ้างไฟฟ้าและการดำเนินการโครงสร้างพื้นฐานสำหรับการชาร์จรถจักรยานยนต์รับจ้างไฟฟ้าในประเทศไทย

1) ค่าใช้จ่ายการลงทุน (CAPEX) ของรถจักรยานยนต์น้ำมันเบนซินอยู่ที่ประมาณ 54,500 บาท ในขณะที่ต้นทุนเฉลี่ยของรถจักรยานยนต์ไฟฟ้ารวมทั้งค่าเปลี่ยนแบตเตอรี่ ณ สิ้นปีที่ 3 อยู่ที่ 135,975 บาท คิดเป็น 2.49 เท่าของรถจักรยานยนต์ทั่วไป
2) มูลค่าปัจจุบันสุทธิของค่าใช้จ่ายการเดินรถจักรยานยนต์ (OPEX) ที่ใช้น้ำมันเบนซินตลอดอายุการใช้งาน 6 ปี อยู่ที่ 209,546 บาท ในขณะที่มูลค่าปัจจุบันสุทธิของรถจักรยานยนต์ไฟฟ้าจะอยู่ที่ประมาณ 60,283 บาท โดยเฉลี่ยหรือคิดเป็น 29% ของรถจักรยานยนต์ที่ใช้น้ำมันเบนซิน
3) ต้นทุนการเดินรถจักรยานยนต์ไฟฟ้าอยู่ที่ประมาณ 1.452 บาท/กม. ซึ่งต่ำกว่ารถจักรยานยนต์ที่ใช้น้ำมันเบนซิน (1.956 บาท/กม.) สรุปได้ว่า ต้นทุนการเดินรถจักรยานยนต์ไฟฟ้า สามารถแข่งขันได้ เมื่อเทียบกับรถจักรยานยนต์ที่ใช้น้ำมันเบนซิน

รูป 8: ต้นทุนการเดินรถจักรยานยนต์เบนซิน และรถจักรยานยนต์ไฟฟ้า (หน่วย: บาท/กิโลเมตร)

Model / Cost	Gasoline motorcycle	Electric motorcycle model					
		NIU / NGT Sport	H SEM MOBILA G	E-TRAN MYRA Plus I	Strong S / Thunder	HONDA / PCX EV	Average
TCO (THB/km)	1.956	1.420	1.226	1.474	1.300	1.842	1.452



1.15 ข้อเสนอโมเดลธุรกิจและกลไกทางการเงินสำหรับรถจักรยานยนต์รับจ้างไฟฟ้าในประเทศไทย

1) โมเดลธุรกิจปัจจุบันที่ใช้สำหรับรถจักรยานยนต์ไฟฟ้าเป็นรูปแบบการจัดหาเงินทุนแบบครบวงจร (Integrated end-to-end financing model) ที่ประกอบด้วยผู้เล่นหลักสองราย ได้แก่ ผู้ให้บริการ SPV แบบครบวงจร และผู้ประกอบการรถจักรยานยนต์ (หรือคนขับ)
2) กรณีตัวอย่างของ Gogoro ที่ประสบความสำเร็จในไต้หวัน ชี้ให้เห็นว่า **การจัดหาสถานีเปลี่ยนแบตเตอรี่หรืออุปกรณ์ชาร์จเป็นกลยุทธ์ที่สำคัญที่สุดในการส่งเสริมการใช้รถจักรยานยนต์ไฟฟ้าทั่วประเทศ** ซึ่งจะช่วยสร้างความมั่นใจให้กับผู้ขับขี่รถจักรยานยนต์เปลี่ยนมาใช้จักรยานยนต์ไฟฟ้า นอกจากนี้ **การสนับสนุนจากรัฐบาลโดยเฉพาะเงินอุดหนุนการลงทุนถือเป็นปัจจัยที่สำคัญที่สุดในการกระตุ้นการขยายตัวของสถานีเปลี่ยนแบตเตอรี่**
3) ในการวิเคราะห์ทางการเงิน ได้จำลองสถานการณ์ 3 สถานการณ์ โดยได้กำหนดเป้าหมายการส่งเสริมยานยนต์ไฟฟ้าในปี ค.ศ. 2030 หรือ พ.ศ. 2573 เป็น 3 กรณีได้แก่ **กรณีที่ 1** จำนวน 10,000 คัน **กรณีที่ 2** จำนวน 85,000 คันและ**กรณีที่ 3** จำนวน 650,000 คัน จากการประเมินพบว่า การลงทุนรถจักรยานยนต์ไฟฟ้าควบคู่กับสถานีเปลี่ยนแบตเตอรี่มีความคุ้มค่า โดยผลตอบแทนการลงทุนไม่ต่ำกว่า 10% ขณะที่ผู้ประกอบการรถจักรยานยนต์ (หรือคนขับ) สามารถลดค่าใช้จ่ายในการเดินรถได้ปีละ 33,300 – 35,800 บาท/ปี

4) อย่างไรก็ตาม เนื่องจากการลงทุนสถานีเปลี่ยนแบตเตอรี่มีมูลค่าสูงประกอบกับความเสี่ยงอันเนื่องมาจากความไม่แน่นอนของผู้ใช้มอเตอร์ไซค์ไฟฟ้า ดังนั้นจึงจำเป็นต้องมีมาตรการสนับสนุนการขยายเครือข่ายของสถานีเปลี่ยนแบตเตอรี่ ซึ่งจากการประมาณเงินอุดหนุนการลงทุนที่ระดับแตกต่างกันในแต่ละกรณีพบว่า ต้องการเงินอุดหนุนการลงทุน จำนวน 288 ล้านบาท 1,218 ล้านบาท และ 4,419 ล้านบาท สำหรับสถานการณ์จำลองในกรณีที่ 1 2 และ 3 ตามลำดับ
5) ปริมาณการลดการปล่อยก๊าซเรือนกระจกจากการส่งเสริมรถจักรยานยนต์ไฟฟ้าในปี ค.ศ. 2030 หรือ พ.ศ. 2573 อยู่ที่ประมาณ 12,032 tCO_2/ปี 102,270 tCO_2 /ปี และ 782,065 tCO_2/ปี ภายใต้สถานการณ์จำลองในกรณีที่ 1 2 และ 3 ตามลำดับ ทั้งนี้ หากพิจารณาเงินอุดหนุนต่อปริมาณก๊าซเรือนกระจกที่สามารถลดได้ตลอดอายุโครงการเท่ากับ 118.27 USD/tCO_2 71.04 USD/tCO_2 และ 36.78 USD/tCO_2 ภายใต้สถานการณ์จำลองในกรณีที่ 1 2 และ 3 ตามลำดับ

1.16 Roadmap ของการดำเนินงานกลไกทางการเงินสำหรับรถจักรยานยนต์ไฟฟ้ารับจ้างในประเทศไทย

1) โมเดลธุรกิจที่เสนอและการสนับสนุนทางการเงินจากรัฐบาลหรือจากกองทุนสภาพภูมิอากาศระหว่างประเทศสามารถลดอุปสรรคทางการเงินและทางเทคนิคที่สำคัญสำหรับการใช้รถจักรยานยนต์ไฟฟ้ารับจ้างในประเทศไทยไปพร้อมกับการสร้างความเชื่อมั่น มีเพียงอุปสรรคบางประการที่เกี่ยวกับกฎระเบียบ เช่น กระบวนการและระยะเวลาสำหรับการรับรองรถจักรยานยนต์ไฟฟ้าที่ผลิตในประเทศ มาตรฐานที่ไม่ชัดเจนและภาครัฐที่รับผิดชอบในสถานีเปลี่ยนแบตเตอรี่จำเป็นต้องมีการดำเนินการเพิ่มเติมจากหน่วยงานของรัฐ
2) แผนงานสำหรับการดำเนินงานเกี่ยวกับกลไกทางการเงินสำหรับรถโดยสารสาธารณะไฟฟ้าในประเทศไทย แบ่งออกเป็น 2 ระยะ คือ ระยะเตรียมการและขั้นตอนการดำเนินการ ซึ่งทั้งหมดได้แสดงไว้ในรายงานฉบับสมบูรณ์

1.17 ข้อเสนอแนะการส่งเสริมยานยนต์ไฟฟ้าสำหรับรถจักรยานยนต์รับจ้างสาธารณะ

1) โมเดลธุรกิจในปัจจุบันดำเนินการโดยผู้ขายรถจักรยานยนต์ไฟฟ้าเป็นส่วนใหญ่ ซึ่งเป็นรูปแบบการดำเนินการแบบครบวงจรที่ช่วยขจัดอุปสรรคทางการเงินสำหรับการใช้รถจักรยานยนต์ไฟฟ้า อย่างไรก็ตาม การขยายตัวของรถจักรยานยนต์ไฟฟ้ายังคงมีอยู่อย่างจำกัด เป็นผลจากความกังวลของผู้ประกอบการรถจักรยานยนต์รับจ้างในเรื่องความจุของแบตเตอรี่ ประกอบกับสถานีชาร์จหรือสถานีเปลี่ยนแบตเตอรี่ที่มีอยู่อย่างจำกัด
2) การประสบความสำเร็จของ Gogoro ในไต้หวัน พิสูจน์ให้เห็นว่า ความครอบคลุมของสถานีเปลี่ยนแบตเตอรี่หรือสถานที่ชาร์จทั่วทั้งเมืองหรือทั่วประเทศสามารถเสริมสร้างความมั่นใจของผู้ใช้ในการเปลี่ยนไปใช้รถจักรยานยนต์ไฟฟ้า ดังนั้น เพื่อเร่งการขยายตัวของเครือข่าย จำเป็นต้องมีการสนับสนุนทางการลงทุนสถานีเปลี่ยนแบตเตอรี่ ซึ่งไม่เพียงแต่ช่วยสนับสนุนทางการเงินให้กับรถจักรยานยนต์รับจ้างสาธารณะเท่านั้น แต่ยังช่วยประเทศในด้านการส่งเสริมการขนส่งที่เป็นมิตรต่อสภาพอากาศ และช่วยปรับปรุงคุณภาพชีวิตของผู้ประกอบการที่มีรายได้ไม่คงที่อีกด้วย

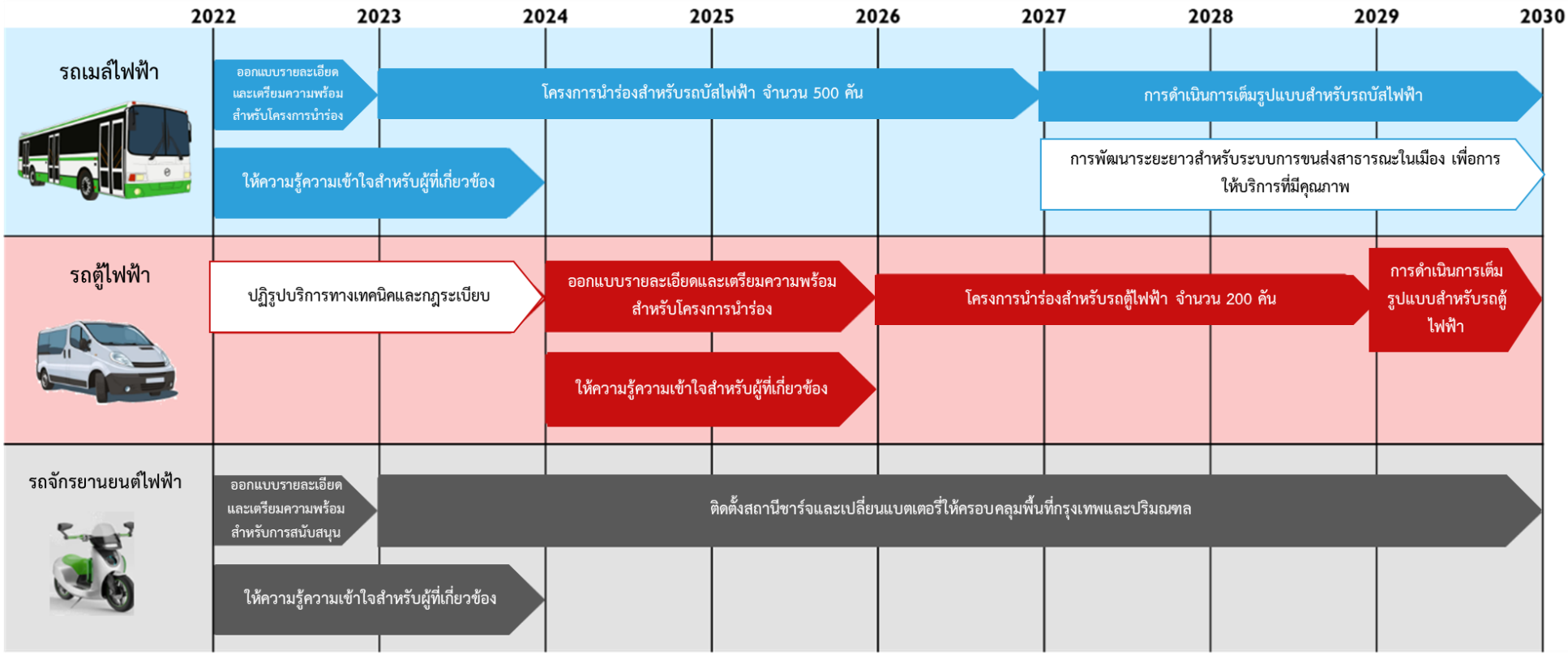
6. บทสรุป

จากการทบทวนข้อมูล การสำรวจภาคสนาม การสัมภาษณ์ผู้มีส่วนได้ส่วนเสีย การจัดประชุมกับผู้ที่เกี่ยวข้อง และการประเมินทางเทคนิคและการเงิน พบว่า ระบบขนส่งสาธารณะ 2 รูปแบบที่พร้อมสำหรับการส่งเสริมยานยนต์ไฟฟ้า ได้แก่ รถเมล์**โดยสารสาธารณะและรถจักรยานยนต์รับจ้าง** ขณะที่รถตู้โดยสารสาธารณะจำเป็นต้องได้รับการปฏิรูปทางเทคนิคและกฎระเบียบก่อนการส่งเสริมยานยนต์ไฟฟ้า

เนื่องจากต้นทุน EV ที่ลดลง ทำให้ต้นทุนรวมในการเดินรถเมล์ไฟฟ้าและรถจักรยานยนต์ไฟฟ้าสามารถแข่งขันได้ เมื่อเทียบกับรถเมล์ดีเซลและรถจักรยานยนต์ที่ใช้น้ำมันเบนซิน อย่างไรก็ตาม อุปสรรคสำคัญในการขับเคลื่อนยานยนต์ไฟฟ้าในระบบขนส่งสาธารณะ ได้แก่ มูลค่าการลงทุนที่สูง ความเสี่ยงในการลงทุนและการเดินรถ และความไม่มั่นใจจากสถาบันการเงิน โดย**รูปแบบการเช่าดำเนินการ และรูปแบบการดำเนินการแบบครบวงจรตั้งแต่ต้นทางจนถึงปลายทาง** ถือเป็นรูปแบบธุรกิจที่มีศักยภาพในการขจัดอุปสรรคที่มีอยู่ของการใช้ยานยนต์ไฟฟ้าในระบบขนส่งสาธารณะในประเทศไทย

การส่งเสริมการเปลี่ยนรถโดยสารสาธารณะที่ใช้น้ำมันดีเซลเป็นรถพลังงานไฟฟ้า จำนวน 3,200 คัน (เทียบเท่าจำนวนรถเมล์ไฟฟ้าที่ ขสมก. กำลังใช้เพื่อทบทวนแผนฟื้นฟูกิจการฯ) นำไปสู่การลดการปล่อยก๊าซเรือนกระจก 275,200 tCO_2/ปี และจำนวนผู้รับผลประโยชน์สูงถึง 7,296 ล้านเที่ยว-ผู้โดยสาร ขณะที่การส่งเสริมรถจักรยานยนต์ไฟฟ้า 85,000 คัน (เทียบเท่าจำนวนผู้ขับขี่รถจักรยานยนต์รับจ้างที่ลงทะเบียนกับกรมการขนส่งทางบกในกรุงเทพมหานคร) จะนำไปสู่การลดการปล่อยก๊าซเรือนกระจก 102,272 tCO_2/ปี โดยที่ผู้ขับขี่รถจักรยานยนต์รับจ้างหรือผู้ประกอบการประมาณ 85,000 ราย สามารถได้รับประโยชน์จากการส่งเสริมดังกล่าวโดยตรง คณะผู้จัดทำเสนอแผนงานการพัฒนาการใช้ยานยนต์ไฟฟ้าในระบบขนส่งสาธารณะ ดังแสดงในรูป

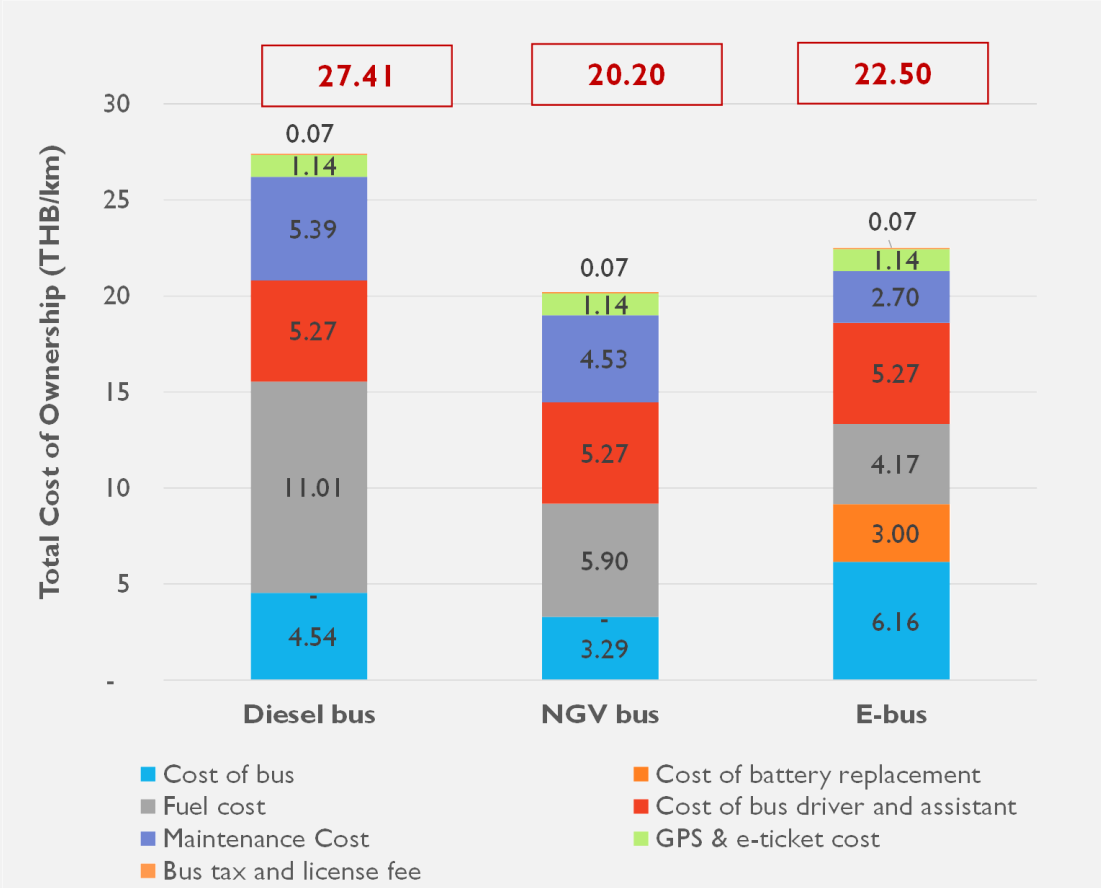
รูป 9: แผนงานการพัฒนาการใช้ยานยนต์ไฟฟ้าในระบบขนส่งสาธารณะ



Executive Summary

Result summary

Bus



- The total cost of ownership (TCO) of an electric bus per distance traveled is 22.50 THB/km which is lower than that of a diesel bus (27.41 THB/km) by 22%.
- The capital expenditure (CAPAX) of a diesel bus is 4.9 million THB which is around half of electric bus's CAPEX. However, the operation expenditure (OPEX) of a diesel bus is 40% higher than that of an electric bus. Although an electric bus has additional cost on battery replacement, the fuel cost of a diesel bus is three times higher than the estimated electricity cost of an electric bus with the same distance travelled.
- The TCO of a NGV Bus is 20.20 THB/km which is around 10% less than that of an electric bus. However, if the NGV price is higher than 20-22 THB/kg and the government subsidy on NGV price is absent, the TCO of an electric bus will be on par with or lower than that of a NGV bus.

Result summary

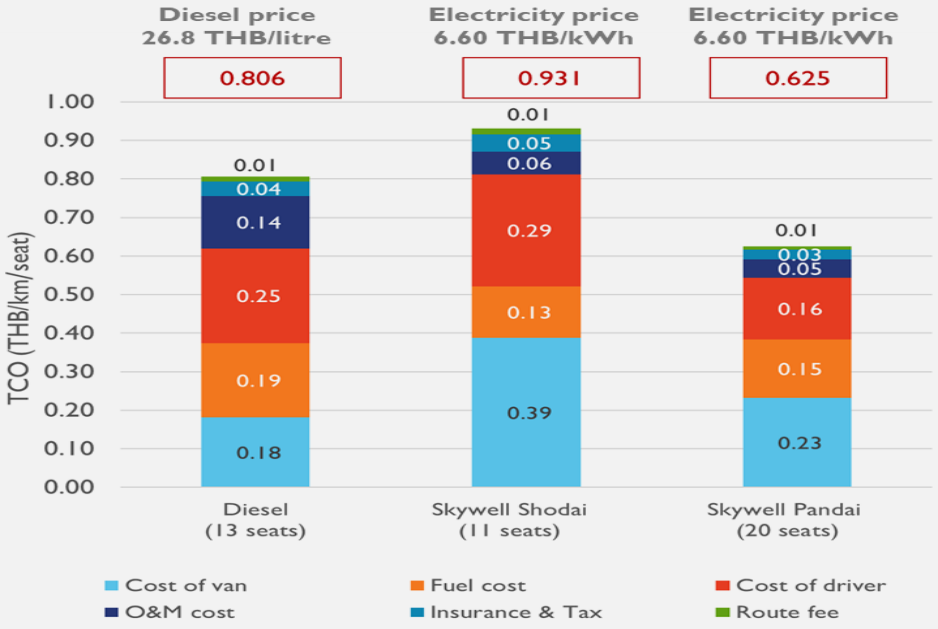
- The study finds that financial supports are still necessary for public bus electrification during the transition to ensure sufficient profit for bus operators as well as to prevent drastic impacts on bus fares and ridership. The investment scenarios and returns are summarized as follows.

	Amount of bus electrification (unit)		
	1	500	3,200 *
Investment on electric bus (million THG)	9	4,450	23,700
Amount of charging socket (socket)	1	313	1,993
Investment on charging socket (million THB)	2.7	650	3,000
Total CAPEX (million THB)	11.7	5,100	26,700
Subsidy needed (million THB)	2.4 - 4	1,300 - 2,000	3,300 – 5,600
Amount of gasoline saved (litre/year)	46,000	23,000,000	147,200,000
Value of gasoline saved (million THB/year)	1.61	805	5,152
Greenhouse gases emission mitigated (tCO_2 /year) in case of replacing diesel buses with electric buses	86	43,000	275,200
Greenhouse gases emission mitigated (tCO_2 /year) in case of replacing NGV buses with electric buses	57	28,750	184,000
Amount of beneficiary (million passenger trip/year)	2.28	1,140	7,296

* BMTA is revising its Rehabilitation Plan to include the procurement of 3,200 electric buses as fleet renewal (https://thainews.prd.go.th/th/news/detail/TCATG220825154840041).

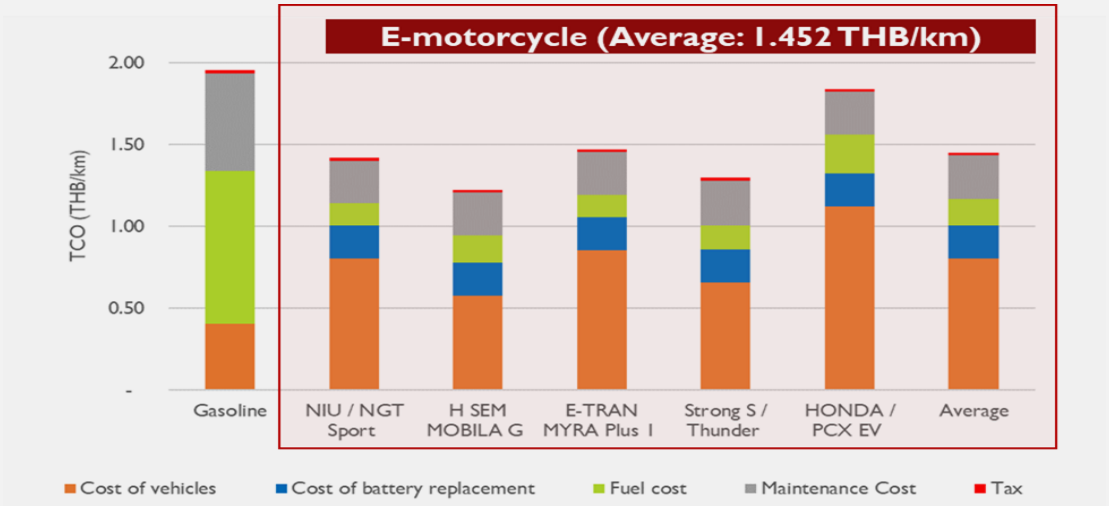
Van

- A market for electric vans is underdeveloped, and available models are not so diverse. Therefore, the 13-passengers vans that are widely used as public fixed-route vans cannot be directly substituted with 11-passengers and 20-passengers electric vans that are currently available in the market.
- The TCO of a 20-passengers electric van (0.625 THB/km/seat) is competitive when comparing to that of a 13-passengers diesel van (0.806 THB/km/seat), but a 11-passengers electric van has a higher TCO (0.931 THB/km/seat) than its diesel counterpart.



Result summary

Motorcycle taxi



- The net present value (NPV) of a gasoline motorcycle's CAPEX and OPEX calculated for a 6-years lifetime is 264,046 THB while that of available electric motorcycles in the market is 196,078 THB averagely or around 74% of its gasoline counterpart.
- The TCO of an electric motorcycle taxi is 1.452 THB/km averagely which is lower than that of a gasoline motorcycle (1.956 THB/km) around 25%. In conclusion, the cost of operating an electric motorcycle taxi is competitive with a conventional one.

	Amount of motorcycle taxi electrification (unit)		
	10,000	85,000 *	650,000 **
Investment on electric motorcycle (million THB)	503	4,276	26,432
Amount of battery (unit)	15,000	127,500	975,000
Amount of battery swapping station (station)	750	6,375	48,750
Investment for battery swapping station (million THB)	960	6,077	44,189
Total investment (million THB)	1,463	10,353	70,621
Subsidy needed (million THB)	288	1,215	4,419
Amount of gasoline saved (litre/year)	7,650,000	65,025,000	497,250,000
Value of gasoline saved (million THB/year)	268	2,276	17,404
Greenhouse gases emission mitigated (tCO2 /year)	12,032	102,272	782,080

* This amount is equivalent to the amount of motorcycle taxi drivers registered with the Department of Land Transport in 2021.

** This amount is equivalent to the amount of targeted electric motorcycle taxi in Thailand's 30@30 plan.

This study finds that electric buses and motorcycle taxis are competitive in comparison to its fossil-fuel counterparts, and the electrification of these two public transport modes has been mature for the blended investment from public and private sector. On the other hand, public van has not yet been ready for the investment, and it is recommended to hold for more clarity on the underway regulatory reform which is expected to majorly affect the van operation.

According to its Nationally Determined Contributions (NDCs), Thailand aims to reduce its greenhouse gas (GHG) emissions by 20%-25% compared to the projected business-as-usual (BAU) level by 2030. Electrification of public transport vehicles is one of the key measures to achieve the GHG emissions reduction targets.

GIZ has been implementing the TRANSfer III project to facilitate ambitious mitigation actions for the transport sector, aiming at supporting developing countries and emerging economies to develop climate-friendly transport environments. The GIZ TRANSfer project is supporting the Office of Transport and Traffic Policy and Planning (OTP) in the "Development on Public Transport Electrification" to identify and develop effective financing and business solutions to upscaling investment in electric public vehicles in Thailand.

The study focuses mainly on three modes of public land transport, including buses, vans, and motorcycle taxi, in the largest metropolitan area, namely the Bangkok Metropolitan Region (BMR), as its road transport sector is most developed and presumably most carbon intensive.

To support the development of public transport electrification in Thailand, a multi-faceted and new approach with practical business models and financing blueprint are very crucial. Four main group of activities including (i) scoping and reviewing situation, (ii) assessing financial and technical needs and challenges, (iii) proposing financing blueprint and mechanisms, and (iv) engaging stakeholders.

Five outputs have been delivered from this study including:

Output 1: Better understanding of existing policy, plan, and situation of public transport electrification, including financial mechanisms for Thai context, including gaps and needs is obtained.

Output 2: Technical and financial needs for public transport electrification of each transport modes, including CAPEX, OPEX, TCOs for various modes and their challenges are assessed.

Output 3: Technology options and abatement costs on public transport electrification and charging infrastructure and potential bottleneck for the implementation are assessed.

Output 4: Policy recommendations to overcome challenges and to enable private and public investment in development on public transport electrification are proposed.

Output 5: A financing blueprint to enhance public and private sector investment in public transport electrification (e.g., financing options, financing conditions, and implementation requirements) is drafted.

The results of the study can be summarized as follows:

1. Global and Regional Trends of Electromobility in Public Transport and Financing Experience

Global sales of electric vehicles have expanded significantly over the last decade and continued increasing sharply in 2022. Based on BloombergNEF's analysis[1], under its EconomicTransition Scenario, where changes are driven by techno-economic trends and market forces, and no new policies are assumed to be enacted, the global sales of electric buses and 2/3 wheelers are expected to reach at 63% and 49% of the total sales for the respective markets by 2030, and 83% by 2040.

[1] https://about.bnef.com/electric-vehicle-outlook/

Meanwhile, the 100% zero-emission vehicle (ZEV) scenario can be achieved by 2050 with proper mitigation supports in place.

The global EV market is fragmentedly developed. While electrification running far ahead in China, Europe, and some smaller markets like Norway, EV adoption remains relatively low in emerging economies. However, spillover effects are expected in emerging economies as the Chinese markets for electric buses and 2/3 wheelers started to saturate.

Three pillars have contributed to the resilience of electromobility against the external shock of the COVID-19 pandemic: 1) supportive regulatory frameworks, 2) additional incentives to safeguard EV sales from the economic downturn, and 3) the expanded number of EV models coupled with a continuous drop in battery cost.

China's experience shows how a strong top-down policy framework coupled with bottom-up actions at municipal level is effective to develop the most successful EV market in the world. **More importantly, it can be observed from local EV promotion policies the intention of depressing private car uses while prioritising electromobility, particularly in public transport.** A variety of policy measures have been adopted by the governments that have been most successful in EV deployment, including but not limited to vehicle emissions regulations, financial incentives, standards on EV chargers, traffic and parking management favourable to EV adopters, etc.

In the ASEAN region, Indonesia is the main competitor for EV production because of its comparative advantage in rich reserves of nickels, the key raw material for batteries. Meanwhile, Singapore is ambitiously expanding EV adoption through a set of demand-driven incentives.

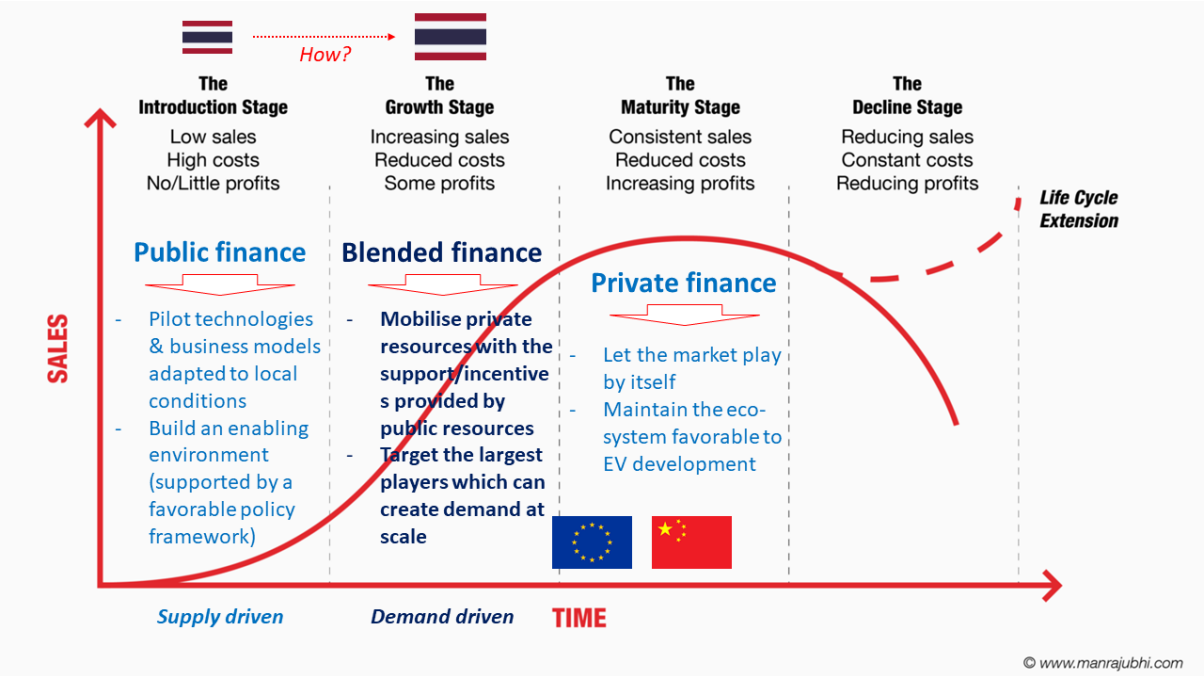
Various forms of financing including public finance, private finance, and blended finance/business models has been adopted for public transport electrification. From India and Hongkong's public finance experiences, governments take the occasion of providing subsidies to trigger a structural reform that will create long-term benefits to the entire sector, as well as encourage R&D and filter the ideal EV technologies adapted to local conditions based on scientific evidence. From UK's private finance experience, a variety of private actors can become finance providers for EV adoption, ranging from financial institutions which offer green lending and leasing to energy product/service providers which offer service-based solutions to sharing financial burden and risk with public transport operators.

From China and Chile's blended finance experience, one may notice that using only public or private resources might be insufficient to scale up EV deployment. In China's case, upfront capital burden is reduced by transforming CAPEX into OPEX through financing leasing. In the meantime, government subsidies further help to reduce the total cost of ownership for electric buses. In Chile's case, the innovative business model that unbundles vehicle ownership and operations successfully allow bus operators to introduce a fleet of 400+ electric buses as the financial burden and investment risk are shared by the energy solution provider. Payment guarantee offered by the government helps to strengthen the risk mitigation mechanism.

Accessing international climate funds remains to be challenging. Several challenges need to be tackled to formulate a meaningful proposal before Thailand can successfully tap into those resources. As Thailand is moving from the introduction stage to the growth stage of the EV market, based on the 4-stage life cycle framework, blended finance which mobilises private resources with public support

is the most appropriate approach to financing the significant amount of investment required to expand the market. In the meantime, the strategy to developing the EV market should be shifted from supply driven to demand driven.

Figure 1: 4-stage life cycle of the EV market



2. Thailand's Policy & Institutional Framework, EV Market Trends Relating to Electromobility

Electromobility has been mostly driven by the policies on economic development and climate change in Thailand. On one hand, as the automotive industry is one of the most important economic sectors in the country, promoting EV manufacturing is a key strategy to enhancing competitiveness of the Thai economy. On the other hand, EV adoption coupled with an energy transition is expected to reduce GHG emissions from road transport, contributing to the country's NDC mitigation targets.

While the NDC action plan for transportation has identified several measures relating to electromobility in public transport, those measures mainly aim for the public vehicles owned by the public operator Bangkok Mass Transit Authority (BMTA), along with a small share of privately-owned vehicles such as vans, taxis, songthaews and delivery motorcycles. However, no financial resources were identified to support electrification of those privately-owned vehicles.

The most directly relevant policy targets on electromobility in Thailand is the EV roadmap and the ZEV 30@30 targets, which aims at reaching 30% of EV production in the total domestic vehicle production by 2030, with a further expansion of 100% EV production by 2035. On the production side, the EV promotion package offered by the Board of Investment (BOI) is the most comprehensive support to EV development in Thailand, which is mainly composed of fiscal incentives to the eligible manufacturers of a variety of vehicles, auto parts, and charging facilities. On the demand side, fiscal benefits are granted to selected types of EVs through subsidy of EV purchase, differentiated reductions in vehicle excise taxes and vehicle registration taxes. The Thai government also sets a 20% target of public budget for vehicle fleet to be used for BEV procurement.

Meanwhile, several supports were identified for charging infrastructure development, standardisation of EV systems and end-of-life management for EV batteries. New EV registrations have been growing in Thailand since 2017, while charging infrastructure is expanded relatively slow. This reflects a chicken-and-egg dilemma where the expansion of chargers will only be feasible when EVs are widely adopted among the population, and vice versa. Meanwhile, most of the growth in EV adoption concerns private passenger cars and motorcycles. Electric buses are marginal.

3. Integrated Assessment of Public Bus Electrification

4. Existing Market Structure of Public Bus Services

a) Public buses contribute to 80% of total commutes by public land transport; however, due to the low quality of buses and poor level of service quality, the majority of bus passengers are people with low income who have limited capacity to switch to other modes.
b) There are 3,786 buses covering 180 routes serving passengers in the Bangkok Metropolitan Region (BMR), as of August 2021. Most of the public buses are deteriorated and not air-conditioned. This causes not only inconvenience for passengers but also high operating costs for the operators.
c) As of 2021, the operators of 3,786 buses can be divided into 3 groups, i.e., (a) BMTA, a state-owned enterprise and a major bus operator, who runs 2,966 buses or 78.3% of total buses in BMR covering 108 routes, (b) private companies with sublicense from BMTA, 196 buses (5.2%), and (c) private companies with direct licenses from Department of Land Transport (DLT), 624 buses (16.5%). However, in the first quarter of 2022, DLT has opened the bidding for the licenses for the bus routes, and it is not yet clear how this would affect the operators.
d) Previously, BMTA was both a regulator and an operator with the authority to sublicense private operators; therefore, there were 2 group of operators, i.e., BMTA and its sublicense companies. This licensing system together with the limited capability of BMTA to control the service quality led to the poor level of service quality. In 2016, the cabinet resolution endorsed the DLT as a regulator and BMTA as a bus operator, aiming to encourage fair competition for all licensed operators as well as to promote delivery of higher performance and better service quality. The reform is undergoing; therefore, some of private companies sublicensed to BMTA still exist. In the long term, all private companies must get licenses directly from DLT so the operators will be divided into 2 groups, i.e., (a) BMTA as a state-owned enterprise and (b) private companies with direct licenses from DLT.
e) The new regulation resolved in 2016 has the mandate over both the quality of buses in service and the standard of service. Approximately 70% of total buses in service must be new or less-than-2-year vehicles and the remaining 30% must be less-than-25-year vehicles.
f) Bus fares are regulated by the government and kept low to ensure that they remain affordable to all commuters especially those with low income. Since the fare is the major source of revenue for the bus operators, the low bus fare forces the operators to minimize their costs; therefore, lowering the service quality for the passengers. The current bus fares are considered highly affordable as per the Sustainable Urban Transport Index (ESCAP, 2017), which implies that they can be adjusted to ensure that the revenues of the bus operators can cover all operating costs of buses as well as allow them to invest in improvement of bus quality and services.

4.1. Financial status and business models of existing bus operators:

a) The assessment of the current financial status of bus operators implies that existing operators, including BMTA and private companies have limited financial capacity. Most of them have been incurring deficits. This can be evidence that the bus fare cannot cover the operating cost of the operators; therefore, results to limited capacity to invest in improvement of bus and service quality. However, there are two new investors from the EV and battery manufacturing sector entering the public bus operation business in deploying electric buses.

b) Business models of three existing groups of bus operators are elaborated. All three groups of operators are owning their own bus fleet, running services, and maintaining their fleet. Only in 2011, BMTA was allowed to rent 117 buses under the performance-based contract which the bus provider provides buses and maintenance services. The operating cost incurred to the operators covers fuel cost, employee wages and benefits, and other costs such as cost of ticket, license fee, etc. while the revenues of the operators mainly come from bus fares. Only BMTA has received subsidies from the government.

4.2. Financial and technical needs assessment of bus fleet electrification and charging infrastructure deployment in Thailand

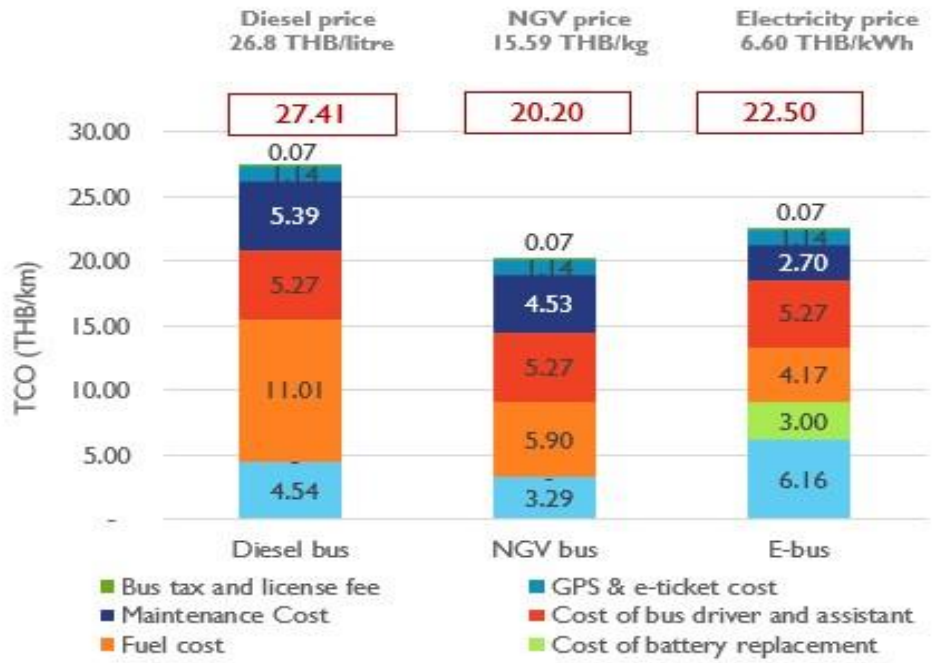
a) The CAPEX of a diesel bus is 4,900,000 THB and that of a NGV bus is 3,600,000 THB, while the CAPEX of an electric bus including battery replacement on the 7th year of operation is 9,000,660 THB. Compared to the CAPEX of a diesel bus, the CAPEX of an NGV bus is 17% lower while that of an electric bus is 102% higher. The total OPEX of a diesel bus is the highest at 2,619,500 THB while that of an NGV bus and an e-bus are 1,964,625 THB and 1,519,310 THB accounting for 75% and 58% of the diesel-bus OPEX, respectively.

b) The TCO of an e-bus is about 22.50 THB/km which is lower than that of a diesel bus (27.41 THB/km) by 22% but higher than that of an NGV bus (20.20 THB/km) by 10%. It can be concluded that the TCO of an e-bus is competitive, compared to that of a diesel bus but not as attractive when compared to an NGV bus. During the beginning of 2022, when natural gas prices continued to rise and the price of NGV without subsidies from the government would have reached 20-22 baht/ kilogram, the TCO of an NGV bus is equivalent to that of an e-bus. However, an e-bus requires higher upfront cost than both a diesel bus and an NGV bus.

c) The TCO of all types of buses changes the largest with the annual distance. Since OPEX during year 1 – year 15 of a diesel bus and an NGV bus are so large that the total NPV of OPEX is almost 80% of the NPV of the total cost, the parameter causing the second largest impact on the change of the TCO of a diesel bus and an NGV bus is the discount rate, followed by cost of bus, fuel cost, maintenance cost, and inflation rate. For an e-bus, the parameter having the second largest impact on the change of its TCO is the cost of bus followed by the discount rate, cost of battery replacement, fuel cost maintenance cost, and inflation rate.

d) The financial and technical challenges categorized by 3 groups of key stakeholders are illustrated in the final report.

Figure 2: Total cost of ownership of public bus operation and maintenance



4.3. Proposed business models and financial mechanisms for public bus electrification in Thailand

a) The operating lease model and integrated end-to-end financing model are considered as potential business models to overcome the existing barriers to public bus electrification in Thailand, mainly regarding the high upfront cost, limited financial capacity to invest new buses, lack of skilled capacity to maintain and repair e-buses.

b) Discounted cash flow models were applied for assessment of feasibility. To attract investors, the 10% IRR is set as a threshold for the return of all players. However, since the fare is the major source of revenue for the bus operators, the current level of bus fares cannot make the bus electrification feasible. Additional financial supports either the government or international sources are needed with the size of 1,303 – 1,983 million THB for making the electrification of 500 public buses feasible depending on the business model selected and the financial options provided.

c) Compared to the existing subsidy scheme for electric personal cars per passenger-trip over the 15-year lifetime (3.11 - 3.33 THB/passenger-trip), the support needed for public bus electrification is smaller (highest at 2.32 THB/passenger-trip). Moreover, the amount of funding required to support the electrification of 500 buses (1,303 – 1,983 million THB) can support about 18,600 – 28,300 electric passenger cars, from which the number of beneficiaries is approximately 510 – 776 million passenger-trips. However, the number of beneficiaries of 500 public buses is 1,140 million passenger-trips, or approximately 1.47 – 2.24 times the number of beneficiaries from promoting electric passenger cars.

d) Further assessment shows that the GHG emission reduction from the electrification of 500 buses is about 43,091 tCO2/year. The support needed for 500-public-bus electrification in all scenarios per the amount of GHG abatement are less than 160 USD/tCO2. The government can use this estimated support per ton of GHG abatement as a reference to compare with

the cost required to support other NDC measures for incentivizing low carbon investment to prioritize public finance support.

Figure 3: Operating lease model

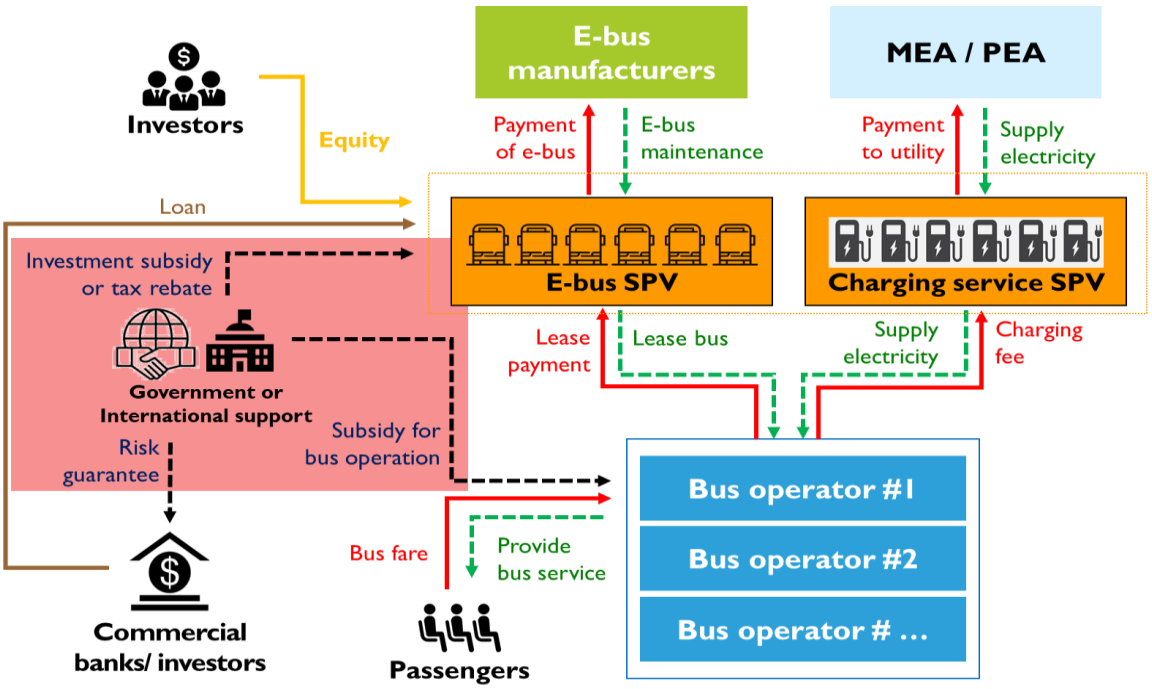


Figure 4: Integrated end-to-end financing model

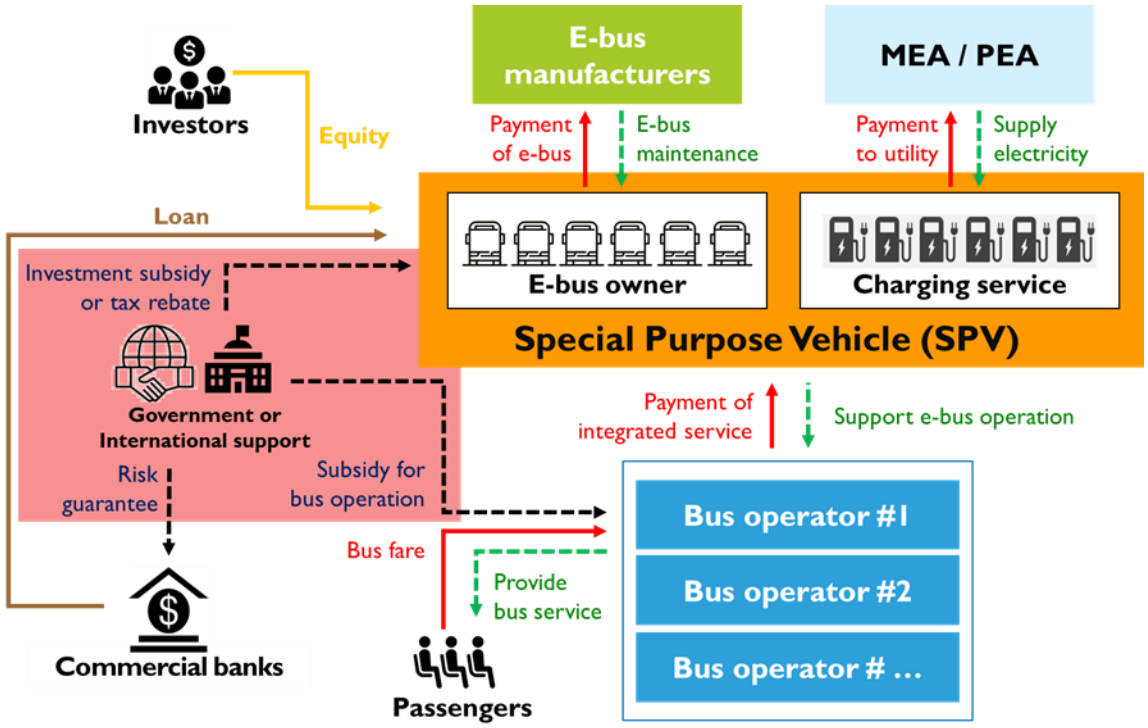


Figure 5: Comparison between the amount of funding to support public bus electrification through the proposed business models and the existing subsidy scheme for electric personal cars

4.4. Roadmap of operationalising financial mechanisms for public bus electrification in Thailand

a) The proposed business model as well as the various financial options can remove the key financial barriers especially those for bus operators including high upfront costs, limited financial capacity, and lack of skilled capacity to maintain and repair e-buses. However, some barriers still exist, and further actions related to government policies addressed in the report are needed.

b) The roadmap for operationalising financial mechanisms for public bus electrification in Thailand requires a three-phase approach, divided into a preparation phase, a piloting phase, and a full implementation phase.

4.5. Recommendations for public bus electrification in Thailand

a) Upgrading the public bus service to become everyone's choice should be the national agenda to reduce traffic congestion and air pollution, to improve the quality of life of citizens in Thailand. To upgrade the public bus service, replacement of new buses, improvement of service standard, and fair adjustment of bus fares are needed.

b) Public bus electrification can be one of the promising solutions for upgrading the public bus service in Thailand. The business models and financial supports are illustrated in the full report.

c) However, the provision of financial supports proposed in this report will allow the modernized public bus service last for 15 years. The long-term development of public transport to remove overlapping routes and improve service quality especially the adoption of new management model for bus operators is crucial for the sustainability of modernised public bus service.

5. Integrated Assessment of Public Van Electrification

6. Existing Market Structure of Public Van Services

a) Among the public transport, public van contributed to 4% of total commutes by public land transport or 142.4 million people-trips/year. In 2019, the number of public van passengers declined from that of 2018 around 30%. This is caused by a decrease in the number of vans (18%) and overlapping between new sky train routes and existing van routes; therefore, some passengers switch to the sky train (BTS).

b) According to the DLT's statistics, there were 13,049 fixed-route public vans registered nationwide in 2019 while BMTA reported that 3,705 public vans provided services covering 147 routes in BMR. There was a decreasing trend of public vans serving in BMR areas since 2015 due to the new regulation prescribing the lifetime of public van and the expiration of licenses by 2022. Most of the existing public vans are diesel vans due to the lower upfront cost compared to the NGV vans.

c) The government has enforced public van regulations under the Land Transport Act since 1999 to set the service standard for the safety of passengers, and to eliminate the competition between vans and buses. Public vans have been regulated by the Land Transport Policy Commission. DLT has played a role as a regulator to supervise and control fixed-route van operations, stipulate service standards of public vans. BMTA has been the only operator granted licenses for operating public vans serving fixed routes in BMR and has been allowed to sub-contract to private operators.

d) In 2019, the cabinet resolved the policy to reform the public land transport system. Until now, the plan to reform public van service including revision of service routes and replacement of 20-seat microbuses is still being developed. DLT will become the regulator stipulating the service standard and granting licenses to van operators.

e) As of 30 September 2019, public vans under BMTA's licences provided services covering 147 routes in BMR. The distance of these routes range between 8 - 67 km.

f) The fares of the public vans depend mainly on the distance of van route with the minimum of 15 THB/passenger-trip. The fares of public van in BMR range 15-62 THB/passenger-trip.

6.1. Financial status and business models of existing van operators:

a) Most public van operators, sub-contracted with BMTA and serving people in Bangkok and the metropolitan area, are small private operators. Net income of a van operator is about 25,000 - 35,000 THB/month while the operating cost is around 62,775 THB/month, covering fuel cost, cost of van, maintenance cost, insurance, tax, route fee, and parking fee.

b) The existing business model of public van operators can be described as follow. Public van operators, which are sub-contractors of BMTA, providing services to passengers. Their revenues come from fare collection without any support from the government. The operators must pay the route fee to BMTA and provide services according to the standards set by DLT. The van manufacturers and the oil companies are the key suppliers for van operators whereas the commercial banks provide loans for acquisition cost of vans so that van operators can reimburse on the monthly basis.

6.2. Financial and technical needs assessment of van fleet electrification and charging infrastructure deployment in Thailand

a) The CAPEX of a 13-seat diesel van is about 1,269,000 THB while the CAPEX of a 11-seat electric van and a 20-seat electric van are about 2,300,000 THB and 2,500,000 THB, respectively.

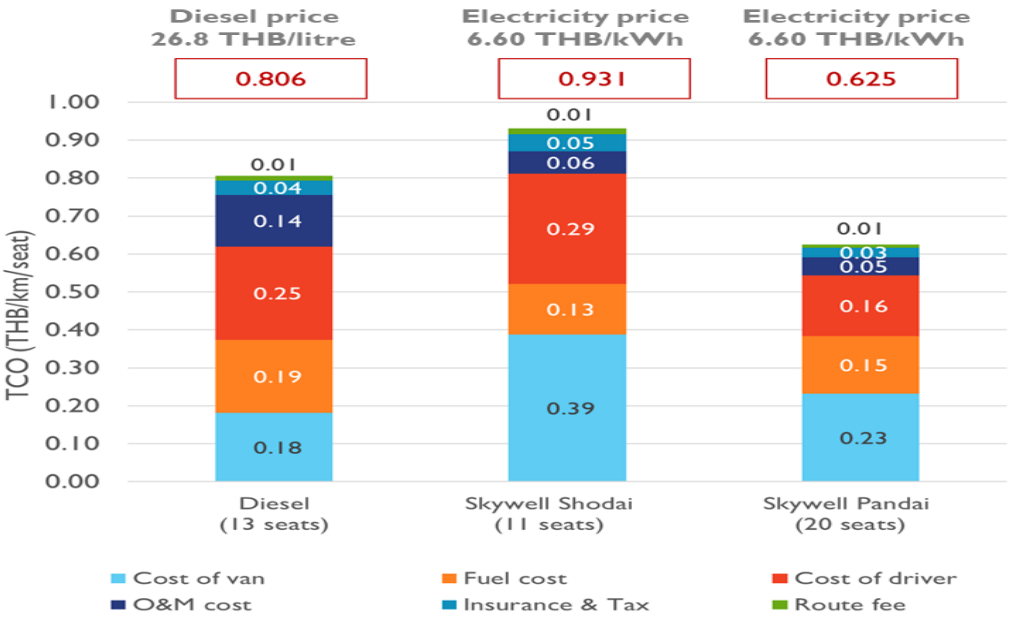
b) The total NPV of OPEX of a 13-seat diesel van over its 10-year lifetime is at 4,391,460 THB while that of a 11-seat electric van and a 20-seat electric van is 3,227,712 THB and 4,247,190 THB, accounting for 74% and 97% of the total NPV of OPEX of a 13-seat diesel van.

c) Comparing to the total cost of ownership per passenger seat of a 13-seat diesel van (0.806 THB/km/seat), the TCO of a 20-seat electric van (0.625 THB/km/seat) is considered competitive; however, that of a 11-seat electric van (0.931 THB/km/seat) is still higher than that of a 13-seat diesel van.

d) The change in distance has the greatest impact on TCO of all types of vans, especially on the TCO of an 11-seats electric van (9.5%). The discount rate has the second largest impact on the TCO of a 13-seat diesel van due to the relatively high share of its OPEX. For both electric vans, the acquisition cost of a van is the second largest factor impacting on its TCO since CAPEX shares 41.6% of its TCO.

e) The financial and technical challenges grouped by key stakeholders into 3 groups, covering the technical and financial dimensions are addressed in the report.

Figure 6: TCO of public van operation and maintenance (THB/km/seat)



6.3. Proposed business models and financial mechanisms for public van electrification in Thailand

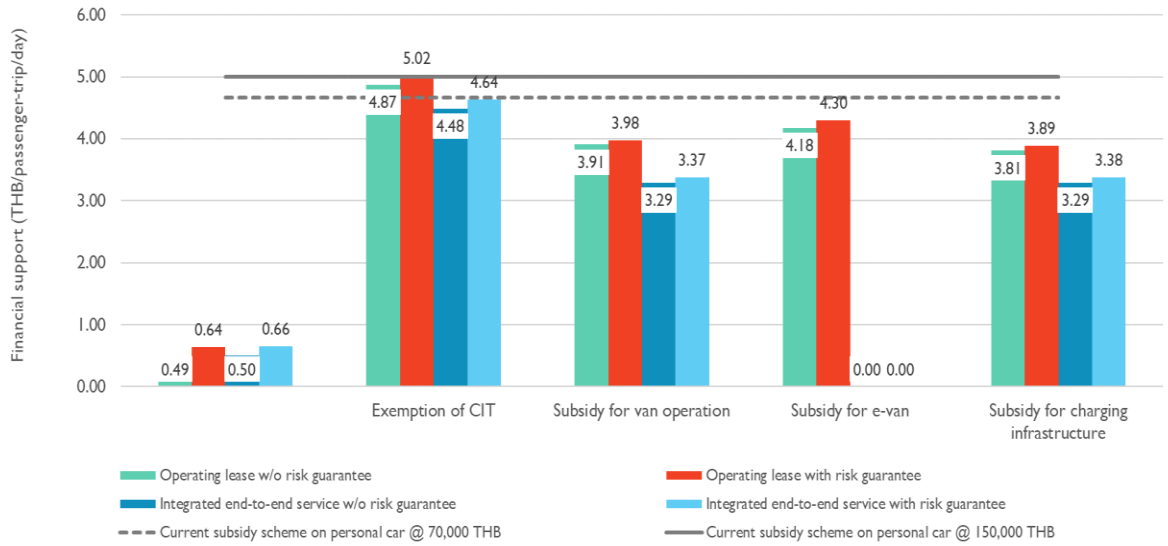
a) The operating lease model and integrated end-to-end financing model are considered as potential business models to overcome the existing barriers to public van electrification in Thailand, mainly regarding the high upfront cost, limited financial capacity to invest new buses, lack of skilled workforce to maintain and repair electric vans.

b) To attract investors, the 10% IRR is set as a threshold for the return of all players. However, the assessment shows that the NPV of the van operator SPV is negative; therefore, additional financial support is needed. The funds with the size of 269 - 399 million THB are needed for making the electrification of 203 public vans feasible depending on the business model and the financial option selected.

c) Compared to the existing subsidy scheme for electric personal cars per passenger-trip over the 10-year lifetime (4.67 – 5.00 THB/passenger-trip), the support needed for public van electrification is larger (5.26 – 8.04 THB/passenger-trip). Moreover, the number of beneficiaries over 10-year lifetime of a personal car is 53.84 – 88.09 million passenger-trips while that of a public van is only 51.16 million passenger-trips. Therefore, the financial support of public van electrification under this analysis is not competitive.

d) Further assessment shows that the support needed for 203-public-van electrification per the amount of GHG abatement under four scenarios ranges 589 - 899 USD/tCO_2, which is considered substantially high. Compared to the support needed for 500-public-bus electrification per the amount of GHG abatement (less than 160 USD/tCO_2), the support needed for 203-public-van electrification per the amount of GHG abatement is about 36-56 times higher; therefore, the public van electrification is less of a priority.

Figure 7: Comparison between the amount of funding to support public van electrification through the proposed business models and the existing subsidy scheme for electric personal cars (over 10-year lifetime)



6.4. Recommendations for public van electrification in Thailand

a) The financial analysis above implies that the financial support of public van electrification is not competitive, which may result from the regulated van fare as well as the overlapping of service routes among public land transport in Bangkok.

b) The review on the public van regulation demonstrates that the public van service in Thailand is under the reform. New route system to deal with the overlapping route problem will be applied and replacement of a 20-seat microbus will be executed. **Therefore, the removal of regulatory barriers is the most urgent to deal with for the public van**

electrification. Once the regulatory barriers are removed, the appropriate financial supports will allow the investment in public van electrification.

7. Integrated Assessment of Motorcycle Taxi Electrification

8. Existing Market Structure of Motorcycle Taxi Services

a) A motorcycle taxi is an important part of the feeder systems connecting local communities in the narrow streets branching off major streets to the main public transport network. They also become the choice of public transport for commuters to beat Bangkok's perpetual traffic jams during rush hour.
b) In 2020, there were 5,564 motorcycle taxi stations with 84,889 motorcycle taxi drivers around the Bangkok Metropolitan Region.
c) Most of the motorcycle taxis registered with DLT use Gasohol 95 and Gasoline as fuels while only 50 motorcycle taxis were electric vehicles.
d) Enforced from 11 May 2005, was the regulation on motorcycle taxi service under the Motor Vehicle Act (Year 2004), entitling the government to control safety standards and driver behavior.
e) Three key regulatory bodies involved in the motorcycle taxi services are DLT, the Bangkok Metropolitan Administration (BMA), and the Royal Thai Police.
f) CLTCB chaired by the Permanent Secretary of the Ministry of Transport sets the guideline for setting the fare for motorcycle taxi services. The service fees start at 25 baht for the first 2 km and are charged according to distance. However, if the distance is longer than 15 kilometers, the passenger and the operator may negotiate and settle the fare.

8.1. Financial status and business models of existing motorcycle taxi operators

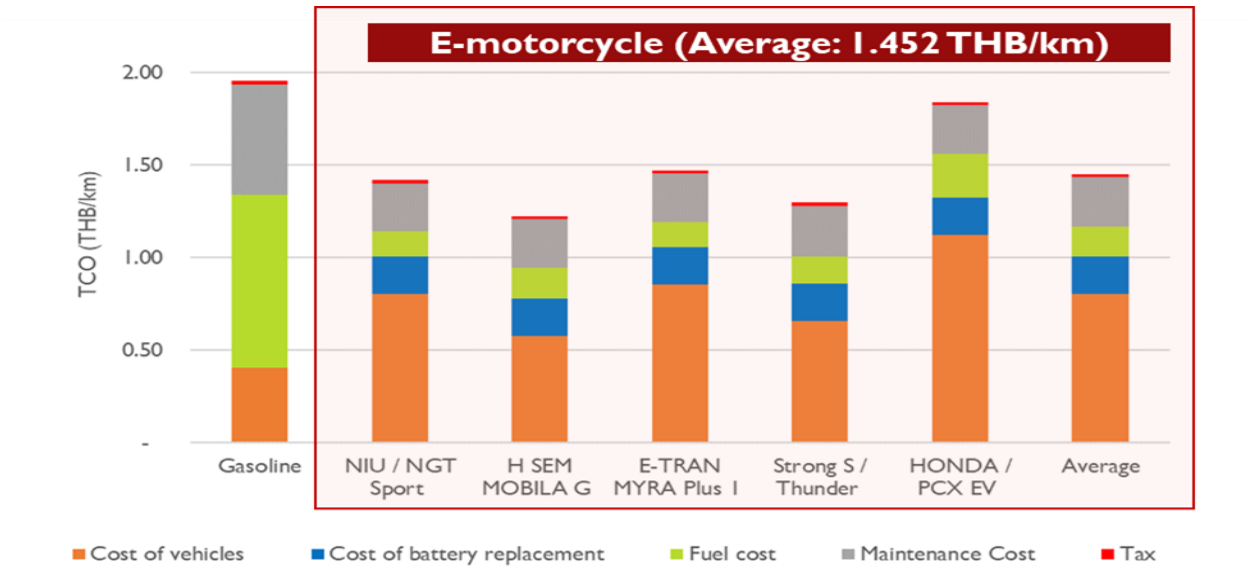
a) Motorcycle taxi operators or drivers in Thailand are classified as independent workers that have unstable incomes. According to a field survey, the revenues of the motorcycle taxi operators range between 300 – 1,000 THB/day with an average of 620 THB/day. The operating cost of a motorcycle taxi ranges between 4,800 – 7,750 THB/month with an average of 6,275 THB/month, covering (1) cost of a motorcycle, (2) fuel cost, (3) other costs including maintenance cost, insurance, and tax.
b) Motorcycle taxi operators individually own their vehicles and pay for the cost directly to suppliers or vendors while revenues come directly from service charges to passengers. Most drivers apply for loans from commercial banks or leasing companies to cover the cost of the motorcycle and pay back in instalments. Drivers are a member of a local operating group called Win, indicating the organization of the motorcycle taxis and the location of their stations. Each Win operates within its own service area to prevent conflicts among other Wins. The motorcycle taxi operators must queue in their own Wins to wait to pick up passengers.

8.2. Financial assessment of electric motorcycle operation and maintenance

a) The CAPEX of gasoline motorcycle is approximately 54,500 THB while the average capital cost of an e-motorcycle including the cost of battery replacement at the end of year 3 is 135,795 THB, accounting 2.49 times of the CAPEX of a conventional motorcycle.
b) The total NPV of the OPEX of a gasoline motorcycle over its 6-year lifetime is at 209,546 THB while that of an e-motorcycle is an average of 60,283 THB, or approximately 71% less than that of gasoline motorcycle.
c) The TCO of an e-motorcycle is approximately 1.452 THB/km which is lower than that of a gasoline motorcycle (1.956 THB/km). It can be concluded that the TCO of an e-motorcycle is competitive, comparing to that of a gasoline motorcycle.
d) The financial and technical challenges are categorized by key stakeholders into 3 groups, covering the technical and financial dimensions are illustrated in this chapter.

Figure 8: TCO of public motorcycle taxi operation and maintenance (THB/km)

Model / Cost	Gasoline motorcycle	Electric motorcycle model					
		NIU / NGT Sport	H SEM MOBILA G	E-TRAN MYRA Plus I	Strong S / Thunder	HONDA / PCX EV	Average
TCO (THB/km)	1.956	1.420	1.226	1.474	1.300	1.842	1.452



8.3. Proposed business models and financial mechanisms for motorcycle taxi electrification in Thailand

a) The current business model applied for electric motorcycle is an integrated end-to-end financing model comprising two key players: an integrated end-to-end service SPV and a motorcycle taxi operator (or driver).
b) The successful case of Gogoro in Taiwan implies that **the provision of battery swapping stations (BSS) or charging facilities is the most crucial strategy to promote the deployment of e-motorcycles nationwide.** This strengthens the confidence of the users in changing to electric vehicles**. Moreover, the support from the government,**

especially subsidy on the investment of BSS is the most essential factor stimulating the expansion of the network.

c) The financial assessment of the business model was conducted for three scenarios with different assumptions on expansion of e-motorcycle taxis and BSS. Scenario I, scenario II, and scenario III are targeted to promote 10,000 e-motorcycles, 85,000 e-motorcycles, and 650,000 e-motorcycles within 2030, respectively. The analysis shows that the investment of e-motorcycles and BSS is feasible in all scenarios, i.e., the IRR of NPV reaches 10% and the operators can save about 33,300 – 35,800 THB/year.

d) However, it requires high investment cost for BSS in the early years and the SPV is facing risks on uncertain demand; therefore, the support is needed to promote the expansion of BSS network. Different level of investment subsidies has been evaluated and a subsidy of 288 million THB, 1,215 million THB, and 4,419 million THB are needed for the investment of BSS under scenario I, scenario II, and scenario III, respectively.

e) Further assessment shows that the annual GHG emission reductions in the target year of 2030 are approximately 12,032 tCO2/year, 102,270 tCO2/year, and 782,065 tCO2/year, under scenario I, scenario II, and scenario III, respectively. The costs of different support levels per the amount of GHG abatement are 118.27 USD/tCO2, 71.04 USD/tCO2, 36.78 USD/tCO2, under scenario I, scenario II, and scenario III, respectively.

8.4. Roadmap of operationalising financial mechanisms for motorcycle taxi electrification in Thailand

a) The proposed business models and the financial support from the government or from the international climate fund on the investment of BSS expansion can remove the key financial and technical barriers for motorcycle taxi electrification in Thailand along with to build confidence in technologies. Some regulatory barriers, e.g., the timely process for local certification of e-motorcycle, the unclear standard and in-charge public sector on battery swapping stations need further actions from government agencies.

b) The roadmap for operationalising financial mechanisms for public motorcycle taxi electrification in Thailand, dividing into two phases, i.e., the preparation phase and the full implementation phases is developed and illustrated in the report.

8.5. Recommendation for motorcycle taxi electrification in Thailand

a) The current business model run by most e-motorcycle suppliers is an integrated end-to-end financing model removing the financial barriers for motorcycle taxi electrification; however, the expansion of e-motorcycle is still limited. This results from the motorcycle taxi operators' concern on the capacity of batteries together with the limited availability of charging stations or battery swapping stations.

b) The review of a successful model of Gogoro in Taiwan proves that the coverage of battery swapping stations or charging facilities citywide or nationwide can strengthen the confidence of the users in changing to electric vehicles. To accelerate the expansion of BSS network, the financial support especially through subsidies on the investment of BSS is needed. The financial support for motorcycle taxi electrification will not only help Thailand to foster climate-friendly transport but also to improve the quality of life for those operators with unstable incomes.

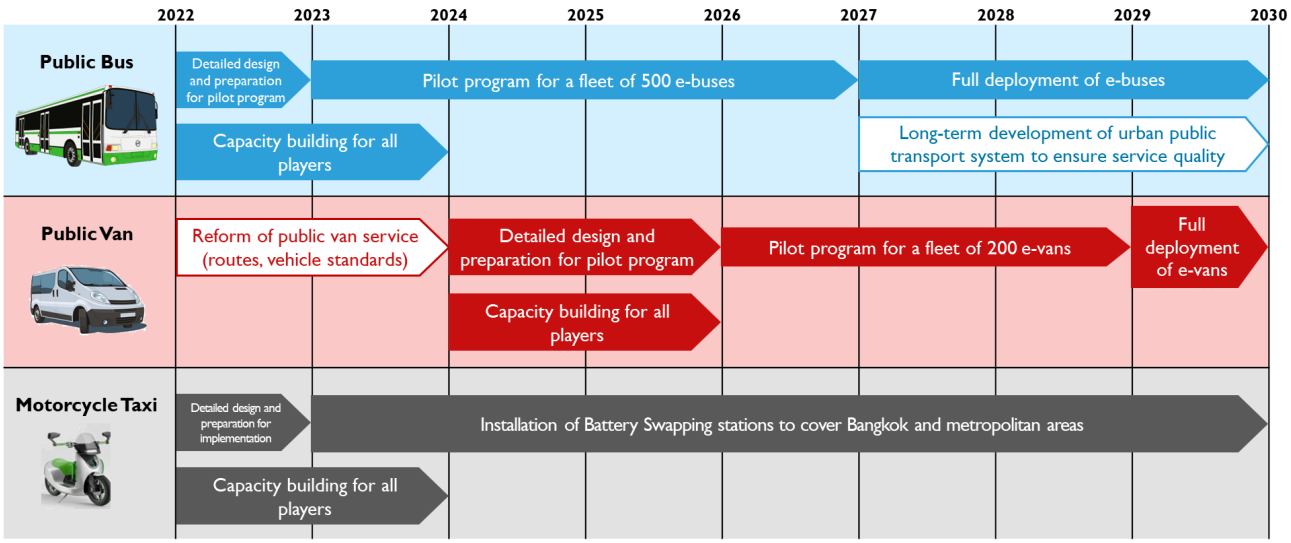
9. Conclusion

Through the process of desk reviews, field surveys, stakeholder interviews and focus group consultations, as well as technical and financial assessment, it is recommended that two modes of public transportation which are ready for electrification are public buses and motorcycle taxis while the electrification of public vans requires technical and regulatory reform of their service.

Due to the decreasing cost of EV, the total cost of ownership of an e-bus as well as an e-motorcycle is competitive, compared to that of a diesel bus and a gasoline motorcycle. However, key barriers to electrification of public fleets include the high upfront cost, the cross-chain risk, the lack of confidence from financial institutions. The operating lease model and the integrated end-to-end financing model are considered as potential business models to overcome the existing barriers to public bus electrification in Thailand while the integrated end-to-end financing model is applicable for motorcycle electrification.

The electrification of 500 public buses leads to 43,091 tCO_2/year GHG emission reductions and the number of beneficiaries is up to 1,140 million passenger-trips while the promotion of 10,000 e-motorcycles will lead to the annual GHG emission reductions of 12,032 tCO_2 and about 10,000 motorcycle taxi drivers or operators can benefit from the program.

The roadmap for development on public land transport electrification is as shown in the figure below:



TRANSfer III Project:

Development on Public Transport Electrification in Bangkok, Thailand

Full Report

1. Introduction

Chapter Objective:
To provide the information on the background, objective, scope, key approach, and outputs of the study

Summary:

1. According to its Nationally Determined Contributions (NDCs), Thailand aims to reduce its greenhouse gas (GHG) emissions by 20%-25% compared to the projected business-as-usual (BAU) level by 2030. Electrification of public transport vehicles is one of the key measures to achieve the GHG emissions reduction targets.
2. GIZ has been implementing the TRANSfer III project to facilitate ambitious mitigation actions for the transport sector, aiming at supporting developing countries and emerging economies to develop climate-friendly transport environments.
3. The GIZ TRANSfer project is supporting the Office of Transport and Traffic Policy and Planning (OTP) in the "Development on Public Transport Electrification" to identify and develop effective financing and business solutions to upscaling investment in electric public vehicles in Thailand.
4. The study focuses mainly on three modes of public land transport, including bus, van and motorcycle taxi, in the largest metropolitan area, namely the Bangkok Metropolitan Region (BMR), as its road transport sector is most developed and presumably most carbon intensified.
5. To support the development of public transport electrification in Thailand, a multi-faceted and new approach with practical business models and financing blueprint are very crucial. Four main group of activities including (i) scoping and reviewing situation, (ii) assessing financial and technical needs and challenges, (iii) proposing financing blueprint and mechanisms, and (iv) engaging stakeholders.
6. Five outputs from this study will be illustrated in the next five chapters.

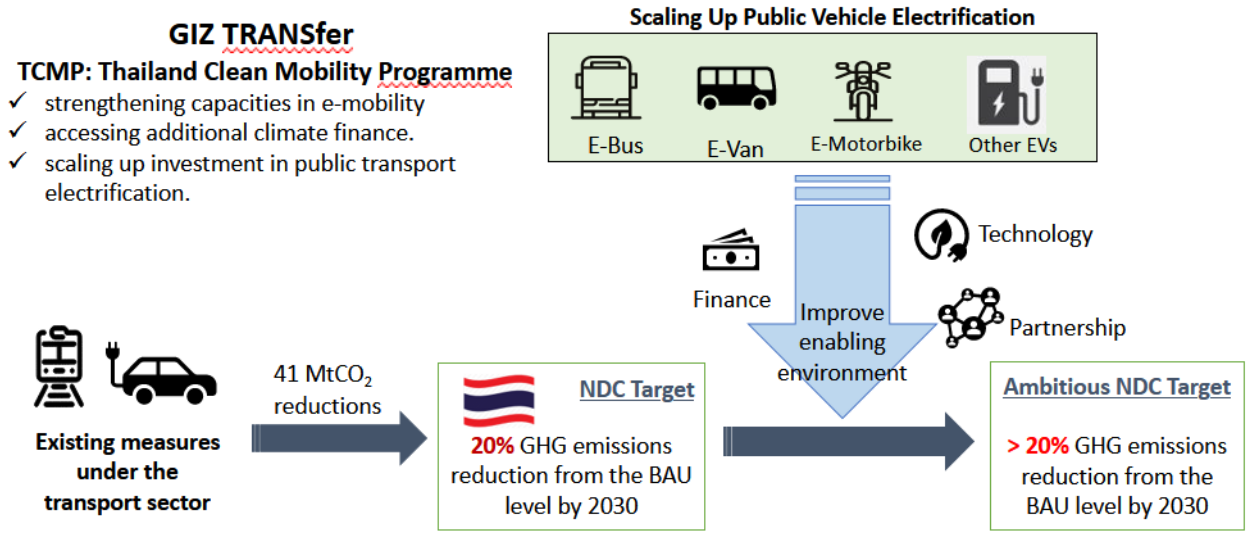
1.1 Background

Thailand aims to reduce its greenhouse gas (GHG) emissions by 20%-25% compared to the projected business-as-usual (BAU) level by 2030. These targets were established in its Nationally Determined Contributions (NDCs) under the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC). To achieve these targets, electrification of public transport vehicles is one of the key measures to reduce GHG emissions and air pollution in Thai cities, given that road transport accounts for the highest CO2 emissions of the whole transport sector. To promote electromobility in Thailand, the National EV Policy Committee has recently announced a master plan aiming for 100% of the vehicles produced in Thailand to be electric by 2035. The plan also targets 50% of the country's total vehicle production to be EVs by 2030. This plan provides a clear direction for the EV market in the country.

The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) has been working in Thailand on behalf of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) since 2009. Funded by the International Climate Initiative (IKI) of the German Federal Ministry for Economic Affairs and Climate Action (BMWK), GIZ has been implementing the TRANSfer III project to facilitate ambitious mitigation actions for the transport sector, aiming at supporting developing countries and emerging economies to develop climate-friendly transport environments.

In Thailand, the GIZ TRANSfer project is supporting the Office of Transport and Traffic Policy and Planning (OTP) in the "Development on Public Transport Electrification" to identify and develop effective financing and business solutions to upscaling investment in electric public vehicles in Thailand. This is part of the activities under the Thailand Clean Mobility Programme (TCMP), which is expected to support Thailand in its pursuit of the NDC target in a more ambitious manner. The rationale of this project is presented in Figure 3 below.

Figure 3: Project rationale



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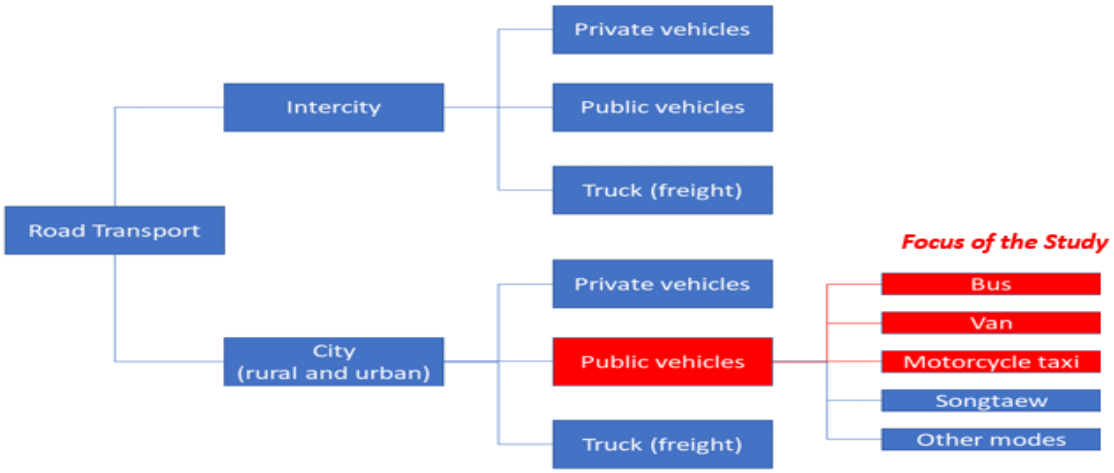
1.2 Objective of the study

Based on the rationale elaborated above, the main objective of this study is to develop a financing blueprint pertinent and effective to mobilise the available sources of finance for upscaling investment in electric public vehicles and charging infrastructure in Thailand.

1.3 Scope of the study

Road transport is the highest emitter of all sub-sectors in transport in Thailand. While there are many components within the road transport sector, this study is focused on the public vehicles of three selected modes of transport, including bus, van, and motorcycle taxi. The reasons of such prioritisation are not only because they are the main modes of public transport in Thai cities, but also because various models of electric buses, electric vans, and electric motorcycle are available in the market. The scope of the study is a part of road transport sector in Thailand as shown in Figure 4.

Figure 4: Scope of the study



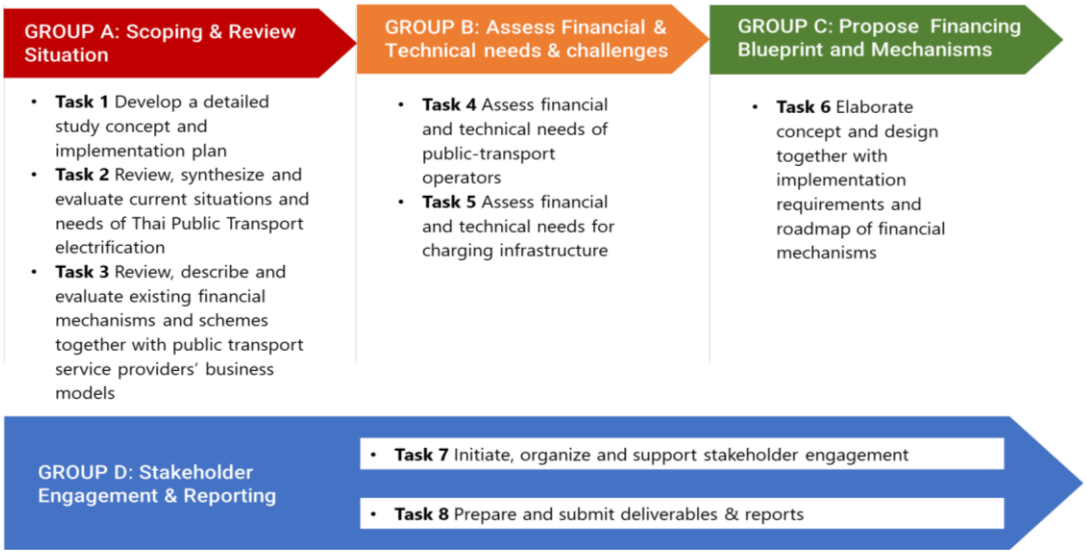
Source: Own design

Moreover, since public transport markets generally differ from one city to another, it would not be practical to study all the markets within the country. The study is therefore specifically focused on the largest metropolitan area, namely the Bangkok Metropolitan Region (BMR), as its road transport sector is most developed and presumably most carbon intensive. Therefore, the results of this study will serve to provide a financing blueprint for large-scale electrification of public transport fleets in the country.

1.4 Key approach and outputs

To support the development of public transport electrification in Thailand, a multi-faceted and new approach with practical business models and financing blueprint are very crucial. It is also important to create structured, systematic, and integrated financial mechanisms to stimulate private sector engagement and investment. Therefore, four main groups of activities as shown in Figure 5 have been conducted in this study.

Figure 5: Technical workflow diagram



Source: Own design

Five outputs have been identified for this study include:

Output 1: Relevant stakeholders have a better understanding of existing policy, plan, and situation of public transport electrification, including financial mechanisms for Thai context, including gaps and needs.

Output 2: Technical and financial needs for public transport electrification of each transport mode, including CAPEX, OPEX, TCOs for various modes and their challenges are assessed.

Output 3: Technology options and abatement costs on public transport electrification and charging infrastructure and potential bottleneck for the implementation are assessed.

Output 4: Policy recommendations to overcome challenges and to enable private and public investment in development on public transport electrification are proposed.

Output 5: A financing blueprint to enhance public and private sector investment in public transport electrification (e.g., financing options, financing conditions, and implementation requirements) is drafted.

Output I is resulted from the desk research on global and regional trends of electromobility in public transport as illustrated in Chapter 2, and on Thailand's policy and institutional framework as well as EV market trends as described in Chapter 3. Output 2-5 are demonstrated in Chapter 4, 5, and 6 for three different modes of public land transport, i.e., public bus, public van, and motorcycle taxi, respectively.

2. Global and Regional Trends of Electromobility in Public Transport and Financing Experience

Chapter Objectives:

To set the scene at global and regional scales for a robust justification of electromobility in public transport (or public transport fleet electrification) in Thailand as well as to draw lessons learned from international practices on financing mechanisms and business models to promote modernization and/or electrification of public transport.

Research Questions:

1. What is the latest development of electromobility in public transport both at global and regional scales?
2. What is the prevailing tendency of policy support towards electrification of public transport fleets amidst the external shock of COVID-19?
3. Which lessons can be drawn from oversea experience in terms of policymaking for promoting electromobility in public transport?
4. What are the financial mechanisms and business models applied in other countries to promote fleet renewal and investment in charging stations?
5. What are the performance and lesson learned of the reviewed financial mechanisms and business models?

Summary:

1. Global sales of electric vehicles have expanded significantly over the last decade and continued increasing sharply in 2022. Based on BloombergNEF's analysis[2], under its Economic Transition Scenario, where changes are driven by techno-economic trends and market forces, and no new policies are assumed to be enacted, the global sales of electric buses and 2/3 wheelers are expected to reach 63% and 49% of the total sales for the respective markets by 2030, and 83% by 2040. Meanwhile, the 100% zero-emission vehicle (ZEV) scenario can be achieved by 2050 with proper mitigation support in place.
2. The global EV market is fragmentedly developed. While electrification running far ahead in China, Europe, and some smaller markets like Norway, EV adoption remains relatively low in emerging economies. However, spillover effects are expected in emerging economies as the Chinese markets for electric buses and 2/3 wheelers started to saturate.
3. Three pillars have contributed to the resilience of electromobility against the external shock of the COVID-19 pandemic: 1) supportive regulatory frameworks, 2) additional incentives to safeguard EV sales from the economic downturn, and 3) the expanded number of EV models coupled with a continuous drop in battery cost.
4. China's experience shows how a strong top-down policy framework coupled with bottom-up actions at municipal level is effective to develop the most successful EV market in the world. More importantly, it can be observed from local EV promotion policies the intention of depressing private car use while prioritising electromobility, particularly in public transport.
5. A variety of policy measures have been adopted by the governments that have been most successful in EV deployment, including but not limited to vehicle emissions regulations, fiscal and financial incentives, standards on EV chargers, traffic and parking management favourable to EV adopters, etc.

[2] https://about.bnef.com/electric-vehicle-outlook/

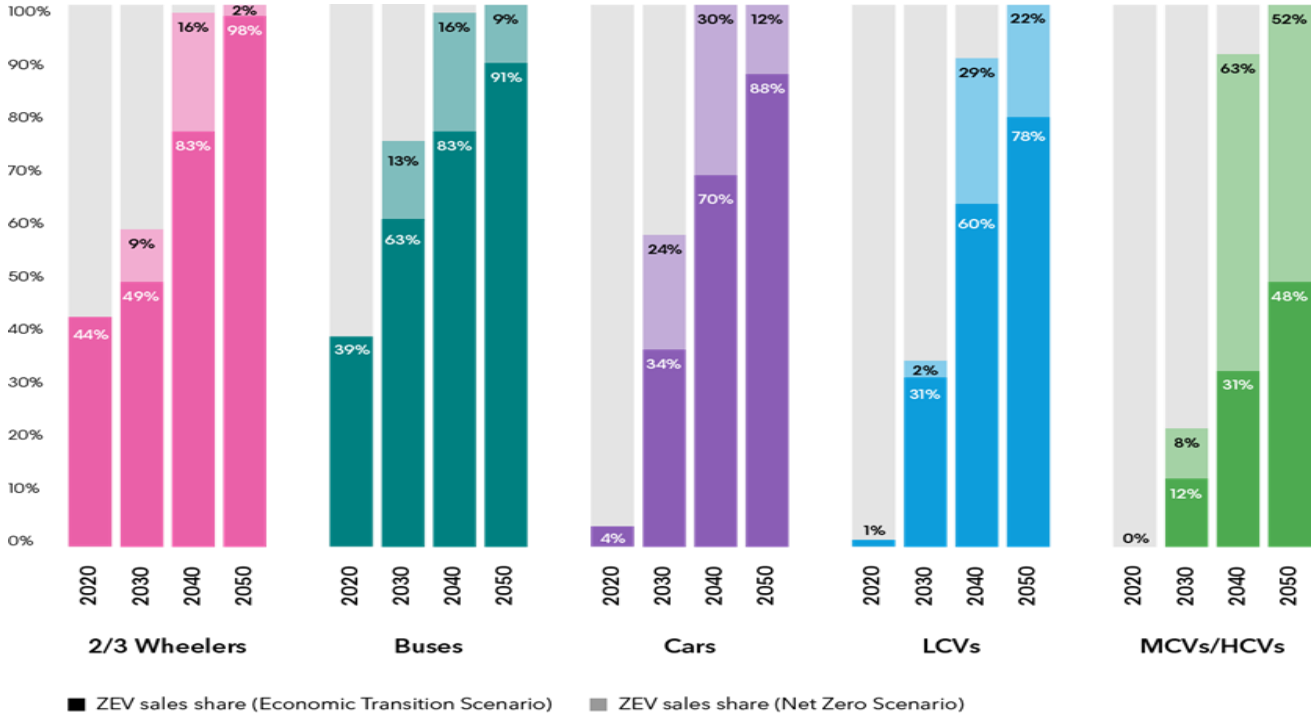
6. In the ASEAN region, Indonesia is the main competitor for EV production because of its comparative advantage in rich reserves of nickel, the key raw material for batteries. Meanwhile, Singapore is ambitiously expanding EV adoption through a set of demand-driven incentives.
7. From India and Hongkong's public finance experience, governments take the occasion of providing subsidies to trigger a structural reform that will create long-term benefits to the entire sector, as well as encourage R&D and filter the ideal EV technologies adapted to local conditions based on scientific evidence.
8. From UK's private finance experience, a variety of private actors can become finance providers for EV adoption, ranging from financial institutions which offer green lending and leasing to energy product/service providers which provide service-based solutions to sharing financial burden and risk with public transport operators.
9. From China and Chile's blended finance experience, one may notice that using only public or private resources might be insufficient to scale up EV deployment. In China's case, upfront capital burden is reduced by transforming CAPEX into OPEX through financing leasing. In the meantime, government subsidies further help to reduce the total cost of ownership for electric buses. In Chile's case, the innovative business model that successfully unbundles vehicle ownership and operation allows bus operators to introduce a fleet of 400+ electric buses as the financial burden and investment risk are shared by the energy solution provider. Payment guarantee offered by the government helps to strengthen the risk mitigation mechanism.
10. Accessing international climate funds remains to be challenging. Several challenges need to be tackled to formulate a meaningful proposal before Thailand can successfully tap into those resources.
11. As Thailand is moving from the introduction stage to the growth stage of the EV market, based on the 4-stage life cycle framework, blended finance which mobilizes private resources with public support is the most appropriate approach to financing the significant amount of investment required to expand the market. In the meantime, the strategy to developing the EV market should be shifted from supply driven to demand driven.

2.1 Global trend: bright prospect for electric buses and 2/3 wheelers with regional fragmentation

Global sales of electric vehicles have expanded significantly over the last decade and continued increasing sharply in 2022. Based on BloombergNEF's analysis[3], under its Economic Transition Scenario, where changes are driven by techno-economic trends and market forces, and no new policies are assumed to be enacted, the share of zero-emission vehicle (ZEV) sales around the world for all types of vehicles[4] would increase to a great extent, among which buses would see a strong growth from 39% in 2020 to 91% in 2050, and electric 2/3 wheelers would even account for 98% of total sales in 2050 from 44% in 2020. Meanwhile, to achieve the net-zero target by 2050, the global fleet of all types of road transport should then be fully electrified. While buses and 2/3 wheelers only require a bit of a push in the net zero scenario, some targeted support would significantly benefit the sales of electric cars and light commercial vehicles (LCVs) as shown in Figure 6.

[3] https://about.bnef.com/electric-vehicle-outlook/
[4] Including 2/3 wheelers, buses, cars, LCVs, and MCVs/HCVs.

Figure 6: Share of global zero-emission vehicle sales by segment under economic transition scenario and net zero emission scenario

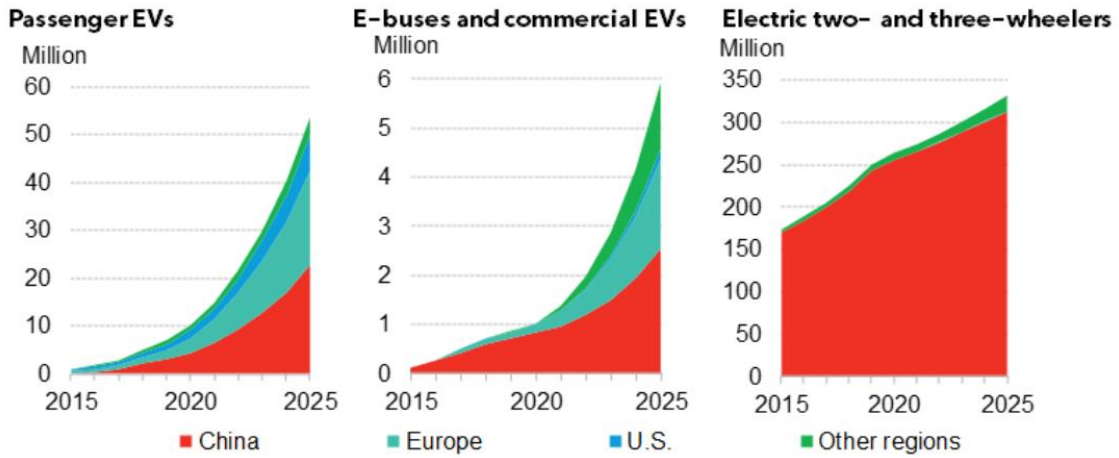


Source: BloombergNEF (2021)

Due to a combination of policy support, improvements in battery technology and cost, more charging infrastructure being built, and new compelling models from automakers, EV sales are surging particularly for buses and 2/3 wheelers. In 2020, the overall size of electric bus fleet was nearly 600 thousand, accounting for 16% of the global fleet, and that of electric 2/3-wheeler fleet reached 260 million, equalling 25% of the existing fleet. The concerned issue of battery pricing has also shown a significant improvement with lithium-ion battery pack falling 89% from 2010 to 2020. The volume-weighted average hit $137/kWh in 2020.

It is worth noting that the global EV market is fragmentedly growing, with electrification running far ahead in China, Europe, and some smaller markets like Norway. In the meantime, EV adoption remains relatively low in emerging economies (Figure 7). While the Chinese market for e-buses and electric 2/3 wheelers have started to saturate, E-bus adoption is picking up in the regions such as North and South America as well as in markets like India, South Korea, etc. For electric 2/3 wheelers, Taiwan, Vietnam, and India are seeing the strongest growth in the sales number.

Figure 7: Near-term outlook for global EV fleet by segment and market



Source: BloombergNEF (2021)

2.1.1 Impacts from COVID: continued policy support and additional stimulus measures to enhance the resilience of EV adoption

According to the International Energy Agency (IEA, 2021), global EV sales have shown great resilience to the COVID-19 pandemic that broke out in early 2020. While global new car registrations dropped about 16%, EV sales share rose 70% to a record 4.6% in 2020. Europe overtook China as the world's largest EV market for the first time. This phenomenon mainly rests on three pillars, including supportive regulatory frameworks, additional incentives to safeguard EV sales from the economic downturn, and the expanded number of EV models coupled with a continuous drop in battery cost.

Prior to the pandemic, e-mobility strategies and policy measures were already developed in most active markets. The "carrot and stick" approach has been adopted where ZEV mandates were specified and regulations on fuel economy and hardware/building standards were formulated on one hand, fiscal incentives were offered on the other hand (Figure 8). In response to the shock of COVID-19, some countries launched recovery packages with automotive or even EV-specific stimulus measures, which primarily took the form of increased purchase incentives or delaying the phase-out of subsidies, while the others took a more integrated approach by supporting charging infrastructure, public transport, and non-motorised mobility. Notably, Germany excluded conventional vehicles in its support package to the automotive sector.

Figure 8: Zero-emission Light-Duty-Vehicles policies & incentives in selected countries and regions

		Canada	China	European Union	India	Japan	United States
Regulations vehicles	ZEV mandate	**British Columbia**: 10% ZEV sales by 2025, 30% by 2030 and 100% by 2040. **Québec**: 9.5% EV credits in 2020, 22% in 2025.	**New Energy Vehicle dual credit system**: 10-12% EV credits in 2019-2020 and 14-18% in 2021-2023.				**California:** 22% EV credits by 2025. **Other states:** Varied between ten states.
	Fuel economy standards (most recent for cars)	114 g CO_2/km or 5.4 L/100 km*** (2021, CAFE)	117 g CO_2/km or 5.0 L/100 km (2020, NEDC)	95 g CO_2/km or 4.1 L/100 km (2021, petrol, NEDC)	134 g CO_2/km or 5.2 L/100 km (2022, NEDC)	132 g CO_2/km or 5.7 L/100 km (2020, WLTP Japan)	114 g CO_2/km or 5.4 L/100 km*** (2021, CAFE)
Incentives vehicles	Fiscal incentives	✓	✓	✓	✓	✓	✓
Regulations chargers**	Hardware standards.	✓	✓	✓	✓	✓	✓
	Building regulations.	✓ *	✓ *	✓	✓		✓ *
Incentives chargers	Fiscal incentives	✓	✓	✓	✓	✓	✓ *

* Indicates that it is only implemented at state/provincial/local level. ** All countries/regions in the table have developed basic standards for electric vehicle supply equipment (EVSE). China, European Union and India mandate specific minimum standards, while Canada, Japan and United States do not. *** Historically, Canada and the United States have aligned emission standards for on-road light-duty vehicles. In April 2020 the United States adopted a final rule to reduce the annual stringency conditions for the 2021-2026 model years. Soon after, Canada finalised its mid-term evaluation of the Passenger Automobile and Light Truck GHG Emissions regulation, indicating a potential separation from the US ruling, pending further consultation. ✓ Indicates that the policy is set at national level.

Notes: g CO_2/km = grammes of carbon dioxide per kilometre; L/100 km = litres per 100 kilometres; CAFE= Corporate Average Fuel Economy test cycle used in the United States and Canada fuel economy and GHG emissions tests; NEDC = New European Driving Cycle; WLTP= Worldwide Harmonized Light Vehicle Test Procedure; WLTP Japan = WLTP adjusted for slower driving conditions in Japan. Building regulations imply an obligation to install chargers in new construction and renovations. Charger incentives include direct investment and purchase incentives for public and private charging.

Source: IEA (2021)

IEA emphasised that post-pandemic policy measures should encompass a broader set of considerations including social and environmental lessons learned from the pandemic, such as allocating incentives proportionally to each model's emissions reduction, and long-term viability with a view to reaching revenue neutrality through differentiated taxation and bonus-malus systems. While COVID-19 may have imposed greater pressure on fiscal management of government budgets, it can in turn be translated into an unprecedented opportunity to trigger a meaningful transformation of economies and transport landscape.

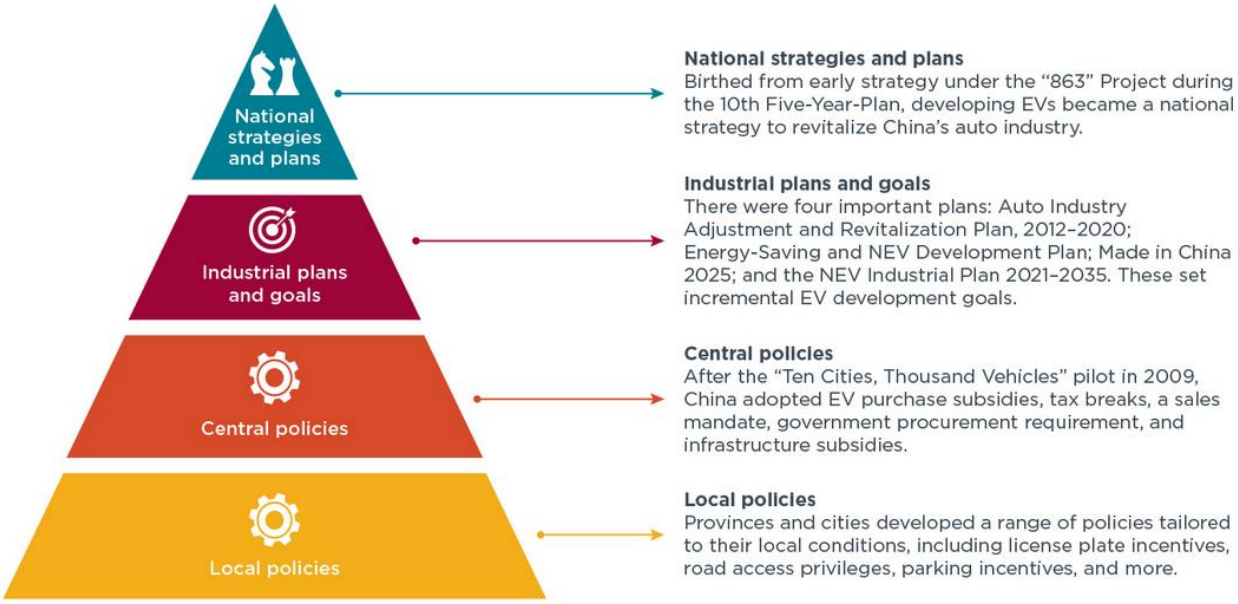
2.1.2 China: a strong and comprehensive policy framework underpins the NEV development

To select an emblematic case study of EV policies, China is definitely the most successful story in the world. At the end of 2020, nearly 5 million so-called new energy vehicles (NEVs), including BEVs, PHEVs, and FCVs were operating on China's roads, accounting for 1.75% of the country's total vehicle stock. This signifies a 250-fold increase in the NEV population from only 20,000 NEVs nationwide ten years ago. Jin et al. (2020) made a retrospective of China's NEV development strategies and key milestones, from which a pyramidal policy architecture that supports China's NEV development can be concluded (Figure 9).

A well-articulated vision for industrial strategy and top-down planning with clear targets and policies have been among the foundations of China's success. The country launched a number of EV pilot programs in its infancy (2009-2013), followed by a wide range of fiscal and financial incentives that mainly took the form of subsidies and tax cuts for both purchasing and producing NEVs as well as constructing charging facilities in the growth stage (2013-2017), and finally strengthened regulations and standards when the market became mature (2018-present). Another key factor to success are

the multistakeholder partnerships established among public authorities, industrial players and R&D agencies to create the enabling environment for NEV development.

Figure 9: China's policy structure for NEV development



Source: He and Jin (2021)[5]

A specific characteristic of China's NEV development is the active and meaningful role of local governments. A variety of policy instruments from sticks (such as car plate and traffic restrictions) to carrots (subsidies for EV purchase and use of charging services) have been employed in major Chinese cities to boost EV adoption (Figure 10). A recent World Bank (2020)[6] study concluded that central and local subsidies accounted for over half of the EVs sold between 2015 and 2018. Investment in charging infrastructure is more cost-effective than consumer purchase subsidies, and finally, the green plate policy or a vehicle registration privilege which was granted to electric vehicles in cities, where vehicle purchases were subject to a certain quota and license plates were issued through an auction or a lottery, was strikingly effective.

[5] https://theicct.org/blog/staff/china-new-energy-vehicles-jan2021

[6] Li, S. Zhu, X., Ma, Y., Zhang, F. & Zhou, H. (2020). The Role of Government in the Market for Electric Vehicles : Evidence from China. Policy Research Working Paper; No. 9359. World Bank, Washington, DC. (https://openknowledge.worldbank.org/handle/10986/34356)

Figure 10: Local EV promotion policies in China's major cities

City	Car plate restrictions and ZEV direct access	Traffic restrictions and ZEV waivers	Lower cost or free parking	Subsidies for the use of charging infrastructure	Direct ZEV purchase subsidies	Public bus fleet electrification
Shanghai	✓	✓		✓ 2020		✓ 2025
Beijing	✓	✓				✓ 2020*
Chengdu		✓	First two hours			✓**
Guangzhou	✓		First hour		✓ 2020/21	✓ 2020
Zhengzhou			50% off		✓ 2020	
Chongqing		✓	100% off	✓	✓ 2020	
Shenzhen	✓		First two hours		✓ 2020/21	
Suzhou			First hour			✓ 2020*
Hangzhou	✓	✓				✓ 2022
Dongguan						✓ 2020
Xi'an		✓	First two hours			✓ 2019
Wuhan		✓	First hour and then 50% off			
Tianjin	✓	✓		✓ 2020		✓ 2020*
Changsha						✓ 2020
Foshan						✓ 2019
Ningbo						✓ 2022
Nanjing			First hour			✓ 2021
Kunming			First two hours			✓**
Jinan		✓	First two hours and then 50% off (BEV)	✓ 2020/21		✓**
Shijiazhuang		✓			✓ Dec 2020	✓ 2020*

* Indicates the full fleet electrification target applies to the city's urban area.
** Indicates that the electrification requirement applies only to new or replacement vehicles.
Notes: ZEV = zero-emissions vehicle. All restrictions refer to privately owned LDVs. Various other restrictions apply to commercial vehicles. The cities are ranked by size of the car fleet in 2019. For the categories *subsidies for the use of charging infrastructure* and *direct ZEV purchase subsidies* the numbers indicate the years for which the policy is active. For the category *public bus fleet electrification*, the numbers specify the year by which the total stock is expected to be electrified.

Source: IEA (2021)

2.2 Regional trend: catching the tailwind of EV adoption in ASEAN

In Southeast Asia, interest in EVs is also growing. On one hand, air pollution from land transport is serious and harmful to human health in many ASEAN cities, which draws much attention towards cleaner fuel technologies[7]. On the other hand, several ASEAN countries in addition to Thailand, such as Indonesia and Malaysia, have been important production bases for the world car manufacturing industry, therefore promoting electric vehicles is often regarded not only as an important measure to pursue cleaner transport, but also as a strategic lever to trigger an industrial transformation towards more sustainability. Although EV adoption has been relatively limited so far, the regional trend is making headway towards a promising EV uptake.

2.2.1 Malaysia: an early goer while the progress remains to be observed

According to Schröder, Iwasaki and Kobayashi (2021)[8], Malaysia is perhaps one of the earliest ASEAN countries to introduce EV-supportive policies due to a mix of policy considerations from environmental, energy and industrial aspects. As early as 2009, Malaysia put EV support on the political agenda in its National Green Technology Policy, which indicates that EV is regarded as a part of a larger transformation towards a sustainable economy and society. Greentech Malaysia (or "MGCC"), a subsidiary organisation under the Ministry of Energy, Green Technology and Water, was established to promote EV development. While the Malaysian government initially set the goals of 2,000 electric buses, 100,000 electric scooters/motorcycles and 120,000 charging stations until 2020,

[7] https://eias.org/op-ed/electric-vehicles-driving-asean-sustainable-growth/

[8] Schröder, M., Iwasaki, F., and Kobayashi, H. (2021). 'Current Situation of Electric Vehicles in ASEAN', in Schröder, M., Iwasaki, F., and Kobayashi, H. (eds.) *Promotion of Electromobility in ASEAN: States, Carmakers, and International Production Networks*. ERIA Research Project Report FY2021 no.03, Jakarta: ERIA, pp.1-32.

reaching the numbers appears to be much difficult than expected as MGCC restated its target of 100 electric buses on road in 2020[9].

In terms of policy measures, the National Automotive Policy 2020 which formulates a major component of EV support is expected to cut the prices of EVs by at least 50% with a set of incentives on tax exemption and reduction for the excise and import duties[10]. In the meantime, the Low Carbon Mobility Blueprint 2021-2030 which is subject to final Cabinet approval would cover the deployment of the charging infrastructure and reform of the fiscal system such as restructuring vehicle taxes to be emission-based and introducing a fuel levy on all diesel and petrol purchases. Moreover, public procurement of BEVs is outlined in the blueprint as a catalyst for wider adoption, which is specified in the target of 10% penetration of BEVs in government fleet by 2022 rising to 20% within 2023 to 2025.

2.2.2 Indonesia: strong competitor in EV production

Indonesia is the second-largest car production hub in the region after Thailand. While the Indonesian government started to pursue a home-grown EV industry in as early as 2017, the concrete policy towards EVs was developed relatively late. The President Joko Widodo issued the Presidential Regulation (No. 55) in 2019 to provide incentives for manufacturing of electric vehicles and auto components. The goals of EV production share that it set up include 20% of all domestic cars manufactured, as well as 20% of the total motorcycle production, by 2025. Strengthening of the EV supply chain will also boost local battery production as Indonesia possesses significant reserves of nickel, a key material for lithium EV battery cathodes[11]. This intention of supporting locally sourced activities is reflected in the high local content requirements (from 35% to 80%) for the EV investment incentives, which are made available in the form of tax and duty exemptions.

While Indonesia's strategy explicitly aims at exporting EVs[12], especially to Australia and within ASEAN under free trade agreements, some domestic initiatives also exist as part of the overall efforts to promote electromobility, including the partnership of Grab Indonesia and Hyundai Motor Group to explore new EV business and financing models[13], as well as the announcement of the bus operator Transjakarta to expand its e-bus fleet to 10,000 units by 2030[14].

2.2.3 Singapore: ambitious commitments to domestic EV deployment

In Singapore, the Land Transport Authority (LTA) and Energy Market Authority initiated an EV task force that represented multiple agencies in 2010 (Schröder, Iwasaki and Kobayashi, 2021)[15]. While the development of EVs has not significantly taken off in the earlier years, the government set up the ambitious goal of phasing out ICE vehicles and having all vehicles running on cleaner energy by 2040. The Singapore Green Plan 2030 set out a comprehensive EV roadmap. The specific targets of EV

[9] https://opengovasia.com/malaysia-targets-100-electrical-buses-on-road/
[10] https://www.mida.gov.my/mida-news/ev-policy-to-be-ready-by-july/
[11] https://eias.org/op-ed/electric-vehicles-driving-asean-sustainable-growth/
[12] https://www.kitco.com/news/2019-02-22/Indonesia-to-tap-nickel-laterite-make-batteries-to-become-EV-hub.html
[13] https://www.grab.com/sg/press/others/hyundai-motor-group-deepens-partnership-with-grab-to-accelerate-ev-adoption-in-southeast-asia/
[14] https://www.thejakartapost.com/news/2020/12/29/transjakarta-wants-10000-electric-buses-in-service-by-2030.html
[15] Same as footnote no. 7

adoption include 60,000 charging points by 2030 of which two-third will be installed in collaboration with the private sectors, in public carparks and the rest in private premises. The LTA has also committed to having 100% clean-energy bus fleet by 2040 by procuring only cleaner energy buses. A cross-ministerial agency, the National Electric Vehicle Center (NEVC) was newly established to lead the promotion of wider EV adoption, such as accelerating the deployment of a nationwide EV charging infrastructure, formulating EV regulations and standards, as well as cultivating a robust EV ecosystem.

A strategic policy measure that the Singaporean government has adopted is to allow the French Bolloré Group to operate a car-sharing service named blueSG, which aimed at providing 1,000 BEVs, on condition that the Group would install 2,000 charging points across the country until 2020 of which 400 should be accessible to the public (Schröder, Iwasaki and Kobayashi, 2021). Moreover, demand-sided incentives have been introduced since 2020 for EV adopters through the programs such as the EV Early Adoption Incentives and Vehicular Emissions Scheme[16]. Car registration tax and road tax are rebated for electric vehicles by restructuring the tax components. In terms of charging network deployment, the LTA has launched the Electric Vehicle Common Charger Grant which will co-fund 50% of the cost components for the charging system, electric worker fees and installation of 2,000 shared EV chargers in non-landed private residences such as condominiums and private apartments[17]. It is worth noting that private car owners are offered fairly limited benefits for EV adoption, while policy instruments are rather prone to support car sharing and public transport. This is in line with the overall transport policies in Singapore.

2.3 International experience in financing public transport electrification

From the review of six successful international case studies on public transport electrification, the underlying financing design can be divided into 3 groups: public finance, private finance, and blended finance/business models. Summary of these cases are shown in Table 1.

Table 1: Summary of the case studies on public transport electrification

Financing	**Public Finance**		**Private Finance**		**Blended Finance**	
Project	JnNURM scheme	New Energy Transport Fund	HSBC Sustainable Leasing Finance	"Battery on the Bus" Scheme	Financial Leasing Model, Shenzhen	PAYS model & PPP
Country	India	Hong Kong	UK	UK	China	Chile
Mechanism	Subsidy	Subsidy	Leasing	Service-based model	Leasing	Unbundled model
Type of vehicles	Bus (not entirely electric)	All types of public vehicles	Bus	Bus	Bus	Bus
Scale	Nationwide (> 23,000 buses)	Territory-wide	Company (25 buses)	Company (34 → 100 buses)	Citywide (> 6,000 buses)	Citywide (> 400 buses)
Feature	Cities seeking the grant are	Subsidise EV applications	Sustainable finance	Battery ownership and	Public subsidy to reduce	Vehicle ownership &

[16] https://www.lta.gov.sg/content/ltagov/en/industry_innovations/technologies/electric_vehicles.html

[17] https://www.lta.gov.sg/content/ltagov/en/industry_innovations/technologies/electric_vehicles/ev_common_charger_grant.html

Financing	Public Finance		Private Finance		Blended Finance	
Project	JnNURM scheme	New Energy Transport Fund	HSBC Sustainable Leasing Finance	"Battery on the Bus" Scheme	Financial Leasing Model, Shenzhen	PAYS model & PPP
	required to undergo fiscal and sectoral reforms	for trial and for use (i.e., testing locally appropriate products)	product initiated by the bank (i.e., HSBC)	charging infrastructure is held by the energy provider	TCO + leasing to reduce capital burden	operations unbundled + payment guarantee by the public authority

2.3.1 Public financing for public transport electrification

Public finance is the most straightforward source of funds that governments can leverage. However, rather than simple allocation of funds to those in need, the way a funding/financing mechanism is designed and operated is crucial to its overall performance. This section will examine two cases, from India and Hong Kong, to draw lessons on how public finance can become a key support to finance electromobility in public transport.

a) JnNURM scheme, India: financial support as an opportunity for major reforms

The Jawaharlal Nehru National Urban Renewal Mission (JnNURM) scheme, launched in 2005 with an overall budget of over US$20 bn over the course of 7 years[18], is not a dedicated mechanism for the transport sector, but rather a massive city-modernisation scheme that aims to deal with the increasing pressure on a variety of social, economic, and environmental issues in urban India, in which more than 30% of the country's population now lives. In 2006, only 20 cities had organised city bus services. Upon recognising the contributing role of buses to urban public transport, JuNURM supported 34 additional cities to establish their city bus services with specific requirements for the quality of bus fleet and intelligent transport system (ITS) applications[19]. The transport sector has received 11% of the total JnNURM investment (Hidalgo et al., 2012[20]), accounting for 22% of the projects sanctioned under JnNURM. While fleet electrification was not exclusively required under JnNRUM, some cities such as Bangalore chose to introduce electric buses as early as in 2014[21].

To get JnNRUM funding support, cities (or "urban local bodies", ULBs) would have to submit project proposals, through the recommendation of state-level nodal agency or steering committee, to the Central Sanctioning & Monitoring Committee, mainly comprised of representatives from the Ministry of Urban Development (MoUD), the Ministry of Urban Employment and Poverty Alleviation (MoUEPA) and other line ministries such as Ministry of Finance. Upon approval, ULBs would receive funding in the form of soft loan or grant-cum-loan, which could be used for not only capital investment but also capacity building activities. At least 25% of the funds released would eventually be recovered

[18] Th JnNURM scheme was supposed to close in March 2012 but was extended to March 2015 for completion of the already approved projects.

[19] https://www.dimts.in/pdf/Symposium-on-Publi-Transportation/S-01-P1-Mr.DIMMTS-Jan10.pdf

[20] Hidalgo, D., Pai, M., Carrigan, A., & Bhatt, A. (2012). National Investment in Urban Transport: Towards People's Cities Through Land Use and Transport Integration. https://wrirosscities.org/sites/default/files/National-Investment-Urban-Transport-EMBARQ-India.pdf

[21] https://www.karnataka.com/bangalore/electric-bus-in-bangalore/

towards a revolving fund, maintained by the nodal agency. This revolving fund would be utilized to leverage market funds for financing of further investment in infrastructure projects, and it might be upgraded to a state-level Urban Infrastructure Fund at the end of the mission period.

Key takeaways:

While a direct subsidy for bus procurement is conceptually simple and straightforward, project screening, approval and fund disbursal can be highly complicated, time-consuming, and costly. Given the tightening fiscal constraints in the era of COVID-19, it is not recommended to solely depend on public subsidies as the incentive for public transport electrification. However, the Indian case highlights the importance of structural reforms at local level, which are crucial to strengthen the financial sustainability and technical capacity of local authorities and public transport services in the long run.

b) New energy transport fund, Hong Kong: from incubation to commercialisation of EV technologies[22]

The transport sector was the largest contributor to air pollution in Hong Kong in 2017, as well as responsible for about 18% of local GHG emissions. As a result, the government of Hongkong put in place in 2011 a $300-million Pilot Green Transport Fund to subsidise the transport trade and charitable/non-profit organisations to try out green innovative transport technologies. Later in 2020, an additional $800 million was injected into the fund, renamed the New Energy Transport Fund (NETF). In addition to the already existing category of "Applications for Trial" ("AT"), the NETF added a new category of "Applications for Use ("AU") to encourage wider use of the proven technologies under AT. New Energy Vehicles including BEVs and PHEVs, either newly manufactured or conversed from in-use conventional vehicles, are eligible for the AT subsidies. Table 2 shows the level and the cap of subsidy provided for new energy vehicles.

Table 2: NETF subsidy conditions relevant to fleet electrification under the AT category

Green innovative technology product under AT	Subsidy level	Subsidy cap
New Energy Vehicles	Price premium between the NEV and its conventional counterpart or 50% of the cost of the NEV, whichever is higher: 75% of the set-up cost, if any	$3 million per vehicle and $10 million per application
Conversion of in-use conventional vehicle to New Energy Vehicles	75% of the conversion cost of the conventional vehicle	$3 million per engine and $10 million per application

Source: NETF[23]

During the trial period, subsidy recipients are requested to record fuel/energy consumption, maintenance cost and other relevant data on a daily basis for performance evaluation of the subsidized product being tested. The performance of conventional product(s) used during the trial period or other historical period should also be provided for comparison. A list and detailed information of all

[22] https://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/new-energy-transport-fund.html
[23] https://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/new-energy-transport-fund.html

the trial products[24] is disclosed and regularly updated on the official website of the Environmental Protection Department (EPD). As of June 30, 2021, the number of products subsidised and tested totalled 227, of which electric and hybrid vehicles for passenger services (incl. bus and taxi), as well as for logistics are the most common types of trial products.

To further move from trial to commercial applications, the AU category was established alongside the AT category. AU Subsidies would only be granted for applicants using the products approved and listed by the NETF steering committee. However, as of September 2021, a list of AU funded product models has not yet been available on the EPD website.

Key takeaways:

To promote green innovative transport technologies, Hongkong supports private operators to choose their preferred EV models for trial. All tested models along with their technical performance data are monitored and disclosed on EPD's website. This can be a good approach to raise awareness and encourage private engagement during the infancy of EV adoption. However, it is not designed for large-scale EV expansion, and again, fiscal constraints remain to be a major challenge.

2.3.2 Private financing for public transport electrification

Public finance is facing increasing challenges as governments have a lot to deal with on their agenda. On the other hand, private finance has much potential to contribute to public transport electrification as financial institutions and companies are increasingly seeking sustainable investments and business models. Below there are two interesting cases in London which are purely financed by private players with innovative financial/business models.

a) HSBC's sustainable lease financing, UK: sustainable and green finance commitments of the banking sector

The HSBC UK Commercial Bank launched a green finance proposition in 2019 containing a wide range of products and services – Green Loan, Green Revolving Credit Facility, Green Hire Purchase, Lease and Asset loan – for small to medium enterprises (SMEs) through to large corporates. The minimum green loans start at £300,000. To enhance the trustworthiness of its products, the HSBC UK has aligned its Green Lending offering to the Loan Market Association's Green Loan Principles, which aims to create market standards and guidelines, providing a consistent methodology for use across the wholesale green loan market[25].

In the eligible criteria for green activities set forth by HSBC UK[26], fuel technologies that are eligible for a green loan include BEVs, PHEVs (excluding those of carbon intensity over 75gCO2e/p-km), and alternative fuels such as biogas (excluding those competing with food production or decreasing

[24] https://www.epd.gov.hk/epd/sites/default/files/epd/english/environmentinhk/air/prob_solutions/files/Approved_Trials_Eng_Chi.pdf

[25] https://www.westlondon.com/hsbc-green-finance/

[26] HSBC's Eligible Criteria for Green Activities. https://www.business.hsbc.uk/corporate/-/media/library/markets/cmb-uk/pdfs/hsbc-eligible-criteria-for-green-activities.pdf

forestation, biodiversity, or carbon pools in soil). Meanwhile, charging infrastructure and manufacturing of EV components are also eligible for a green loan.

In 2020, London General Transport Services (LGTS), part of London's largest bus company Go-Ahead Group, invested in 25 electric double decker buses following a £10 million-pound sustainable leasing package from HSBC UK. This offering allowed the Go-Ahead Group to expand its electric bus fleet to over 100 vehicles, at the time when it was awarded London Stock Exchange's Green Economy accreditation. Over 50% of the Group's annual revenue is driven from products that contribute to the green economy. Moreover, LGTS and the Go-Ahead Group set the targets of per vehicle-mile emissions reduction by 20% over 2021 as well as building a zero-emissions fleet by 2035[27].

Key takeaways:

The banking sector is increasingly active to engage in sustainable finance activities. In Thailand, the Working Group on Sustainable Finance, consisting of the Fiscal Policy Office, the Bank of Thailand, the Securities and Exchange Commission, the Office of Insurance Commission, and the Stock Exchange of Thailand, have joined forces to steer and align the direction of Thailand's sustainable finance policies. The Sustainable Finance Initiatives for Thailand have been developed in recognition of the significant role that the banking sector plays in tackling Thailand's sustainability challenges and realising Thailand's sustainability commitments. This represents an extraordinary opportunity to tap into abundant resources from the credit institutions in Thailand for public transport electrification.

b) "Battery on the Bus" scheme: Abellio (operator) & Zenobe Energy (battery storage), UK: service-based model to enable EV investment

Not only financial institutions can provide financing to EV investment, but battery storage services providers can also play a role in building the financial model. Zenobe Energy, a leading owner and operator of battery storage, announced £120 million-pound partnership funding in May 2019 to facilitate the electrification of public transport fleets. The first deal of this kind is the collaboration with Abellio, a public transport operator in London.

To launch its first electric bus fleet of 34 vehicles in 2020, Abellio adopted the first and ever "battery on the bus" scheme which allows bus operators not to purchase the whole fleet with batteries, but rather leaves battery management and ownership to Zenobe Energy. This helps bus operators to lower the capital cost as well as financial and maintenance risks. Also, Zenobe Energy funded the remainder of the buses[28].

According to the Guardian[29], British bus operators have pledged to buy only ultra-low or zero-emission vehicles from 2025 with the help of state funding for electric buses. In the meantime, private actors such as Zenobe Energy can also contribute to accelerating this process. The company has

[27] https://london-post.co.uk/london-bus-company-drives-greener-future-following-funding-from-hsbc/

[28] https://www.sustainable-bus.com/news/abellio-owns-the-buses-zenobe-owns-the-batteries-a-new-financing-scheme-in-london/

[29] https://www.theguardian.com/business/2020/jun/23/uk-electric-buses-battery-deal-zenobe-energy

further secured a £20m loan from NatWest to finance enough batteries to power about 100 electric buses owned by private transport firms and councils around the UK.

Key takeaways:

The business model applied in the UK case is that the operator owns buses, while the battery company owns batteries (and charging infrastructure). This way, the traditional product-based model is transformed into the service-based model, where the operator is paying the battery company for its services of battery charging and maintenance. By doing so, the operator is exposed to a lower capital cost and operating risk relating to potential battery failure. This is the essence of the "Battery on the bus" scheme. However, since it depends on the capacity and willingness of the battery company to transform their business model, further exploration is necessary through stakeholder interviews to identify the potential of this model in Thailand.

2.3.3 Blended financing for public transport electrification

Apart from solely public or private finance, blended finance coupled with an innovative business model can be more powerful and sustainable to finance and operate electric public fleets. In the developing world, China has been most successful in bus electrification supported by a strong policy framework coupled with ambitious action taking at municipal level. Apart from China, Latin America has been an area of focus where the major cities are actively seeking to transform their public transport services towards cleaner and low carbon solutions. More importantly, they are realizing public fleet electrification through innovative business models that have the potential for replication around the world. The IFC and C40 report (2020) [30] analysed and compared the traditional model to the innovative models for city bus systems in Latin America, from which it concluded that unbundling asset (i.e., vehicles, batteries, charging infrastructure, etc.), ownership, and operation is the crucial innovation that enables the business models some Latin American cities are experimenting. The unbundled model for funding, financing, procuring and operating city buses can accelerate public fleet electrification mainly because of its risk sharing mechanisms. Below two cases respectively from China and Chile are presented to demonstrate how unbundling ownership and operation can support bus fleet electrification in the studied cities.

a) Financial leasing model, Shenzhen: pioneer in EV leasing at scale

Shenzhen, a city of 17.56 million population, has the world's first and largest fully electrified bus and taxi fleet: around 16,000 electric buses and 22,000 electric taxis[31]. On the supply side, the famous electric bus manufacturer BYD is based in Shenzhen, which has provided almost 80% of the electric buses run by the Shenzhen Bus Group (SZBG), a state-owned local public transport operator in Shenzhen. SZBG has a fleet of more than 6,000 electric buses and 5,000 electric taxis, which was mostly deployed between 2016 and 2017. In June 2019, SZBG had 1,707 charging terminals at 104

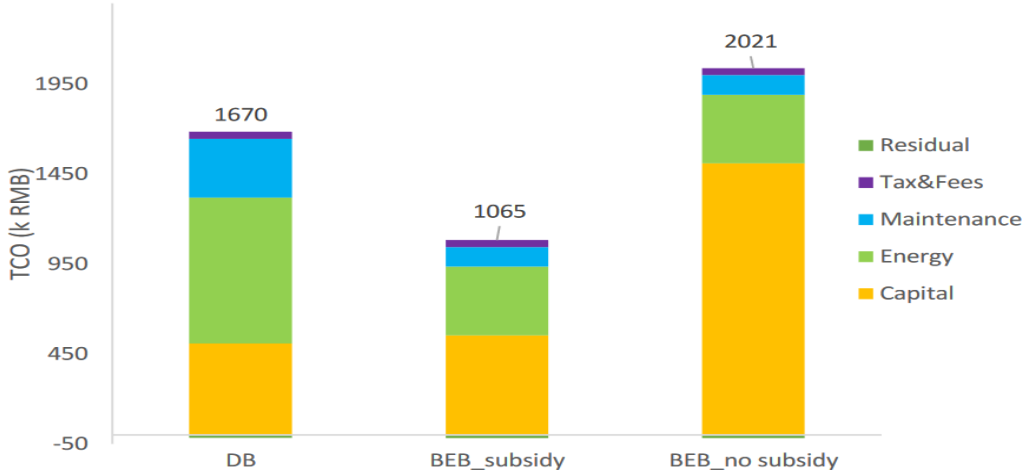
[30] Graham, J. & Courreges, A. (2020). Leading a Clean Urban Recovery with Electric Buses: Innovative Business Models Show Promise in Latin America. IFC & C40. https://www.ifc.org/wps/wcm/connect/ab54df3f-ea06-434c-9827-0522a942c11f/IFC-InfraNote-EBus-FINAL_web.pdf?MOD=AJPERES&CVID=nouB55N

[31] https://www.forbes.com/sites/brookecrothers/2021/02/14/this-chinese-city-has-16000-electric-buses-and-22000-electric-taxis/?sh=34e2f6263a92

stations. These charging facilities are constructed and managed by 9 operators, of which the state-owned Potevio and the private Winline are the two major players.

Thanks to the active and generous policy support (as described in Section 2.1.2), SZBG enjoyed a national subsidy of 500,000 RMB per bus in 2015. This significantly cut the total cost of ownership of an electric bus by almost half, making it 36% less than that of a diesel bus (Figure 11). For charging infrastructure investment, the service providers also enjoyed a subsidy of 200-300 RMB/kW under the "Shenzhen Blue Plan" adopted by the municipality. This allowed the investment in charging stations to breakeven in 5-6 years. The main challenge however laid in land acquisition to accommodate all buses at depots and terminals for charging. Therefore, the local government simplified and accelerated the process for all land use applications and approvals for charging infrastructure construction.

Figure 11: Total cost of ownership for diesel bus and BEB in Shenzhen's Case

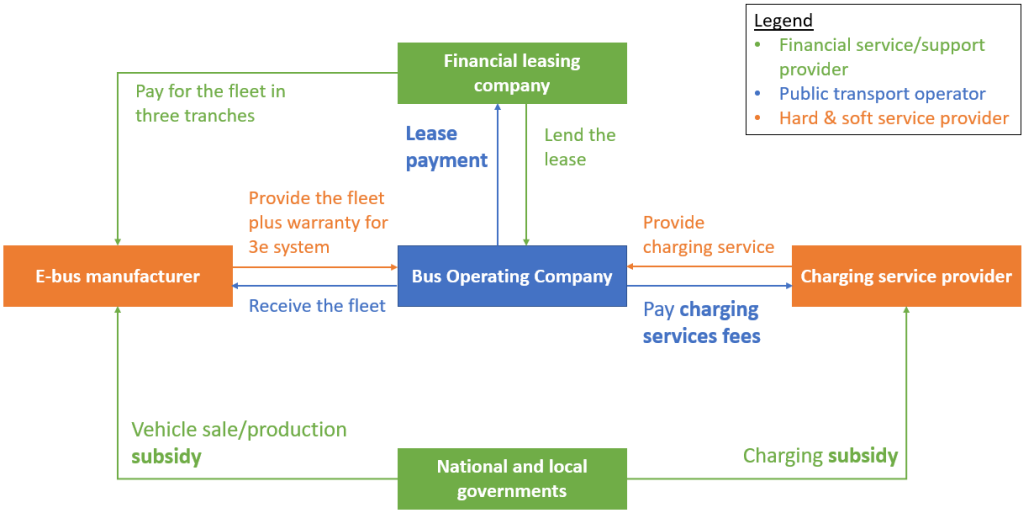


Source: Berlin, A., Zhang, X., Chen, Y. (2020)

On top of the subsidies, SZBG adopted a financing leasing model as shown in Figure 12 to further reduce the upfront costs of the entire fleet renewal. Different from the "Battery on the bus" system in the UK, the leasing finance is provided by a financial leasing company for a period of 8 years. Vehicle ownership will be transferred to SZBG upon termination of the lease. While electric bus manufacturer provides the fleet, it also provides warranty for the 3e system including battery, electric motor, and controller. Charging infrastructure and services are owned and managed by the charging operators. In this way, the costs of electric buses and charging are converted from upfront CAPEX to OPEX installments, reducing SZBG's financial burden especially when the procurement is in bulk.

Finally, the total life of these electric buses is set the same as the leasing period. This means that upon taking the ownership of its buses, SZBG will not continue to operate the vehicles. Instead, it will disassemble the components, returning the batteries to the manufacturer for recycling and disposal and sending the vehicle bodies for scrappage and metal recycling.

Figure 12: Financial leasing model in Shenzhen's case



Source: adapted from Berlin, A., Zhang, X., Chen, Y. (2020)

Key takeaways:

The China case first suggests how public subsidies can be influential to reduce the total cost of ownership for battery electric buses. However, this is not enough to overcome the capital barrier of large-scale BEB procurement. The financial leasing model, while not being an innovative concept, can crucially help to reduce the significant upfront investment required by transforming CAPEX into OPEX over the life span of BEBs. Finally, end-of-life management for EV batteries is also considered to minimize any negative impact from battery disposal.

b) PAYS model & PPP, Santiago, Chile: multistakeholder collaboration to build a sound and scalable business model

Santiago is one of the largest metropolitan areas in Latin America. It is home to over 7 million people, more than 40% of the country's population. In line with the National Electromobility Strategy and the declaration of the new government in 2019 which specified the target of a 100% electric public transport fleet in its capital Santiago by 2040, the city has built the largest fleet of electric buses outside China since the target's announcement. By June 2020, there were 411 battery electric buses in the city, with an additional 365 planned by the end of 2020[32].

Santiago is the first Latin American city to implement an e-bus pilot study in 2013. Several more studies and pilots were conducted along the way, until the private operator Metbus started operating on a 30-km long route with 2 electric buses, in collaboration with the manufacturer BYD and the energy solution provider Enel. While Enel provided financing for the procurement of electric buses and charging infrastructure through a leasing scheme, BYD agreed to take care of maintenance in

[32] Galarza, S. (2020). From Pilots to Scale: Lessons from Electric Bus Deployments in Santiago de Chile. ZEBRA. https://www.c40knowledgehub.org/s/article/From-Pilots-to-Scale-Lessons-from-Electric-Bus-Deployments-in-Santiago-de-Chile?language=en_US

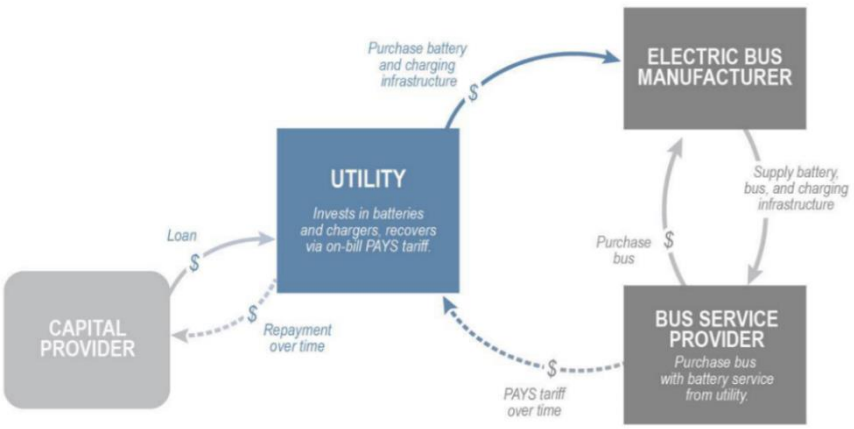
addition to supply of vehicles and charging infrastructure. In 2018, the same model was applied to the introduction of 100 BYD electric buses for scaling up electric bus operation of Metbus services[33].

In addition to Metbus, Enel and BYD, which are all private actors, the city's transport authority DPTM and financial manager of Sangtiago's bus system AFT have also played a role in making the deal happen. The business model developed in Santiago's case can be regarded as a modified PAYS model with a public-private partnership (PPP).

- **PAYS Model**

PAYS stands for Pay-As-You-Save. It describes a business model where a utility makes site-specific investments to help reduce the upfront cost of energy upgrades or zero emission energy technology. To apply PAYS to public transport electrification, the utility would establish a terms of service agreement (a tariff) for investing in the batteries and charging infrastructure for each electric bus operating in its service area. Bus service providers which invested in the electric bus fleet would opt into a terms of service agreement (a tariff) which allows the utility to charge a monthly expense which is capped at a level below the estimated savings from replacing the existing fuel technology with EVs, and to recover its costs within the warranty period of the equipment (i.e., batteries and chargers) it has financed (Figure 13).

Figure 13: Conceptual framework of a PAYS model



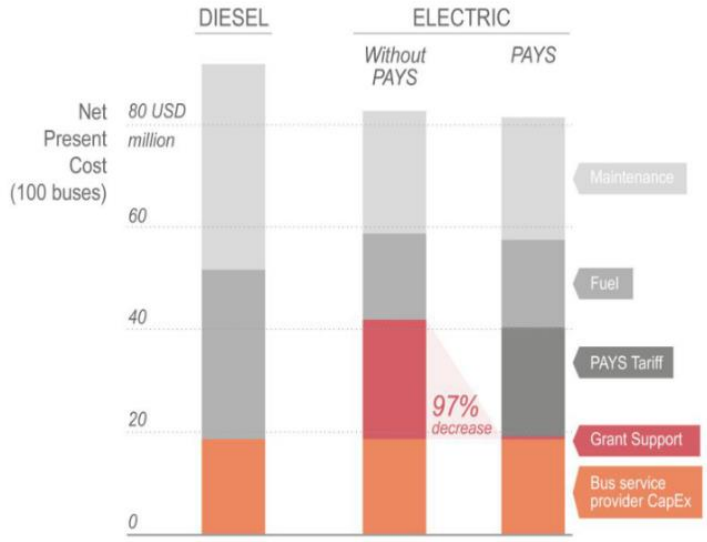
Source: Clean Energy Works (https://www.cleanenergyworks.org/clean-transit/)

The PAYS model unbundles asset ownership and operation, which would have fallen on the shoulder of bus service providers in a conventional business model. By inviting the utility to take on the costs of batteries and charging infrastructure, this PAYS model would encourage bus service providers to choose EVs of which the upfront investment cost would be the same or lower than the existing technology. The utility would fund the energy savings from the switch to EVs, while recovering its investment from the long-term fee collection over the life of each electric bus. In Santiago's case a similar mechanism has been applied as that of the PAYS model.

[33] World Bank (2020). Lessons from Chile's Experience with E-mobility: the Integration of E-buses in Santiago.

What exactly is the influence of the PAYS model on the financial burden of fleet procurement? The Lab (2018)[34]simulated the total costs of ownership between that of diesel buses and that of electric buses with/without PAYS with the procurement data of 100 electric buses in Santiago. The result shows that while electric buses without PAYS would already have a TCO lower than diesel buses, mainly because of cheap electricity and financing costs in Chile[35], applying the PAYS model can further replace the grant support needed by the collection of PAYS tariff, strengthening the financial soundness of the project (Figure 14). In the Santiago case electric buses financed through PAYS are around US$ 104,000 cheaper over their lifecycle than diesel buses.

Figure 14: Comparison of total costs of ownership for the 100-bus electrification in Santiago



Source: Clean Energy Works (https://www.cleanenergyworks.org/clean-transit/)

- **Public private partnership[36]**

The regulator of Santiago's public transport system Transantiago (or RED) is the DTPM, the city transport authority. Meanwhile, DTPM procured a financial manager AFT to manage the system's finance, which would collect operators' revenues while allocating remunerations back based on a payment per transported passenger (approximately 70% of bus operators' revenues) and a payment per kilometer traveled (accounting for the other 30%).

To boost core business (i.e., energy sales from providing charging services) from public transport fleet electrification, Enel as the energy service provider (the "utility" in the PAYS model) had the incentive to finance 100 electric buses and charging infrastructure[37] through a 10-year lease agreement at a total of about $40 million with Metbus as bus operator[38]. The latter would make

[34] The Lab (2018). Pay as You Save for Clean Transport: Lab Instrumental Analysis. https://www.climatefinancelab.org/wp-content/uploads/2018/02/PAYS-for-Clean-Transport_Instrument-Analysis.pdf

[35] IFC (2020). E-bus Economics: Fuzzy Math? https://www.ifc.org/wps/wcm/connect/2feab98d-96de-4bb9-a03c-85e3a9793c5a/IFC-TransportNotes-FuzzyMath-final.pdf?MOD=AJPERES&CVID=m-Ln.tz

[36] Ibid.

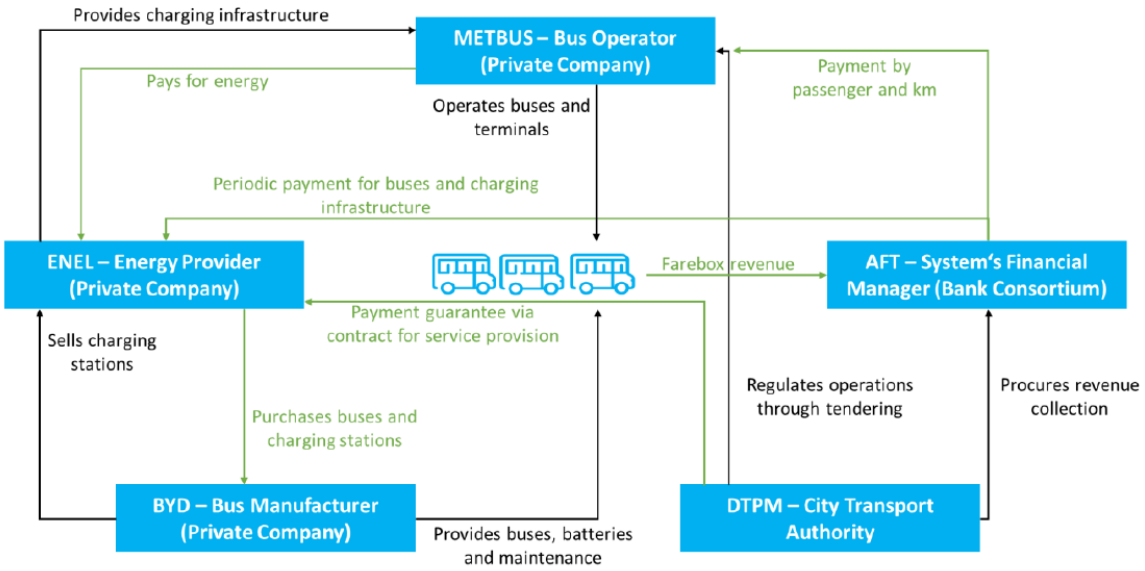
[37] Including the grid upgrades in two "electroterminals" (depots) and 100 AC chargers.

[38] Galarza, S. (2020). From Pilots to Scale: Lessons from Electric Bus Deployments in Santiago de Chile. ZEBRA.

monthly payments to Enel covering fleet provision, charging infrastructure, and energy supply[39]. At the end of the lease agreement, vehicle ownership would be transferred to Metbus.

In terms of risk sharing, since Metbus is required to transfer its farebox revenue and receive remunerations to/from AFT, the monthly payments that were supposed to be made by Metbus are now made directly by AFT, while Metbus only receives its remunerations deducted by the monthly payments. This helps to reduce the risk of non-payment that Enel would have borne. In the meantime, BYD the bus manufacturer would not only provide buses and batteries, but also take on maintenance at a rate of $0.09/km, helping to mitigate the risk of technology failure. Another important support comes from the government, which endorsed the provision contract between Metbus and Enel on guaranteeing the electric buses would remain in the system until the debt is cleared. This minimizes the risk to Enel which financed the procurement as the debt is secured by the government (Figure 15). This business model was replicated in another deal in late 2017 among the energy service provider Engie, the bus manufacturer Yuton, and the bus operator Buses Vule in Santiago.

Figure 15: Financial and operational model for e-buses in Santiago, Chile



Source: GIZ (2019)[40]

Key takeaways:

The business model applied in the Santiago case is referred to in the literature as the "unbundled model", which successfully enabled BEB procurement at scale. This is attractive mainly from a risk management perspective. While operators do not have the financial or technical capacity to absorb the existing risks, the unbundle model distributes the risks among the players, and creates a chance of generating commercial interest from private capital providers to support the transition. However, several "x-factors" are identified to improve the likelihood of success of the unbundled

[39] Enel and Metbus have also signed an agreement to provide certified renewable energy at a 40% discount—approximately $0.06/kW.
[40] Jatin, M. G. (2019). Financial Mechanisms for Electric Bus Adoption. GIZ: Eschborn.

model, including managing demand risk, structuring municipal payment risk, or better allocation of technology risk[41].

2.4 Case studies of financial mechanisms and business models using international resources

For developing countries, a number of financial resources from overseas can play a catalytic role in implementing projects of significant scale. In terms of public transport fleet electrification, two main types of funding support from the international society are commonly discussed: International climate funds (e.g., Global Environmental Facility, NAMA Facility, Green Climate Fund, Clean Technology Fund, etc.) and concessional finance provided by multilateral development banks (e.g., World Bank, Asian Development Bank, Inter-American Development Bank, etc.). This section will examine two cases using the international resources to support electromobility in public transport (Table 3).

Table 3: Summary of international financing cases

	Green Climate Fund	Clean Technology Fund
Project	Shandong Green Development Fund (SGDF)	Concessional Loans/Credit Lines for electric mobility
Country	China	Peru & Ecuador
Accredited Entity	Asian Development Bank	Inter-American Development Bank
Type of vehicles	Not specified, which may cover the value chain of EV industry. Transportation is expected to account for 6.27% of the target portfolio.	Peru: Buses, taxis & 3-wheeled mototaxis, and charging facilities (preferably renewable powered) Ecuador: Buses, taxis
Mechanism	Senior loans from IFIs (incl. ADB, AFD, KFW) and GCF injected into SGDF as catalytic funding	CTF concessional loans blended with IDB's capital resources in the form of loans/conditional credit lines
Feature	GCF resources can be enormous (e.g., 180 million USD in SGDF), but the project must demonstrate transformational potentials.	CTF resources most come in the form of concessional loans to increase bankability of the investment. However, funding request can only be made through accredited MFIs.

2.4.1 GCF via Asian Development Bank: Shandong Green Development Fund

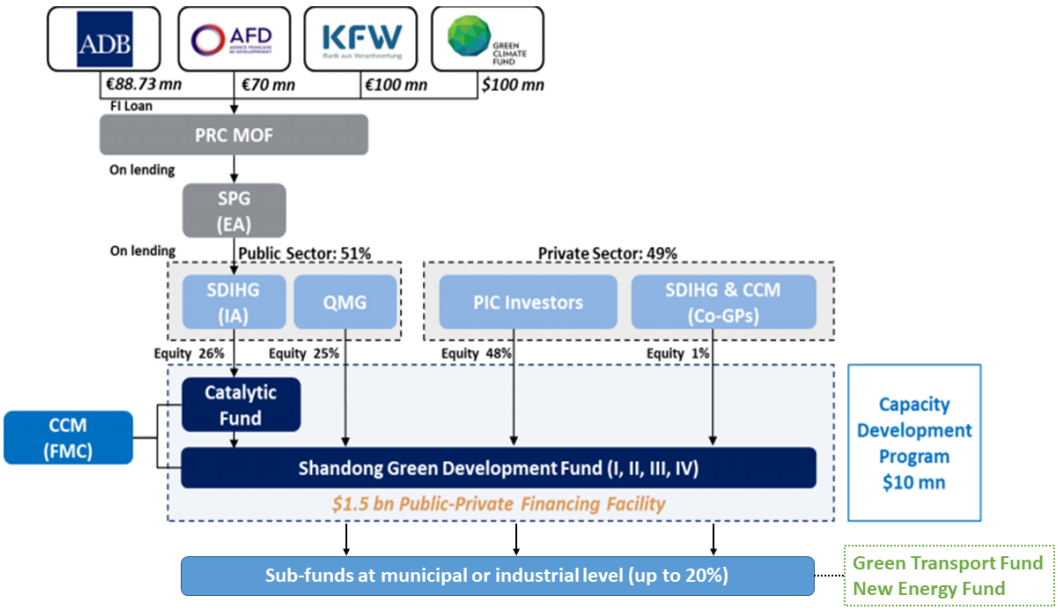
The Shandong Green Development Fund (SGDF) is not a dedicated project for public transport fleet electrification. While public transport is one of the components eligible for funding support from SGDF, the most important feature of this project is to use low-cost international and public capital to crowd-in private, institutional, and commercial (PIC) capital for climate positive subprojects assessed against both climate and financial eligibility criteria.

While the Qingdao Municipal Government (QMG) invests about €320 million (or US$375 million), international financial institutions (IFIs), including the Green Climate Fund, provided about €340 million (or US$400 million) of sovereign loans as catalytic funding, private capital raised from PIC sources is at around $626 million and another $15 million from general partners. The total project size therefore adds up to US$1.5 bn.

[41] Graham J. & Courreges, A. (2020). Leading a Clean Urban Recovery with Electric Buses: Innovative Business Models Show Promise in Latin America, IFC & C40 Cities.

The IFIs involved in this project include Asian Development Bank (ADB, US$100 million, 20 years, LIBOR-based), Agence française de développement (AFD, €75 million, 20 years, EURIBOR-based), Kreditanstalt Fὺr Wiederaufbau (KfW, €100 million, 20 years, EURIBOR-based), in addition to the Green Climate Fund (GCF, US$100 million, 20 years, 0.75%) administered by ADB. These loan processes are channelled through the Ministry of Finance (MoF), the Shandong Provincial Government (SPG) and the Shandong Development and Investment Holding Group (SDIHG) into a 20-year Catalytic Fund. Blended with other capital resources including the QMG, PIC investors, and general partners, the long-term Catalytic Fund is finally transformed into four shorter-term Shandong Green Development Funds (SGDFs) of which each has an investment period of 4-5 years. Distributions of SGDFs will be made to the Catalytic Fund and reinvested into the next-round SGDF after deduction of the payments to the IFIs. A professional fund management company (FMC) was appointed as the manager of the Catalytic Fund and the SGDFs. Eventually, SGDFs intend to participate in up to 20% share of sub-funds at municipal or industrial level, of which Green Transport Fund and New Energy Fund can further contribute to building the value chain and encouraging adoption of EVs (Figure 16).

Figure 16: Financial structure of the Shandong Green Development Funds



Source: Adapted from ADB, 2020[42]

The project was born out of the realization that traditional sovereign financing and banking systems have little incentive to cater to the huge investment needs for climate actions that are consistent with the government's strong policy framework for climate change. There is an inadequate pipeline of projects that can bring about transformational and advanced benefits to address priority climate impacts and vulnerabilities in Shandong. Therefore, the financial structure is designed in such a way that sub-sovereign and private finance can be unlocked to support the subprojects with higher risk profiles beyond business-as-usual (BAU): while concessional sovereign and development finance helps to mitigate risks with clear conditionalities, the return on investment from the SGDFs will be

[42] Shandong Green Development Fund Project: Project Administration Manual (adb.org)

satisfactory to the hurdle rates required by each counterpart investor (PIC investors - 8%, public investors - 2% and SDIHG - 3%). A mix of these funding resources allows the SGDFs to invest in the subprojects that would otherwise rely exclusively on long-term sovereign funding or not proceed because of public funding gap.

To ensure the harvest of transformational and advance benefits, all subprojects are categorized into three climate-related levels (transformational, advanced benefits, and good practices) based on the GCF Investment Framework with different catalytic and financing terms and conditions from the most favorable to the least. Over 10% of the funds should be invested in transformational subprojects, and over 60% in advanced benefits and transformational subprojects (Table 4). One of the transformational and transport-related subprojects proposed in its funding proposal to GCF is the establishment of a technology park "Hydrogen Valley" to regroup R&D and manufacturing businesses related to the production, distribution, and storage of hydrogen for mobility. The investment of all SGDFs is expected to achieve a minimum actual carbon emissions reduction of 1.5 million tons per annum.

Table 4: Indicative terms and conditions provided by an SGDF fund to a Qualified Enterprise for a Qualified Subproject for debt and equity investment

Debt investment			
Climate assessment	Maximum Catalytic Funding	Maximum Tenor	Indicative Interest Rate
Transformational	67%	10	Discounted
Advanced Benefits	50%	8	In line
Good Practice	25%	5	Premium
Equity investment			
Climate assessment	Maximum Catalytic Funding	Exit Strategy	
Transformational	50%	< 10 years	
Advanced Benefits	30%	< 10 years	
Good Practice	0%	-	

Source: ADB, 2020

Meanwhile, a US$10 million technical assistance (TA) program was set up to support project development through subproject screening as well as capacity development through a reporting module support on Monitoring, Evaluation and Verification, Green and Financial Rating, etc. All downstream investment by the SGDFs will comply with the GCF Investment Framework and covenants and principles agreed with ADB and the co-financiers, including but not limited to governance, subproject eligibility selection criteria, ESMS, Gender, M&E, and verification[43].

This project pilots the Green Finance Catalyzing Facility (GFCF) model promoted by ADB, which leverages sovereign and development finance to attract private investment at scale in transformational and advanced approaches to maximizing climate benefits. As the transport sector involves a variety of players from both public and private sectors, and the investment gap remains significant in most developing countries, the GFCF model appears to be a promising way to unlock and crowd-in essential private finance for scaling up decarbonization efforts.

[43] https://www.greenclimate.fund/sites/default/files/document/funding-proposal-fp082-adb-china.pdf

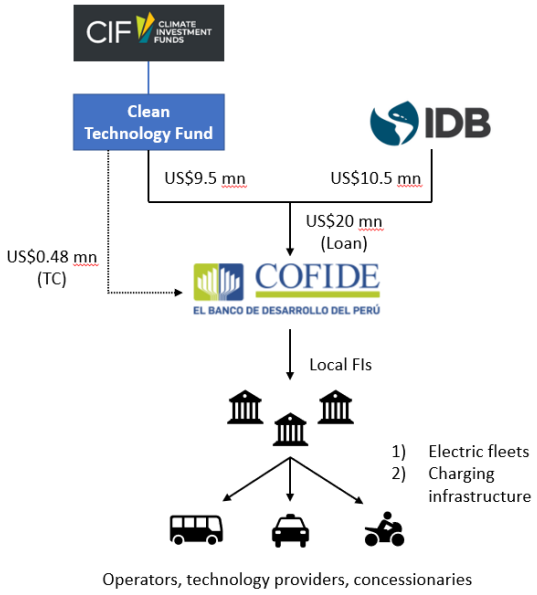
2.4.2 Clean Technology Fund via Inter-American Development Bank: concessional loans/credit lines through Clean Technology Fund for electric mobility (incl. e-buses & taxis) in Peru and Ecuador

Clean Technology Fund is a component of the Climate Investment Fund (CIF), one of the world's largest multilateral climate finance mechanisms for developing countries seeking to shift to low carbon and climate resilient development, and to accelerate climate action. Since its launch in 2008, CIF has been working in partnership with multi-stakeholders to provide competitive financing that reduces risk for investors, lowering barriers to piloting new technologies, scaling up proven solutions, creating sustainable markets, and mobilizing private sector capital for climate action[44].

Under CIF, three-fourth (over US$4 bn) of the US$5.4 bn Clean Technology Fund (CTF) is approved for implementation in renewable energy, energy efficiency and clean transport. Co-finance is an important feature of CTF. It is expected the CTF resources could leverage nearly at a ratio of 1:10 (equaling US$47 bn) in co-financing from other resources[45].

In 2020, the Inter-American Development Bank (IDB) as one of CIF's key partners supported Peru to win a concessional loan of US$20 million for capital investment, coupled with a grant of US$0.48 million for technical assistance to provide long-term financial support to private-led EV projects for urban transport[46]. The loan component is jointly provided by IDB (US$10.5 million) and CTF (US$9.5 million) (Figure 17).

Figure 17: Project structure for financing sustainable electric transport solutions in Peru



Source: Compiled from https://ewsdata.rightsindevelopment.org/projects/pe-l1254-financing-sustainable-electric-transport-solutions/

At the end of year 2020, IDB further supported Ecuador with a US$43 million conditional credit line for a duration of 10 years, also co-financed by CTF's concessional resources at the amount of up to

[44] https://www.climateinvestmentfunds.org/about-cif
[45] https://www.climateinvestmentfunds.org/topics/clean-technologies
[46] https://ewsdata.rightsindevelopment.org/projects/pe-l1254-financing-sustainable-electric-transport-solutions/

US$23,000,000, to enable long-term credit to finance the acquisition of EVs[47]. The Ecuadorian project structure is similar to that of the Peruvian project, except that the funds are locally administered by the National Financial Corporation, the oldest public financial institutions in the country. Some details about these two cases are provided below.

a) Financing sustainable electric transport solutions, Peru

In the Peruvian case, the IDB-CTF resources are executed under a sole financing component by COFIDE, Peru's second-tier national development bank, for two types of capital investments: 1) the replacement of fossil fueled vehicles with new EV fleets for buses, taxis, and moto-taxis; 2) power generation for green mobility solutions, mainly EV charging stations (preferably solar powered). The funds are distributed towards end beneficiaries (i.e., operators, technology providers, concessionaries of the selected public transport) via first-tier local financial institutions. Meanwhile, risk transfer mechanisms such as guarantee and insurance are also available from other sources (i.e., the local CRECER Fund managed by COFIDE & local insurance supported with technical cooperation through another IDB program).

b) Conditional credit line for investment projects, Ecuador

In the Ecuadorian case, the IDB-CTF resources are planned to finance the purchase of about 80 buses and 370 taxis in the country, which will provide a clean public transportation service. The program also has a grant component of around US$1 million for technical cooperation. The first operation consists of a Global Credit Program of US$33 million, of which US$30 million will finance the purchases of EVs, as well as installation of charging stations if required, while US$3 million is reserved for providing scrappage certificates or payments to beneficiaries who will eliminate the ICE vehicles replaced by the newly purchased EVs. The beneficiaries of the project are transportation concession holders, as well as the providers and operators of EVs in the country, which are mostly micro, small and medium enterprises.

2.4.3 How to tap into the resources from the international climate funds

The two case studies were selected mainly because GCF and CTF are among the international resources the most active and most likely to provide essential finance for public transport electrification. The cases above share some similarities. First and foremost, the beneficiary countries accessed these multi-donor climate funds through the respective multilateral development banks (i.e., ADB and IDB) in their region, rather than on their own. While CTF works exclusively with its six partner multilateral development banks (MDBs[48]), GCF can be accessed by its accredited entities of all types. Even though currently, there is no direct access entity (DAE) in Thailand, several international access entities to GCF are active in the region. Partnering with MDBs would be even better as they might be able to provide co-financing. The challenge is about **how to develop an attractive and meaningful proposal** that can gain support from any partner entities and catch the eyes of the Board of these climate funds.

[47] https://www.iadb.org/en/news/ecuador-boost-private-sector-investment-electric-vehicles-idb-support

[48] These include the African Development Bank (AfDB), Asian Development Bank (ADB), European Bank for Reconstruction and Development (EBRD), Inter-American Development (IDB), World Bank Group and the International Finance Corporation (IFC).

It is noticeable that GCF has been relatively less engaged in the transport sector, although transport is one of the priority areas. None of the GCF-approved projects is solely focused on electrification of public transport fleets. However, one may notice that GCF tends to prefer large-scale projects or programs that are transformative and cross-cutting at sectoral level. Moreover, **the mitigation effect from electromobility must be justified by a significant share of clean energy sources**. This implies that any projects relating to public transport fleet electrification should not neglect the issue of energy transition. Therefore, to develop a GCF funding proposal for financing public transport fleet electrification, further analyses would be required to figure out how to produce or purchase green electricity for charging the fleets. To increase the chance of success, it would also be advisable to **consider any cross-cutting opportunities** such as improving urban resilience to natural disasters that might cause any disruption on public transport operations.

2.5 Lessons learned from international experiences on financing public transport electrification

The oversea case studies of public and private finance using domestic resources demonstrate that by offering subsidies or concessional financing as an incentive to local municipalities or public transport operators, governments can take the occasion of providing subsidies to trigger **a structural reform** (e.g., fiscal and transport management at local level in India's case) that would **create long-term benefits** to the entire sector, as well as encourage R&D and filter the **ideal EV technologies adapted to local conditions** based on scientific evidence (e.g., NETF in Hongkong's case). In the meantime, a variety of private actors can become finance providers for EV adoption, ranging from financial institutions which offer **green lending and leasing** (e.g., in HSBC UK's case) to product/service providers which offer **service-based solutions** (e.g., in Zenobe Energy's case) to share the financial burden and risk that public transport operators would otherwise bear all by themselves.

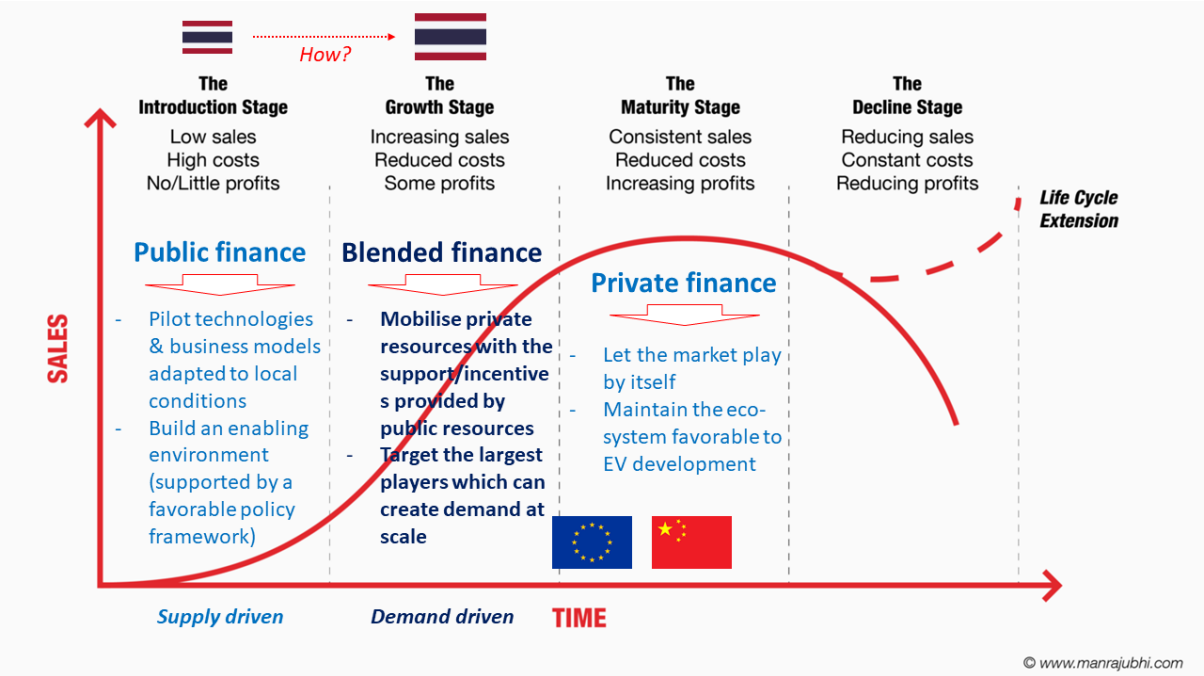
However, using only public or private resources can be insufficient to scale up EV deployment, given the significant size of capital investment required. Blended finance from both public and private resources is therefore crucial to such efforts. A key success factor is to **unbundle the ownership and operations of electric fleets**, such that capital investment in EV fleets and charging infrastructure as well as the risks derived from this investment can be shared across relevant stakeholders. In fact, public actors do not necessarily have to provide finance in all cases. Their main role is to ensure an enabling environment that can mobilise private resources for EV deployment. Private actors, once mobilised at scale, can then possibly afford the relevant costs and risks which are properly shared by the unbundled business model.

Meanwhile, the external resources are available from several international climate funds, but several challenges remain to be tackled to formulate a meaningful proposal before Thailand can successfully tap into those resources.

All in all, if we consider EV fleet transformation in public transport, from a macro perspective, as a market, Thailand is still at the introduction stage where electric public transport vehicles are expensive and few, with no to little profits. This is when public finance plays a major role in identifying the locally suitable technologies and business models, while building an enabling environment through a strong policy framework that is favorable to EV development. This is also when the market is driven

by supply-side efforts, which aim at increasing number of EV products with better performance. Thailand is facing the challenge of moving towards the growth stage, where blended finance would be crucial to mobilise private resources to finance the significant size of investment required. At this stage, the market would become demand driven. The most efficient strategy would be targeting the largest players in the market which have sufficient capacities to drive a fairly substantial demand for the market to grow. Once the market becomes mature, such as in the case of China and Europe, governments can just let the market to run its course, while maintaining the eco-system that is favorable to EV development (Figure 18).

Figure 18: 4-stage life cycle of the EV market



Source: Own design from www.manrajubhi.com

3. Thailand's Policy and Institutional Framework, EV market trends

Chapter Objective:
To review, synthesize and evaluate current Thai Government policies, plans, strategies and implemented measures as well as private-sector engagement, investments, partnerships, and initiatives regarding public-transport electrification

Research Questions:
1. What is the policy overview on public-transport electrification across ministries?
2. What is the investment trend from private sector in electric vehicles, especially on ones applicable to public transport?

Summary:
1. Electromobility has been mostly driven by the policies on economic development and climate change in Thailand. On one hand, as the automotive industry is one of the most important economic sectors in the country, promoting EV manufacturing is a key strategy to enhancing competitiveness of the Thai economy. On the other hand, EV adoption coupled with an energy transition is expected to reduce GHG emissions from road transport, contributing to the country's NDC mitigation targets.
2. While the NDC action plan for transportation has identified several measures relating to electromobility in public transport, those measures mainly aim for the public vehicles owned by the public operator Bangkok Mass Transit Authority (BMTA), along with a small share of privately-owned vehicles such as vans, taxis, songthaews and delivery motorcycles. However, no financial resources were identified to support electrification of those privately-owned vehicles.
3. The most directly relevant policy targets on electromobility in Thailand is the EV roadmap and the ZEV 30@30 targets, which aims at reaching 30% of EVs in the overall domestic vehicle production by 2030, with a further expansion of 100% EV domestic usage by 2035.
4. On the production side, the EV promotion package offered by the Board of Investment (BOI) is the most comprehensive support to EV development in Thailand, which is mainly composed of fiscal incentives to the eligible manufacturers of a variety of vehicles, auto parts, and charging facilities.
5. On the demand side, fiscal benefits are granted to selected types of EVs through subsidy of EV purchase, differentiated reductions in vehicle excise taxes and vehicle registration taxes. The Thai government also set a 20% target of public budget for vehicle fleet to be used for BEV procurement.
6. Meanwhile, support was identified for charging infrastructure development, standardisation of EV systems and end-of-life management for EV batteries.
7. EV registrations have been growing in Thailand since 2017, while charging infrastructure is expanding relatively slow. This reflects a chicken-and-egg dilemma where the expansion of chargers will only be feasible when EVs are widely adopted among the population, and vice versa. Meanwhile, most of the growth in EV adoption concerns private passenger cars and motorcycles. Electric buses are marginal.

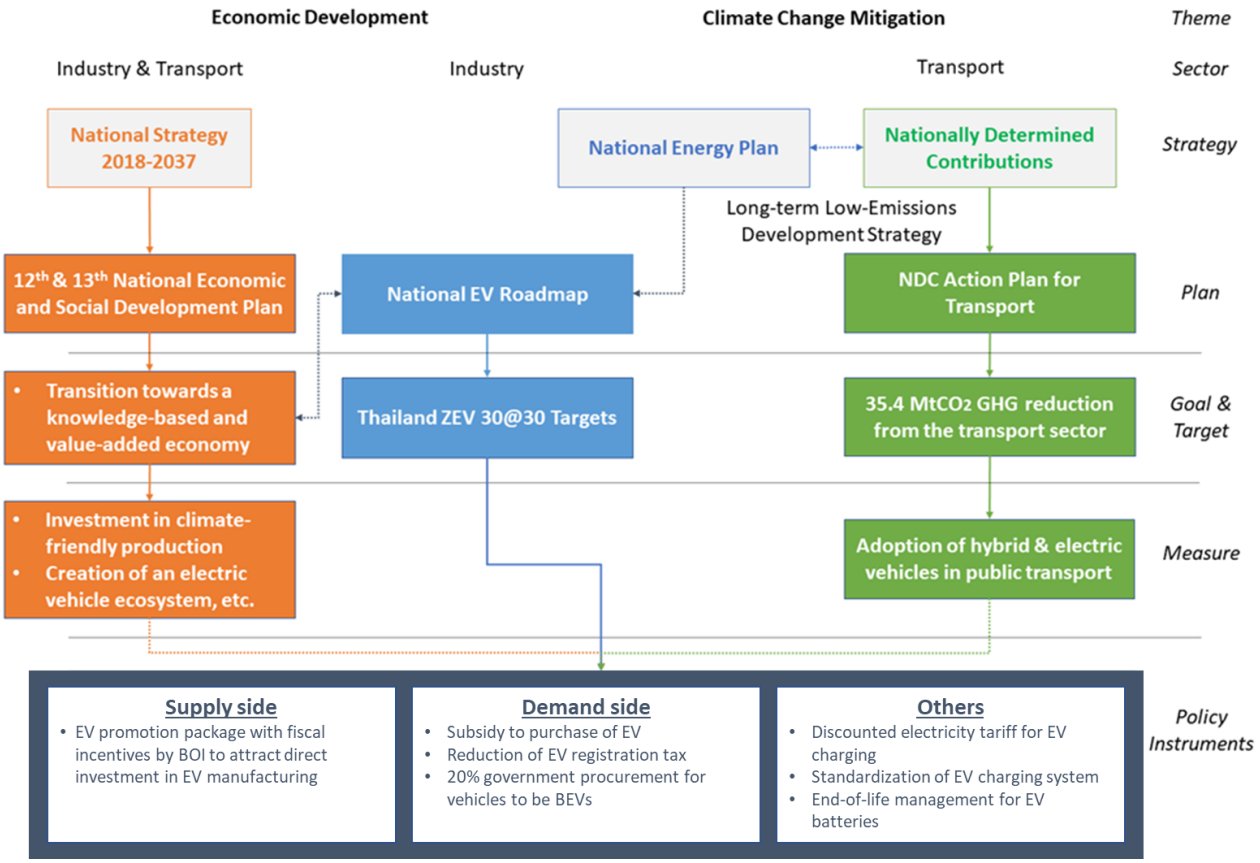
3.1 Policy framework

Public transport electrification is closely linked to a variety of policies, which can be roughly categorized into two main themes: **economic development** and **climate change mitigation**. As the foundation of all policies, the National Strategy 2018-2037 paves the country's pathway towards a secure, prosperous, and sustainable future. From the economic perspective, the 12th and 13th

National Economic and Social Development Plan (NESDP) highlight the goal of transitioning towards a knowledge-based and value-added economy, of which EV production is one of the strategic industries to be promoted. Linking to this economic development goal, the National EV Roadmap was formulated as the master plan to guide the country's pathway towards electromobility. The ZEV 30@30 targets send a clear message that the automotive industry in Thailand will undergo a profound transformation for EV production. Finally, EV development is one of the areas covered by the National Energy Plan in formulating the country's Low-term Low-Emissions Development Strategy, which further supports Thailand's Nationally Determined Contributions (NDCs) for climate change. EV adoption coupled with public transport modernization is considered a key measure for GHG reduction from the transport sector.

In short, the policy framework relating to transport sector electrification in Thailand can be structured in a simplified manner as shown in Figure 19. Most of the components covered in this framework will be elaborated and discussed in the following sub-sections of this chapter.

Figure 19: Policy framework for transport sector electrification

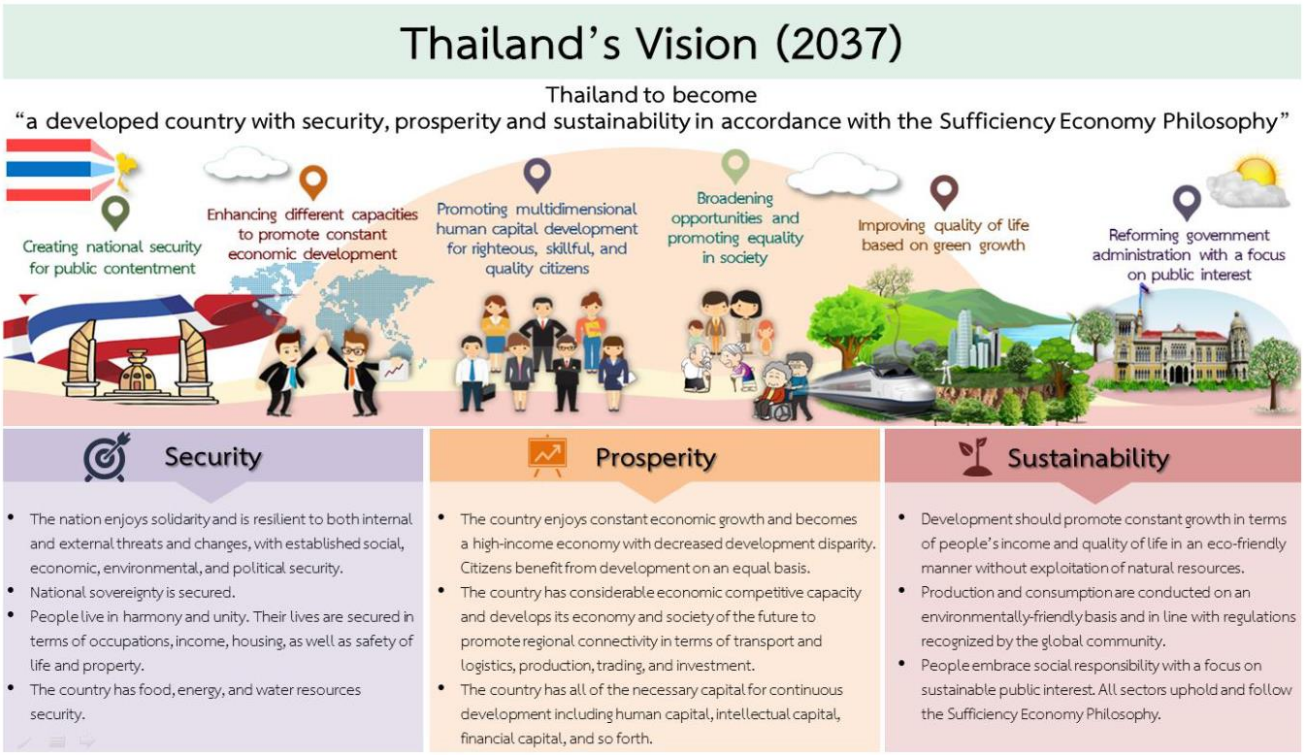


3.1.1 Economic development: industry & transport

Section 65 of the Constitution of the Kingdom of Thailand stipulates that the State should develop a national strategy to be employed as the country's goal for sustainable national development in accordance with the principle of good governance. To this end, the National Strategy (2018-2037) was drawn up as the country's first national long-term strategy pursuant to the Constitution. It shall be pursued to ensure that the country achieves its vision of becoming "a developed country with

security, prosperity and sustainability in accordance with the Sufficiency Economy Philosophy" (Figure 20).

Figure 20: Thailand's Vision (2037)



Source: National Strategy 2018-2037[49]

The National Strategy highlights the goal of enhancing the country's competitiveness. Restructuring manufacturing and services to follow major shifts is in a great need for Thailand. Particularly for the auto manufacturing industry, promotion of the shift from conventional automobiles to electric vehicles, development of energy storage system technology and industry, as well as encouragement of supporting activities in Research and Development (R&D) are specified in the National Strategy. Moreover, to transform Thailand into the hub of the economic corridor for transport, trade, investment and tourism within the region, the National Strategy also highlights the importance of developing seamless transport networks as well as modern public transport and related facilities to accommodate growing urbanisation and to connect cities within the country and with the neighboring countries.

In line with the National Strategy's framework, the 12th National Economic and Social Development Plan (2017-2021) started to lay out the agendas and flagship projects required to achieve the nation's economic and social development goals. Supporting small and medium enterprises (SMEs) of high potential through innovation and technology, increasing value-added of the existing production and service bases, as well as investment in knowledge-based production and services, which are both localised and environmentally friendly, are among the strategic measures identified to enhance the competitiveness of the Thai Economy. In the meantime, reducing Thailand's energy use intensity,

[49] http://nscr.nesdb.go.th/wp-content/uploads/2019/10/National-Strategy-Eng-Final-25-OCT-2019.pdf

raising the proportion of passengers using public transportation systems in urban areas, as well as strengthening the supporting components of Thailand's transportation systems, by encouraging development of transport-related industries and strengthening the managerial and regulatory components of the transport sector, are specified as part of the strategy for advancing infrastructure and logistics.

Looking ahead, the Thai Government is formulating the forthcoming 13th National Economic and Social Development Plan (2023-2027), of which the first goal is to transition the country from natural resources-based industries towards a knowledge-based and high value-added economy that is environmentally friendly. An electric vehicle ecosystem, emphasized by the National Economic and Social Development Council, will play a crucial role in enabling supporting industries including smart electrical parts and a smart grid[50].

3.1.2 Climate change mitigation: transport

Thailand submitted the Intended Nationally Determined Contribution (INDC) to the UNFCCC in 2015, which aims to reduce its greenhouse gas (GHG) emissions by 20%-25% compared to the projected business-as-usual (BAU) level by 2030. After the INDC submission, the NDC Roadmap on mitigation (2021-2030) was developed to provide a policy direction in achieving the GHG emission reduction targets, with the transport sector being one of the four main sectors that have been tasked to fulfil the country´s climate pledge. According to the Roadmap, transport sector is responsible for a GHG emission reduction of 41 $MtCO_2$ in 2030, which comprises of 31 $MtCO_2$ from energy efficiency improvements led by the Ministry of Transport and 10 $MtCO_2$ from biofuel consumption under the responsibility of the Ministry of Energy.

Following the NDC Roadmap, the Office of Transport and Traffic Policy and Planning (OTP) under the Ministry of Transport developed the NDC Action Plan for the Transport Sector in a comprehensive stakeholder consultation and modelling process. The Action Plan identifies detailed measures for achieving the NDC GHG emission reduction target. The Avoid-Shift-Improve (A-S-I) approach is put forward as one of the measures with an overall GHG reduction potential of 35.4 $MtCO_2$, exceeding the 31 $MtCO_2$ reduction target.

To achieve the existing NDC target of 20% GHG reduction, vehicle electrification is one of the core measures listed under the NDC action plan for the transport sector. Existing measures related to EV promotion under the current NDC action plan in the transport sector include:

- The purchase of 35 electric buses including charging stations,
- The purchase of 1,453 hybrid buses,
- The rental of 400 hybrid buses for 7 years,
- The supporting measure to promote public van to electric minibus of 4,626 vehicles,
- The supporting measure to promote public vehicles (e.g., taxi, songthaew) to hybrid vehicles, and
- The change of Internal Combustion Engine (ICE) delivery motorcycle to electric motorcycle in 6 major provinces.

[50] https://www.bangkokpost.com/business/2104323/development-plan-targets-adding-value

However, these measures only represent a relatively small part of Thailand's ambition in EV development. More specific, concrete, and ambitious targets and measures can be found in the National EV Roadmap, described in Section 3.1.3.

3.1.3 Cross-cutting area: EV and Energy Transition to support LT-LEDS

Promoting electric vehicles has its cross-cutting mission, which on one hand supports the country's long-term economic development goal, and on the other hand helps the country to achieve its NDC commitments towards climate change mitigation. However, EV development must go with an energy transition to become meaningful in terms of mitigation. That's how the energy sector comes into play. Thailand's energy policies are closely linked to its efforts in advancing NDC implementation. In October 2020 Thailand submitted an updated version of NDC without increasing its mitigation target but laying out the domestic processes to ensure the integration of the NDC target and actions into the National Strategy. The updated NDC indicates Thailand's plan to formulate Long-term Low Emissions and Development Strategy (LT-LEDS) that will guide the country towards a climate-resilient and low GHG emission development. At the same time the LT-LEDS will serve as a basis for enhancing subsequent NDCs to be more ambitious.

While Thailand plans to submit its LT-LEDS at COP26, the formulation of LT-LEDS encourages participatory processes, and close consultations with the energy sector. In August 2021, the National Energy Policy Council (NEPC) approved the framework for the National Energy Plan (NEP) with the key objective to support Thailand in pursuing clean energy and become carbon neutral in the energy sector by 2065/2070. Also included in the NEP is Thailand's EV 30@30 policy with the target of 30% of EVs in the overall domestic vehicle production by 2030. To reach the EV 30@30 target, the Thai government has assigned a National EV Policy Committee to develop and implement an EV Roadmap, clearly committing to e-mobility as a key measure for NDC and LT-LEDS realization. The approved NEP and EV framework is a positive sign that lays out a solid foundation for Thailand to increase its ambition in LT-LEDS and upcoming NDCs.

The National EV Policy Committee recently agreed on an ambitious master plan aiming for 100% of the vehicles produced in Thailand to be electric, as Zero Emission Vehicle (ZEV) comprising of Battery Electric Vehicle (BEV) and Fuel Cell Electric Vehicle (FCEV), by 2035. The plan also targets 50% of the country's total vehicle production to be ZEVs by 2030, which provides a clearer direction for EV market in the country (Table 5).

Table 5: ZEV targets set by the National EV Policy Committee

Target	Type	ZEV Target (Vehicle / year)		
		By 2025	By 2030	By 2035
Production	Car / Pick up	225,000 10%	725,000 30%	1,350,000 50%
	Motorcycle	360,000 20%	675,000 30%	1,850,000 70%
	Bus / Truck	18,000 35%	34,000 50%	84,000 85%
	Car / Pick up	225,000 30%	440,000 50%	1,154,000 100%

Target	Type	ZEV Target (Vehicle / year)		
		By 2025	By 2030	By 2035
Deployment (Domestic registrations)	Motorcycle	360,000 20%	650,000 40%	1,800,000 100%
	Bus / Truck	18,000 20%	33,000 35%	83,000 100%

The upcoming LT-LEDS can incorporate these updated EV targets and measures, which will enhance Thailand's mitigation ambition, and provide concrete guidance towards Thailand's subsequent NDC update.

3.2 Policy instruments supporting EV development

To support the above-mentioned policies and targets, the Thai Government has adopted a series of instruments, mostly using fiscal incentives, i.e., tax exemptions and deductions, to stimulate capital investments in EV manufacturing and charging infrastructure on the supply side, while encouraging car users to choose EVs against ICE vehicles on the demand side. In the meantime, some supports have also been put in place for charging infrastructure development, standardization of EV components and end-of-life management for batteries, etc. These instruments are categorized into 3 groups including supply side, demand side, and other supporting measures as shown in Figure 21. Details of each policy instrument are illustrated in Table 6.

Figure 21: Policy instruments supporting EV development

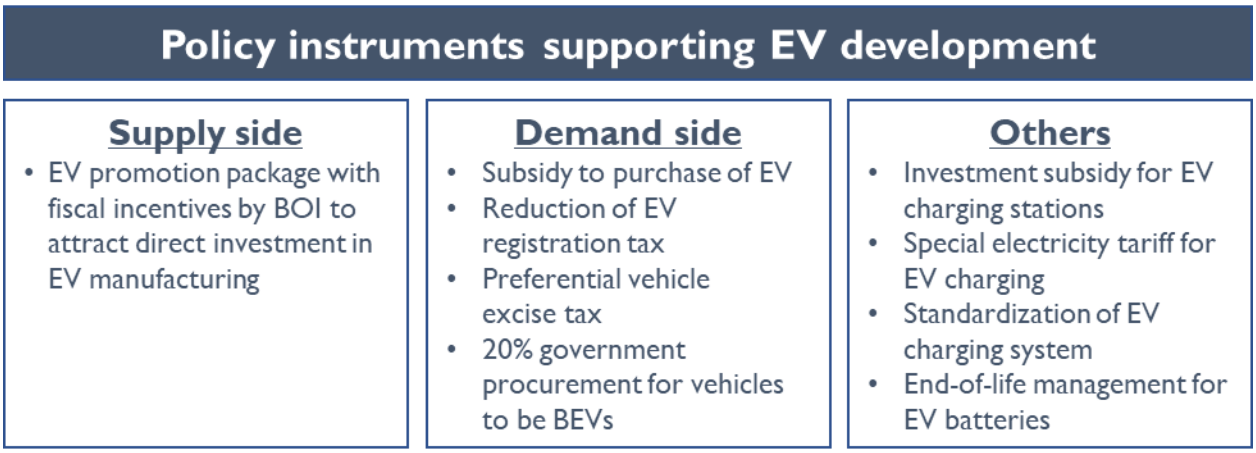
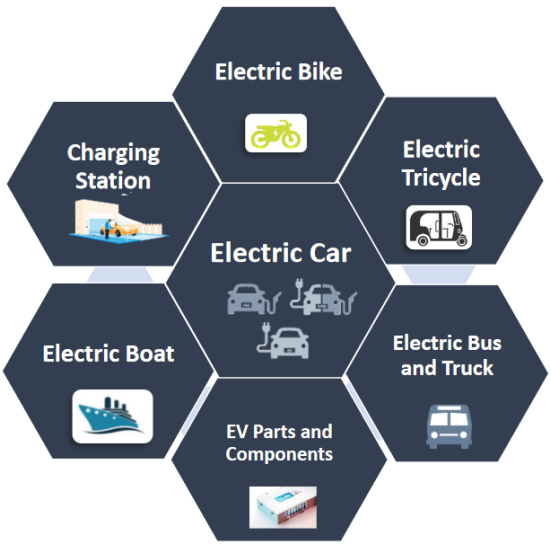


Table 6: Policy instruments supporting EV development

Type	Policy	Description
Supply-side policy instruments	EV manufacturing promotion package by BOI	Thailand's Board of Investment (BOI) has been an important promoter of EV investment in the country. It acts under the Investment Promotion Act, which allows it to grant tax incentives and non-tax incentives. For tax incentives, the main types of taxation that BOI may exempt or reduce include corporate income tax and import duties on machinery and essential materials. For non-tax incentives, they can issue a variety of permits to bring in foreign experts, skilled workers, etc.as well as to own land and remit money abroad in foreign currency. The first EV promotion package launched in 2017 focused on the production of three types of EVs: hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs). The package covered passenger cars, pickup trucks, and buses, with different rates of privileges based on production technology. During this first promotion period, 26 projects were approved by BOI, of which 7 have already started commercial operations from Nissan, Honda, Toyota, Mercedes-Benz, BMW, and Fomm and Takano. After the expiration of the first EV promotion package in 2018, BOI approved a new list of incentives for EV manufacturing in 2020. In face of a tough competition with Indonesia, the new BOI package aims at covering the supply chain of the entire EV ecosystem (Figure 22), including a variety of vehicle types (i.e., motorbike, tricycle, bus, truck, passenger car and boat) as well as EV parts and components, and charging stations. To enjoy the privileges, companies should submit their business project to BOI for screening and approval. Different types of activities are pre-categorised into 6 groups, which are applicable to different levels of privileges[51]. **Figure 22: Eligible Components of The EV Promotion Package by BOI**  Source: BOI (2021)[52] EV promotion package from BOI include:

<table>
<tr><th>Type</th><th>Policy</th><th>Description</th></tr>
<tr><td></td><td></td><td>• 3-year tax holidays for PHEV & BEV investments less than 5 billion THB and 8-year corporate income tax exemption (CIT) for BEVs, if the investment exceeds 5 billion THB,
• Extension of some incentives for BEVs if they meet the requirements set by the government such as minimum production and commencement of commercial operation deadline,
• 90% reduction on import duties for two years on EV battery raw material both for modules and cells granted to promote local EV battery production,
• Specific to electric motorbikes and buses, manufacturers can enjoy 3 years of CIT exemption in general and a possible extension of 1-3 years under different conditions.</td></tr>
<tr><td rowspan="2">Demand-side Policy instruments</td><td>Subsidy on EV purchase[53]</td><td>In August 2022, the cabinet approved 2.92 billion THB to subsidise EV purchase. The subsidy rate is different by type of vehicle as shown in Table 7.

Table 7: Subsidy rate for EV purchase
<table>
<tr><th>Type of EV</th><th>Rate of subsidy</th></tr>
<tr><td>Passenger cars with a price of less than 2 MB & a battery of 10 - 30 kWh</td><td>70,000 THB/unit</td></tr>
<tr><td>Passenger cars with a battery of more than 30 kWh for completely knocked down (CKD) and completely built-up (CBU) units</td><td>150,000 THB/unit</td></tr>
<tr><td>CKD pickups with a price of less than 2 million baht & a battery size of more than 30 kWh</td><td>150,000 THB/unit</td></tr>
<tr><td>Electric motorcycles with a price up to 150,000 baht for both CKD and CBU units</td><td>18,000 THB/unit</td></tr>
</table></td></tr>
<tr><td>Reduction of vehicle registration tax</td><td>Vehicle registration tax is levied on an annual basis by the Department of Land Transport. In July 2022, the cabinet approved additional tax incentives for EVs by lowering the annual car tax for EVs which are registered between Oct 1, 2022 and Sept 30, 2025 by 80%.

While the vehicle registration tax may not be considered as a significant cost component relative to the entire cost of purchasing and owning a vehicle, this is still a benefit to vehicle owners especially given that it is a regular expense throughout the entire period of vehicle ownership. It can become quite important to any public transport operators holding a fairly large fleet of vehicles.</td></tr>
</table>

[51] From the most privileged to the least is A1, A2, A3, A4, B1, and B2. Take CIT as an example, activities in Group A1 can enjoy a CIT exemption for a duration of more than 8 years (no cap), 8 years for Group A2, 5 years for Group A3, 3 years for Group A4, none for Group B1 and B2.

[52] https://www.boi.go.th/upload/content/New%20Investment%20Promotion%20Policies%20EN_6034b5448182b.pdf

[53] https://www.bangkokpost.com/auto/news/2375490/cabinet-approves-b2-92bn-ev-subsidy-package

Type	Policy	Description
	Preferential excise tax rate	The current Thai excise tax structure of vehicles is based on carbon dioxide (CO_2) emissions, and there are four vehicle categories: 1) passenger cars with seats for no more than 10 people; 2) pick-up trucks that are passenger vehicles, double cabs and space cabs; 3) eco-cars and cars that use E85 and B10 biofuel; and 4) EVs. Under the current excise tax structure, battery EVs are tax-exempt from Jan 1, 2020, to Dec 31, 2022, for car makers granted Board of Investment privileges, with the rates levied at 2% after 2022. Manufacturers that did not receive incentives are charged 8% tax[54]. Meanwhile, electric motorcycles are subject to an excise tax at 1% while other types of motorcycles are levied at between 3% and 18% depending on their CO_2 emissions. Note that vehicle excise tax is only levied on those considered as luxury items. Therefore, buses and vans of more than 10 seats as public transport vehicles are not subject to excise tax.
	20% government budget for vehicle fleet to be used for BEV procurement	According to EVAT[55], the Thai government has set the target that 20% of government budget for vehicle fleet to be used for BEV procurement. For that, public agencies, state enterprises and academic institutions have been planning or introducing EVs, such as the procurement of electric and hybrid buses by Bangkok Mass Transit Authority (BMTA), planning by the Office of Transport and Traffic Policy and Planning (OTP) for a public transport network in the Eastern Economic Corridor (EEC) to be served by electric buses, minibuses and trams[56], and the Thammasat Smart City initiative with EVs as a transit mode in Rangsit and Tha Prachan campus[57].
Other supporting policy instruments	Investment subsidy for EV charging stations	The Ministry of Energy launched a 3-yr pilot project between 2017 and 2019 to subsidise investment in charging stations, funded by the Thailand Energy Conservation Fund (ENCON Fund). While the subsidy scheme was open to both public and private actors, including government agencies, academic institutions, state enterprises and private companies, the public sector received more support than the private sector. This was done by allowing the subsidy to cover the costs of chargers and installations if the operator is from the public sector, while private operators could only receive a subsidy for the cost of chargers. While the scheme was not of great success financing a total of 48 normal chargers and 32 fast chargers in 68 locations nationwide[58], it kick-started to some degree the deployment of EV charging facilities.

[54] https://www.bangkokpost.com/business/2060363/excise-tax-rejig-seeks-to-make-thailand-an-ev-hub

[55] https://www.boi.go.th/upload/content/2.%20[PPT]%20Thailand%27s%20Automotive%20Industry%20and%20Current%20EV%20Status_5c864c90761f6.pdf

[56] https://www.nationthailand.com/in-focus/30391711

[57] https://tu.ac.th/en/thammasat-smart-city-mou-4-companies-for-ev-car

[58] Thananusak, T. Punnakitikashem, P., Tanthasith, S. & Kongarchapatara, B. (2021). The Development of Electric Vehicle Charging Stations in Thailand: Policies, Players, and Key Issues (2015–2020). *World Electr. Veh. J.* 2021, 12(1), 2; https://doi.org/10.3390/wevj12010002

Type	Policy	Description
Other supporting policy instruments	Special electricity tariff for EV charging	In September 2020, the Thai government approved a special electricity tariff for all EV charging stations at 2.63 THB/kWh for the off-peak tariff, which is lower than the average tariff of THB 3.20 THB/kWh. The on-peak tariff is set at 4.3 THB/kWh[59].
	Standardisation of EV systems	The Thailand Industrial Standard Institute (TISI) has worked to set up the technical requirements for electric vehicles, traction batteries, and charging systems, through 21 Thai Industrial Standards (TIS). 40 additional standards for next-generation vehicles are being considered for approval. This is an important approach to ensuring the quality of products in the market. TISI classified Thai standards for EVs into 9 categories, including 1) Sockets and outlets, 2) Charging systems, 3) Safety for various types of EVs, 4) Performance, 5) Motors, 6) Batteries, 7) Other equipment, 8) Communication system, and 9) Other. While standards under Category 1, 2, 5, and 7 have been almost completely developed and issued, most of standards under Category 3, 4, 6, and 8 have not been developed. This insufficient coverage of standards for EV components remains to be improved to boost manufacturing of EVs in Thailand[60].
	End-of-life management for EV Batteries	To ensure sustainability in the life cycle of EVs, Thailand has also been working on end-of-life management for EV batteries. The Thailand Energy Storage Technology Alliance (TESTA) is formed by the Ministry of Higher Education, Science, Research and Innovation, EVAT and a number of science and engineering academic institutions. It aims at driving progress in local energy storage technology and enhanced end-of-life management for batteries. As a member of the Basel Convention, regulations related to hazardous waste treatment exist in Thailand. There is a working group chaired by Pollution Control Department and Industrial Works Department set up under the Basel Convention, and a working group on Energy Storage System chaired by the Ministry of Energy that addresses the issue of battery recycling.

3.3 Institutional framework

The Government has initiated its policy to promote electric vehicle since 2015. Various measures to promote electric vehicle production were launched in 2017. However, the development of EV requires the transition of a whole supply chain from production, infrastructure, and deployment,

[59] https://www.fnsyrus.com/uploads/research/20210111ThailandUtilities-ThailandEV;Rechargingforafulldischarge.pdf

[60] https://publicpartnershipdata.azureedge.net/gef/GEFProjectVersions/f566cba6-caee-ea11-a818-000d3a337c9e_PIF.pdf

covering technical, financial, and regulatory dimensions. To drive the electric vehicle industry in the most efficiency and effective way, as well as, to integrate the operations, the National Electric Vehicle Policy Committee was established in February 2020. The committee will set the direction and goal of EV development and to approve plans and projects from government agencies to achieve the national EV goal. Several government agencies must coordinate together to support the goals. As shown in Figure 23, there are 4 main groups of government agencies, i.e., environment, infrastructure, safety, & standard, transport & licensing, and incentives.

Figure 23: Institutional framework for EV development in Thailand

National Electric Vehicle Policy Committee

Chairman: Prime Minister;

Committee:

1. Industry minister,
2. Transport minister,
3. Energy minister,
4. Permanent Secretary of Ministry of Finance,
5. Permanent Secretary of Ministry of Transport,
6. Permanent Secretary of Ministry of Energy,
7. Secretary, Board of Investment,
8. Secretary, Office of the National Economic and Social Development Council,
9. Chairman of the Federation of Thai Industries,
10. Chairman of the Thai Chamber of Commerce,
11. President of The Thai Automotive Industry Association,
12. Mr. Bundhit Eua-arporn expert,
13. Mr. Werachet Khan-ngern expert,
14. Mr. Siri Jirapongphan expert,
15. Mr. Yossapong Laoonual expert,

Secretaries:

1. Permanent Secretary of Ministry of Industry,
2. Director, Office of Industrial Economics,
3. Director, Energy Policy and Planning Office

Environment	Infrastructure Safety & Standard	Transport & Licensing	Incentives
• **Department of Industrial Work** to prepare EV battery end-of-life plan • **Pollution Control Department** to enact Acts for EV battery end-of-life management	• **Ministry of Energy** to subsidise charging infrastructure • **TISI** to proceed on National Automotive and Tire Testing Facility, to proceed on standards of EV charging system, etc.	• **Ministry of Transport** to support the national policy • **Department of Land Transport** to regulate land transportation	• **Ministry of Finance** to launch EV stimulation package • **Excise Department** to provide special excise tax rate • **BOI** to provide privileges on investment of EV • **EPPO** to provide financial support for replacement of EV and charging infrastructure

Source: https://www.thaiauto.or.th/2020/news/news-detail.asp?l=&news_id=4773 & BOI (2022)

3.4 EV investment trends in Thailand

As of 30th April 2022, there are 31 projects with a total amount of 1,674 million USD investing in HEV, PHEV, BEV, and battery electric bus applying for BOI privileges whereas 11 projects are commercially distributed (BOI, 2022).

Figure 24: Promoted EV projects under BOI

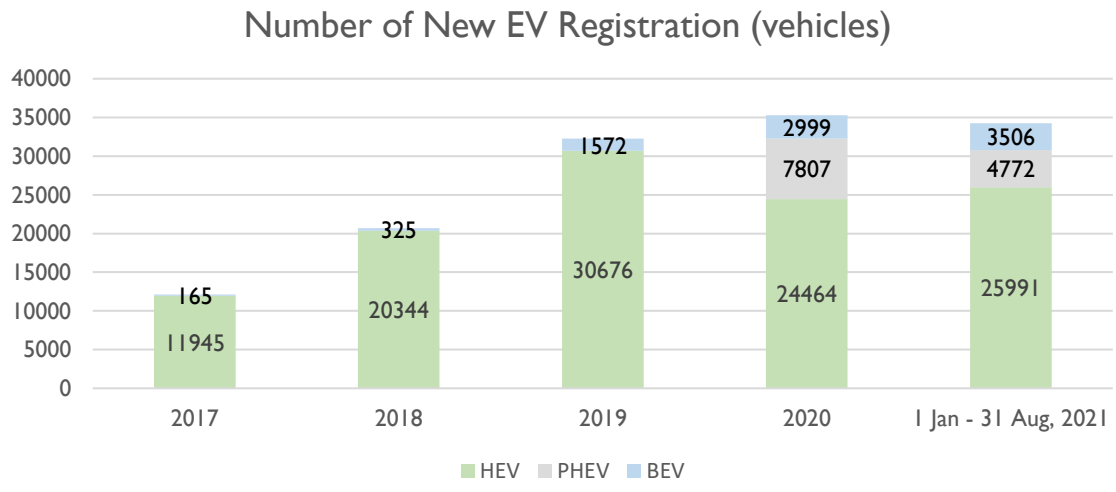
		31 Projects *	1,677.4 Million USD**	Promoted Projects 31	Certificate Issuance (Projects) 15	Commercialized Distribution 11
666,855 units	HEV (438,455)	7	1,078.4			
	PHEV (92,600)	7	224.6			
	BEV (131,200)	14	305.0			
	Battery Electric Bus (4,600)	3	69.4			

Remarks * 17 promoted entities,
** Investment values excluding cost of land and working capital, 34.5 THB = 1 USD (May, 2022)

Source: BOI, 2022

The popularity for electric vehicles in Thailand was fairly limited before 2017 but started growing year after year since then. According to the latest statistics from the Electric Vehicle Association of Thailand (EVAT), the number of new EV registrations has been increasing since 2017. The compound annual growth rate of newly registered hybrid EVs (HEVs) and Plug-in EVs (PHEVs) is 39% between 2017 and 2020, while that of newly registered battery EVs (BEVs) is 163%. The year 2021 has set a historical record in the growth of new EV registrations with nearly the same number of new registrations from the previous year in 8 months (Figure 25).

Figure 25: Evolution of new EV registration during 2017 - 2021



Source: EVAT, 2021

However, most of the newly registered vehicles are electric passenger cars and motorcycles. For buses, only 4 battery electric buses (BEBs) were added to the market in the first eight months of 2021, amounting to 126 BEBs in total, as well as 1 hybrid electric bus (HEB).

Charging infrastructure remains quite limited. The total number of outlets nationwide as of 22 September 2021, amounts to 2,285, spreading over a total of 693 charging stations, according to EVAT[61]. There is a chicken-egg dilemma in charger deployment. As EV adoption is still limited, the concern over profitability might have constrained the expansion of chargers. However, without sufficient charging infrastructure, people would be less willing to adopt EVs. This is obviously an important issue to be taken into account in the overall analysis of large-scale EV deployment.

[61] http://www.evat.or.th/attachments/view/?attach_id=256246

4. Integrated Assessment of Public Bus Electrification

Chapter Objective:

To elaborate concept and design together with implementation requirements and roadmap of financial mechanisms for public bus electrification through (i) detailed examination of the demand and supply side of the public bus service market, covering a comprehensive assessment of the organisational structures and technical and financial performance of the operators including financial situation, characteristics of fleet ownership, management, and operation, and applied business models, and (ii) assessment of financial and technical needs of the operators to electrify their fleets covering identification of financial and technical challenges of public bus operation and maintenance, detailed review and analysis of CAPEX, OPEX, TCOs as well as the feasibility of the proposed business model

Research Questions:

1. What is the structure, organization, and stakeholder map of the public bus service market in Thai cities, e. g. Bangkok?
2. What are the key performance characteristics on the supply side of the public bus service market?
3. What are the current financial and operational status of the operators?
4. What are the financial and technical support frameworks appealing to these operators? How?
5. What are the potential financial mechanisms for the public bus electrification?

Summary of Key Results:

1. Existing Market Structure of Public Bus Services
   - g) Public buses contribute to 80% of total commutes by public land transport; however, due to the low quality of buses and poor level of service quality, the majority of bus passengers are people with low income who have limited capacity to switch to other modes.
   - h) There are 3,786 buses covering 180 routes serving passengers in the Bangkok Metropolitan Region (BMR), as of August 2021. Most of the public buses are deteriorated and not air-conditioned. This causes not only inconvenience for passengers but also high operating costs for the operators.
   - i) The operators of 3,786 buses can be divided into 3 groups, i.e., (a) Bangkok Mass Transit Authority (BMTA), a state-owned enterprise and a major bus operator, who runs 78.3% of total buses in BMR covering 108 routes, (b) private companies with sublicense from BMTA and (c) private companies with direct licenses from Department of Land Transport (DLT).
   - j) Previously, BMTA was both a regulator and an operator with the authority to sublicense private operators; therefore, there were 2 group of operators, i.e., BMTA and its sublicense companies. This licensing system together with the limited capability of BMTA to control the service quality led to the poor level of service. In 2016, the cabinet resolution endorsed DLT as a regulator and BMTA as a bus operator, aiming to encourage fair competition for all licensed operators as well as to promote delivery of higher performance and better service quality. The reform is undergoing; therefore, some of private companies sublicensed to BMTA still exist. In the long term, all private companies must get licenses directly from DLT so the operators will be divided into 2 groups, i.e., (a) BMTA as a state-owned enterprise and (b) private companies with direct licenses from DLT.
   - k) The new regulation resolved in 2016 has the mandate over both the quality of buses in service and the standard of service. Approximately 70% of total buses in service must be new or less-than-2-year vehicles and the remaining 30% must be less-than-25-year vehicles.
   - l) Bus fares are regulated by the government and kept low to ensure that they remain affordable to all commuters especially those with low income. Since the fare is the major source of revenue for the bus operators, the low bus fare forces the operators to minimize their costs; therefore, lowering the service quality for the passengers. The current bus fares are considered highly affordable as per

the Sustainable Urban Transport Index (ESCAP, 2017), which implies that they can be adjusted to ensure that the revenues of the bus operators can cover all operating costs of buses as well as allow them to invest in improvement of bus quality and services.

2. Financial status and business models of existing bus operators:
   c) The assessment of the current financial status of bus operators implies that existing operators including BMTA and private companies have limited financial capacity. Most of them have been incurring deficits. This proves that the bus fare cannot cover the operating cost of the operators, resulting into limited capacity to invest in improvement of bus and service quality. However, there are two new investors from the EV and battery manufacturing sector entering the public bus operation business with electric buses.
   d) Business models of three existing groups of bus operators are elaborated. All three groups of operators are owning their own bus fleet, running services, and maintaining their fleet. Only in 2011, BMTA was allowed to rent 117 buses under the performance-based contract with the bus provider delivering buses and maintenance services. The operating cost incurred to the operators covers fuel cost, employee wages and benefits, and other costs such as cost of ticket, license fee, etc. while the revenues of the operators mainly come from bus fares. Only BMTA has received subsidies from the government.
3. Financial and technical needs assessment of bus fleet electrification and charging infrastructure deployment in Thailand
   e) The CAPEX of a diesel bus is 4,900,000 THB. Compared to that, the CAPEX of an NGV bus is 17% lower while that of an electric bus is 102% higher. The total OPEX of a diesel bus is the highest at 2,619,500 THB/year while that of an NGV bus and an e-bus account for 75% and 58% of the OPEX of a diesel bus, respectively.
   f) The TCO of an e-bus is about 22.50 THB/km which is by 22% lower than that of a diesel bus (27.41 THB/km), but higher by 10% compared to a NGV bus (20.20 THB/km). It can be concluded that the TCO of an e-bus is competitive, compared to that of a diesel bus but not as attractive when compared to a NGV bus. However, an e-bus requires higher upfront cost than both a diesel bus and a NGV bus.
   g) The TCO of all types of buses changes with the annual distance. Since OPEX during year 1 – year 15 of a diesel bus and a NGV bus are so large that the total NPV of OPEX is almost 80% of the NPV of the total cost, the parameter has an impact on the change of the TCO of a diesel bus and a NGV bus is the discount rate, followed by cost of bus, fuel cost, maintenance cost, and inflation rate. For an e-bus, the parameter having the second largest impact on the change of its TCO is the cost of bus followed by the discount rate, cost of battery replacement, fuel cost maintenance cost, and inflation rate.
4. Proposed business models and financial mechanisms for public bus electrification in Thailand
   e) The operating lease model and integrated end-to-end financing model are considered as potential business models to overcome the existing barriers to public bus electrification in Thailand, mainly regarding the high upfront cost, limited financial capacity to invest new buses, lack of skilled capacity to maintain and repair e-buses.
   f) Discounted cash flow models were applied for assessment of feasibility. To attract investors, the 10% IRR is set as a threshold for the return of all players. However, since the fare is the major source of revenue for the bus operators, the current level of bus fares cannot make the bus electrification feasible. Additional financial support either from the government or international sources are needed within the scope of 1,303 – 1,983 MB for making the electrification of 500 public buses feasible depending on the business model selected and the financial options provided.

g) Compared to the existing subsidy scheme for electric passenger cars as per passenger-trip over the 15-year lifetime (3.11-3.33 THB/passenger-trip), the support needed for public bus electrification is smaller (highest at 2.32 THB/passenger-trip).

h) Moreover, with the same amount of funding, about 18,600 – 28,300 electric passenger cars can be supported, depending on the scenario; therefore, the number of beneficiaries over 15-year duration of the subsidy program on passenger cars is approximately 510 - 776 million passenger-trips while the number of beneficiaries from 500 public buses is 1,140 million passenger-trips, or approximately 1.47 – 2.24 times of personal cars.

i) Further assessment shows that the GHG emission reduction from the electrification of 500 buses is about 43,091 tCO_2/year whereas the cost of the support needed in all scenarios per the amount of GHG abatement are less than 160 USD/tCO_2. The government can use this estimated GHG abatement cost as a reference to compare with the GHG mitigation cost of other NDC measures for incentivizing low carbon investment and to prioritize the public finance support.

5. Roadmap of operationalising financial mechanisms for public bus electrification in Thailand

c) The proposed business model as well as the various financial options can remove the key financial barriers especially those for bus operators including high upfront costs, limited financial capacity, and lack of skilled capacity to maintain and repair e-buses. However, some barriers still exist, and further actions related to government policies addressed in the report are needed.

d) The roadmap in this chapter is developed for operationalising financial mechanisms for public bus electrification in Thailand. The roadmap is divided into three phases, i.e., preparation phase, piloting phase, and full implementation.

6. Recommendations for public bus electrification in Thailand

d) Upgrading the public bus service to become everyone's choice should be the national agenda to reduce traffic congestion and air pollution, to improve the quality of life of citizens in Thailand. To upgrade the public bus service, replacement of old buses, improvement of service standard, and fair adjustment of bus fares are needed.

e) Public bus electrification can be one of the promising solutions for upgrading the public bus service in Thailand.

f) The provision of financial support proposed in this report will allow the modernization of the public bus service last for 15 years. The long-term development of public transport to remove overlapping routes and improve service quality, including the adoption of new models of bus operation is crucial for the sustainability of a modern public bus service.

4.1 Existing market structure of public bus

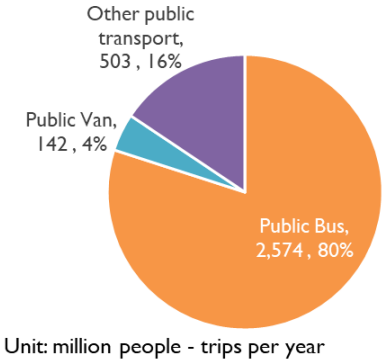
4.1.1 Demand for public bus

In 2019, the total number of commutes in Bangkok Metropolitan Region was 11,124.30 million passenger-trips per year whereas public transport has a share of 19.42%. Among the public transport, public bus contributed 80% to the total commutes by public land transport or 2,574 million people-trips/year (Figure 26).

The number of passengers using public buses is fluctuating (Figure 27). The decreasing trend during 2014 – 2017 was caused by undesired conditions of buses and poor level of service quality, i.e., unpunctual service, and risky driving practices. The majority of bus passengers still remain people with low income who have limited capacity to switch to other modes. The provision of new 489 air-conditioned natural gas vehicles (NGV) in 2018 and the rising price of petroleum products during

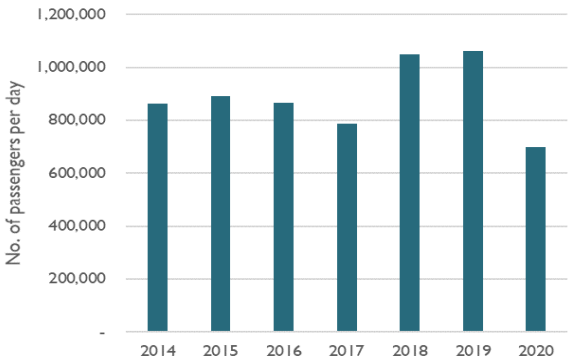
2018-2019 stimulated the number of passengers of public buses. However, the ridership dropped again in 2020 due to COVID-19.

Figure 26: Share of commutes by public land transport in 2019



Source: Transport Infrastructure Report 2019, Office of transport and traffic policy and planning

Figure 27: Number of passengers per day during 2014 – 2020

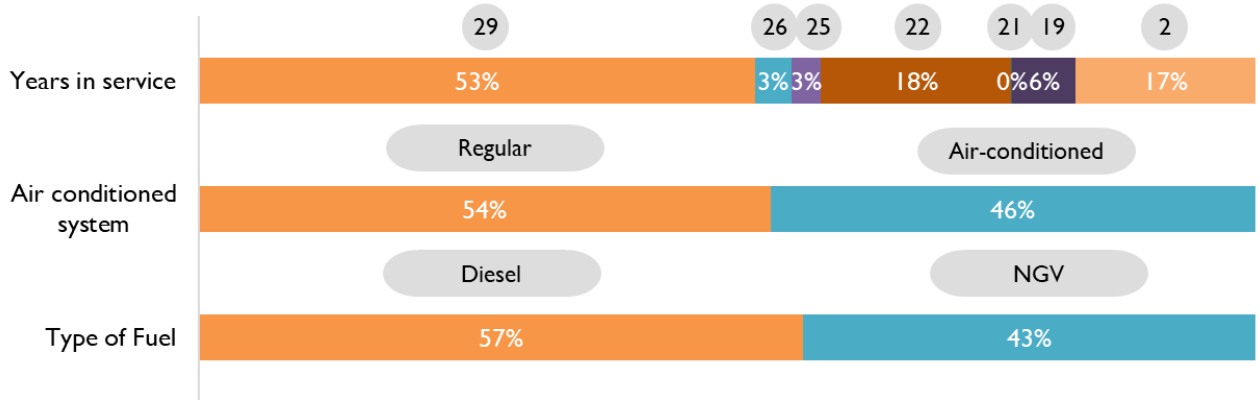


Source: Bangkok Mass Transit Authority's Rehabilitation Plan (New Revision), 21 April 2020

4.1.2 Supply of public bus

The conditions of public buses in service are not desirable. There are 3,786 buses covering 180 routes serving passengers in the Bangkok Metropolitan Region, as of August 2021. 53% of them had been in services for more than 29 years and 54% of them are not air-conditioned (Figure 28). This causes not only inconvenience for passengers but also high operating cost for the operators. Some of these buses are not well functioning; therefore, insufficient supply of buses lowers the service quality and reduces the income of the operators. Moreover, 57% of these buses rely on diesel whereas the specific fuel consumption is high with a volatile diesel price. Moreover, a diesel bus has 1.5 to 8 times the GHG emissions of an electric bus.

Figure 28: Conditions of public buses in service



Sources: Bangkok Mass Transit Authority's Rehabilitation Plan (New Revision), 21 April 2020, BMTA's 2020 annual report

Operators of these buses can be divided into 3 groups, i.e., (a) Bangkok Mass Transit Authority (BMTA), a state-owned enterprise, which is a major bus operator with a market share of 83% covering 116 routes, (b) private companies with sublicense of BMTA and (c) private companies with

direct licences from DLT. Table 8 shows the number of buses serving in the Bangkok Metropolitan Region by operators in 2021.

Table 8: Number of buses serving in the Bangkok Metropolitan Region in 2021

Operators	Number of buses	Share in %
BMTA	2,966	78.3%
Private companies (Sublicence of BMTA)	196	5.2%
Private companies (Direct licences from DLT)	624	16.5%
Total	3,786	100%

Source: ***http://www.bmta.co.th/sites/default/files/files/about-us/o15-october63-december64.pdf***

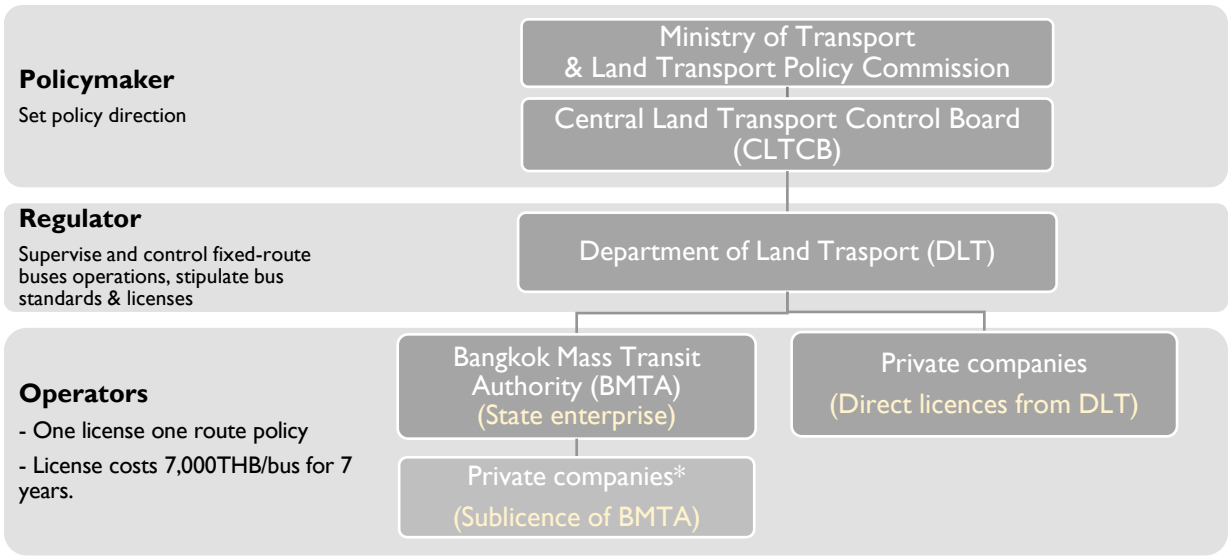
The new regulation, resolved by the cabinet in 2016, controls the quality of buses in service. About 70% of total buses in the fleet must be new or less-than-2-year vehicles and the remaining 30% must be less-than-25-year vehicles. The regulation allows gradual replacement of old buses in the fleet. The share of new or less-than-2-year vehicles must increase to 30% within the 1st year after getting license, 50% within the 2nd year, and 70% within in the 3rd year. It is expected that in 2022, 70% of buses covering 54 routes that obtained licenses in 2019 must be new or less-than-2-year vehicles.

4.1.3 Institutional arrangement of public bus market

As public buses are the basic transport mode of the country, government supervision is necessary to ensure comprehensive coverage and accessibility as well as to maintain fair pricing. Following the Land Transport Act, the Land Transport Policy Commission chaired by Minister of Transport has been established to determine long-term and short-term policies while the Central Land Transport Control Board (CLTCB) chaired by the Permanent Secretary of Ministry of Transport has been put in place to prescribe the routes, number of transport operators and vehicle for both the fixed routes and the non-fixed routes in Bangkok, between provinces and between countries, to prescribe the rates of transport charges, to lay down measures for the prescribing, permitting, revoking of licenses and controlling the land transport affaires, and to carry out other activities prescribes in the Land Transport Act.

Previously, BMTA was both a regulator and an operator with the power to sublicense private operators; therefore, there were 2 groups of operators, i.e., BMTA and its sublicense companies. This licensing system together with the limited capability of BMTA to control the service quality led to the poor level of service. In 2016, the cabinet resolution endorsed the Department of Land Transport (DLT) as a regulator and BMTA as a bus operator, aiming to encourage fair competition for all licensed operators as well as to promote delivery of higher performance and better service quality. The reform is undergoing; therefore, some of private companies sublicensed to BMTA still exist. In the long term, all private companies must get licenses directly from DLT so the operators will be divided into 2 groups, i.e., (a) BMTA as a state-owned enterprise and (b) private companies with direct licenses from DLT.

Figure 29: Institutional arrangements of public bus services in Bangkok Metropolitan, 2022



Remark: *When the BMTA licenses granted to these private joint companies expire, they must apply for licenses from DLT.

Source: Own design

a) Route and licensing

To prevent overlapping service routes and to ensure coverage and connection to other transportation modes including rail, water, and air, the Department of Land Transport (2019) has reformed service routes of public buses in Bangkok and its vicinity areas. Key issues regarding route and licensing can be summarized as follows:

- The "one route one operator" policy is applied strictly for licensing bus operators.
- The fee of the license is 7,000 THB and the license is valid for 7 years.
- The new regulation has also mandated the quality of buses in service mentioned earlier and DLT has established 12 indicators to conduct regular evaluation of their service quality, e.g. driving within the specified route, reaching the specified number of trips, punctual schedule.

As per the cabinet resolution on 27 September 2016, the reform plan announced 269 service routes covering the distance of 7,833 kilometres.

Table 9 describes allocation of licenses or routes granted from DLT by operators.

- From further reviews of operators, the following was found:
    - Thai Smile bus Co.,Ltd. had 9 licenses in 2021 and received another 71 licenses in 2022.
    - E Transport Holdings Co.,Ltd., which is the subsidiary of Energy Absolute Plc., has acquired 99.99% of the ordinary shares of Smart Bus Co.,Ltd. who received 31 licenses directly from DTL and was also the major shareholders of 6 companies that received 6 another licenses from DTL during 2019-2020.
    - Other private companies granted licenses during 2019-2020 were companies sublicensed from BMTA.

Table 9: Number of licenses or routes granted from DLT by operator (updated in April 2022)

Operators	Number of licences / routes
BMTA	108
Thai Smile Bus Co.,Ltd.	80
E Transport Holdings Co.,Ltd.	37
Other private companies	14
Subtotal	239
Not granted	30
Total	**269**

Sources: Bangkok Mass Transit Authority's Rehabilitation Plan (New Revision), 21 April 2020, https://classic.set.or.th/dat/news/202204/22041019.pdf, https://thaismilebus.com/about-us/, https://classic.set.or.th/dat/news/202203/22035439.pdf

b) Bus fares

Bus fares are regulated by the government and kept low to ensure that they remain affordable to all commuters especially those with low income. CLTCB has the responsibility to set the ceiling of bus fares, but the actual rates are negotiated between DLT and bus operators. The latest fares were resolved in 2019, with an increase by 1-2 THB compared to the rates in 2015. Bus fares vary upon operators, types of buses and distance travelled as shown in Table 10.

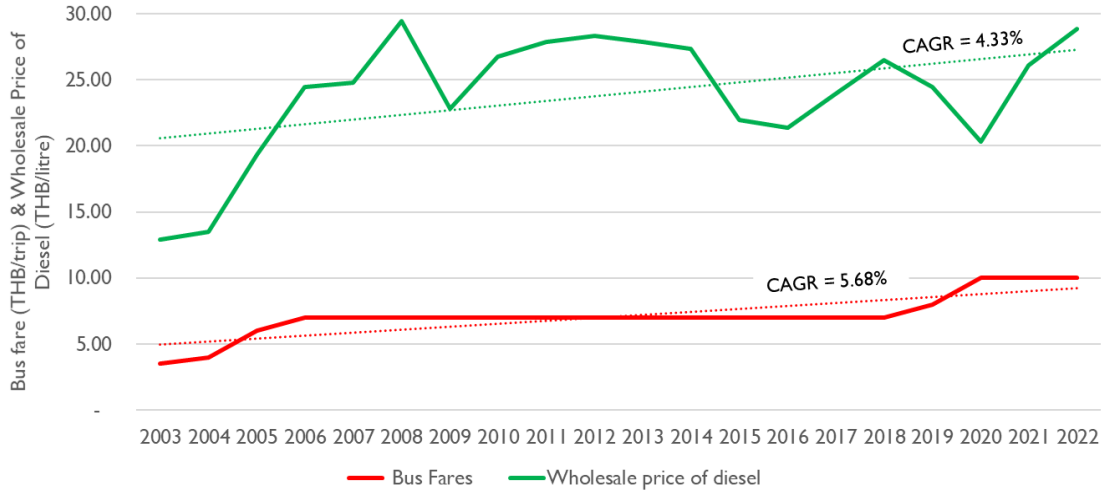
Table 10: Bus fares applied since 22 April 2019

Types of Buses	Bus Fares (Unit: THB)		
	Ceiling Set by CLTCB	Actual Operated by BMTA	Actual Operated by private companies
 Non-airconditioned	10 (0.50 - 10)	8 (0.40 - 8)	10 (0.50 - 10)
 Air-conditioned (old model)	13 – 21 (1.05 - 13)	12 - 20 (1.05 - 12)	13 - 21 (1.05 - 13)
 Air-conditioned (EURO)	14 – 26 (1.30 - 14)	13 - 25 (1.25 - 13)	14 - 26 (1.30 - 14)
 Air-conditioned (new model)	15, 20, 25 (1.25 - 15)	15, 20, 25 (1.25 - 15)	15, 20, 25 (1.25 - 15)

Remark: Numbers in () are the average fares per km of distance assuming that the longest distance is 20 km.
Source: https://mgronline.com/business/detail/9620000039833

There were 6 adjustments of minimum bus fares during 2003 – 2022 where the key factor determining the adjustment of bus fares has been the fuel price. Figure 30 illustrates changes of minimum bus fares and diesel price during 2003 – 2022.

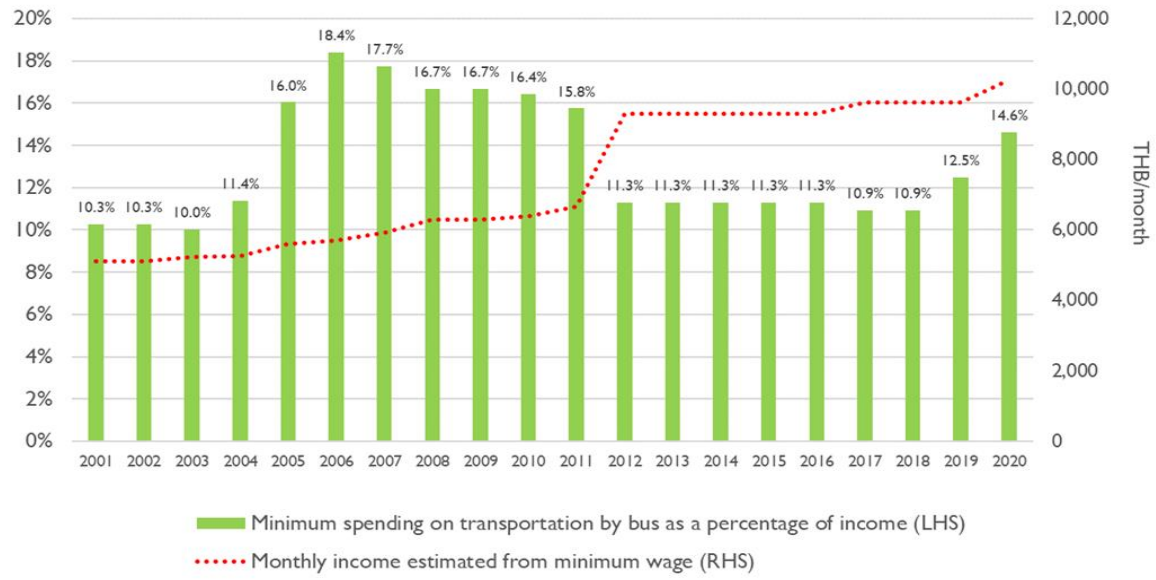
Figure 30: Changes of minimum bus fares and diesel price during 2003 – 2022



Sources: https://mgronline.com/business/detail/9620000039833, http://www.eppo.go.th/index.php/th/energy-information

The Sustainable Urban Transport Index on affordability measures monthly expenditure on public transport compared to mean monthly income of the poorest quartile of the population of the city, and should range 3.5% - 35% of the income (ESCAP, 2017). In comparison to the index, the fares of public buses in Bangkok are considered as highly affordable since the monthly expenditure on public bus use ranged between 10% - 18% of the minimum monthly income per capita during 2003 – 2019 (Figure 31).

Figure 31: Ratio of monthly expenditure on public transport compared to the monthly income estimated from minimum wages



Remark: The minimum cost of commuting by buses per capita in Bangkok is calculated from minimum bus fares multiplying by 6 trip/day and 25 day/month.
Sources: http://social.nesdc.go.th/SocialStat/StatReport_Final.aspx?reportid=3817&template=2R1C&yeartype=M&subcatid=11

However, the cost of bus operation depends upon not only fuel price but also other economic indicators, e.g., consumer price index, labour cost index. Since the fare is the major source of revenue for the bus operators, a low bus fare forces the operators to minimize their costs; therefore, lowering the service quality for the passengers. The bus fares should be adjusted to cover all operating costs of buses as well as allow bus operators to invest in improvement of bus and service quality. To ensure affordability for low-income passengers, the government should support the service provision through direct subsidies to low-income passengers, instead of keeping the fare at a low level. Fair pricing together with regular evaluation of operators' performance will lead to higher service quality which is key to encourage the use of public transport for all groups and finally leading towards an improvement in the overall traffic situation of Bangkok.

4.2 Financial status and business models of existing bus operators

4.2.1 Current financial status of bus operators

a) Bangkok Mass Transit Authority (BMTA)

BMTA has been incurring deficits since its establishment in 1976 resulting from its high operating costs and low revenues due to fares regulated by the government. Key figures drawn from the review of BMTA's financial status (Figure 32) can be summarized as follows:

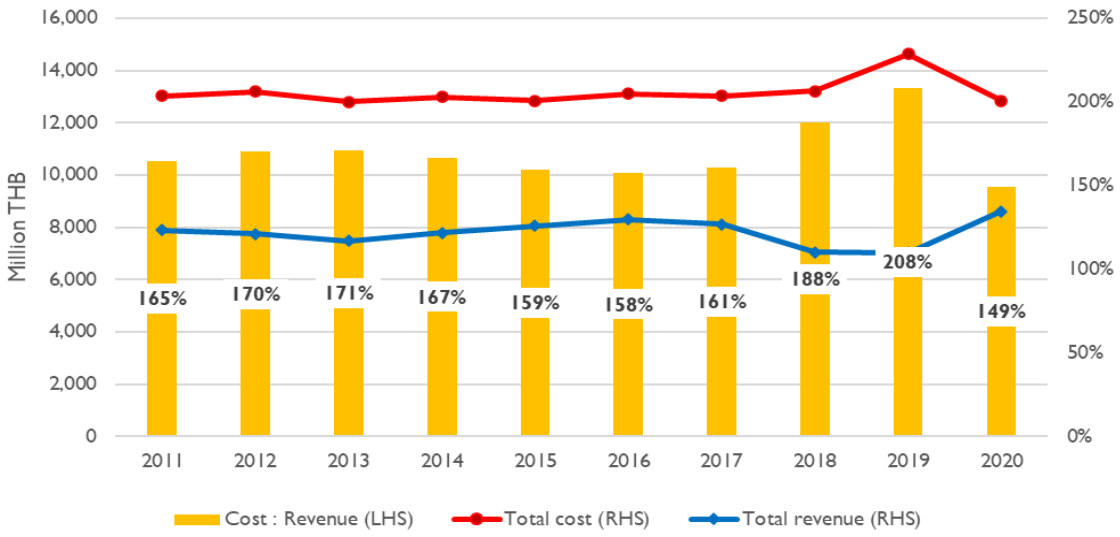
- Total cost of BMTA was about 49% - 108% higher than its revenue during 2011 – 2020.
- BMTA's revenues came mainly from the support of the government (55% of total revenue) while only 39% of the revenues came from sales of tickets.
- Wages and benefits of all BMTA staff including bus drivers, bus assistants, management team, maintenance team and administration team account for 44% of total cost for BMTA, which is the highest, followed by interest rates, fuel cost and maintenance cost accounting for 21.3%, 13.9%, and 12.7%, respectively. Considering only the operating cost, wages and benefits, fuel cost and maintenance cost amount to share of 56.5%, 17.7%, 16.2%, respectively. As identified in BMTA's rehabilitation plan (2020), the average manpower for operation of a public bus was at 4.65 persons/bus, which is high compared to other cities/countries. For example, there were 4,749 staff operating 2,378 buses, accounting 2 persons/bus in Wales, UK, whereas 79% of the staff are drivers[62].

It is recognized that most buses under BMTA are deteriorated leading to high operating costs and low service quality. Additionally, further restraints on capacity result from new regulation determining that 70% of buses in service by operators must be new or less-than-2-year vehicles. BMTA currently has limited capacity to invest in new fleets and as highlighted by BMTA Director, BMTA is seeking for Public-Private Partnership (PPP) to meet the investment needs in new buses.

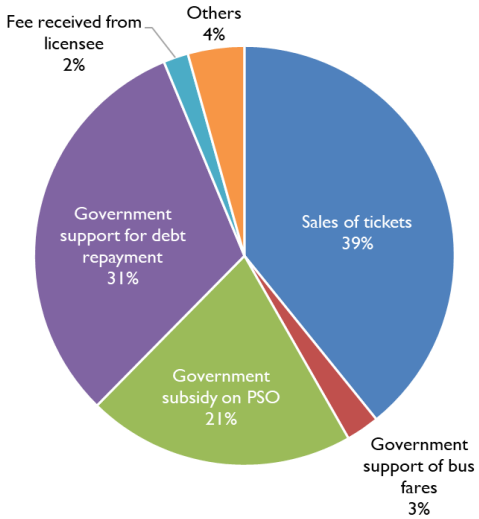
[62] https://gov.wales/sites/default/files/pdf-versions/2022/4/3/1649859506/public-service-vehicles-buses-and-taxis-april-2019-march-2020.pdf

Figure 32: Financial status of BMTA

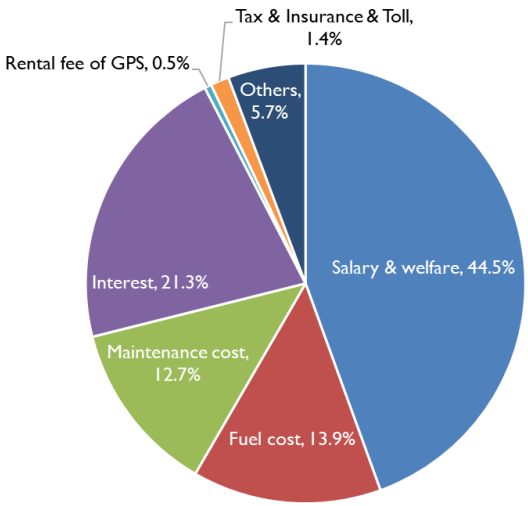
a) Total revenue and cost of BMTA during 2011 - 2020



b) Shares of BMTA's revenues in 2020 (Unit: MB)



c) Shares of BMTA's costs in 2020 (Unit: MB)



Source: Compiled from BMTA annual report, 2020 & http://www.bmta.co.th/sites/default/files/files/about-us/o20_0.pdf

b) Private companies

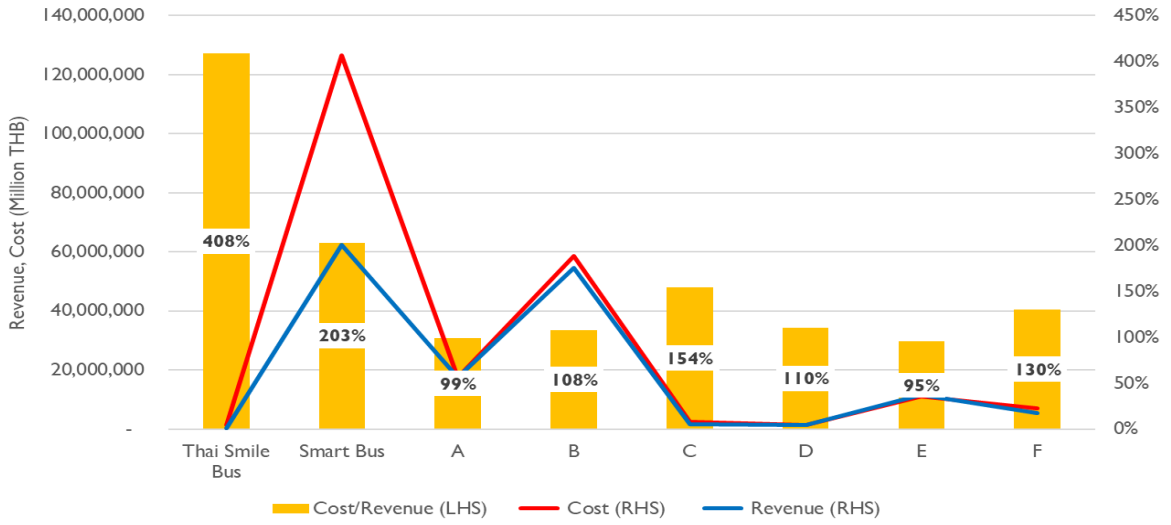
Besides BMTA, operators comprise Thai Smile Bus Co.,Ltd, E Transport Holdings Co.,Ltd., and other private companies. The financial status of some private operators is described below:

- Thai Smile Bus Co.,Ltd. (TSB), is a private company registered with a capital of 910 million baht on June 9, 2020, to provide public bus services in Bangkok and its vicinity by deploying EVs. In 2021, the company had 9 licenses from DLT and obtained an additional of 71 licenses in 2022. According to the financial statement of TSB in 2020, the total asset of TSB was 214.3 million THB and a loss of 1.07 million THB was reported. The deficit in 2020 resulted from the high depreciation cost in the early years of operation.
- E Transport Holdings Co.,Ltd., which is the subsidiary of Energy Absolute Plc., has acquired 99.99% of the ordinary shares of Smart Bus Co.,Ltd. on March 18, 2022. Smart Bus Co.,Ltd. is a private company registered with the purpose to provide public bus services in Bangkok and

surrounding provinces, obtaining 37 licenses directly from DTL. The financial statement of Smart Bus Co.,Ltd. in 2019 & 2020 shows that the total assets of Smart Bus Co.,Ltd. were 2,635 and 2,721 million THB, respectively. The income statement shows that the loss in 2019 and 2020 were 64.2 and 372.5 million THB.

- The current bus fare levels cannot cover the operating cost resulting in limited capacity to invest in improvement of bus infrastructure and service quality. Figure 33 illustrates the total revenues and costs of private bus operators in 2019. Companies A to F were formerly sublicensed by BMTA. Companies C and D are the operators with total revenues below 3 million THB. The proportions of cost to revenue of Thai Smile Bus and Smart Bus are high, resulting mainly from their initial investment. The cost of operator A and E were lower than their revenues while the costs of other operators were about 8% - 54% higher than their revenues, causing net loss.

Figure 33: Total revenues and costs of private bus operators in 2019



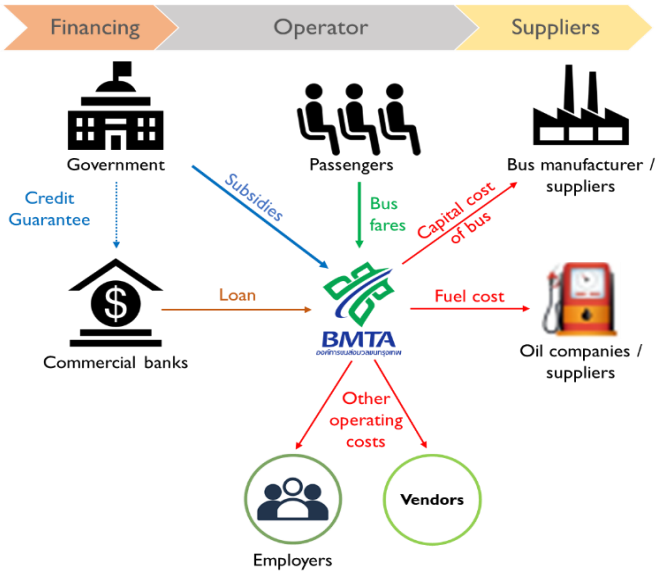
Source: Compiled from financial statement and income statement from https://datawarehouse.dbd.go.th/

4.2.2 Existing business models of bus operators

As described earlier, there are three groups of operators in 2022 including BMTA, private companies sublicensed from BMTA, and private companies getting licenses directly from DLT. The existing business models of bus operators show that all three groups of operators are owning their vehicles, running services, and maintaining their fleet (Figure 34). Only in 2011, BMTA was allowed to rent 117 buses under the performance-based contract where the bus service provider is in charge of buses and maintenance services. The operating cost includes fuel cost, employee wages and benefits, and other costs such as cost of ticket, license fee, etc. while the revenues of the operators mainly come from bus fares. Only BMTA has received subsidies from the government. The annual subsidies were about 1,917 – 2,338 million THB during 2018 – 2022.

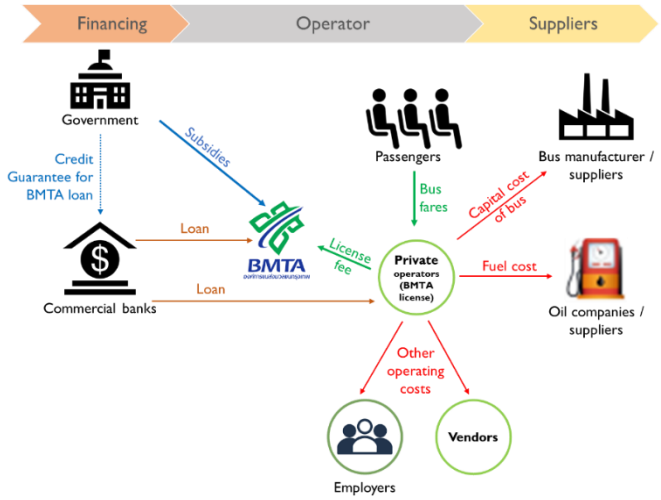
Figure 34: Existing business models of bus operators

a) Business model of BMTA



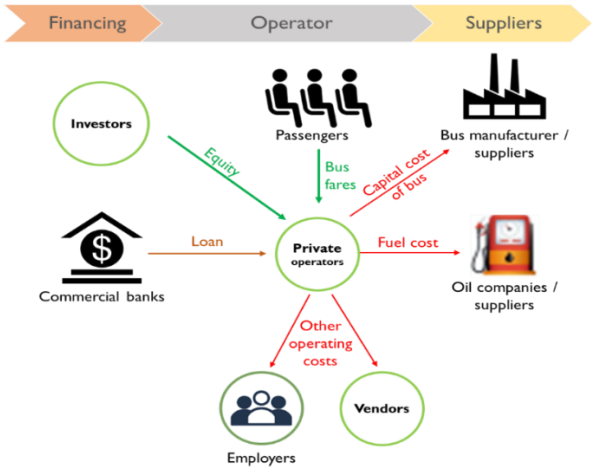
- BMTA is a state enterprise receiving various forms of subsidies from the government to support its operation.
- Due to its continuous deficit, BMTA must acquire loans from the commercial banks through the credit guarantee supported by the Ministry of Finance.
- Revenues of BMTA mainly come from bus fares.
- BMTA must own and operate the fleet and pay both the capital cost and the operating cost. The operating cost covers fuel cost, employee wages and benefits, and other operating costs.

b) Business model of private companies sublicensed from BMTA



- In this model, BMTA sublicensed the companies to own and operate the public buses.
- The operating cost as well as the collection of bus fares are incurred by the private operators.
- Also, the private operators must pay a license fee to BMTA.
- The new regulation does not allow this model since the service quality was very poor.

c) Business model of private companies getting licenses directly from DLT



- In this model, private operators receive licenses directly from DLT.
- The operators own and operate the fleet by themselves.
- The revenues of the operators come from the collection of bus fares without any financial support from the government.

Source: Own design

4.3 Financial and technical needs assessment of bus fleet electrification and charging infrastructure deployment in Thailand

4.3.1 Financial assessment of electric bus operation and maintenance

This section explores the capital expenses (CAPEX) as well as operational expenses (OPEX) of a diesel bus, a NGV bus, and an electric bus and provides a comparative analysis of the results from the evaluation of the total costs of ownership (TCO) covering CAPEX and OPEX over the lifetime of a diesel bus, a NGV bus, and an e-bus. The data used for the evaluation of TCO have been collected through both desk research, direct interviews, and stakeholder consultation workshops. This section describes key findings from the analysis.

a) CAPEX and OPEX of bus operation and maintenance

Capital Expense (CAPEX) is the total cost of bus acquisition. For a diesel bus and an NGV bus, the CAPEX will only be the cost of a bus invested in Year 0 while the CAPEX of an electric bus will cover the cost of the bus invested in Year 0 and the cost of battery replacement after 2000 charging cycles or approximately 7 years of operations. Compared to the CAPEX of a diesel bus, the CAPEX of an NGV bus is 17% lower while that of an electric bus is 102% higher (Table 11).

Table 11: CAPEX of a diesel bus, a NGV bus, and an electric bus

Items	CAPEX (THB)			Description
	Diesel bus	NGV bus	E-bus	
Cost of bus at Year 0	4,900,000	3,600,000	6,650,000	12-m bus with 31 seats
Cost of battery at Year 7	-	-	3,500,000	Battery size: 350 kWh
NPV of CAPEX	4,900,000	3,600,000	9,000,660	
Ratio of the CAPEX of a diesel bus, an NGV bus, and an electric bus compared to the CAPEX of diesel bus	100%	73%	202%	
Remarks: 1. Cost of a diesel bus and an e-bus is collected from the interview and stakeholders' consultation workshop. 2. Cost of a NGV bus is obtained from BMTA' Rehabilitation Plan (Revision: May 2019).				

OPEX of a public bus covers fuel cost, maintenance cost, cost of a bus driver and an assistant, bus tax and license fee, GPS, and ticket costs. The total OPEX of a diesel bus is the highest at 2,619,500 THB/year while that of a NGV bus and an e-bus account for 75% and 58% of the OPEX of a diesel bus, respectively (Table 12). The largest contribution to the OPEX of a diesel bus and a NGV bus is fuel cost while that of an e-bus is the cost of a bus driver and an assistant (Figure 35).

Table 12: OPEX of a diesel bus, an NGV bus, and an electric bus

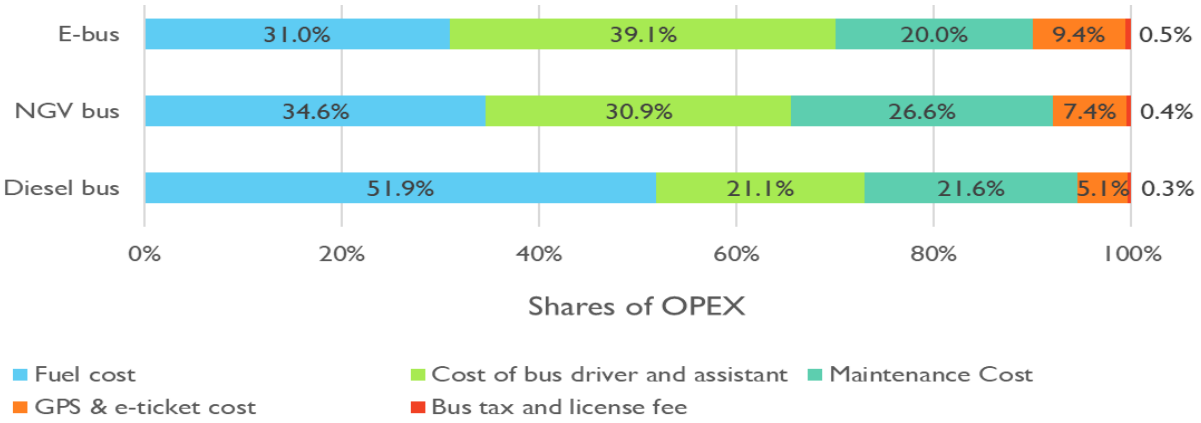
Items	OPEX (THB/year)		
	Diesel bus	NGV bus	E-bus
1. Fuel cost [1]	1,252,987	693,701	468,000
• Fuel consumption	0.65 litre/km	0.60 kg/km	1.1 kWh/km
• Fuel price	26.8 THB/litre	16.09 THB/kg	6 THB/kWh

Items	OPEX (THB/year)		
	Diesel bus	**NGV bus**	**E-bus**
2. Bus driver and assistant cost [2]	600,000	600,000	600,000
3. Maintenance cost [3]	614,073	516,000	307,037
4. GPS & e-ticket cost [4]	144,000	144,000	144,000
5. Bus tax & license [5]	8,440	8,440	8,440
Total	2,619,500	1,962,141	1,527,477
Ratio of the OPEX of a diesel bus, an NGV bus, and an electric bus compared to the OPEX of diesel bus	100%	75%	58%

Remarks:

1. Estimated from the service distance of 72,000 km/year (30 km/trip * 8 trips/day * 300 day/year)
2. Estimated at 50,000 THB/month
3. 2,046.91 THB/day for diesel bus, 1,720 THB/day for NGV bus, and 1,023.46THB/day for e-bus (BMTA's Rehabilitation Plan (New Revision), 21 April 2020)
4. Estimated from the 2020 BMTA's annual report
5. License fee at 7,000 THB/year and bus tax at 1,440 THB/year

Figure 35: Share of OPEX



b) Total cost of ownership of bus operation and maintenance

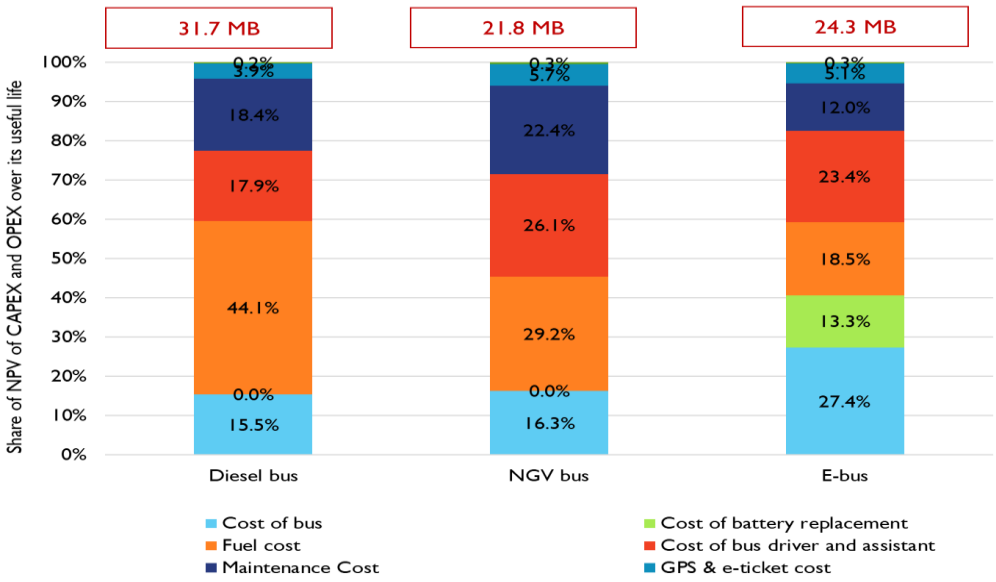
The total cost of ownership (TCO) is estimated by the following formula:

$$TCO = \frac{\text{Net Present Value (NPV) of (CAPEX + OPEX over the lifetime)}}{\text{Total distance in service over the lifetime}}$$

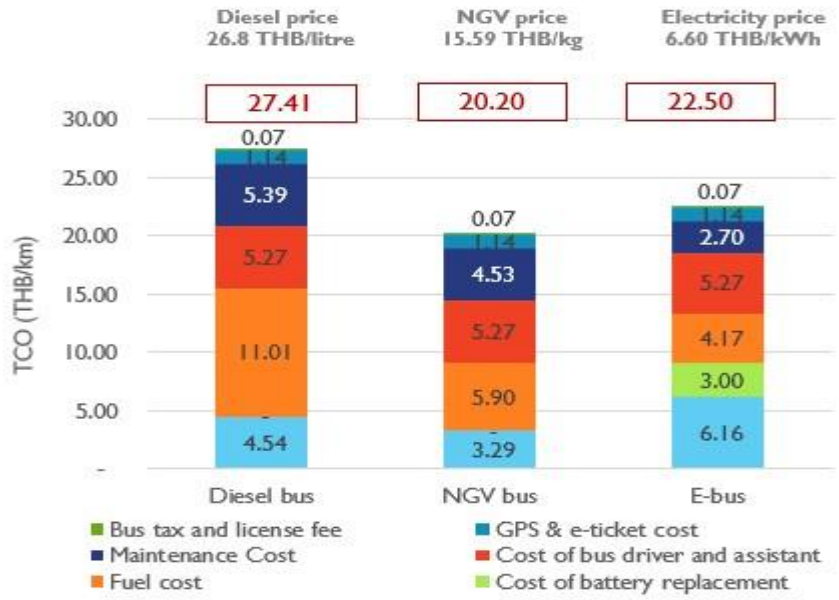
The result of the estimation is shown in Figure 36.

Figure 36: Key results of the analysis on TCO of public bus operation and maintenance

a) NPV of CAPEX and OPEX over the lifetime



b) TCO of public bus operation and maintenance



Remark: Other assumptions applied in the analysis are shown in the table below:

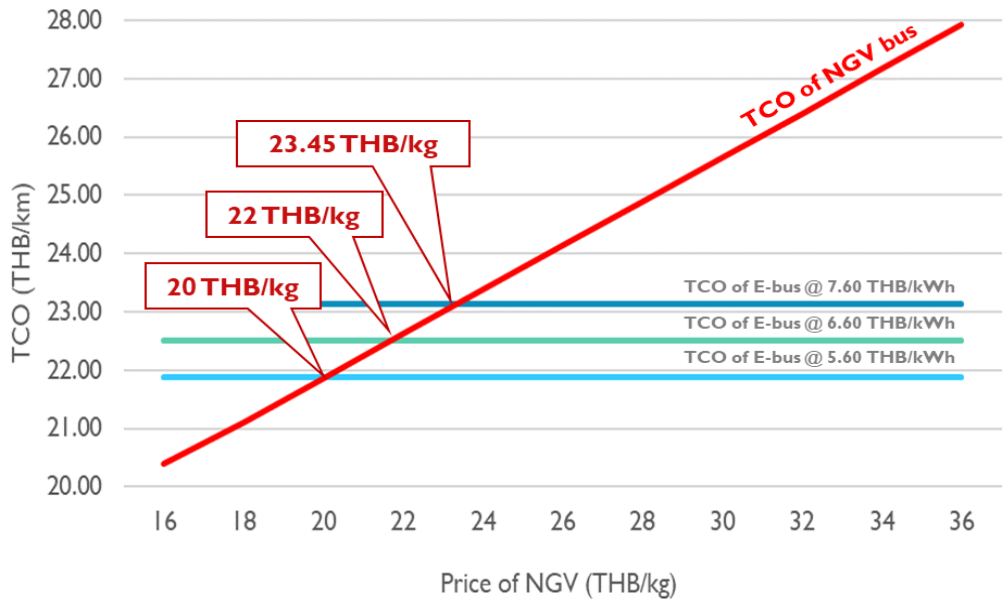
Assumptions	Amount
Inflation rate	1.8%
Discount rate	8.0%
Project lifetime	15 years
Operating days	300 days/year

From the analysis, the TCO of an e-bus is about 22.50 THB/km which is lower than that of a diesel bus (27.41 THB/km) by 22% but higher than that of a NGV bus (20.20 THB/km) by 10%. The total NPV of capital expenses and operating expenses over the lifetime of a diesel bus is the highest at 31.7 MB while that of an e-bus and a NGV bus, account for 77% and 69% of the total NPV of the diesel bus, respectively. The share of the total NPV on the CAPEX of a diesel bus and a NGV bus is

approximately 15%-16% while that of an electric bus is 41% since the CAPEX of an electric bus covers both cost of a bus and cost of battery replacement.

It can be concluded that the TCO of an e-bus is competitive, compared to that of a diesel bus but not as attractive when compared to a NGV bus. During the beginning of 2022, when natural gas prices continued to rise and the price of NGV without subsidies from the government would have reached 20-22 baht/ kilogram, the total cost of ownership of a NGV bus is equivalent to that of an e-bus (Figure 37). However, an e-bus requires higher upfront cost than both a diesel bus and a NGV bus.

Figure 37: TCO of an NGV bus at different NGV prices



c) Sensitivity analysis on TCO of buses

The sensitivity analysis helps assess the importance of parameters on the TCO of the bus. When adjusting the value of each parameter by 10%, the changes of the TCO are as shown in Figure 38.

The increase of annual distance and discount rate reduces the TCO for all 3 types of buses while the cost of the buses, the cost of battery replacement (for an e-bus only), fuel costs, maintenance costs, and the inflation rate increase the TCO. The TCO of all types of buses changes the largest with the annual mileage travelled. The impact of change in the annual mileage travelled on the TCO of an e-bus (7.4%-9.1%) is the highest among the three types of buses (5.1%-6.2% for a diesel bus and 6.4%-7.9% for a NGV bus).

Since OPEX during year 1 – year 15 of a diesel bus and a NGV bus are so large that the total NPV of OPEX is almost 80% of the NPV of the total cost. The parameter causing the second largest impact on the change of the TCO of a diesel bus and a NGV bus is the discount rate, followed by cost of bus, fuel cost, maintenance cost, and inflation rate. The increase of the discount rate by 10% reduces the TCO of a diesel bus and a NGV bus by 4.5% and 4.4%, respectively.

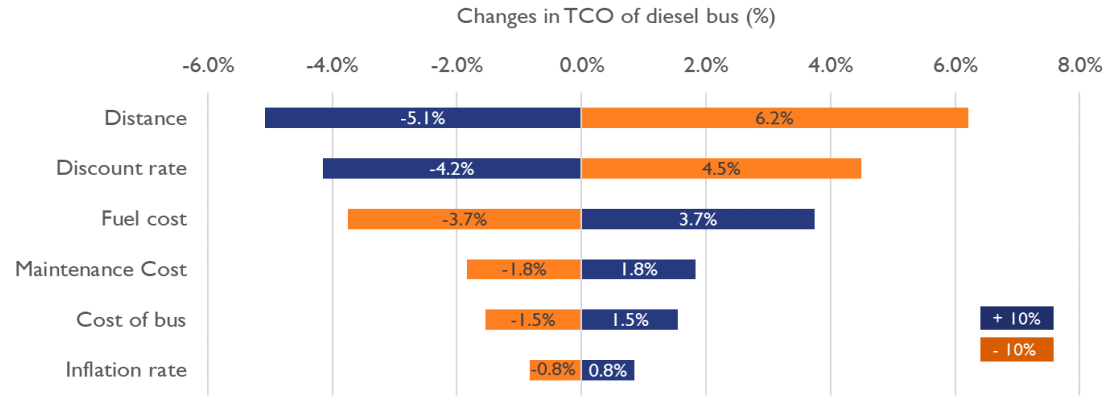
For an e-bus, the parameter having the second largest impact on the change of its TCO is the cost of bus followed by the discount rate, cost of battery replacement, fuel cost, maintenance cost, and

inflation rate. The change of cost of the bus by 10% leads to the changes of TCO by 1.5%, 1.7%, and 2.7% (4.3% when including the cost of battery replacement) for a diesel bus, a NGV bus, and an e-bus, respectively.

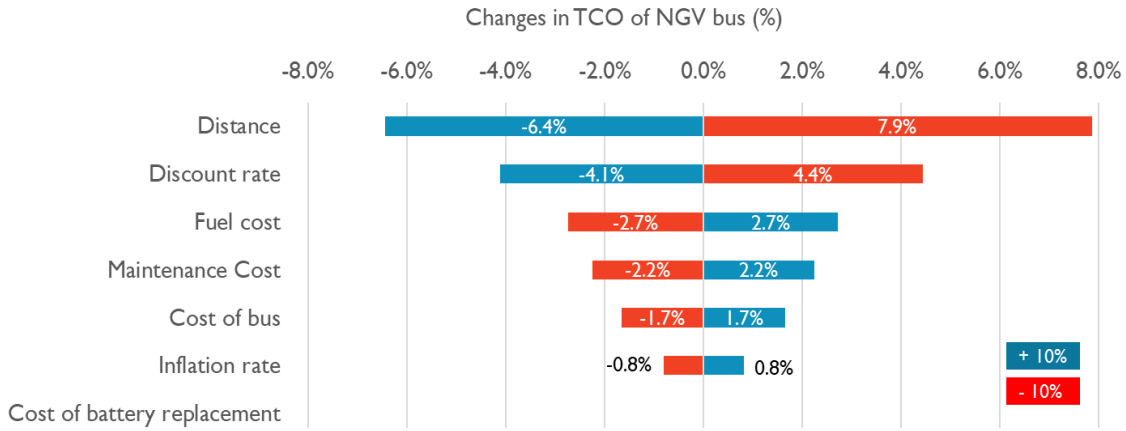
As the price of fossil fuel is on an upward trend and the change in fuel cost has the second highest impact on the TCO of a NGV bus and a diesel bus, the TCO of both types of buses moves upwards accordingly. Meanwhile, the costs of an e-bus and batteries are decreasing; therefore, the TCO of an e-bus tends to move downward. The gap between the TCO of ICE buses and an e-bus will increase over time, increasing the attractiveness of e-bus investment. Moreover, since the change of fuel cost incurred during the operation has more impact on the TCO of ICE buses than that of an e-bus, the volatile fossil fuel price leads to a higher risk in the operation of a diesel bus and a NGV bus.

Figure 38: Sensitivity analysis on TCO of buses

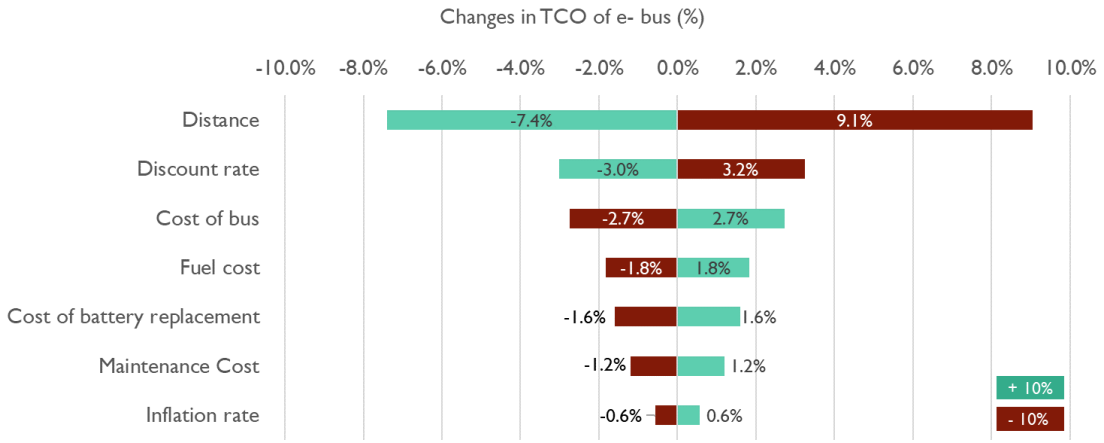
a) Sensitivity analysis on TCO of a diesel bus



b) Sensitivity analysis on TCO of a NGV bus



c) Sensitivity analysis on TCO of an e-bus



4.3.2 Financial and technical challenges of public bus electrification

The financial and technical challenges of public bus electrification are gathered from the various interviews of stakeholders from both, public and private sectors, the stakeholder consultation workshops together with desk research and analysis. Thus, the financial and technical challenges are divided by three groups of key stakeholders: e-bus manufacturers, public bus operators, and charging service providers, covering the technical and financial dimensions as shown in Table 13.

Table 13: Financial and technical challenges of public bus electrification

	Technical	Financial
Bus manufacturer	• Uncertain demand of e-buses • Regulations on technical specification of public buses do not support local EV manufacturers • Limited production capacity of local manufacturers	• Difficult access to financing • Lack of confidence from financial institutions on the EV system integrating business • No benchmark for the residual value of e-buses causing difficulties for commercial banks to provide loans
Bus operator	• Overlapping of routes in service • Lack of skilled capacity to maintain and repair e-buses • Lack of confidence on sufficient charging structure	• High upfront cost of e-buses • Difficult access to financing • Regulated bus fare leading to the low bus fare and limited financial capacity of operators to improve their fleets • Lack of confidence from financial institutions and insurance sector
Charging service provider	• Uncertain demand due to small number of e-buses • Availability of land or space for charging infrastructure • Timely and complicated permission process	• High upfront cost especially when upgrading transformer needed • Uncertain electricity prices

4.4 Proposed business models and financial mechanisms for public bus electrification in Thailand

4.4.1 Review and assessment of financial options for public bus electrification

Existing financial options for public bus electrification can be divided into five groups as shown in Table 14. The potentials to overcome the upfront cost and other financial challenges are described and the potentials to overcome the existing barriers to public bus electrification in Thailand are also evaluated in Table 15. Table 16 describes the case study of two financial models that have considerable potential for the promotion of public bus electrification in Thailand.

Table 14: Existing financial options for public bus electrification

Types	Options
Specific for electric fleet	• Demand aggregation • Integrated end-to-end financing • Revolving fund
Lease	• Sale-and-leaseback • Operating lease • Component lease • Financial lease
Bond	• Green bond
Loan	• Concessional loan • Mezzanine Loan
Guarantee	• Partial risk guarantee (PRG) • Residual value guarantee

Source: Compiled from https://www.cpt-uk.org/media/yo2du40i/ze-bus-financing-information-and-ideas-pack.pdf

Table 15: Potential of financing options to overcome the upfront cost and other financial challenges

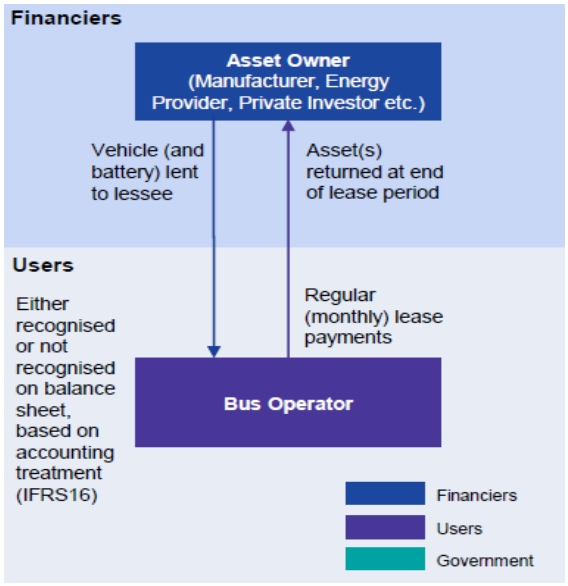
Financial option	*Upfront costs*	*Maintenance costs*	*Access to funding / financing*	*Financing costs / Income*
Demand Aggregation	Lower upfront cost	Incurred by either the operator or asset owner	Dependent upon the financing deal agreed	Dependent upon the financing deal agreed
Integrated end-to-end financing	None –operator simply pays for use of service	None –responsibility of service provider	Operators pays for service dependent on its own levels of ridership/bus usage	Operators pay more for integration and a more streamlined interface with infrastructure and energy providers.
Revolving fund	Lower upfront cost	Benefits from the managed services provided by the SPV	Operators only need to be able to afford the rent or lease	Bus operators benefit from better deals from energy companies.
Sale-and-leaseback	Frees up capital for the operator	Dependent upon the leasing arrangement with the asset purchaser	Asset purchaser may not be as willing to refinance mid-life assets	Operators may have to sell the asset at lower than market value as sale-and-leaseback is typically used to recover cash in the short term.
Operating lease	Spread high upfront costs over the leasing period	Maintenance is typically covered by lessor	Lessee needs to show robust / strong balance sheet position	Relatively manageable lease costs over a short period, and the potential to exclude from balance sheet.
Component lease	Lower the cost of acquiring batteries / infrastructure	The operator is responsible for vehicle maintenance only.	Relatively affordable in the short term	Potentially high lease costs over the period in order to also cover asset maintenance, monitoring, training, etc.
Finance lease	Diminish upfront costs significantly	The lessee bears the maintenance costs	A relatively strong balance sheet is required to enter into finance lease	Relatively manageable lease costs over the period; however, a longer lease period (i.e., over the UEL of the asset) may mean higher costs overall than owning / short-term leasing due to the

Financial option	*Upfront costs*	*Maintenance costs*	*Access to funding / financing*	*Financing costs / Income*
				uncertainties around RV of batteries as more time lapses.
Green bonds	Potentially cheaper access to capital	Responsibility of operator	Competition from other types of bonds makes operators exposed to the volatility of the capital market, which may commensurately affect interest rates in the long-term.	Financing costs should be lower if a concessional (ESG) loan is accessible. Interest rates may be more volatile as it is subject to the fluctuations of the green bond market.
Concessional loans	Lessen the impact of upfront costs through use of loan	The operator bears the maintenance costs	Concessional loans can provide access to low-cost capital	Financing costs should be lower if a concessional (ESG) loan is accessible. However, this depends on the operator's ability to demonstrate a strong balance sheet and certain level of revenue certainty.
Mezzanine Loan	Lower upfront cost	Incurred by either the operator or operating lease provider	There is a need to demonstrate a strong credit rating.	Financing cost could be higher due to the higher risk of nonrepayment to financier.
Partial Risk Guarantee (PRG)	Lower upfront cost	Incurred by either the operator or operating lease provider	There is a need to demonstrate a strong credit rating	Financing cost could be lower because the government absorbed some of the risks.
Residual value guarantee	Spread high upfront costs over the leasing period	Incurred by either the operator or asset owner	Guarantee scheme providers may provide on a first come first serve market	Minimum level of guarantee may reduce interest rates / lease payments

Source: Compiled from https://www.cpt-uk.org/media/yo2du40i/ze-bus-financing-information-and-ideas-pack.pdf

Table 16: Case study of operating lease model and integrated end-to-end financing model

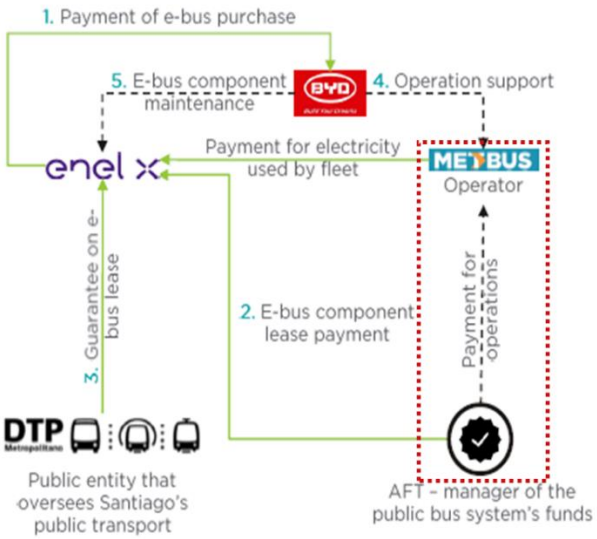
a) Operating lease model: Case study of India (2021)



Sources: https://www.cpt-uk.org/media/yo2du40i/ze-bus-financing-information-and-ideas-pack.pdf & https://timesofindia.indiatimes.com/city/bengaluru/karnataka-govt-eyes-green-rewards-from-pricey-electric-push/articleshow/80182608.cms

- The local government of Karnataka, India, provided support for 390 electric buses (90 small feeder buses, 300 full-size buses).
- The central and local governments jointly provided investment subsidies of approximately 3.8 million THB/vehicle to the operating lessor, provided that the lease fee charged to operators can be increased by not more than 1% per year (from the base level of about 10% per year).
- Transport Department provides a 15-year operating lease to the Bangalore Metropolitan Transport Corporation.
- The local government subsidizes around 5% - 8% of the operating cost per kilometer in the early years.
- The local government is the fare collector, and it is expected to break even in the 4th year.
- The government supports the domestic battery manufacturing industry, which aims to lower battery prices and reduce the cost of electric buses.

b) Integrated end-to-end financing model: Case study of Chile (2016 - 2019)



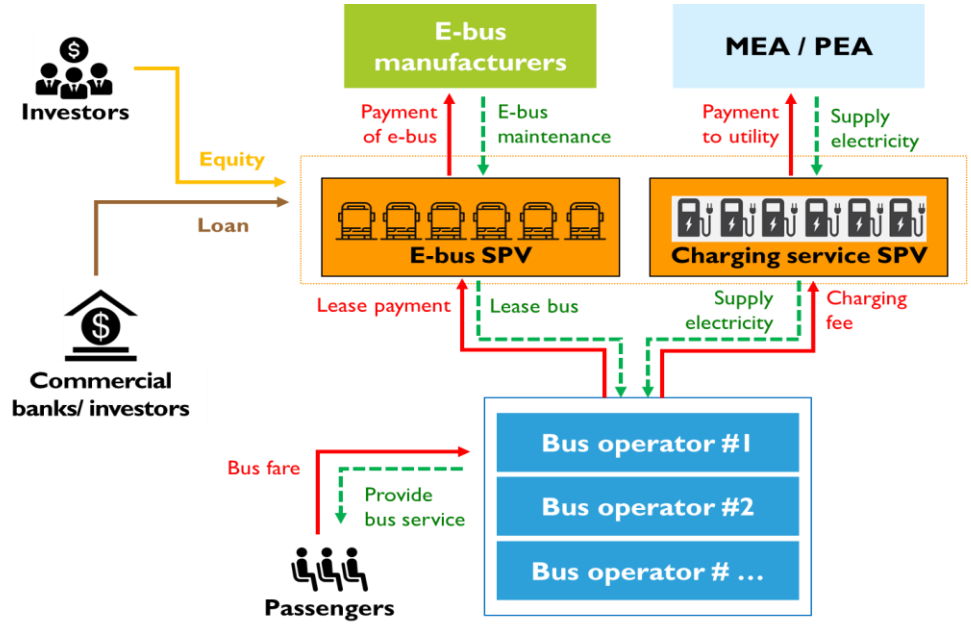
Source: https://www.c40knowledgehub.org/s/article/Accelerating-a-market-transition-in-Latin-America-New-business-models-for-electric-bus-deployment?language=en_US

- Activity: Deployment of 100 electric buses in Santiago, Chile
- Investor: ENEL X
  - ✓ ENEL X is one of the ENEL Group's businesses, being an investor of electric buses and charging stations. ENEL Group is the large energy company with a global investment.
  - ✓ It provides an integrated service to operators under a 10-year concession contract.
- AFT (manager of the public bus system's funds) pays a monthly lease.
- A bus operator pays for electricity used by fleet.
- Operator: METBUS
- Electric bus manufacturer: BYD
  - ✓ BYD sells electric buses to ENEL X together with a service package on maintenance and operation support.
  - ✓ BYD provides warranties on all components
- The government provided guarantee for the lease payment provided by AFT.

4.4.2 Conceptual framework for the proposed business model

From the assessment above, the financing options applicable to the context of Thailand that has a high potential to remove the key challenges for bus operators on the high upfront cost of e-buses and the lack of skilled capacity to maintain and repair electric buses are (i) operating lease and (ii) integrated end-to-end financing. Description of each model is illustrated in Table 17 & Table 18.

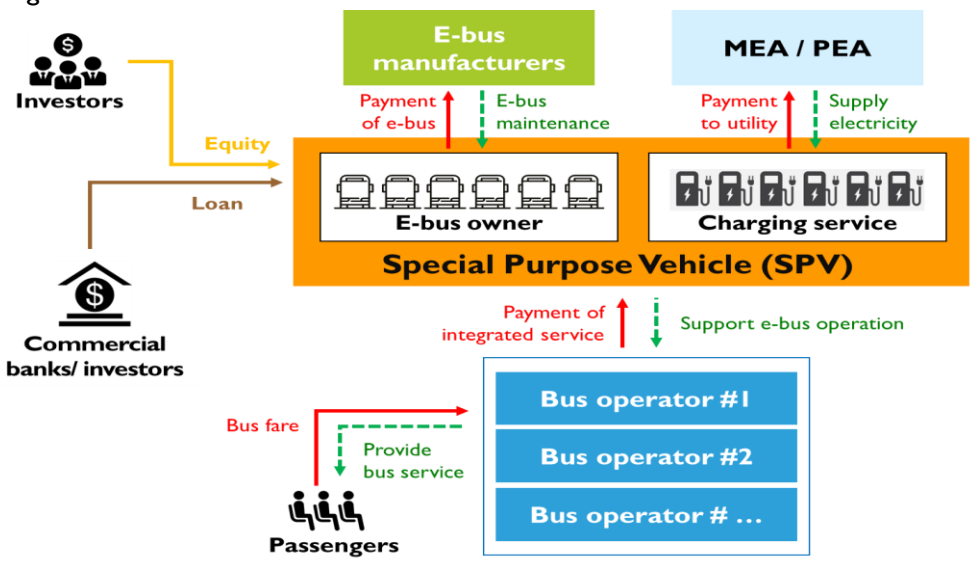
Table 17: Operating lease model

Operating lease model
Diagram:    Source: Own design
Description: An operating lease is a contract model which allows the lessee use of a vehicle in return for regular lease payments.[63] Key players in this model include: • *a Special Purpose Vehicle (SPV) or E-bus SPV* setting up for owning e-bus through long-term contract between e-bus SPV and e-bus manufacturers, and providing lease and maintenance service of e-buses to the operator through leasing agreement between e-bus SPV and bus operators to cover all maintenance services, • *an operator* running public buses under the above-mentioned leasing agreement with e-bus SPV and receiving charging services from charging SPV through long-term contracts between bus operators and charging service SPV, and • *another Special Purpose Vehicle (SPV) or charging SPV* setting up for owning charging infrastructure and providing charging service to the fleet under long-term contracts between bus operators and charging service SPV.

[63] https://www.cpt-uk.org/media/yo2du40i/ze-bus-financing-information-and-ideas-pack.pdf

E-bus SPV and *charging service SPV* may be the same or different entities upon the readiness of technical and financial capacity. SPV can be established by the support from the government or potential investors, e.g., bus manufacturers, battery manufacturers, or energy companies.

Table 18: Integrated end-to-end financing model

Integrated end-to-end financing model
Diagram:    Source: Own design
Description: This model aims to bundle all services/products required for public bus electrification including vehicles, batteries and charging infrastructure to provide an integrated solution. Key players in this model include: • *a Special Purpose Vehicle (SPV)* owning all assets required for public bus electrification through long-term contracts with e-bus manufacturers as well as charging infrastructure suppliers and providing an integrated end-to-end service to the bus operators under long-term contracts with bus operators, • *a bus operator* running buses for public service under the long-term contract on provision of an integrated service between the integrated service SPV and bus operators. The key advantage of this model is that the operator does not need to pay any upfront cost. Additionally, the operator will engage with only one entity, which is potentially cost saving as it requires less time and effort. The SPV can be bundled up by potential investors from bus manufacturers, component providers, financing institutions, or power companies. This model relies heavily on the capacity of the SPV which must be highly mature and able to assure the availability and the quality of the services provided to the bus operator.

4.4.3 Detailed assessment of the proposed business models

To conduct a detailed assessment of the proposed models, the net present value (NPV), internal rate of return (IRR), and payback period of both models were estimated using discounted cash flow (DCF) analysis.

a) Detailed assessment of the operating lease model

- Three DCF models were assessed for three key players including an e-bus SPV, a bus operator, and a charging SPV. The analysis was conducted for the investment of 30, 100, and 500 buses. The investment cost is assumed to decrease by 5% for the fleet with 100 buses and 10% for the fleet with 500 buses.
- Table 19 shows the revenues, CAPEX, and OPEX of the three key players in the operating lease model.
  - For the e-bus SPV, revenue comes from the lease fee. Its CAPEX covers the cost of buses and cost of battery replacement at year 7 while its OPEX covers annual cost of maintenance, GPS system, insurance, and administration.
  - For the charging SPV, revenue comes from the charging fee. Its CAPEX covers the cost of charging sockets, charging stations, and upgradation of transformers as well as cost of overhauling charging sockets at year 8 while its OPEX covers annual cost of electricity, land rental, operation and maintenance (O&M), and administration.
  - For the bus operator, revenue comes from collection of bus fares and advertisement on the bus. No CAPEX is required while its OPEX covers lease payments, fuel costs, cost of bus drivers and assistants, tax fee, license fees, and administration.
- The amount of annual lease payment and charging cost, which the bus operator must pay to the e-bus SPV and the charging SPV, is estimated with the concept that the IRR of both the E-bus SPV and the charging SPV are more than 10% to ensure the attractive investment of both players. However, the NPV of the bus operator is negative; therefore, additional financial support is needed (Table 20).

Table 19: Investment costs for the operating lease model

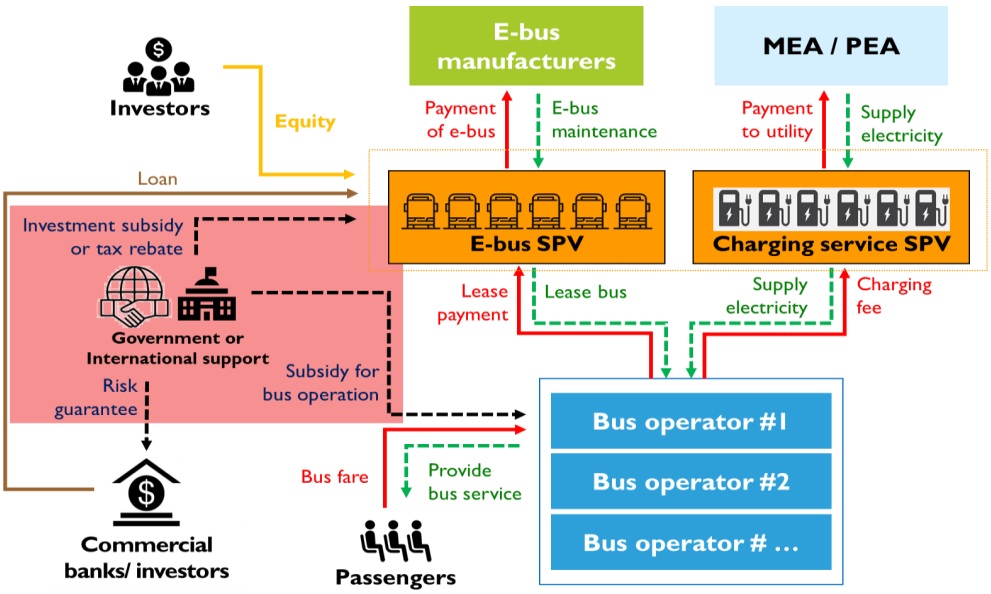
Items	Number of buses in the fleet		
	30 buses	100 buses	500 buses
Numbers of sockets	20	63	313
1) E-bus SPV			
Total NPV of revenues from rental fee over 15 years (MB)	469.48	1,517.51	7,350.44
Total NPV of CAPEX (MB)	296.72	939.62	4,450.83
- Cost of bus at Year 1 (MB)	199.50	631.75	2,992.50
- Cost of battery replacement at Year 7 (MB)	105.00	332.50	1,575.00
Total NPV of OPEX over 15 years (MB)	180.97	597.49	2,958.63
2) Charging SPV			
Total NPV of revenues from charging fee over 15 years (MB)	152.62	484.84	2,338.86
Total NPV of CAPEX (MB)	41.01	121.06	567.92
- Investment cost at Year 1 (MB)	33.60	98.90	463.59
- Overhaul at Year 8 (MB)	8.00	23.94	112.68
Total NPV of OPEX over 15 years (MB)	110.40	358.20	1,754.83
3) Bus operator			
Total NPV of revenues (MB) from collection of bus fare and bus advertisement over 15 years	676.05	2,253.50	11,267.51
Total NPV of OPEX over 15 years (MB)	827.66	2,687.55	13,115.27

Items	Number of buses in the fleet		
	30 buses	100 buses	500 buses
Total investment of e-bus SPV and charging SPV			
Total CAPEX at Year 1 (MB)	**233.10**	**730.65**	**3,456.09**
Total NPV of CAPEX (MB)	**337.73**	**1,060.68**	**5,018.76**

Table 20: Key results of the operating lease model

Items	Unit	Number of buses to invest		
		30 buses	100 buses	500 buses
Annual lease payment	THB/bus/year	1,650,000	1,600,000	1,550,000
Charging price	THB/kWh	7.45	7.10	6.85
Annual ridership	Passenger-trip	152,000		
Bus fare	THB/passenger-trip	15		
Revenue from bus fares	THB/bus/year	2,280,000		
Return on investment				
1) E-bus SPV				
· NPV	MB	25.68	87.28	444.73
· IRR	%	10.09%	10.24%	10.40%
· ROE	%	13.48%	13.79%	14.12%
· Payback Period	years	12.86	12.73	12.59
2) Charging SPV				
· NPV	MB	3.98	13.72	55.15
· IRR	%	10.14%	10.49%	10.15%
· ROE	%	13.35%	14.05%	13.38%
· Payback Period	years	12.08	11.70	12.08
3) Bus operator				
· NPV	MB	(140.38)	(401.89)	(1,710.89)

Figure 39: Financial support needed to promote public bus electrification applying the operating lease model



- Further analysis was conducted to evaluate additional financial support needed to make the NPV of the bus operator positive along with the scenario that allows the IRR of both the E-bus SPV and the charging SPV to be more than 10%. Five financial options including the exemption of corporate income tax, performance-based subsidy for bus operation, investment subsidy for bus and charging infrastructure, and risk guarantee were analysed (Figure 39). The exemption of corporate income tax and performance-based subsidies for bus operation can only be implemented by the government while the remaining options can be done through either the government or international support. Table 21 summarises the results of the analysis on financial support needed for investing in 500 buses. Key findings are:
    - For scenario I, the 5-year exemption of corporate income tax (CIT) is evaluated. In this scenario, the government revenues will decrease by 274 MB from the exemption of CIT from e-bus SPVs and charging SPVs. Adding the risk guarantee, the funding sums up to 379 MB in total. However, the 5-years exemption of corporate income tax will not be sufficient to make the NPV for the bus operator positive.
    - For scenario II, the performance-based subsidy for a bus operator is evaluated. By providing 5.50 THB/km subsidy to the bus operator, the NPV of the bus operator becomes positive. However, this option requires the largest funding of the total volume of 1,878 MB. Adding the risk guarantee, the funding requirement amounts to 1,983 MB in total.
    - For scenario III, the investment subsidy for an e-bus SPV is evaluated. Providing 35% of investment cost to subsidise the e-bus SPV can help reduce the annual lease fee collected from the bus operator; as a result, all players win. The funding required for this option is 1,558 MB. Adding the risk guarantee, the funding requires 1,641 MB in total.
    - For scenario IV, the investment subsidy for a charging SPV is evaluated. By providing up to 80% of investment cost to subsidise the charging SPV alone cannot lower the level of charging fee to make the NPV of the bus operator positive, the charging SPV subsid needs to be combined with either investment subsidy for an e-bus SPV (in scenario III) or the performance-based subsidy (in scenario II) for a bus operator. In the case of combining with the performance-based subsidy for a bus operator, a 3.55 THB/km subsidy is needed, and the funding required is 1,666 MB. Adding the risk guarantee, the funding sums up to 1,764 MB in total.
    - For scenario V, bundling the 5-year exemption of corporate income tax (CIT) and the investment subsidy for an e-bus SPV is evaluated. Both financial options are aligned with the existing mechanisms that have been launched in Thailand but may not cover the public transportation sector. The extension of the coverage may be conducted with the concrete rationale. Compared to Scenario II – V, the funding required for this package is the smallest at 1,543 MB. Adding the risk guarantee, the funding requires 1,629 MB in total.

Table 21: Key results on financial support needed to promote public bus electrification applying the operating lease model

Items	Scenario I	Scenario II	Scenario III	Scenario IV	Scenario V
Number of buses in the fleet	500 vehicles				
Annual lease payment (THB/bus/year)	1,470,000	1,550,000	1,160,000	1,550,000	1,175,000
Charging price (THB/kWh)	6.600	6.850	6.850	4.950	6.600
Financial options implemented by government only					
- Exemption of corporate income tax (years)	5 years				5 years
- Subsidy for bus operation (THB/km)		5.50		3.55	
Financial options implemented by government or international support					
- Investment subsidy for e-bus (%)			35%		30%
- Investment subsidy for charging infra.				80%	
- Risk guarantee	Fee at 3% of total NPV of debt				
Total NPV of investment (MB)	5,018.76				
Total NPV of debt (MB)	3,513.13	3,513.13	2,779.97	3,523.52	2,884.70
Size of fund needed (MB)					
- Subsidy for bus operation (15 years)		1,877.92		1,212.11	
- Investment subsidy for e-bus			1,557.79		1,335.25
- Investment subsidy for charging infra.				454.34	
- Decrease of govt revenues due to tax exemption	273.95	-	-	-	207.45
Sub-total	273.95	1,877.92	1,557.79	1,666.45	1,542.70
- Risk guarantee	105.39	105.39	83.40	97.61	86.54
Total	379.34	1,983.31	1,641.19	1,764.06	1,629.24
Return on investment					
1) E-bus SPV					
· NPV (MB)	387.04	444.73	285.46	444.73	321.00
· IRR (%)	10.19%	10.40%	10.34%	10.40%	10.55%
· ROE (%)	14.00%	14.12%	14.67%	14.12%	15.39%
· Payback Period (years)	12.75	12.59	12.66	12.59	12.45
2) Charging SPV					
· NPV (MB)	49.70	55.15	55.15	14.93	49.70
· IRR (%)	10.05%	10.15%	10.15%	10.87%	10.05%
· ROE (%)	13.57%	13.38%	13.38%	17.70%	13.57%
· Payback Period (years)	12.06	12.08	12.08	11.30	12.06
3) Bus operator					
· NPV (MB)	(1,383.02)	24.13	1.37	10.47	14.13

b) Detailed assessment of the integrated end-to-end financing model

- Two DCF models were assessed for two key players including an integrated end-to-end service SPV and a bus operator. Analysis was conducted for investment of 30, 100, and 500 buses. The investment cost is assumed to decrease by 5% for the fleet with 100 buses and 10% for the fleet with 500 buses.
- Table 22 shows the revenues, CAPEX, and OPEX of two key players in the integrated end-to-end financing model.
  - For the integrated end-to-end service SPV, revenue comes from the charge per km of an integrated end-to-end service. Its CAPEX covers cost of the buses, cost of battery replacement at year 7, cost of charging sockets, cost of charging stations, and upgradation of transformers as well as cost of overhauling charging sockets at year 8 while the OPEX covers maintenance cost of buses, charging infrastructures, GPS systems, insurance, cost of electricity, land rental, and administration.
  - For the bus operator, revenue comes from collection of bus fares and advertisement on the buses. No CAPEX is required while its OPEX covers charge fees from the SPV, cost of bus drivers and assistants, tax fees, license fees, and administration.

Table 22: Revenues, CAPEX, and OPEX for the integrated end-to-end financing model

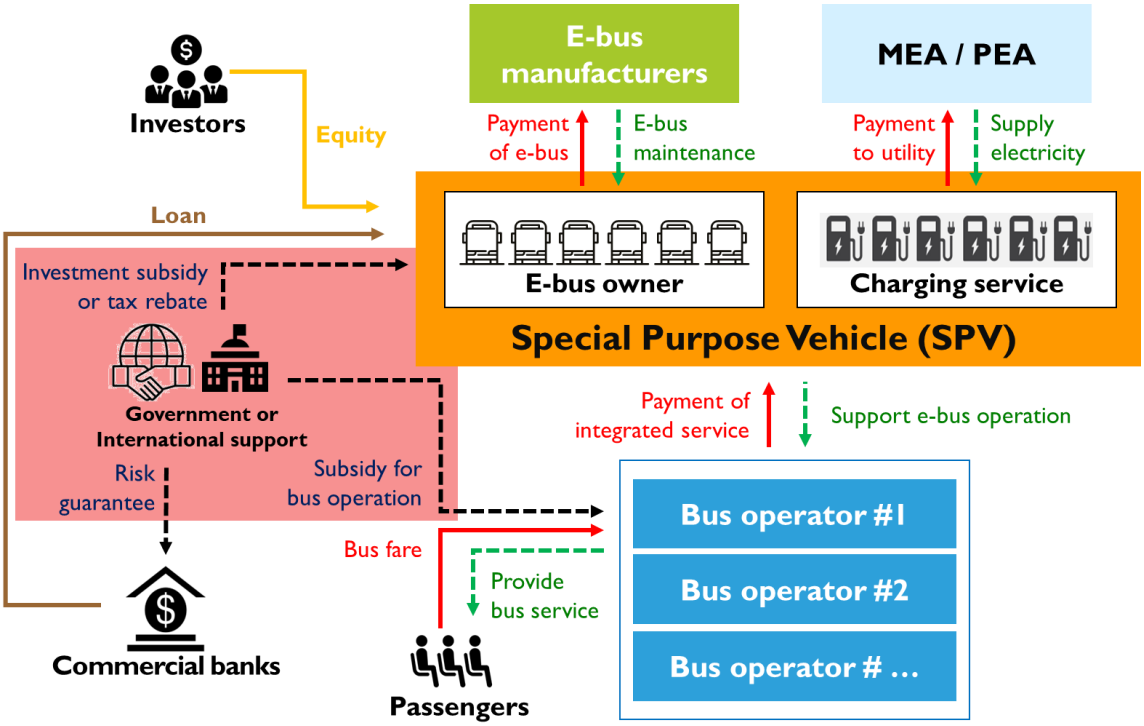
Items	Number of buses to invest		
	30 buses	100 buses	500 buses
Numbers of sockets	20	63	313
1) Integrated end-to-end service SPV			
Total NPV of revenues (MB)	614.59	1,963.28	9,474.95
CAPEX (MB)			
- Cost of bus	199.50	631.75	2,992.50
- Cost of charging socket	20.00	59.85	281.70
- Cost of charging station	10.00	29.93	140.85
- Cost of transformer	3.60	9.12	41.04
Total CAPEX at Year 1 (MB)	233.10	730.65	3,456.09
- Battery at Year 7	105.00	332.50	1,575.00
- Overhaul of charging infrastructure at Year 8	8.00	23.94	112.68
Total CAPEX at Year 1, 7 &8 (MB)	337.73	1,060.68	5,018.76
2) Bus operator			
Total NPV of revenues (MB)	676.05	2,253.50	11,267.51
Total NPV of OPEX over 15 years (MB)	820.15	2,648.47	12,900.92

- The amount of service charge which the bus operator must pay to the SPV was estimated with the concept that the IRR of the SPV is more than 10% to attract investment of the SPV. However, the NPV of the bus operator is negative; therefore, additional financial support is needed (Table 23).

Table 23: Key results of the integrated end-to-end financing model without any financial support

Items	Unit	Number of buses in the fleet		
		30 buses	100 buses	500 buses
Total charge for end-to-end service	THB/km/bus	30.00	28.75	27.75
Revenue from bus fares	THB/bus/year	2,280,000		
Annual ridership	Passenger-trip	152,000		
Bus fare	THB/passenger-trip	15.00		
Return on investment				
1) Integrated service SPV				
· NPV	MB	33.46	100.35	469.73
· IRR	%	10.17%	10.08%	10.06%
· ROE	%	13.59%	13.41%	13.37%
· Payback Period	years	12.73	12.82	12.84
2) Bus operator				
· NPV	MB	(144.10)	(394.97)	(1,633.41)

Figure 40: Financial support needed for the integrated end-to-end financing model



- Similar to the operating lease model, four types of financial supporting mechanisms including exemption of corporate income tax, performance-based subsidy for bus operation, investment subsidy for the SPV, and risk guarantee were analysed (Figure 40). Table 24 summarises the results of the analysis on financial support needed for investing in 500 buses. Key findings are:
  - For scenario I, the 5-year exemption of corporate income tax (CIT) is evaluated. In this scenario, the government revenues will decrease by 245 MB from the exemption of CIT from the SPV. Adding the risk guarantee, the fund required in total is 350 MB. However, the

exemption of 5 – years of corporate income tax will not be sufficient to make the NPV for the bus operator positive.

- For scenario II, the performance-based subsidy for a bus operator is evaluated. By providing 4.80 THB/km subsidy to the bus operator, the NPV of the bus operator becomes positive. However, this option requires the largest funding at 1,639 MB. Adding the risk guarantee, the funding required is 1,744 MB in total.
- For scenario III, the subsidy provided to the SPV for the investment of e-buses and charging infrastructure is evaluated. Providing 26% of the total investment cost to subsidize the SPV can help reduce the fee charged by the SPV for an integrated end-to-end service and turn the NPV of the bus operator into positive. The funding required for this option is 1,303 MB. Adding the risk guarantee, the funding required is 1,389 MB in total.
- For scenario IV, the 5-year exemption of corporate income tax (CIT) and the investment subsidy for the SPV are bundled into one package. Both financial options are aligned with the existing mechanisms that have been launched in Thailand but may not cover the public transportation sector. The extension of the coverage may be conducted with the concrete rationale. Compared to Scenario II – IV, the total fund required for this package is the smallest at 1,290 MB. Adding the risk guarantee, the fund requires 1,379 MB in total.

Table 24: Key results on financial support needed for the integrated end-to-end financing model

Items	*Scenario I*	*Scenario II*	*Scenario III*	*Scenario IV*
Number of buses in the fleet	500 vehicles			
Total charge for end-to-end service (THB/km/bus)	26.75	27.75	22.95	22.95
Options for financial support from government only				
- Exemption of corporate income tax (years)	5 years			5 years
- Subsidy for bus operation (THB/km)		4.80		
Options for financial support from government or international agencies				
- Investment subsidy for e-bus (%)			26%	23%
- Investment subsidy for charging infra.				
- Risk guarantee	Fee at 3% of total NPV of debt			
NPV of total investment (MB)	5,018.76			
NPV of total debt (MB)	3,507.72	3,507.72	2,878.71	2,951.29
Size of fund needed (MB)				
- Subsidy for bus operation (15 years)		1,638.91		
- Investment subsidy for e-bus & charging infra.			1,302.87	1,152.54
- Decrease of govt revenues due to tax exemption	244.66			137.85
Sub-total	**244.66**	**1,638.91**	**1,302.87**	**1,290.39**
- Risk guarantee	105.23	105.23	86.36	88.54
Total	**349.89**	**1,744.14**	**1,389.23**	**1,378.93**
Return on investment				
1) End-to-end service SPV				
• NPV (MB)	450.46	469.73	345.66	349.96
• IRR (%)	10.05%	10.06%	10.04%	10.04%
• ROE (%)	13.63%	13.37%	13.73%	13.89%
• Payback Period (years)	12.81	12.84	12.86	12.84
2) Bus operator				
• NPV (MB)	(1,291.97)	4.40	4.40	4.88

4.4.4 Assessment of feasibility on support needed for the proposed business models

The detailed assessment of the two proposed business models leads to the estimation of the financial support needs to ensure that the investment is attractive for the key stakeholders. Table 25 summarises the amount of funding required to support the two proposed business models in various scenarios.

The amount of funding required for the operating lease model for all scenarios are slightly higher than that required for the integrated end-to-end service. This is because there are only two key stakeholders in the integrated end-to-end service, therefore, the total administration cost incurred is lower than the administration cost required for three parties in the operating lease model. However, the integrated service SPV in the integrated end-to-end service model must have a large investment potential since the investment cost covers both e-buses and charging infrastructure. Both models can be applied to the existing context of Thailand. The selection of the model depends upon the investment and technical capacity of the SPV and the direction of policy.

Table 25: Amount of funds required to support the two proposed business models (Unit: MB)

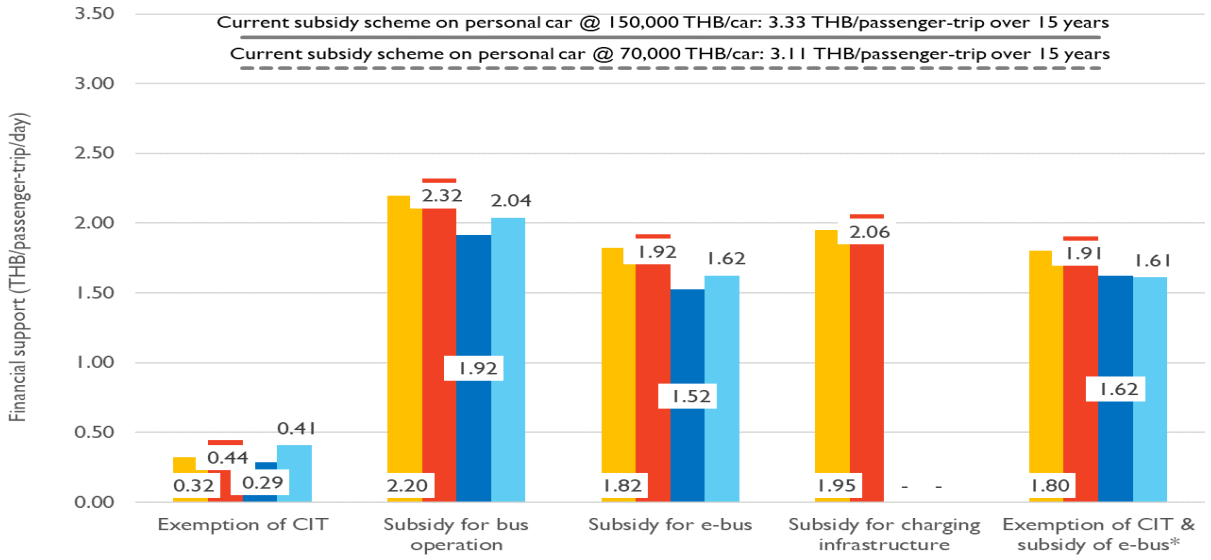
Scenario	Financial options	Operating lease		Integrated end-to-end service	
		w/o risk guarantee	with risk guarantee	w/o risk guarantee	with risk guarantee
I	Exemption of CIT*	274	379	245	350
II	Subsidy for bus operation	1,878	1,983	1,639	1,744
III	Subsidy for e-bus**	1,558	1,641	1,303	1,389
IV	Subsidy for charging infrastructure	1,666	1,764	-	-
V	Exemption of CIT & subsidy of e-bus*	1,543	1,629	1,291	1,379

Remarks:
* The exemption of CIT only cannot make the project feasible.
** Subsidy is provided for the investment cost of both e-buses and charging infrastructure in the integrated end-to-end service model.

When comparing between the support needs estimated for promoting public bus electrification using the proposed business models (as shown in Table 25) and the existing subsidy scheme for electric passenger cars per passenger-trip over the 15-year lifetime, the current scheme providing 70,000 THB/car (or 3.11 THB/passenger-trip) and 150,000 THB/car (or 3.33 THB/passenger-trip) spends approximately 34% and 44% higher than the highest funding required for supporting the public bus electrification through the operating lease model (2.32 THB/passenger-trip) as shown in Figure 41.

Moreover, the amount of funding required to support the electrification of 500 buses (1,303–1,983 MB) can support about 18,600–28,300 electric passenger cars, from which the number of beneficiaries is approximately 510–776 million passenger-trips. However, the number of beneficiaries of 500 public buses is 1,140 million passenger-trips, or approximately 1.47–2.24 times the number of beneficiaries from promoting electric passenger cars.

Figure 41: Comparison between the amount of funding to support public bus electrification through the proposed business models and the existing subsidy scheme for electric passenger cars



Further assessment shows that the GHG emission reduction from the electrification of 500 buses is about 43,091 tCO_2/year. The support needed for 500-public-bus electrification in all scenarios per per total amount of GHG abatement over 15-year lifetime are less than 160 USD/tCO_2 (Table 26). The government can use this estimated support per ton of GHG abatement as a reference to compare with the cost required to support other NDC measures for incentivizing low carbon investment to prioritize public finance support.

Table 26: Support needed for promoting 500-public-bus electrification per the amount of GHG abatement (Unit: USD/tCO_2)

Scenario	Financial options	Operating lease		Integrated end-to-end service	
		w/o risk guarantee	with risk guarantee	w/o risk guarantee	with risk guarantee
I	Exemption of CIT	22.26	30.49	19.67	28.12
II	Subsidy for bus operation	150.95	159.42	131.74	140.19
III	Subsidy for e-bus*	125.22	131.92	104.73	111.67
IV	Subsidy for charging infrastructure	133.95	141.80	-	-
V	Exemption of CIT & subsidy of e-bus*	124.00	130.96	103.74	110.86

Remarks:

1. The exemption of CIT only (Scenario I) cannot make the project feasible.
2. Subsidy is provided for the investment cost of both e-buses and charging infrastructure in the integrated end-to-end service model.
3. The discounted amount of tCO_2 over 15-year lifetime is 368,836 tCO_2.
4. Exchange rate: 1 USD = 33.73 THB (Data from BOT during Jan – Jun 2022)

4.5 Roadmap of operationalising financial mechanisms for public bus electrification in Thailand

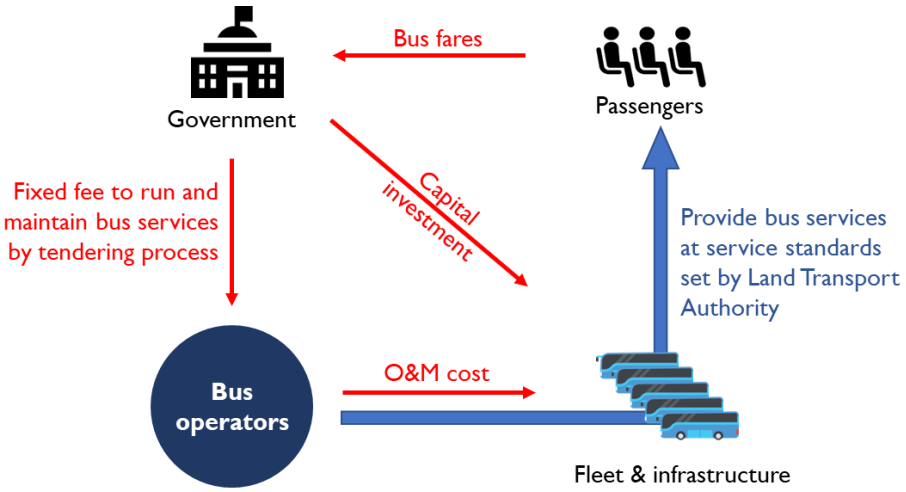
4.5.1 Analysis of existing and potential barriers and opportunities

The proposed business model as well as the various financial options illustrated in Section 4.4 of this chapter can remove the key financial barriers especially those for bus operators including high upfront costs, limited financial capacity, and lack of skilled capacity to maintain and repair e-buses. However, some barriers still exist, and further actions related to government policies and its roles are addressed in Table 27.

Table 27: Further needs to support public bus electrification

Barriers	Further needs
Overall planning of public land transport	
Unclear planning of public land transport electrification	• Electric buses have a limited driving range and long recharging times. Therefore, electrification of bus fleets requires careful planning in terms of strategic, tactical, and operational planning to tackle problems such as placement of charging infrastructure, the electric vehicle scheduling problem, the charging scheduling problem, etc. • The integration with other modes of transport must be clear to ensure the convenience of passengers as well as the feasibility of the investment in public bus electrification.
For e-bus manufacturers:	
Uncertain demand of e-buses	Clear target setting of public bus electrification
For bus operators:	
Regulated bus fares at low level, since collection of bus fares is the main source of revenues for the bus operators, the bus operators focus mainly on high passenger volume and minimizing their costs, as a result providing low service quality for passengers	The Government may consider a new model which allows the main source of revenue of bus operators be linked to the service quality provided. For example, in Singapore, the bus contracting model is applied, i.e., the Government invests in all infrastructure including buses and hires private companies to run public buses through a tendering process. All bus fares are collected by the government (Figure 42).
For charging service providers:	
• Timely and complicated permission process • Availability of land or space for charging infrastructure	• Improved permission process for charging service providers • Allocation of land and improvement of grid infrastructure to promote the investment on charging services

Figure 42: Singapore's Bus Contracting Model

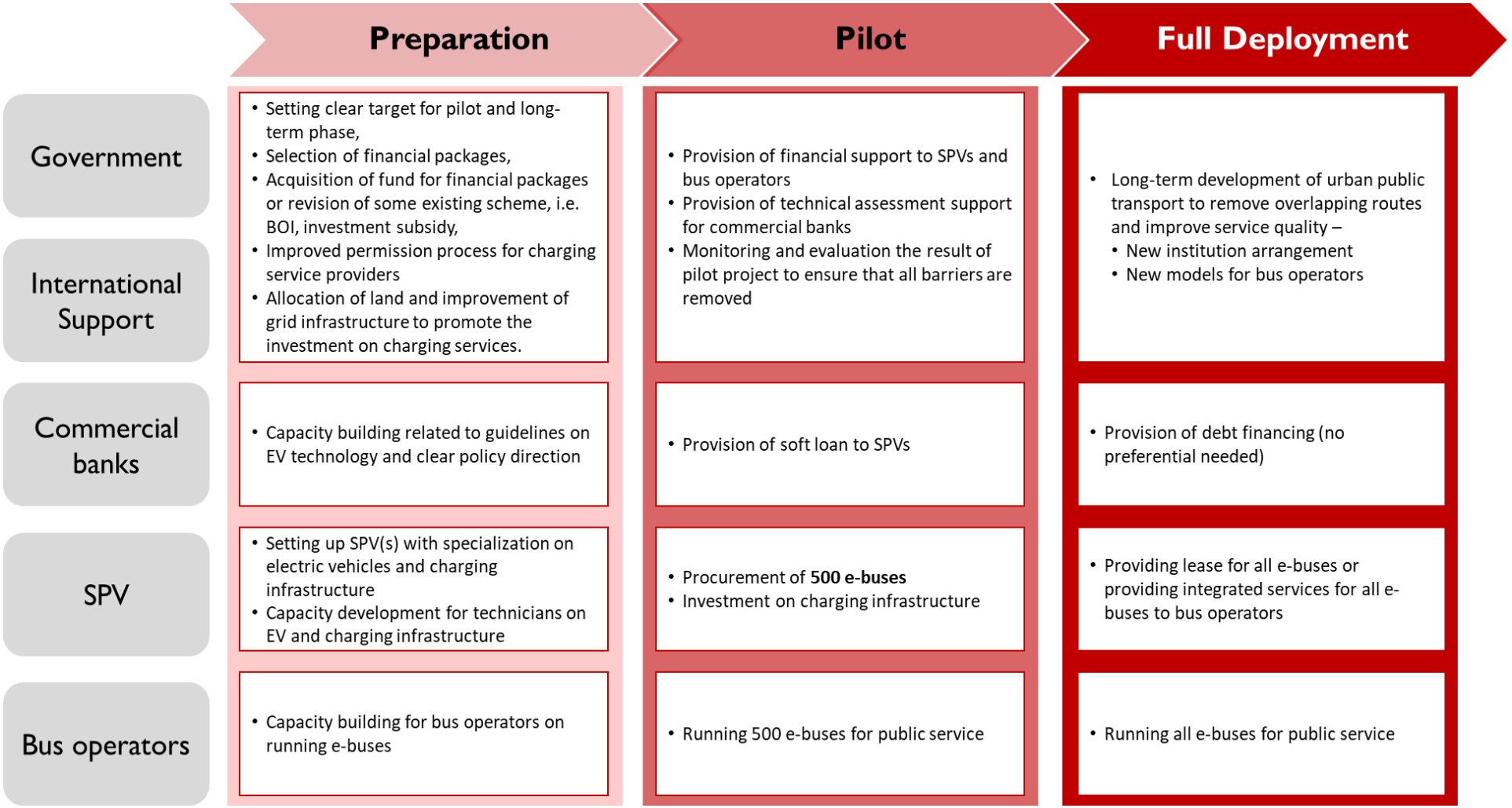


Source: Compiled from
https://www.lta.gov.sg/content/ltagov/en/who_we_are/our_work/public_transport_system/bus/bus_contracting_model.html

4.5.2 Roadmap for operationalising financial mechanisms for public bus electrification in Thailand

The roadmap below is developed for operationalising financial mechanisms for public bus electrification in Thailand. The roadmap is divided into three phases, i.e., preparation phase, piloting phase, and full implementation. During the preparation phase, the clear target setting as well as the detailed design of financial supports together with the capacity building programs for relevant stakeholders, mainly commercial banks and technicians will be conducted. During the pilot phase, the first 500 electric bus should be demonstrated. Finally, at the full deployment phase, the entire fleet transitions towards e-buses without additional financial support, but the reform of public bus financing is needed to ensure that the financial status of bus operators will not incur deficit and lack investment capacities to keep improving fleets in the long run. The actions needed by the primary stakeholder groups in each phase are highlighted in Figure 43.

Figure 43: Roadmap for operationalising financial mechanisms for public bus electrification in Thailand



4.6 Recommendations for public bus electrification in Thailand

Upgrading the public bus service to become everyone's choice should be the national agenda to reduce traffic congestion and air pollution, to improve the quality of life of citizens in Thailand. To upgrade the public bus service, the following actions are needed.

a) Replacement of new buses: Approximately 50% of public buses in BMR have been operated for more than 29 years. The replacement of new buses will reduce maintenance cost born by the operators, reduce air pollution from the deteriorated diesel buses, and allow the provision of better service with reliable schedule. The better quality of service will escalate the number of passengers leading to higher revenues for the operators.

b) Improvement of service standard: DLT as a regulator has set a plan to reform service routes and networks, promote safety standard for public transport, and connect all modes of transportation. To ensure the standard of service, the Government may consider a new business model which allows the main source of revenue of bus operators to be linked to the quality of service provided. For example, in Singapore, the bus contracting model is applied, i.e., the Government invests in all infrastructure including buses and hires private companies to run public buses through a tendering process. All bus fares are collected by the government.

c) Fair adjustment of bus fares: Most of public bus operators were facing net loss from their operation. This shows that the bus fares cannot cover the operating cost resulting in limited capacity to invest in improvement of bus infrastructure and service quality. Compared to the Sustainable Urban Transport Index on affordability, the fares of public buses in Bangkok are considered as highly affordable. There still exists the gap for adjustment of bus fares to cover all operating costs of buses as well as allow bus operators to invest in improvement of bus quality and services. To ensure affordability for low-income passengers, the government should support the service provision through subsidies, instead of keeping the fare at a low level. Fair pricing together with regular evaluation of operators' performance will lead to higher service quality which is key to encourage the use of public transport for all groups and finally leading towards an improvement of the life quality of local citizens.

Public bus electrification can be one of the promising solutions for upgrading the public bus service in Thailand. The investment on electric buses becomes more attractive. The financial analysis on TCO reveals that the TCO of an e-bus is competitive, compared to that of a diesel bus. The costs of an e-bus and batteries are decreasing further lowering the TCO of an e-bus. Moreover, since the fuel cost incurred during the operation has more impact on the TCO of ICE buses than that of an e-bus, the volatile fossil fuel prices lead to higher risks in the operation of a diesel bus and a NGV bus.

The operating lease model and integrated end-to-end financing model are considered as potential business models to overcome the existing barriers to public bus electrification in Thailand. However, since the fare is the major source of revenue for the bus operators, the current level of bus fares cannot make the bus electrification feasible. Additional financial support either from the government side or from international sources are needed. A funding volume of 1,303 – 1,983 MB is needed for make the electrification of 500 public buses feasible depending on the business model selected and the financial options provided.

Compared to the existing subsidy scheme for electric passenger cars per passenger-trip over a 15-year period (3.11-3.33 THB/passenger-trip), the support needed for public bus electrification is smaller (highest at 2.32 THB/passenger-trip). Moreover, the amount of funding required to support the electrification of 500 buses (1,303–1,983 MB) can support about 18,600–28,300 electric passenger cars, from which the number of beneficiaries is approximately 510–776 million passenger-trips. However, the number of beneficiaries of 500 public buses is 1,140 million passenger-trips, or approximately 1.47–2.24 times the number of beneficiaries from promoting electric passenger cars.

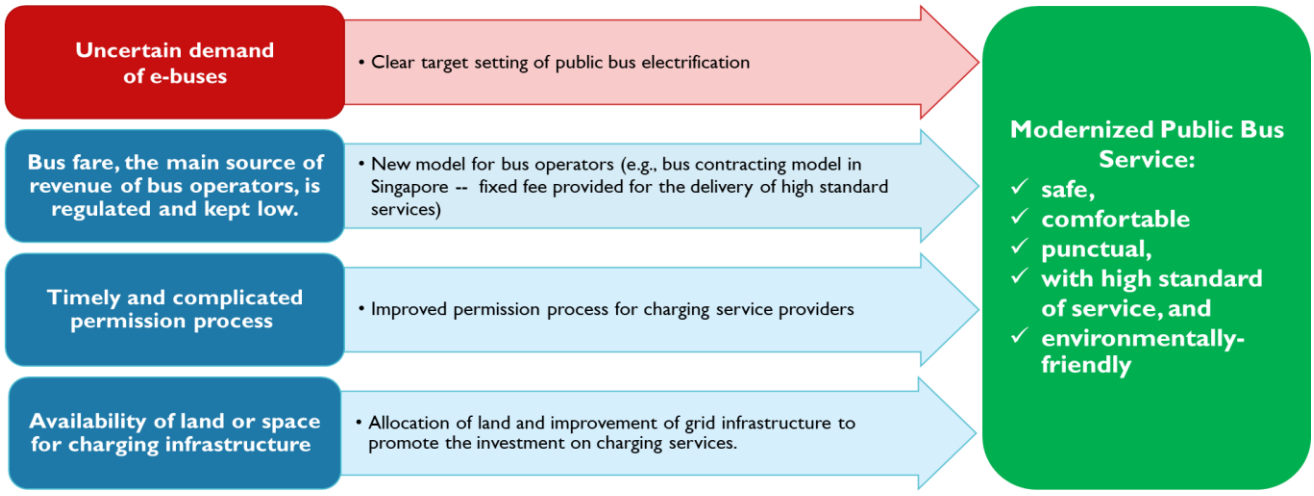
Further assessment shows that the GHG emission reduction from the electrification of 500 buses is about 43,091 tCO_2/year. The support needed for 500-public-bus electrification in all scenarios per total amount of GHG abatement over 15-year lifetime are less than 160 USD/tCO_2. The government can use this estimated support per ton of GHG abatement as a reference to compare with the cost required to support other NDC measures for incentivizing low carbon investment to prioritize public finance support.

The implementation of public bus electrification can be divided into 2 groups depending on the types of the operators. The first group is BMTA as a state-owned enterprise. The consultation with BMTA suggests that the integrated end-to-end financing model is more suitable for the current situation of BMTA. The model can overcome the barriers that BMTA is facing on public bus electrification including the limited financial capacity to invest into new buses and the lack of skilled capacity to maintain and repair EVs. Also, it can help mitigate the risks on uncertainty of fuel supply. However, the implementation shall comply with the Public Private Partnership Act B.E.2562 (2019).

The second group is a group of private companies with direct licenses from DLT. Currently, there is a new investor from the EV and battery manufacturing sector with strong financial and technical capacities, E-Transport Holdings Co.,Ltd. entering the public bus operation business in deploying electric buses.

The proposed business models together with the financial support can remove the key financial barriers especially those for bus operators including high upfront costs, limited financial capacity, and lack of skilled capacity to maintain and repair e-buses. However, some barriers still exist, and further actions related to government policies and its roles are needed as shown in Figure 44.

Figure 44: Further needs to support public bus electrification



To initiate the electrification for public buses, investment subsidy is needed for modernized public bus service over the next 15-year lifetime. The long-term development of public transport to remove overlapping routes and improve service quality especially the adoption of new models for bus operation and fair adjustment of bus fares is crucial for the sustainability of the public bus service.

5. Integrated Assessment of Public Van Electrification

Chapter Objective:

To elaborate concept and design together with implementation requirements and roadmap of financial mechanisms for public van electrification through (i) detailed examination of the demand and supply side of the public van service market, covering a comprehensive assessment of the organizational structures, technical and financial performance, including i. a. financial situation, characteristics of fleet ownership, management and operation, applied business models, and (ii) assessment of financial and technical needs of the operators to electrify their fleets covering identification of financial and technical challenges of public van operation and maintenance, detailed review and analysis of CAPEX, OPEX, TCOs as well as the feasibility of the proposed business model

Research Questions:

1. What is the structure, organization, and stakeholder map of the public van service market in Thai cities, e. g. Bangkok?
2. What are the key performance characteristics on the supply side of the public van service market?
3. What are the current financial and operational status of the operators?
4. What are the financial and technical supports appealing to these operators? How?
5. What are the potential financial mechanisms for the development of public van electrification?

Summary of Key Results:

1. Existing Market Structure of Public Van Services
   g) Among the public transport, public van contributed to 4% of total commutes by public land transport or 142.4 million people-trips/year. In 2019, the number of public van passengers declined from that of 2018 around 30%. This is caused by a decrease in number of vans (18%) and overlapping between new sky train routes and existing van routes; therefore, some passengers switch to the sky train (BTS).
   h) According to the DLT's statistics, 13,049 fixed-route public vans were registered nationwide in 2019 while BMTA reported that 3,705 public vans provided passenger transportation services covering 147 routes in BMR, with a distance ranging between 8-67 km. There was a decreasing trend of public vans serving in BMR areas since 2015 due to the new regulation fixing the lifetime of public van and the expiration of licenses by 2022. Most of existing public vans are diesel vans due to the lower upfront cost compared to the NGV vans.
   i) The government has enforced public van regulation under the Land Transport Act since 1999 to set the service standard for the safety of passengers, and to eliminate the competition between vans and buses. Public vans have been regulated by the Land Transport Policy Commission. DLT has played a role as a regulator to supervise and control fixed-route van operations, stipulating service standards of public vans. BMTA has been the only operator granted licenses for operating public vans serving fixed routes in BMR and has been allowed to sub-contract to private operators.
   j) In 2019, the cabinet resolved the policy to reform the public land transport system. Until now, the plan to reform public van service, including revision of service routes and replacement of 20-seat microbuses, is still being developed.
   k) The fares of the public vans are determined by the distance travelled, with a minimum charge of 15 THB/passenger-trip. The fares of public van in BMR range 15-62 THB/passenger-trip.
2. Financial status and business models of existing van operators:
   c) Most public van operators, sub-contracted with BMTA and serving people in Bangkok and the metropolitan area, are small private operators. Net income of a van operator is about 25,000 -

35,000 THB/month while the operating cost is around 62,775 THB/month, covering fuel cost, cost of van, maintenance cost, insurance, tax, route fee, and parking fee.

d) The existing business model of public van operators can be described as follow. Public van operators, which are sub-contractors of BMTA provide services to passengers. Their revenues come from fare collection without any support from the government. The operators must pay the route fee to BMTA and provide services according to the standards set by DLT. The van manufacturers and the oil companies are the key suppliers for van operators whereas the commercial banks provide loans for acquisition cost of vans so that van operators can reimburse on a monthly basis.

3. Financial and technical needs assessment of van fleet electrification and charging infrastructure deployment in Thailand
   f) The CAPEX of a 13-seat diesel van is about 1,269,000 THB while the CAPEX of a 11-seat electric van and a 20-seat electric van are about 2,300,000 THB and 2,500,000 THB, respectively.
   g) The total NPV of OPEX of a 13-seat diesel van over its 10-year lifetime is at 4,391,460 THB while that of a 11-seat electric van and a 20-seat electric van is about 3,227,712 THB and 4,247,190 THB, accounting for 74% and 97% of the total NPV of OPEX of a 13-seat diesel van.
   h) Comparing to the total cost of ownership per passenger seat of a 13-seat diesel van (0.806 THB/km/seat), the TCO of a 20-seat electric van (0.625 THB/km/seat) considers competitive; however, that of a 11-seat electric van (0.931 THB/km/seat) is still higher than that of a 13-seat diesel van.
   i) The change in distance has the greatest impact on TCO of all types of vans, especially on the TCO of an 11-seats electric van (9.5%). The discount rate has the second largest impact on the TCO of a 13-seat diesel van due to the relatively high share of its OPEX. For an 11-seat electric van, the acquisition cost of a van is the second largest factor impacting on its TCO since CAPEX shares 41.6% of its TCO.
4. Proposed business models and financial mechanisms for public van electrification in Thailand
   e) The operating lease model and integrated end-to-end financing model are considered as potential business models to overcome the existing barriers to public van electrification in Thailand, mainly regarding the high upfront cost, limited financial capacity to invest new vehicles, lack of skilled capacity to maintain and repair electric vans.
   f) DCF models were applied for assessment of feasibility. To attract investors, the 10% IRR is set as a threshold for the return of all players. However, the assessment shows that the NPV of the van operator SPV is negative; therefore, additional financial support is needed. A funding volume of 269 - 399 MB is needed for making the electrification of 203 public vans feasible depending on the business model and the financial option selected.
   g) Compared to the existing subsidy scheme for electric passenger cars per passenger-trip over a 10-year lifetime (4.67 – 5.00 THB/passenger-trip), the support needed for public van electrification is higher (5.26 – 8.04 THB/passenger-trip). Moreover, the number of beneficiaries over 10-year lifetime of a passenger car is 53.84 – 88.09 million passenger-trips while that of a public van is only 51.16 million passenger-trips. Therefore, the financial support of public van electrification under this analysis is not competitive.
   h) Further assessment shows that the support needed for 203-public-van electrification per the amount of GHG abatement under four scenarios ranges between 589-899 USD/tCO_2, which is considered substantially high. Compared to the support needed for 500-public-bus electrification per the amount of GHG abatement (less than 160 USD/tCO_2), the support needed for 203-public-van electrification per the amount of GHG abatement is about 36-56 times higher; therefore, the public van electrification is less of a priority.

5. Recommendations for public van electrification in Thailand
   c) The financial analysis implies that the financial support of public van electrification is not competitive, which may result from the regulated van fare as well as the overlapping of service routes within public land transport in Bangkok.
   d) The review on the public van regulation demonstrates that the public van service in Thailand is under the reform. New route system to deal with the overlapping route problem will be applied and replacement of 20-seat microbus will be executed. Therefore, the removal of regulatory barriers is the most urgent to deal with for the public van electrification.

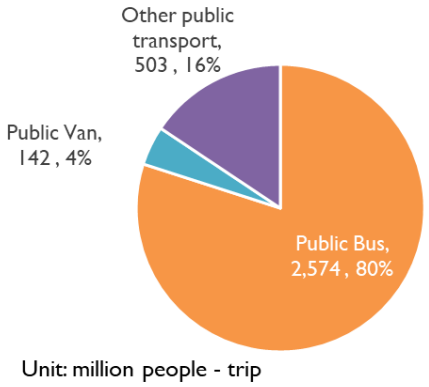
5.1 Existing market structure of public van

5.1.1 Demand of public van

In 2019, the total number of commutes in Bangkok Metropolitan Region was 11,124.30 million passenger-trips per day whereas public transport has a share of 19.42%. Among the public transport, public van contributed to 4% of total commutes by public land transport or 142.4 million passenger-trips/year (Figure 45).

In 2019, the number of public van passengers declined by round 30%. compared to 2018 This is caused by a decrease in number of vans (18%) and overlapping between new sky train (BTS) routes and existing van routes.

Figure 45: Share of commutes by public land transport in 2019



Source: Transport Infrastructure Report 2019, Office of transport and traffic policy and planning

5.1.2 Supply of public van

According to the DLT's statistics, 13,049 fixed-route public vans were registered nationwide in 2019 while BMTA reported that 3,705 public vans provided services covering 147 routes in BMR. The BMTA's annual reports from 2013 to 2019 show the decreasing trend of public vans serving in BMR areas since 2015 as shown in Figure 46. This may result from the regulation enforced in 2010 that the lifetime of public van in service must not exceed 10 years and nearly a quarter of public vans operating in the BMR areas were decommissioned by the end of 2018[64]. Moreover, it is noted that 70% of the permits granted to van service operators will expire by 2022 and BMTA plans to fully commence the 20-seat microbus service.[65]

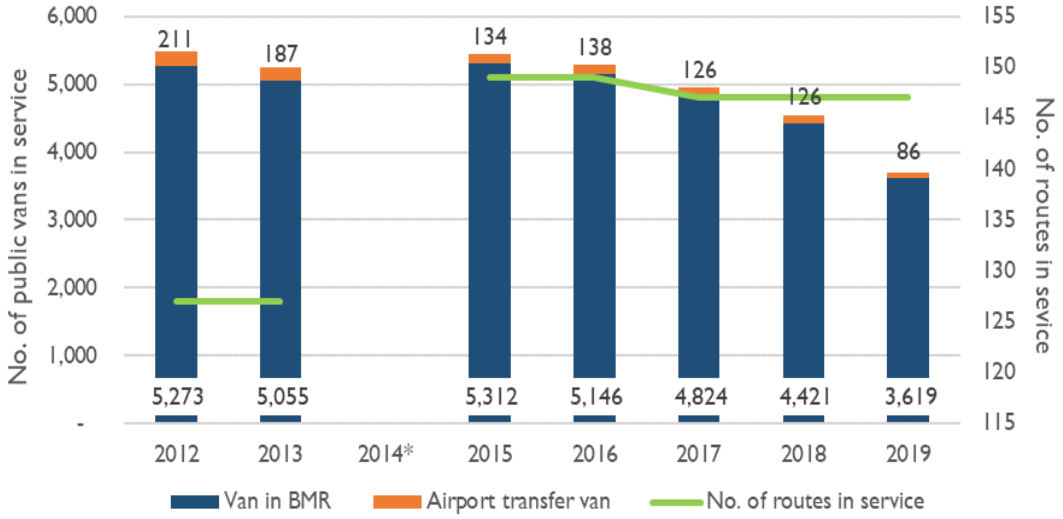
It was during 2006 – 2009 that the government promoted NGV vans for public van service and in 2009, all public vans under BMTA's supervision were changed to NGV vans. However, since the

[64] https://www.bangkokpost.com/thailand/general/1545946/quarter-of-citys-public-vans-to-be-retired

[65] https://www.bangkokpost.com/thailand/general/1229936/all-vans-to-be-replaced-by-microbuses

maximum age of vans allowed for public transport services is 10 years, most of the NGV vans turned into diesel vans in 2019 due to the rising NGV price and the lower cost of diesel van.

Figure 46: Number of public vans and routes serving in BMR areas during 2012-2019



Source: BMTA annual report, 2012 - 2019
Remark: * It is intended to leave 2014 blank due to data is missing.

5.1.3 Institutional arrangement of public van market

The public van service started illegally in 1992 to provide transport services for people commuting from outskirts to downtown areas, whereas other public transport modes did not exist. Vans can deliver faster and more comfortable services compared to public buses at affordable prices, so they became popular among passengers. However, a number of accidents from passenger vans occurred, and the government has enforced public van regulation under the Land Transport Act since 1999 to set the service standard for the safety of passengers, and to eliminate the competition between vans and buses.[66]

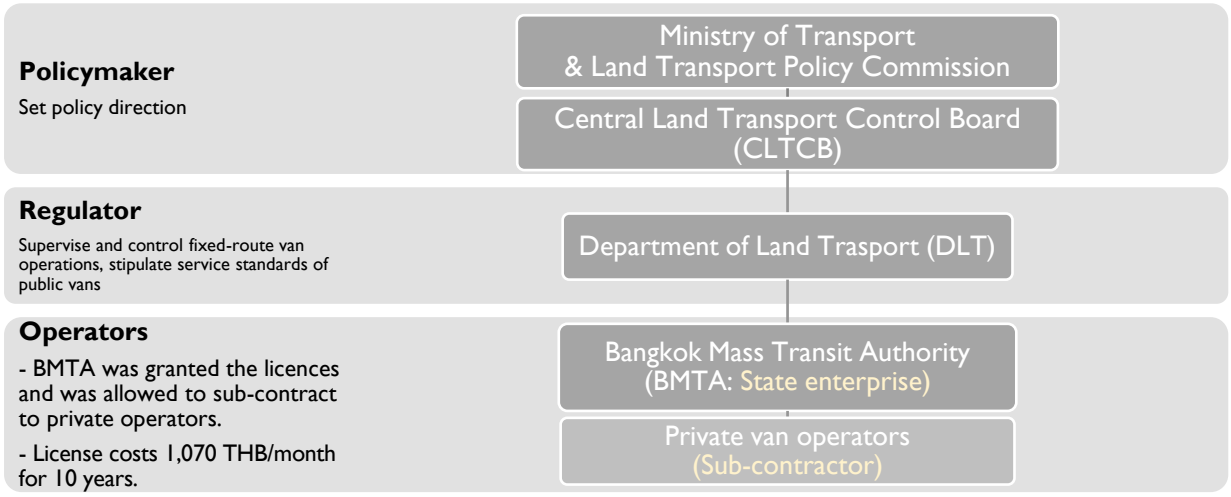
Similar to the institutional arrangement of public buses, public vans have been regulated by the Land Transport Policy Commission chaired by Minister of Transport determining long-term and short-term policies and CLTCB chaired by the Permanent Secretary of Ministry of Transport approving fixed-route vans routes, fares, etc. DLT has played a role as a regulator to supervise and control fixed-route van operation and stipulate service standards of public vans. BMTA has been the only operator granted licences for operating public vans serving fixed routes in BMR and has been allowed to sub-contract to private operators. The private operators must comply with the service standard of DLT and pay fees to BMTA. The institutional arrangement of public van service in BMR is shown in Figure 47.

In 2019, the cabinet resolved the policy to reform the public land transport system. Until now, the plan to reform public van service, including revision of service routes and replacement of 20-seat

[66] https://www.apec.org/docs/default-source/Publications/2011/1/The-Impacts-and-Benefits-of-Structural-Reforms-in-Transport-Energy-and-Telecommunications-Sectors/TOC/Road-transport-in-Thailand.pdf

microbuses, is still being developed. DLT will become the regulator stipulating the service standard and granting licenses to van operators.

Figure 47: Institutional arrangement of public van service in BMR



Source: Own design

a) Route and licensing

As of 30 September 2019, public vans under BMTA's licences provided services covering 147 routes in BMR. These were the existing routes of the vans between important locations in the city and suburbs with distances ranging between 8-67 km.[67] The shortest routes with 8 km distance were No. 25 (Minburi - Rom Klao Housing) and No. 86 (The Mall Lifestore Ngamwongwan - Mueang Thong Thani Village) while the longest route was No. 63 (Rangsit – Bang Phli Housing).

b) Van fares

CLTCB has the responsibility to set the maximum fares. Resolved in December 2018 and mandated in April 2019, the fares of the public vans depend mainly on the distance of the van route as described in Table 28 while the minimum fare is 15 THB/passenger-trip. Less than 5 THB/passenger-trip can be added to the fares of public vans routing through the expressway. Thus, the fares of public van in BMR range 15-62 THB/passenger-trip.[68]

Table 28: Fares of public vans and minibuses (mandated in 2019)

Trip length	Van fare	Minibus fare
Minimum	15 Baht	20 Baht
1 – 10 km.	1 Baht/km.	1.06 Baht/km.
11 – 20 km.	0.6 Baht/km.	1.06 Baht/km.
21 km. onwards	0.6 Baht/km.	0.87 Baht/km.

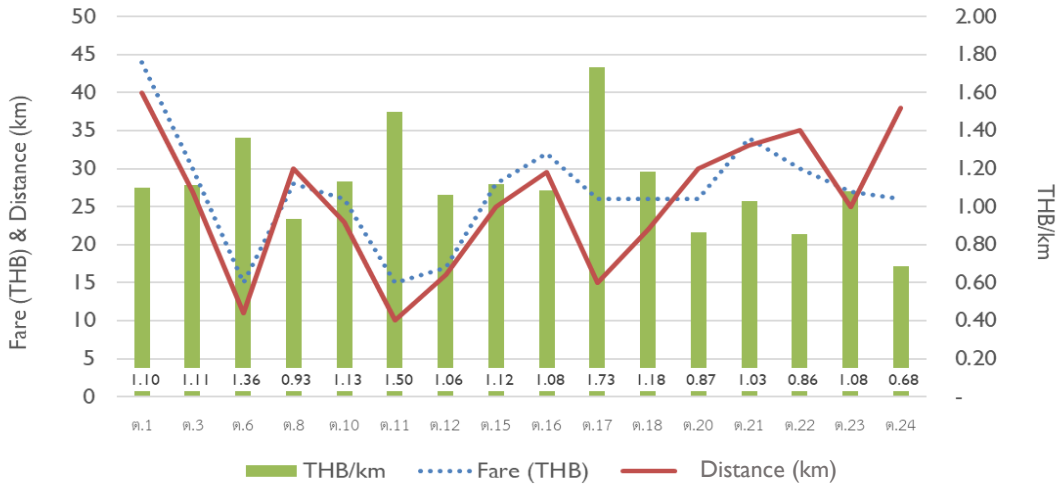
[67] http://library.dlt.go.th/book-detail/9969

[68] https://www.dlt.go.th/site/ptb/m-download/8262/

Sources: https://www.prachachat.net/property/news-327933

Figure 48 shows the fares and the distances of public vans in some selected routes in BMR. The fare per kilometre ranges from 0.86 – 1.73 Baht/km. Higher rates per kilometre were caused mainly by the expressway toll.

Figure 48: Fares and distances of public vans in some selected routes in BMR



Source: Estimated from the data https://www.dlt.go.th/site/ptb/m-download/8262/

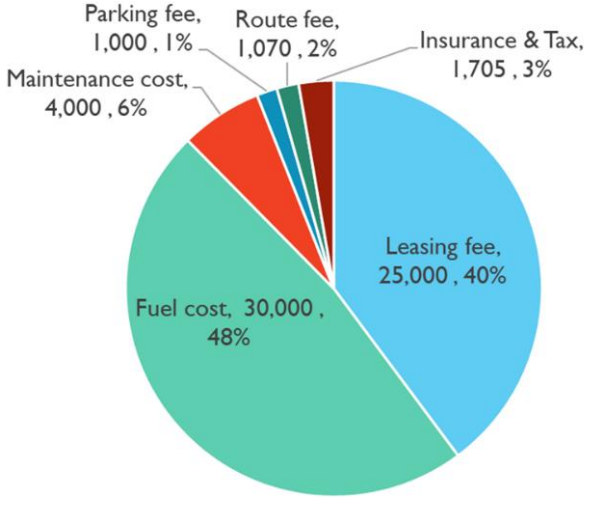
5.2 Financial status and business models of existing van operators

5.2.1 Current financial status of private operators

Most public van operators, sub-contracted with BMTA and serving people in Bangkok and the metropolitan area, are small private operators who own 2-3 vans and operate their own vans or share the vans with others based on a rental agreement. Interview with representatives of the Van Association Bangkok and Metropolitan regarding operating costs and revenues can be summarized as follows:

- Net income of a van operator is about 25,000 - 35,000 THB/month while the operating cost is around 62,775 THB/month.
- Monthly operating costs cover (1) fuel cost at 30,000 THB/month accounting for 48% of the total cost, (2) van loan repayment at 25,000 THB/month accounting for 40% of the total cost, (3) maintenance cost at 4,000 THB/month accounting for 6% of the total cost, and (4) others including insurance, tax, parking fee and route fee at 3,775 THB/month accounting for 6% of the total cost Figure 49.
- Currently, operators' revenues have significantly declined due to the COVID situation and the work-from-home policy. In addition, the opening of new

Figure 49: Monthly operating costs of public van



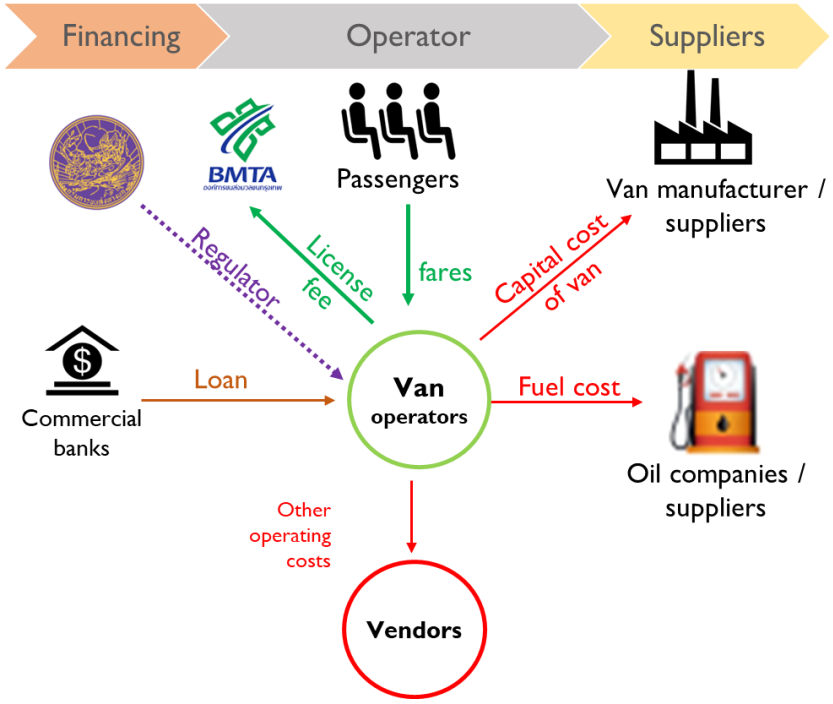
BTS routes and the exemption of fare collection cause significantly fewer van passengers.

Source: Interview of representatives of Van Association Bangkok and Metropolitan

5.2.2 Existing business model of public van operators

The legalization of the public van started in 1999. The regulation specified BMTA to grant licences for public van operation and allowed to sub-contract to van drivers. Most of these drivers are the owners of the vans and their revenues come from fare collection without any support from the government. The operators must pay the route fee to BMTA and provide services according to the standards set by DLT. The van manufacturers and the oil companies are the key suppliers to van operators whereas the commercial banks provide loans for acquisition cost of vans so that van operators can reimburse on the monthly basis. Figure 50 describes the existing business model of public van operators. There will be an adjustment in the near future due to the reform policy on public land transport resolved by the cabinet in 2019.

Figure 50: Existing business model of public van operators



Source: Own design

5.3 Financial and technical needs assessment of public van fleet electrification and charging infrastructure deployment in Thailand

5.3.1 Financial assessment of electric van operation and maintenance

This section explores the CAPEX as well as OPEX of a conventional van and an electric van. It also provides the results from the evaluation of TCO covering CAPEX and OPEX over the lifetime of a conventional van and its counterpart. The data used for the evaluation of TCO have been collected through both desk research, direct interviews, and stakeholder consultation workshops. This section describes key findings from the analysis.

a) CAPEX and OPEX of van operation and maintenance

Capital Expense (CAPEX) is the total cost of van acquisition. For both diesel van and electric van, CAPEX is the cost of van invested in Year 0. It is assumed that the battery replacement of an electric van is needed after 10 years from the start of operation while the the maximum age of vans allowed for public services is 10 years; therefore, the battery will not be replaced during the 10-year public van service. The CAPEX of a 13-seat diesel van is about 1,269,000 THB while the CAPEX of a 11-seat electric van and a 20-seat electric van are about 2,300,000 THB and 2,500,000 THB, respectively.

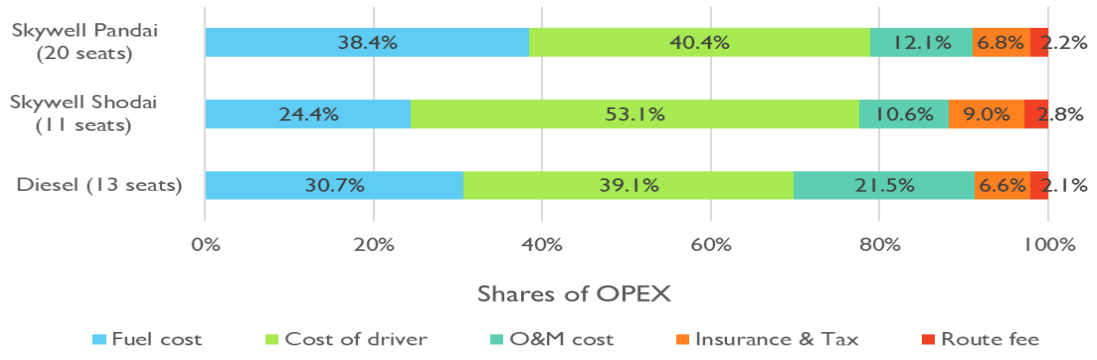
Operating Expense (OPEX) of a public van comprises fuel costs, cost of driver, maintenance cost, and others which are insurance, tax, route fee, parking fee. The total NPV of OPEX of a 13-seat diesel van over its 10-year lifetime is at 4,391,460 THB while that of a 11-seat electric van and a 20-seat electric van is about 3,227,712 THB and 4,247,190 THB. Table 29 describes the yearly OPEX of a 13-seat diesel van, a 11-seat electric van and a 20-seat electric van, accounting for 74% and 97% of the total NPV of OPEX of a 13-seat diesel van. Cost of a driver shares the largest on OPEX of all types of public vans, followed by fuel cost as shown in Figure 51.

Table 29: OPEX of a 13-seat diesel van, a 11-seat electric van and a 20-seat electric van

Items	OPEX (THB/year)		
	Diesel van (13 seats)	Electric van (11 seats)	Electric van (20 seats)
1. Fuel cost [1]	188,136	110,484	228,096
• Fuel consumption	0.13 litre/km	0.31 kWh/km	0.64 kWh/km
• Fuel price	26.8 THB/litre	6.60 THB/kg	6.60 THB/kWh
2. Driver [2]	240,000	240,000	240,000
3. Maintenance cost	132,000	48,000	72,000
4. Others (insurance, tax, route fee, parking fee) [3]	53,500	53,500	53,500
Total	**613,636**	**451,984**	**593,596**
% of OPEX of diesel van	100%	74%	97%

Remarks:
1. Estimated from the service distance at 54,000 km/year (30 km/trip * 6 trips/day * 300 day/year)
2. Estimated at 20,000 THB/month
3. Parking fee at 1,000 THB/month route fee at 1,070 THB/month, and van tax at 1,900 THB/year

Figure 51: Share of OPEX



b) Total cost of ownership of van operation and maintenance

Total cost of ownership (TCO) is estimated by the following formula:

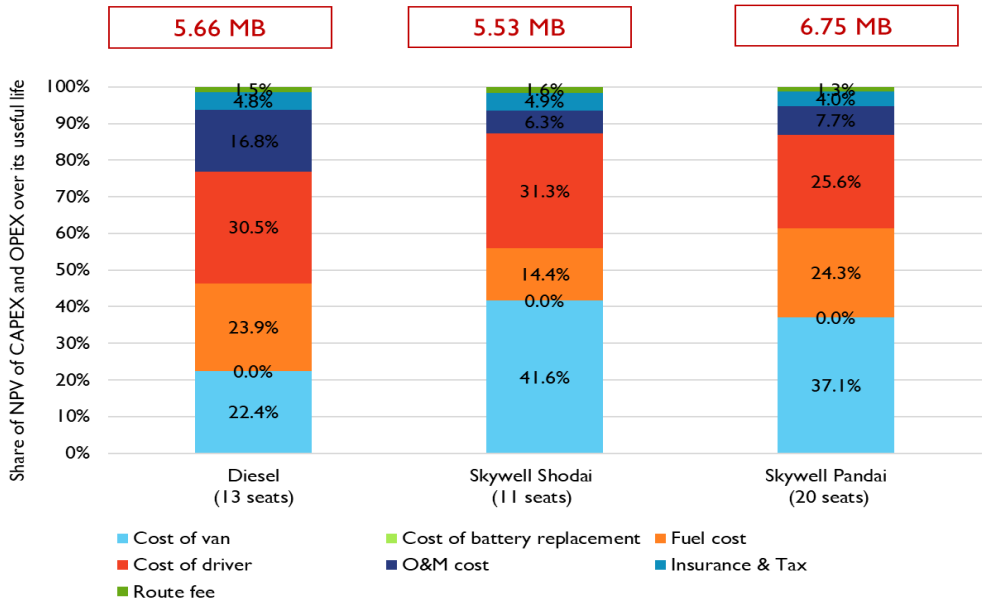
$$TCO = \frac{\text{NPV of (CAPEX + OPEX over its lifetime)}}{\text{Total distance in service over its lifetime}}$$

whereas NPV stands for net present value and the results from the analysis of TCO are shown in Figure 52. Since the number of passenger seats for the diesel van and the electric vans applied in this analysis are different, TCO is estimated in the term of THB/km/seat.

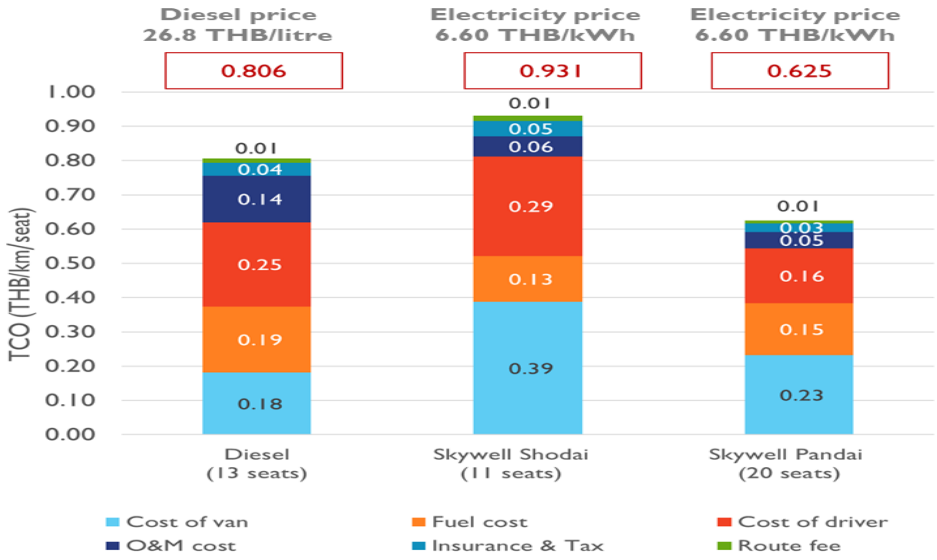
The total of CAPEX and OPEX over the lifetime of a 13-seat diesel van, a 11-seat electric van and a 20-seat electric van are 5.66 MB, 5.53 MB, and 6.75 MB, respectively. For the diesel van, the driver cost shares are the largest, followed by the fuel cost and the acquisition cost of the vehicle. For the electric van the vehicle acquisition cost share is the largest followed by the cost of driver and the fuel cost.

Figure 52: Key results of the analysis on TCO of van operation and maintenance

a) NPV of CAPEX and OPEX over the vehicle lifetime

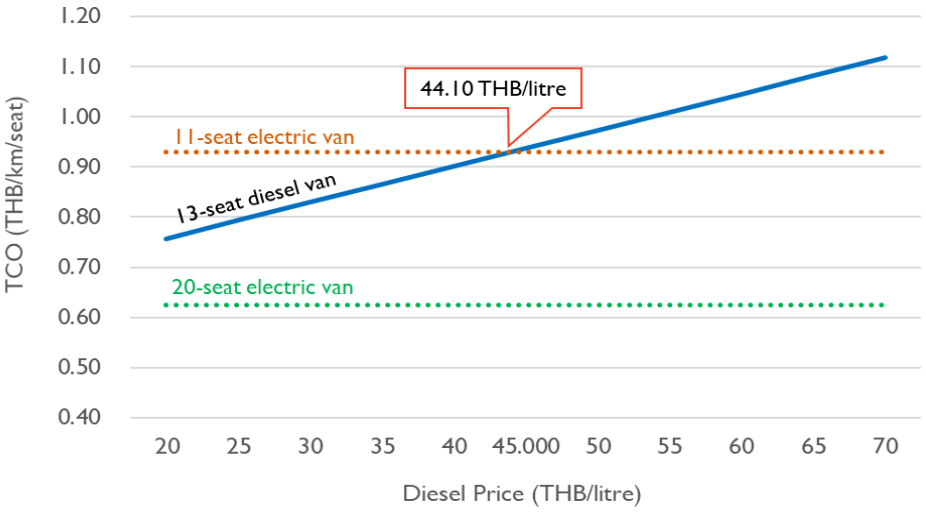


b) TCO of van operation and maintenance (THB/km/seat)



Comparing to the total cost of ownership per passenger seat of a 13-seat diesel van (0.806 THB/km/seat), the TCO of a 20-seat electric van (0.625 THB/km/seat) considers competitive. The TCO of a 11-seat electric van (0.931 THB/km/seat) is still higher than that of a 13-seat diesel van. Further analysis was conducted to find the level of diesel price that allows the TCO of a 11-seat electric van break-even with that of a 13-seat diesel van. The result shows that once the diesel price reaches 44.10 THB/litre, the TCO of 13-seat diesel van meets the TCO of 11-seat electric van. As of July 2022, the monthly weighted average retail price of diesel fuel was 34.97 Baht/litre, with a subsidy of 4.15 Baht/litre from the oil fund, which means that the actual price is 39.12 Baht/litre, getting closer to the cutting point of two lines shown in Figure 53.

Figure 53: TCO of a 13-seat diesel van at different diesel prices compared to the TCO of 11-seat electric van and 13-seat diesel van at the 6.60 THB/kWh electricity price



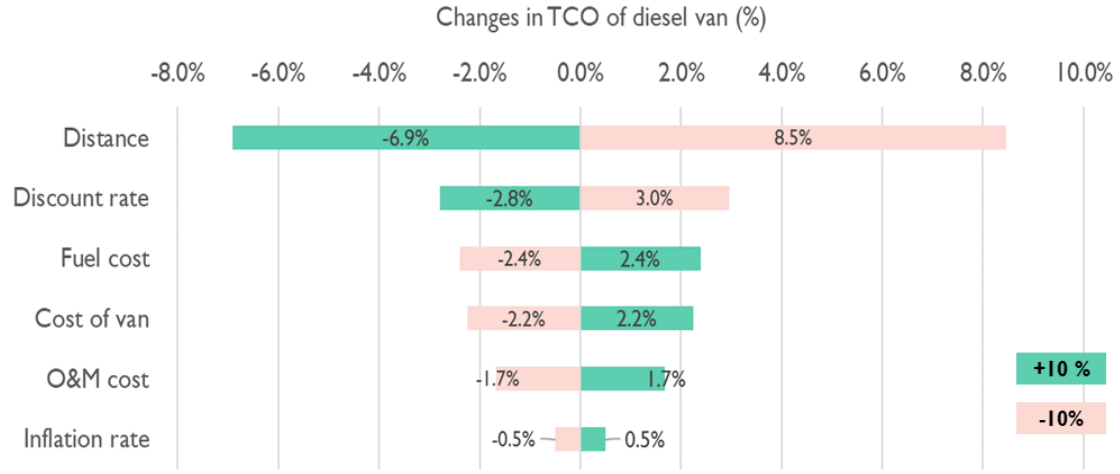
c) Sensitivity analysis on TCO of public van

The sensitivity analysis helps assess the importance of parameters on the TCO of the public vans. When adjusting the value of each parameter by 10%, the changes of TCO are as shown in Figure 54. Key findings are:

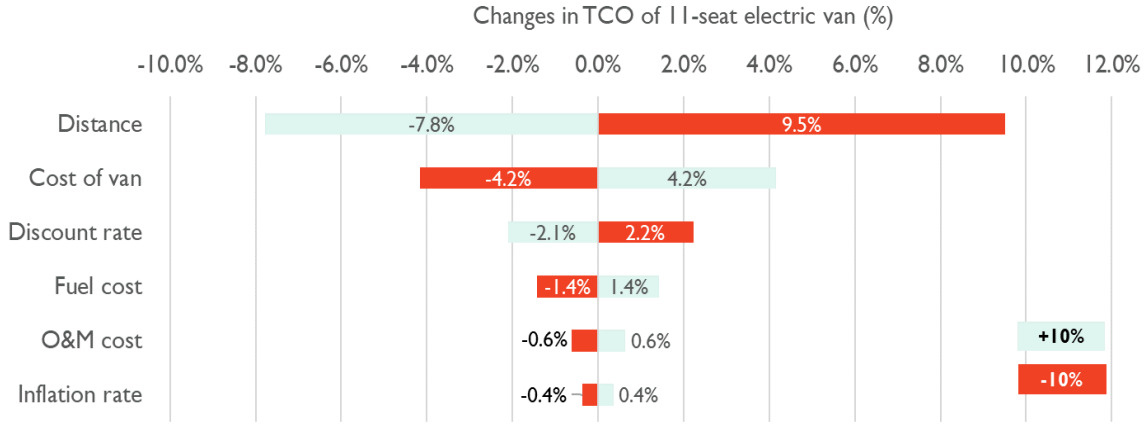
- The change in distance has the greatest impact on TCO of all types of vans, especially on the TCO of an 11-seat electric van (9.5%).
- Discount rate has the second largest impact on TCO of a 13-seat diesel van. This results from the relatively high share in operating cost of the diesel van with the fuel cost being the largest contributor.
- The acquisition cost has the second largest impact on TCO of an electric van. The change in the acquisition cost has higher impact on the change of an 11-seat electric van (4.2%) than of a 20-seat electric van (3.7%).

Figure 54: Sensitivity analysis on TCO of public van

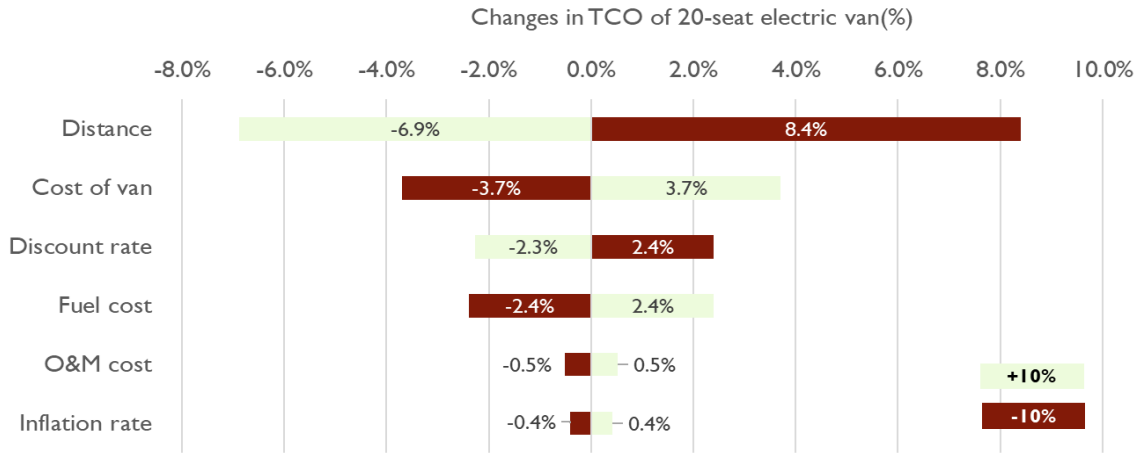
a) Sensitivity analysis on TCO of 13-seat diesel van



b) Sensitivity analysis on TCO of 11-seat electric van



c) Sensitivity analysis on TCO of 20-seat electric van



5.3.2 Financial and technical challenges of public van electrification

From interviews of various stakeholders from both public and private sectors as well as stakeholder consultation workshop together with the results from the desk research and analysis, financial and technical challenges of public van electrification have been addressed. Considering the existing business model of public van and the ecosystem required for electric van, the three key players for public van electrification are **e-van manufacturers, public van operators, and charging service providers**. Thus, the financial and technical challenges are divided by three groups of key players, covering technical, and financial dimensions as shown in Table 30.

Table 30: Regulatory, financial, and technical challenges of public van electrification

	Technical	Financial
E- van and battery manufacturer	• Uncertain demand of e-vans • Only a few models of e-vans available in the market • Limited domestic electric van manufacturing	• Limited access to financing and lack of confidence from financial institutions in EV manufacturers • No benchmark for the residual value of e-vans especially public EV for commercial banks to apply for assessing project financing
Motorcycle operator	• Overlapping of routes in service • Lack of skilled capacity to maintain and repair e-vans • Lack of confidence in sufficient charging infrastructure	• High upfront cost of e-van • Limited access to financing and guarantee mechanism • Regulated van fares • Limited investment capacity of van operators • Lack of confidence from financial institutions and insurance sector

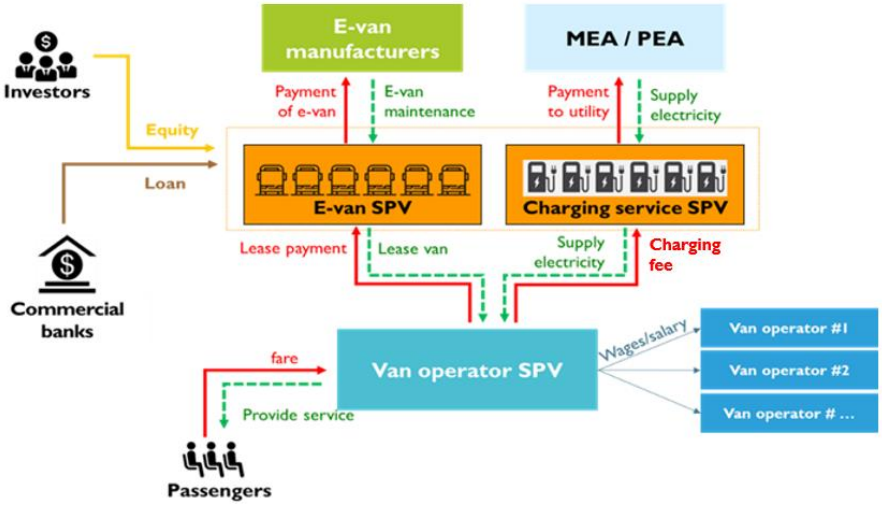
	Technical	Financial
Battery swapping station	• Uncertain demand due to small number of e-vans • Availability of land or space for charging infrastructure • Timely and complicated permission process	• High upfront cost especially when upgrading transformer needed • Unstable electricity prices

5.4 Proposed business models and financial mechanisms for public van electrification in Thailand

5.4.1 Conceptual framework for the proposed business model

As described in Section 5.3, various financial options have been developed all over the world to promote public transport electrification. Considering the context of Thailand, the suitable financing options with significant potential in removing financial and technical barriers to public transport electrification are **(i) operating lease** and **(ii) integrated end-to-end financing.** Description of each model is illustrated in Table 31 and Table 32.

Table 31: Operating lease model

Operating lease model
Diagram:  Source: Own design
Description: An operating lease is a contract model which allows the lessee use of a vehicle in return for regular lease payments. Key players in this model include: • ***an e-van SPV:*** targeting e-van ownership through long-term contracts between e-van SPVs and e-van manufacturers and providing lease and maintenance service to the van operator SPVs through leasing agreement covering maintenance services between e-van SPVs and van operator SPVs, • ***a van operator SPV*:** targeting van operators who are primarily small operators to strengthen their capacities to provide standardized services and receive a certain income in the form of wages or salaries, and

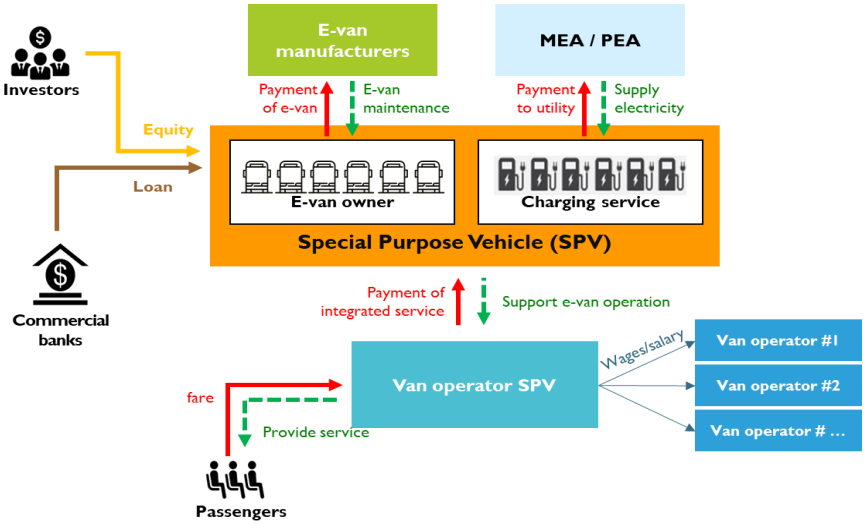
- ***a charging SPV:*** targeting charging infrastructure ownership and provision of charging service to EV fleets under long-term contracts between van operator SPVs and charging service SPVs.

The three SPVs may be the same or different entities upon the readiness of technical and financial capacity. SPVs can be established with the support from the government or potential investors, e.g. van manufacturer, battery manufacturer, energy companies.

Table 32: Integrated end-to-end financing model

Integrated end-to-end financing model

Diagram:



Source: Own design

Description:

This model aims to bundle all services/ products required for public van electrification including vehicles, batteries, and charging infrastructure to provide an integrated solution. Key players in this model include:

- ***An integrated end-to-end service SPV:*** Owning all assets required for public van electrification through long-term contracts with e-van manufacturers as well as charging infrastructure suppliers and providing an integrated end-to-end service to the van operator SPVs under long-term contracts with van operator SPVs,
- ***A van operator SPV:*** Setting up a group of van operators who are primarily small operators to help them to provide standardized services and receive a certain income in the form of wages or salaries.

The key advantage of this model is that the operator does not need to pay any upfront cost. Additionally, the operator will engage with only one entity, which is potentially cost saving as it requires less time and effort. The SPV can be bundled up by potential investors from manufacturer, component provider, financing institution, or power company side. This model relies heavily on the capacity of the SPV which must be highly mature and able to assure the availability and the quality of the services provided to the van operator SPVs.

5.4.2 Detailed assessment of the proposed business model

To conduct detailed assessment of the proposed models, the net present value (NPV), internal rate of return (IRR), and payback period of both models were estimated using discounted cash flow (DCF) analysis.

a) Detailed assessment of the operating lease model

- Three DCF models were assessed for three key players including an e-van SPV, a van operator SPV, and a charging SPV. The analysis was conducted for the investment of 20 and 203 vans. The investment cost is assumed to decrease by 5% for the fleet with 20 vans and 10% for the fleet with 203 vans.[69]
- Table 33 shows the revenues, CAPEX, and OPEX of the three key players in the operating lease model.
  - For the e-van SPV, revenue comes from the lease fee. Its CAPEX covers cost of vans while its OPEX covers maintenance cost and insurance.
  - For the charging SPV, revenue comes from the charging fee. Its CAPEX covers the cost of charging sockets, charging stations, and upgradation of transformers while its OPEX covers cost of electricity, land rental, operation and maintenance (O&M), and administration.
  - For the van operator SPV, revenue comes from collection of fares. No CAPEX is required while its OPEX covers lease payment, fuel costs, costs of van drivers, tax fee, license fee, and administration.
- The amount of annual lease payment and charging cost, which the van operator SPV must pay to the e-van SPV and the charging SPV, were estimated with the concept that the IRR of both the e-van SPV and the charging SPV are more than 10% to ensure the attractive investment to both players. However, the assessment shows that the NPV of the van operator SPV is negative; therefore, additional financial support is needed (Table 34).

Table 33: Revenues, CAPEX, and OPEX for the operating lease model

Items	Number of vans in the fleet	
	20 vans	203 vans
Numbers of socket (70 kW/socket)	14	136
1) E-van SPV		
Total NPV of revenues from rental fee over 10 years (MB)	**77.75**	**759.94**
Total NPV of CAPEX (MB)	**47.50**	**456.75**
- Cost of van at Year 1 (MB)	47.50	456.75
- Cost of battery replacement at Year 7 (MB)	0.00	0.00
Total NPV of OPEX over 10 years (MB)	**25.26**	**252.80**
2) Charging SPV		
Total NPV of revenues from charging fee over 10 years (MB)	**59.87**	**564.25**
Total NPV of CAPEX (MB)	**16.25**	**141.48**
- Investment cost at Year 1 (MB)	16.25	141.48
- Overhaul at Year 8 (MB)	0.00	0.00

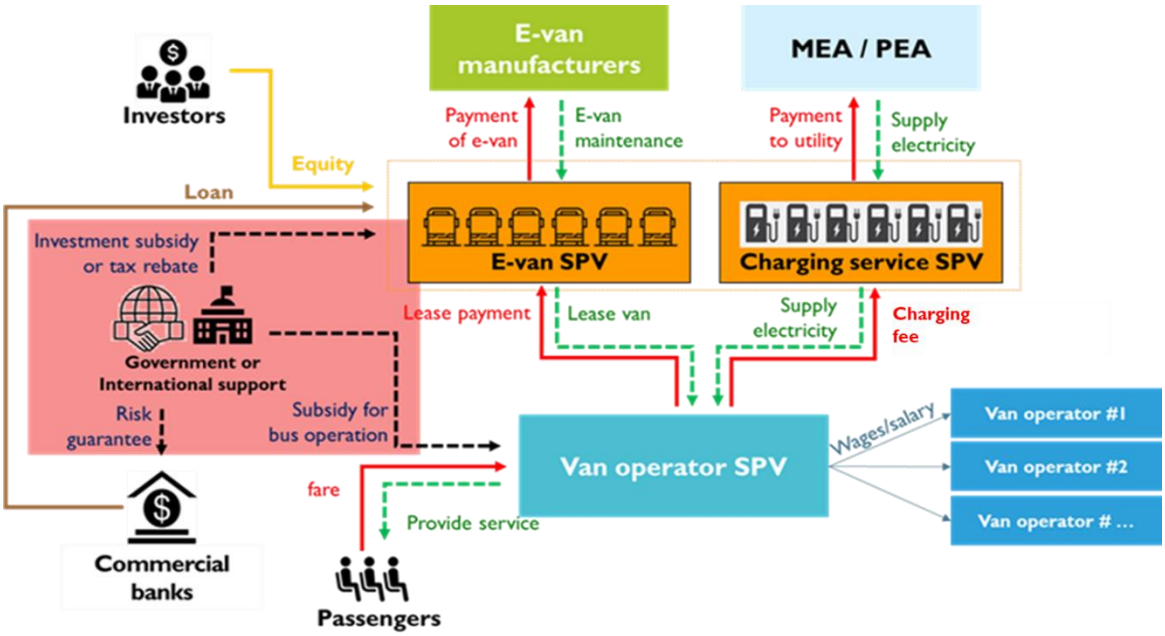
[69] According to the study of Chulalongkorn University, 11 routes are suitable for operating with 203 vans with 20 passenger seats. (http://library.dlt.go.th/book-detail/9969)

Items	Number of vans in the fleet	
	20 vans	203 vans
Total NPV of OPEX over 10 years (MB)	**41.89**	**409.19**
3) Van operator SPV		
Total NPV of revenues (MB) from collection of fare over 10 years	**132.70**	**1,539.29**
Total NPV of OPEX over 10 years (MB)	178.96	1,550.33
Total investment of e-van SPV and charging SPV		
Total CAPEX at Year 1 (MB)	63.75	598.23
Total NPV of CAPEX (MB)	**63.75**	**598.23**

Table 34: Key results of the operating lease model without financial support

Items	Unit	Number of vans in the fleet	
		20 vans	203 vans
Annual lease payment	THB/van/year	540,000	520,000
Charging price	THB/kWh	7.70	7.15
Revenue from fares	THB/van/year	921,623	
Annual ridership	Passenger-trip/van	25,200	
Fare	THB/passenger-trip	36.57	
Return on investment			
1) E-van SPV			
· NPV	MB	4.62	46.65
· IRR	%	10.22%	10.33%
· ROE	%	14.25%	14.49%
· Payback Period	Years	8.74	8.69
2) Charging SPV			
· NPV	MB	1.61	12.58
· IRR	%	10.26%	10.04%
· ROE	%	14.39%	13.90%
· Payback Period	Years	8.71	8.83
3) Van operator SPV			
· NPV	MB	(46.27)	(396.96)

Figure 55: Financial supports needed for the operating lease model



- Further analysis was conducted to evaluate additional financial support needed to make the NPV of the van operator SPV positive along with the scenario that allows the IRR of both the e-van SPV and the charging SPV to be more than 10%. Five financial options including exemption of corporate income tax, performance-based subsidy for van operation, investment subsidy for van and charging infrastructure, and risk guarantee were analysed (Figure 55). The exemption of corporate income tax and performance-based subsidy for van operation can be implemented by the government only while the remaining options can be done through either the government or international support. Table 35 summarizes the results of the analysis on financial support needed for investing in 203 vans. Key findings are:
    - For scenario I, the 5-year exemption of corporate income tax (CIT) is evaluated. In this scenario, the government revenue will decrease by 39.82 MB from the exemption of CIT from e-van SPVs and charging SPVs. Adding the risk guarantee, a funding volume of 52.38 MB would be required. However, the exemption of 5-years of corporate income tax will not be sufficient to make the NPV for the van operator SPV positive.
    - For scenario II, the performance-based subsidy for a van operator SPV is evaluated. By providing 5.05 THB/km subsidy to the van operator SPV, the NPV of the van operator SPV becomes positive. However, this option requires the largest funding support of 398.53 MB. Adding the risk guarantee, the funding would increase to 411.09 MB in total.
    - For scenario III, the investment subsidy for an e-van SPV is evaluated. Providing 70% of investment cost to subsidise the e-van SPV can help reduce the annual lease fee collected from the van operator SPV; as a result, all players win. The funding required for this option is 319.73 MB. Adding the risk guarantee, the funding increases to 325.58 MB in total.
    - For scenario IV, the investment subsidy for a charging SPV is evaluated. By providing up to 80% of investment cost to subsidise the charging SPV alone cannot lower the level of charging fee to make the NPV of the van operator SPV positive. Additional investment subsidy is required for an e-van SPV or a performance-based subsidy for a van operator

SPV. The performance-based subsidy for a van operator SPV would amount to 2.90 THB/km with a total funding volume of 342.04 MB. Adding the risk guarantee, the funding would sum up to 352.23 MB in total.

- For scenario V, bundling the 5-year exemption of corporate income tax (CIT) and the investment subsidy at 62.5% of total investment cost for an e-van SPV is evaluated. Both financial options are aligned with the existing mechanisms that have been launched in Thailand but may not cover the public transportation sector. The extension of the coverage may be conducted with the concrete rationale. Compared to Scenario II – V, the funding required for this package is the smallest at 311.85 MB. Adding the risk guarantee, the funding would result into 318.42 MB in total.

Table 35: Key results on financial support needed for the operating lease model

Items	Scenario I	Scenario II	Scenario III	Scenario IV	Scenario V
Number of vans in the fleet	203 vans				
Annual lease payment (THB/van/year)	495,000	520,000	240,000	520,000	260,000
Charging price (THB/kWh)	6.800	7.150	7.150	5.000	6.800
Financial options implemented by government only					
- Exemption of corporate income tax (years)	5 years				5 years
- Subsidy for van operation (THB/km)		5.05		2.90	
Financial options implemented by government or international support					
- Investment subsidy for e-van (%)			70%		62.5%
- Investment subsidy for charging infrastructure				80%	
- Risk guarantee	Fee at 3% of total NPV of debt				
NPV of total investment (MB)	598.23				
NPV of total debt (MB)	418.76	418.76	194.95	339.53	218.93
Size of fund needed (MB)					
- Subsidy for van operation (15 years)		398.53		228.86	
- Investment subsidy for e-van			319.73		285.47
- Investment subsidy for charging infrastructure				113.18	
- Decrease of government revenue due to tax exemption	39.82				26.38
Sub-total	**39.82**	**398.53**	**319.73**	**342.04**	**311.85**
- Risk guarantee	12.56	12.56	5.85	10.19	6.57
Total	**52.38**	**411.09**	**325.58**	**352.23**	**318.42**
Return on investment					
1) E-van SPV					
• NPV (MB)	42.66	46.65	15.01	46.65	16.30
• IRR (%)	10.17%	10.33%	10.49%	10.33%	10.21%
• ROE (%)	14.33%	14.49%	14.85%	14.49%	14.42%
• Payback Period (years)	8.73	8.69	8.61	8.69	8.71
2) Charging SPV					
• NPV (MB)	13.69	12.58	12.58	3.00	13.69
• IRR (%)	10.32%	10.04%	10.04%	10.42%	10.32%
• ROE (%)	14.93%	13.90%	13.90%	14.73%	14.93%
• Payback Period (years)	8.59	8.83	8.83	8.63	8.59
3) Van operator SPV					
• NPV (MB)	(332.81)	1.25	9.79	1.25	9.72

b) Detailed assessment of the integrated end-to-end financing model

- Two DCF models were assessed for two key players including an integrated end-to-end service SPV and a van operator SPV. The analysis was conducted for investment of 20 and 203 vans. The investment cost is assumed to decrease by 5% for the fleet with 20 vans and 10% for the fleet with 203 vans.[70]
- Table 36 shows the revenues, CAPEX, and OPEX of two key players in the integrated end-to-end financing model.
  - For the integrated end-to-end service SPV, revenue comes from the charge per km of an integrated end-to-end service. Its CAPEX covers cost of the vans, cost of charging stations, charging sockets, and upgradation of transformers while its OPEX covers maintenance cost of e-vans and charging infrastructure, cost of electricity, cost of drivers, and insurance.
  - For the van operator SPV, revenue comes from collection of fares. No CAPEX is required while its OPEX covers charge fees from the SPV, cost of van drivers, tax fees, route fees, and administration.
- The amount of service charge which the van operator must pay to the SPV was estimated with the concept that the IRR of the SPV is more than 10% to attract investment of the SPV. However, **the NPV of the van operator SPV is negative; therefore, additional financial support is needed** (Table 37).

Table 36: Revenues, CAPEX, and OPEX for the integrated end-to-end financing model

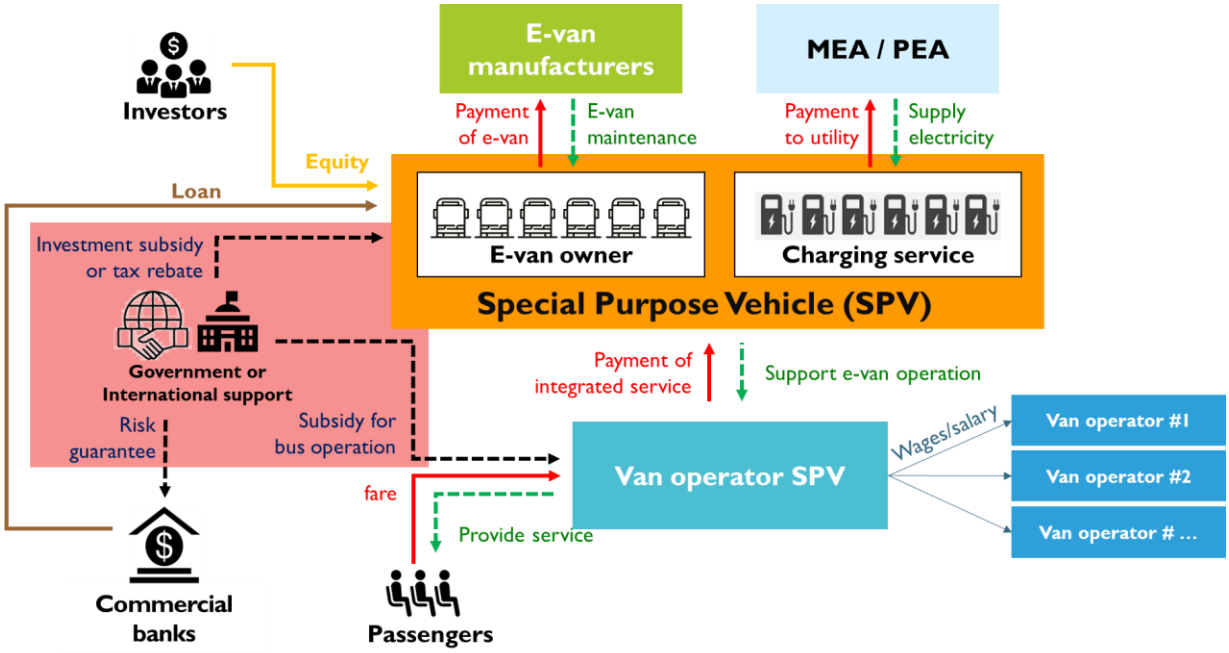
Items	Number of vans in the fleet	
	20 vans	203 vans
Numbers of socket	14	136
1) Integrated end-to-end service SPV		
Total NPV of revenues (MB)	**136.06**	**1,321.85**
CAPEX (MB)		
- Cost of van	47.50	456.75
- Cost of charging socket	9.31	85.68
- Cost of charging station	4.66	42.84
- Cost of transformer	2.28	12.96
Total CAPEX at Year 1 (MB)	**63.75**	**598.23**
- Battery at Year 7	0.00	0.00
- Overhaul of charging infra at Year 8	0.00	0.00
Total CAPEX at Year 1, 7 & 8 (MB)	**63.75**	**598.23**
2) Van operator SPV		
Total NPV of revenues (MB)	**132.70**	**1,346.87**
Total NPV of OPEX over 15 years (MB)	**177.41**	**1,741.50**

[70] According to the study of Chulalongkorn University, 11 routes are suitable for operating with 203 vans with 20 passenger seats. (http://library.dlt.go.th/book-detail/9969)

Table 37: Key results of the integrated end-to-end financing model without any financial support

Items	Unit	Number of vans in the fleet	
		20 vans	203 vans
Total charge for end-to-end service	THB/km/van	17.50	16.75
Revenue from fares	THB/van/year	921,623	
Annual ridership	Passenger-trip	25,200	
Fare	THB/passenger-trip	36.57	
Return on investment			
1) Integrated service SPV			
· NPV	MB	5.88	61.25
· IRR	%	10.10%	10.33%
· ROE	%	14.00%	14.49%
· Payback Period	years	8.80	8.69
2) Van operator SPV			
· NPV	MB	(41.40)	(365.39)

Figure 56: Financial support needed for the integrated end-to-end financing model



- Similar to the operating lease model, four types of financial supporting mechanisms including exemption of corporate income tax, performance-based subsidy for van operation, investment subsidy for the SPV, and risk guarantee were analysed. Table 38 summarises the results of the analysis on financial support needed for investing in 203 vans. Key findings are:
    - For scenario I, the 5-year exemption of corporate income tax (CIT) is evaluated. In this scenario, the government revenues will decrease by 41.09 MB from the exemption of CIT from both SPVs. Adding the risk guarantee, the funding requires 53.65 MB in total. However, only 5-year

exemption of corporate income tax is not sufficient to make the NPV for the van operator SPV positive.

- For scenario II, the performance-based subsidy for a van operator is evaluated. By providing 4.65 THB/km subsidy to the van operator SPV, the NPV of the van operator SPV becomes positive. However, this option requires the largest funding at the total size of 366.96 MB. Adding the risk guarantee, the funding would sum up to 379.52 MB in total.
- For scenario III, the investment subsidy to the integrated end-to-end service SPV for the investment of e-vans and charging infrastructure is evaluated. Providing 45% of investment cost to subsidize the integrated end-to-end service SPV can help reduce the annual lease fee collected from the van operator SPV; as a result, all players win. The funding required for this option is 269.20 MB. Adding the risk guarantee, the funding requires 276.11 MB in total.
- For scenario IV, bundling the 5-year exemption of corporate income tax (CIT) and the investment subsidy for an e-van SPV is evaluated. Both financial options are aligned with the existing mechanisms that have been launched in Thailand but may not cover the public transportation sector. The extension of the coverage may be conducted with the concrete rationale. Compared to scenario II – IV, the funding required for this package is the smallest at 269.65 MB. Adding the risk guarantee, the funding would result into 276.56 MB in total.

Table 38: Key results of the integrated end-to-end financing model with financial support

Items	Scenario I	Scenario II	Scenario III	Scenario IV
Number of vans in the fleet	203 vans			
Total charge for end-to-end service (THB/km/van)	15.90	16.35	11.70	11.70
Options for financial support from government only				
- Exemption of corporate income tax (years)	5 years			5 years
- Subsidy for van operation (THB/km)		4.65		
Options for financial support from government or international agencies				
- Investment subsidy for e-van & charging infrastructure (%)			45%	45%
- Risk guarantee	Fee at 3% of NPV of total debt			
NPV of total investment (MB)	598.23			
NPV of total debt (MB)	418.76	418.76	230.32	230.32
Size of fund needed (MB)				
- Subsidy for van operation (15 years)		366.96		
- Investment subsidy for e-van & charging infrastructure			269.20	269.20
- Decrease of government revenue due to tax exemption	41.09	-	-	0.45
Sub-total	**41.09**	**366.96**	**269.20**	**269.65**
- Risk guarantee	12.56	12.56	6.91	6.91
Total	**53.65**	**379.52**	**276.11**	**276.56**
Return on investment				
1) End-to-end service SPV				
· NPV (MB)	52.10	53.93	39.38	39.38
· IRR (%)	10.04%	10.06%	10.70%	10.70%
· ROE (%)	14.10%	13.91%	15.28%	15.28%
· Payback Period (years)	8.79	8.82	8.51	8.51
2) Van operator SPV				
· NPV (MB)	(303.28)	2.89	2.89	3.31

5.4.3 Assessment of feasibility of support needed for the proposed business models

The detailed assessment of the two proposed business models leads to the estimation of the financial support needs to ensure that the investment is attractive for the key stakeholders. Table 39 summarises the amount of funding required to support the two proposed business models in various scenarios. The amount of funding required for the operating lease model for all scenarios is slightly higher than that required for the integrated end-to-end service. This is because there are only two key stakeholders in the integrated end-to-end service, therefore, the total administration cost incurred is lower than the administration cost required for three parties in the operating lease model. However, the integrated end-to-end service SPV in the integrated end-to-end service model must have a large investment potential since the investment cost covers both e-vans and charging infrastructure. Both models can be applied to the existing context of Thailand. The selection of the model depends upon the investment and technical capacity of the SPV and the direction of policy.

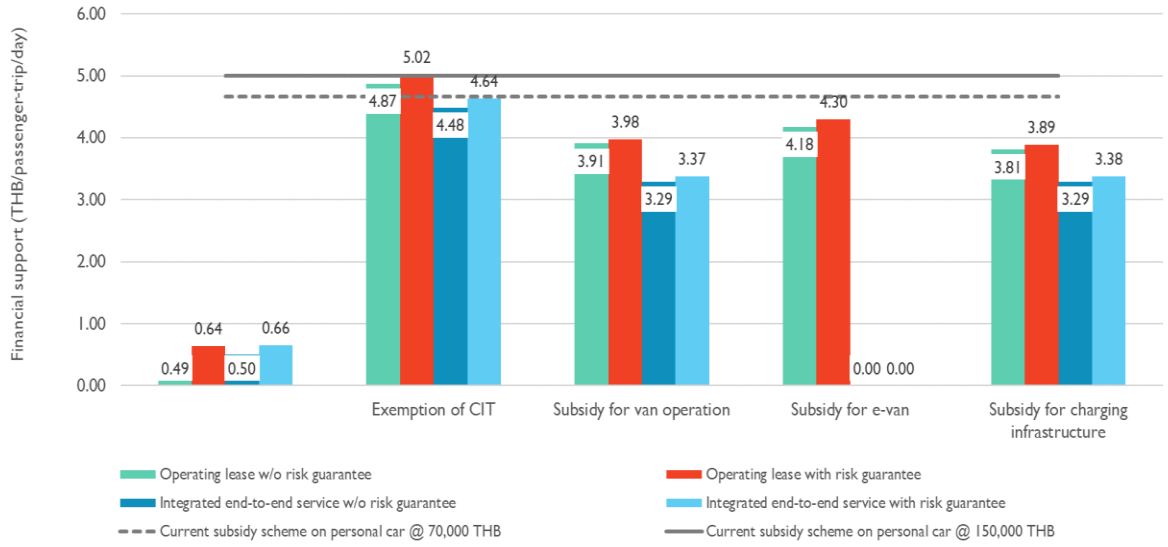
Table 39: Amount of funding required to support the two proposed business models (Unit: MB)

Scenario	Financial options	Operating lease		Integrated end-to-end service	
		w/o risk guarantee	with risk guarantee	w/o risk guarantee	with risk guarantee
I	Exemption of CIT	40	52	41	54
II	Subsidy for van operation	399	411	367	380
III	Subsidy for e-van	320	326	269	276
IV	Subsidy for charging infrastructure	342	352		
V	Exemption of CIT & subsidy of e-van	312	318	270	277

When comparing between the support needs estimated for promoting public van electrification using the proposed business models as shown in Table 39 and the existing subsidy scheme for electric passenger cars, the rate of funding required for supporting the public van electrification per passenger-trip over the 10-year lifetime ranges between 5.26 – 8.04 THB/passenger-trip which is higher than the rate of subsidy per passenger-trip over the 10-year lifetime of the current subsidy scheme for passenger cars, ranging 4.67 – 5.00 THB/passenger-trip as shown in Figure 57.

Moreover, the amount of funding required to support the electrification of 203 public vans (296-411 MB) can support about 3,846-5,873 electric passenger cars, from which the number of beneficiaries is approximately 70.18-107.18 million passenger-trips. However, the number of beneficiaries of 203 public vans is only 51.16 million passenger-trips. In summary, the support needed for the public van electrification is higher than the existing support scheme for passenger cars launched by the government. Therefore, the financial support of public van electrification under this analysis is not competitive. This may result from the regulated van fare as well as the small number of passengers per trip due to overlapping of service routes among public land transport in Bangkok decreasing the number of the van passengers.

Figure 57: Comparison between the amount of funding to support public van electrification through the proposed business models and the existing subsidy scheme for electric personal cars (over 10-year lifetime)



Further assessment shows that the support needed for 203-public-van electrification per the amount of GHG abatement under scenario II – V ranges between 589-899 USD/tCO_2, which is considered substantially high. The government can use this estimated support per ton of GHG abatement as a reference to compare with the cost required to support other NDC measures for incentivizing low carbon investment to prioritize public finance support. Compared to the support needed for 500-public-bus electrification per the amount of GHG abatement (less than 160 USD/tCO_2), the support needed for 203-public-van electrification per the amount of GHG abatement is about 36-56 times higher; therefore, the public van electrification is less of a priority.

Table 40: Support needed for promoting 203-public-van electrification per the amount of GHG abatement (Unit: USD/ tCO_2)

Scenario	Financial options	Operating lease		Integrated end-to-end service	
		w/o risk guarantee	with risk guarantee	w/o risk guarantee	with risk guarantee
I	Exemption of CIT[1]	87	115	90	117
II	Subsidy for van operation	872	899	803	830
III	Subsidy for e-van[2]	699	712	589	604
IV	Subsidy for charging infrastructure	748	771	-	-
V	Exemption of CIT & subsidy of e-van[2]	682	697	590	605

Remark:

1. The exemption of CIT only (Scenario I) cannot make the project feasible.

2. Subsidy is provided for the investment cost of both e-buses and charging infrastructure in the integrated end-to-end service model.

3. The discounted amount of tCO_2 over 10-year lifetime is 13,553 tCO_2.

4. Exchange rate: 1 USD = 33.73 THB (Data from BOT during Jan – Jun 2022)

5.5 Recommendations for public van electrification in Thailand

The financial assessment described earlier in this chapter illustrates that funding volumes of 269 - 399 MB are needed for making the electrification of 203 public vans feasible depending on the business model and the financial option selected. However, compared to the existing subsidy scheme for electric passenger cars per passenger-trip over the 10-year lifetime (4.67 – 5.00 THB/passenger-trip), the support needed for public van electrification is larger (5.26 – 8.04 THB/passenger-trip).

Moreover, the amount of funding required to support the electrification of 203 public vans (296-411 MB) can support about 3,846-5,873 electric passenger cars, from which the number of beneficiaries is approximately 70.18-107.18 million passenger-trips. However, the number of beneficiaries of 203 public vans is only 51.16 million passenger-trips.

Further assessment shows that the support needed for 203-public-van electrification per the amount of GHG abatement under scenario II – V ranges between 589-899 USD/tCO_2. This is considered substantially high comparing to the TVER prices which is less than 10 USD/tCO_2 as well as the international carbon prices of carbon tax and emission trading systems (ETSs) which remain below 140 USD/tCO_2.[71]

Although the proposed business models and the financial supports can help to remove to some extent the financial barriers of public van electrification, the financial analysis above implies that the financial support of public van electrification is not competitive. This may result from the current van fare regulation as well as the overlapping of service routes among public land transport in Bangkok decreasing the number of van passengers. The review on the public van regulation demonstrates that the public van service in Thailand is under the reform. A new route system to deal with the overlapping route problem will be applied and a replacement of 20-seat microbus will be executed. Therefore, the removal of regulatory barriers is the most urgent to deal with for the public van electrification.

[71] https://openknowledge.worldbank.org/handle/10986/37455

6. Integrated Assessment of Motorcycle Taxi Electrification

Chapter Objective:

To elaborate concept and design together with implementation requirements and roadmap of financial mechanisms for motorcycle taxi electrification through (i) detailed examination of the demand and supply side of the motorcycle taxi service market, covering a comprehensive assessment of the organisational structures and technical and financial performance of the operators including financial situation, characteristics of fleet ownership, management, and operation, and applied business models, and (ii) assessment of financial and technical needs of the operators to electrify their fleets covering identification of financial and technical challenges of electric motorcycle taxi operation and maintenance, detailed review and analysis of CAPEX, OPEX, TCOs as well as the feasibility of the proposed business model

Research Questions:

1. What is the structure, organization, and stakeholder map of the public motorcycle service market in Thai cities, e. g. Bangkok?
2. What are the key performance characteristics on the supply side of the public motorcycle service market?
3. What are the current financial and operational status of the operators?
4. What are the financial and technical supporting frameworks appealing to these operators? How?
5. What are the potential financial mechanisms for the motorcycle taxi electrification?

Summary of Key Results:

1. Existing Market Structure of Motorcycle Taxi Services
   a) A motorcycle taxi is an important part of the feeder system connecting local communities in the narrow streets branching off major streets to the main public transport network. Motorcycle taxi is also the public transport mode choice for commuters to beat Bangkok's perpetual traffic jams during rush hour.
   b) In 2020, there were 5,564 motorcycle taxi stations with 84,889 motorcycle taxi drivers around the Bangkok Metropolitan Region.
   c) Most of the motorcycle taxis registered with DLT use Gasohol 95 and Gasoline while only 50 motorcycle taxis were electric vehicles.
   d) Enforced from 11 May 2005, the regulation on motorcycle taxi service under the Motor Vehicle Act (Year 2004) entitles the government to control safety standards and driver behavior.
   e) Three key regulatory bodies involved in the motorcycle taxi services are DLT, the Bangkok Metropolitan Administration (BMA), and the Royal Thai Police.
   f) CLTCB chaired by the Permanent Secretary of the Ministry of Transport provides the guideline for setting the fare for motorcycle taxi services. The service fees start at 25 baht for the first 2 km and are charged according to distance. However, if the distance is longer than 15 kilometers, the passenger and the operator may negotiate and settle the fare.
2. Financial status and business models of existing motorcycle taxi operators
   c) Motorcycle taxi operators or drivers in Thailand are classified as independent workers that have unstable incomes. According to a field survey, the revenues of the motorcycle taxi operators range between 300 – 1,000 THB/day with an average of 620 THB/day. Three main sources of operating costs come from (1) cost of a motorcycle, (2) fuel cost, (3) maintenance cost, and (4) other costs including insurance and tax. The operating cost of a motorcycle taxi ranges between 4,800 – 7,750 THB/month with an average of 6,275 THB/month.

d) Motorcycle taxi operators individually own their vehicles and pay for the cost directly to suppliers or vendors while revenues come directly from service charges to passengers. Most drivers apply for loans from commercial banks or leasing companies to cover the cost of the motorcycle and pay back in instalments. Drivers are members of a local operating group called Win, indicating the organization of the motorcycle taxis and the location of their stations. Each Win operates within its own service area to prevent conflicts among other Wins. The motorcycle taxi operators must queue in their own Wins to wait to pick up passengers.

3. Financial assessment of electric motorcycle operation and maintenance
   a) The CAPEX of gasoline motorcycle is approximately 54,500 THB while the average capital cost of an e-motorcycle including the cost of battery replacement at the end of year 3 is 135,795 THB and therefore accounting for 2.5 times the CAPEX of a conventional motorcycle.
   b) The total NPV of the OPEX of a gasoline motorcycle over its 6-year lifetime is at 209,546 THB while that of an e-motorcycle is an average at 60,283 THB, or approximately 71% less than that of a gasoline motorcycle.
   c) The TCO of an e-motorcycle is approximately 1.452 THB/km which is lower than that of a gasoline motorcycle (1.956 THB/km). It can be concluded that the TCO of an e-motorcycle is competitive, comparing to that of a gasoline motorcycle.
   d) The financial and technical challenges are categorized by key stakeholders into 3 groups, covering the technical and financial dimensions.
4. Proposed business models and financial mechanisms for motorcycle taxi electrification in Thailand
   a) The current business model applied for electric motorcycle is an integrated end-to-end financing model comprising two key players: an integrated end-to-end service SPV and a motorcycle taxi operator (or driver).
   b) The successful case of Gogoro in Taiwan implies that the provision of battery swapping stations (BSS) or charging facilities is the most crucial strategy to promote the deployment of e-motorcycles nationwide. This strengthens the confidence of the users in changing of electric vehicles. Moreover, the support from the government especially subsidy on the investment of BSS is the most essential factor stimulating the expansion of the network.
   c) The financial assessment of the business model was conducted for three scenarios with different assumptions on expansion of e-motorcycle taxis and BSS. Scenario I, scenario II, and scenario III are targeted to promote 10,000 e-motorcycles, 85,000 e-motorcycles, and 650,000 e-motorcycles by 2030, respectively. The analysis shows that the investment in e-motorcycles and BSS is feasible in all scenarios, i.e., the IRR of NPV reaches 10% and the operators can save about 33,300 – 35,800 THB/year.
   d) However, it requires high investment cost for BSS in the early years and the SPV is facing risks on uncertain demand; therefore, support is needed to promote the expansion of BSS network. Different levels of investment subsidies have been evaluated and a subsidy of 288 MB, 1,215 MB, and 4,419 MB are needed for the investment of BSS under scenario I, scenario II, and scenario III, respectively.
   e) Further assessment shows that the annual GHG emission reductions in the target year of 2030 are approximately 12,032 tCO_2, 102,270 tCO_2, and 782,065 tCO_2, under scenario I, scenario II, and scenario III, respectively. The costs of different support levels per the amount of GHG abatement are 118.27 USD/tCO_2, 71.04 USD/tCO_2, 36.78 USD/tCO_2, under scenario I, scenario II, and scenario III, respectively.
5. Roadmap of operationalising financial mechanisms for motorcycle taxi electrification in Thailand
   a) The proposed business model and the financial support from the government or from the international climate fund on the investment in BSS expansion can remove key financial and technical

barriers for motorcycle taxi electrification in Thailand along with building confidence in the upscaling of the technology. Only some barriers on regulations, e.g., the timely process for local certification of e-motorcycle, the unclear standard and in-charge public sector on battery swapping stations needs further actions from government agencies.

b) The roadmap for operationalising financial mechanisms for motorcycle taxi electrification in Thailand requires a two-phase approach, divided into a preparation phase and a full implementation phase.

6. Recommendation for motorcycle taxi electrification in Thailand
   a) The current business model run by most e-motorcycle suppliers is an integrated end-to-end financing model removing the financial barriers for motorcycle taxi electrification; however, the expansion of e-motorcycle is still limited. This results from the motorcycle taxi operators' concern about the capacity of batteries together with the limited availability of charging stations or battery swapping stations.
   b) The review of a successful model of Gogoro in Taiwan proves that the coverage of battery swapping stations or charging facilities citywide or nationwide can strengthen the confidence of the users in changing to electric vehicles. To accelerate the expansion of BSS network, the financial support especially through subsidies on the investment of BSS is needed. The financial support for motorcycle taxi electrification will not only help Thailand to foster climate-friendly transport but also to improve the quality of life for those operators with unstable incomes.

6.1 Existing market structure of motorcycle taxis

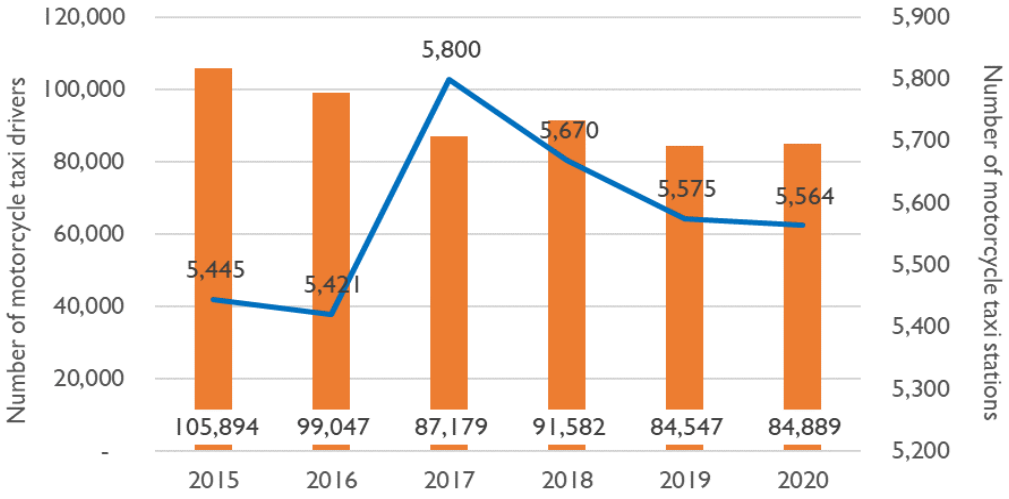
6.1.1 Demand for motorcycle taxis

Motorcycle taxis have been one of the key elements of Bangkok's public transport system since 1979. They serve as an informal feeder system connecting local communities in the narrow streets branching off major streets to the main public transport network. Additionally, they have become the mode of choice for commuters to beat Bangkok's perpetual traffic jams during rush hour. Statistics on the numbers of passengers commuting by motorcycle taxi are limited. However, a rough estimation can be made from the field survey that the average daily service provided by a motorcycle taxi driver is around 10 – 13 passenger-trip/day. When considering that there were 84,889 motorcycle taxi drivers in 2020, according to the statistics of the Department of Land Transport, the annual demand amounts to 300 million passenger-trips. The areas with high demand are those with high density of motorcycle taxi drivers including Chatuchak District, Bang Khun Thian District, Din Daeng District, Bang Kapi District, and Sathorn District. The number of motorcycle taxi drivers in such areas exceeds 2,000 with an average of 15 drivers in one station.

6.1.2 Supply of motorcycle taxis

From the statistics of the Department of Land Transport, there were 5,564 motorcycle taxi stations with 84,889 motorcycle taxi drivers around Bangkok Metropolitan Region in 2020. The number of motorcycle taxis and public motorcycle riders in Bangkok decreased at the rate of 4.33% during 2015 – 2020, resulting from the reduction of passengers due to the expansion of public transport network in the Bangkok Metropolitan Area (Figure 58).

Figure 58: Number of motorcycle taxi drivers and stations in Bangkok (2015-2020)



Source: Compiled from DLT statistics, 2021

The most popular brands of motorcycle taxis include Honda, Yamaha, and Suzuki. ***As of December 2021, most of the motorcycle taxis registered with DLT use Gasohol 95 and Gasoline as fuels while only 50 of the motorcycle taxis are electric vehicles.***

6.1.3 Institutional arrangement of the motorcycle taxi market

The motorcycle taxi service had not been regulated until 2005. Enforced from 11 May 2005, the regulation on motorcycle taxi services under the Motor Vehicle Act (Year 2004)[72] entitled the government to control the safety standards and driver behavior. The regulation also includes setting fare rates, issuing specific license plates for motorcycle taxis (yellow plate with black font) and regulating drivers wearing the Win[73] specified jackets.

The key regulatory bodies involved in the motorcycle taxi services include, DLT, the Bangkok Metropolitan Administration (BMA), and the Royal Thai Police as shown in Figure 59. Roles and responsibilities of the three agencies are:

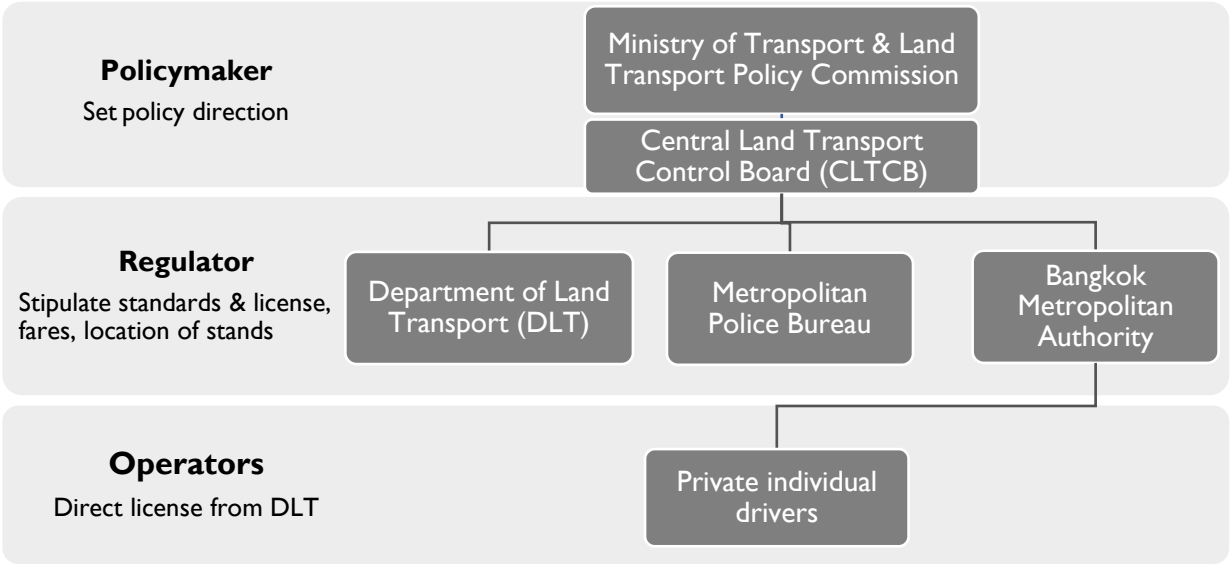
- ***BMA:*** Each of the 50 District Offices of the BMA is responsible for the registration of motorcycle taxi operators whose Wins are in the respective districts, according to the DLT regulation on Registration of Public Motorcycle Taxis, B.E. 2548 (2005). BMA has the responsibility and authority to give permission to the operators to establish a new Win, and to coordinate between relevant government agencies and motorcycle taxi operators. However, since May 2013, the BMA has transferred the responsibility of registering motorcycle taxi services to the Department of Land Transport.
- ***DLT:*** DLT issues the "yellow plate" licenses for the motorcycle taxi owned by the operator who have already registered as a public motorcycle taxi operator.

[72] https://www.jstage.jst.go.jp/article/easts/7/0/7_0_1828/_pdf & http://www.cuurp.org/wp-content/uploads/2019/09/Final-report-Embracing-mobility-in-Bangkok_compressed.pdf

[73] *"Win"* is a term used in Thailand referring to the group of motorcycle taxi service.

- ***Royal Thai Police:*** Each district office of the Metropolitan Police Bureau is responsible for enforcing traffic laws and disciplining and arresting violators, according to the Land Traffic Act, B.E.2522 (A.D.1979).

Figure 59: Institutional arrangements of motorcycle taxi services



Source: Own design

a) Routing and pricing

CLTCB chaired by the Permanent Secretary of the Ministry of Transport sets the guidelines for setting fares of motorcycle taxis (Table 41). The service fees start at 25 baht for the first 2 kilometer and are charged according to distance. There is a maximum rate cap of not more than 5 baht per kilometre for the first 2-5 km and not more than 10 baht per kilometre for the rest of the travel. However, if the distance is greater than 15 kilometres, the passenger and the operator may negotiate and settle the fare.

Table 41: Pricing Structure of Motorcycle Taxi Services

Distance	Price
First 2 km	< 25 Baht
2 - 5 km	≤ 5 Baht/km
5 - 15 km	≤ 10 Baht/km
> 15 km	Depends on riders' and clients' agreement

Source: Announcement of the Department of Land Transport (2016)[74]

[74] https://www.dlt.go.th/th/announce/view.php?_did=1406

6.2 Financial and technical needs assessment of motorcycle taxi electrification and charging infrastructure deployment in Thailand

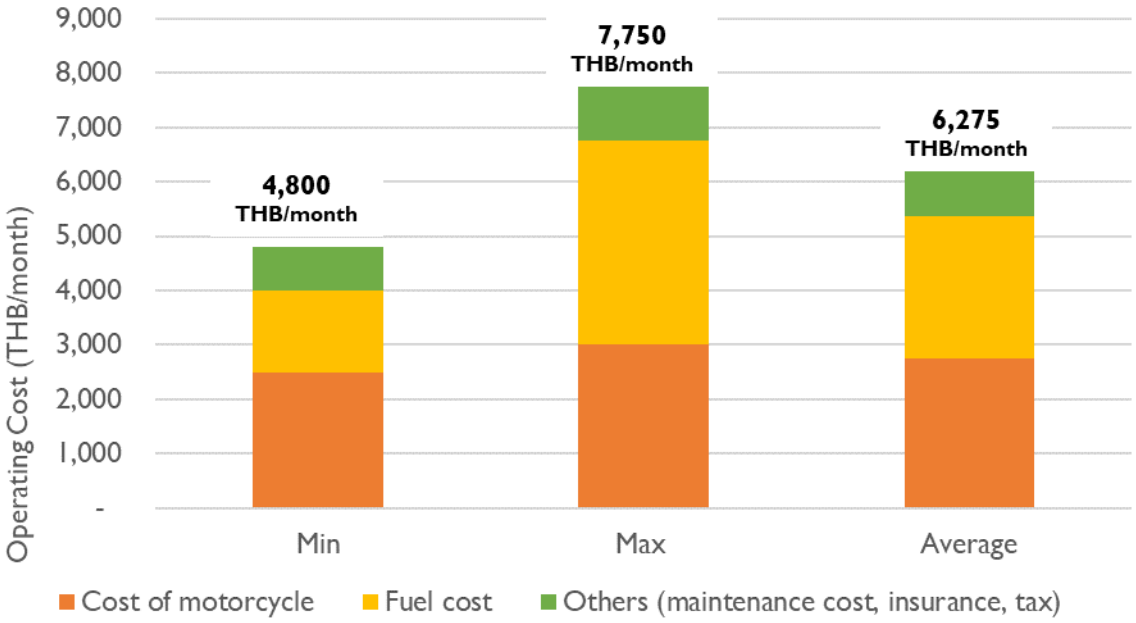
6.2.1 Current financial status of motorcycle taxi operators

Motorcycle taxi operators or drivers in Thailand are classified as independent workers that have unstable incomes. According to a field survey, the revenues of the motorcycle taxi operators range between 300 – 1,000 THB/day with an average of 620 THB/day. Three main sources of operating costs come from (1) cost of a motorcycle, (2) fuel cost, (3) maintenance cost, and (4) other costs including insurance and tax.

- Costs of a motorcycle: The cost of a motorcycle is around 37,000 – 55,000 THB/vehicle. Most operators pay for their own motorcycles in instalments. The repayment term is not more than 3 years or 36 months, and the repayment does not exceed 5,000 THB per month, depending on the model of the motorcycle, interest rate and down payment. The survey results imply that the loan repayment is about 2,500 – 3,000 THB/month.
- Fuel cost: Most of the motorcycles use gasoline as fuel. The field survey shows that the daily cost of fuel ranges between 50-150 THB/day or about 1,500 – 3,750 THB/month.
- Others: Other costs include insurance, tax, and maintenance cost. It can be drawn from the field survey that the maintenance cost is about 600 – 800 THB/month. The tax for a motorcycle is 500 THB/year while the insurance is at 2,000 THB/year. The total cost is therefore about 800 – 1,000 THB/month.

In summary, the operating cost of a motorcycle taxi ranges between 4,800 – 7,750 THB/month with an average of 6,275 THB/month (Figure 60).

Figure 60: Monthly operating costs of motorcycle taxi

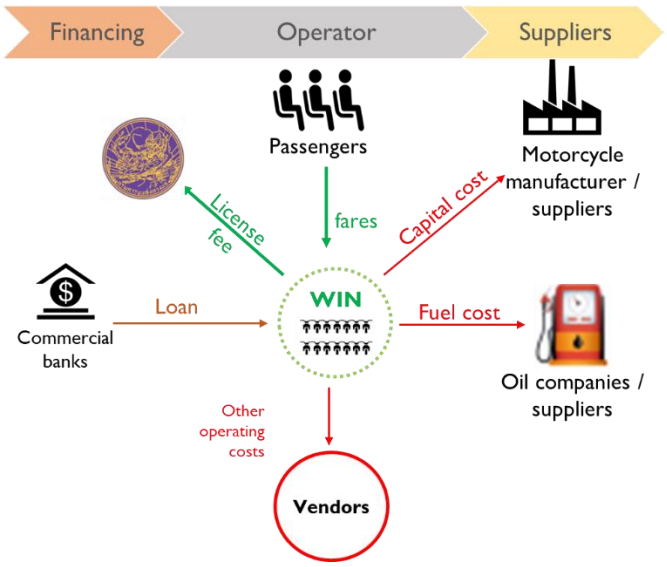


Source: Field survey

6.2.2 Existing business model of motorcycle taxi operators

Motorcycle taxi operators individually own their vehicles and pay for the cost directly to suppliers or vendors while revenues come directly from service charges to passengers. Most drivers apply for loans from commercial banks or leasing companies to cover the cost of the motorcycle and pay back in instalments. Drivers are a member of a local operating group called Win, indicating the organization of the motorcycle taxis and the location of their stations. Each Win operates within its own service area to prevent conflicts among other Wins. The motorcycle taxi operators must queue in their own Wins to wait to pick up passengers.

Figure 61: Existing business model of motorcycle taxi operators



Passengers make their payment once arriving at their destinations. If motorcycle taxi operators do not receive passengers on the way back, they must return to their Win and wait for the next passenger.

In addition, motorcycle taxis can join ride-hailing applications. For example, GoBike, in 2016, the official motorcycle taxi-hailing application from the Motorcycle Taxi Drivers Association that was authorized by DLT to open the service with a starting price of 20 baht. The distance and cost of the service was calculated in advance. There were more than 100,000 motorcycles registered in the system. However, in 2021, Gobike shifted its business model to focus on messenger and food delivery, but its market share is too trivial compared to other platforms like Grab, LineMan, Robinhood.

6.3 Financial and technical needs assessment of motorcycle taxi electrification and charging infrastructure deployment in Thailand

6.3.1 Financial assessment of electric motorcycle operation and maintenance

This section explores the capital expenses (CAPEX) as well as operational expenses (OPEX) of a gasoline motorcycle and an electric motorcycle and provides the results from the evaluation of the total costs of ownership (TCO) covering CAPEX and OPEX over the lifetime of both types of motorcycles for comparative analysis. The data used in the evaluation of TCO have been collected through both desk research, direct interviews, and stakeholder consultation workshops. This section describes key findings from the analysis.

a) CAPEX and OPEX of motorcycle operation and maintenance

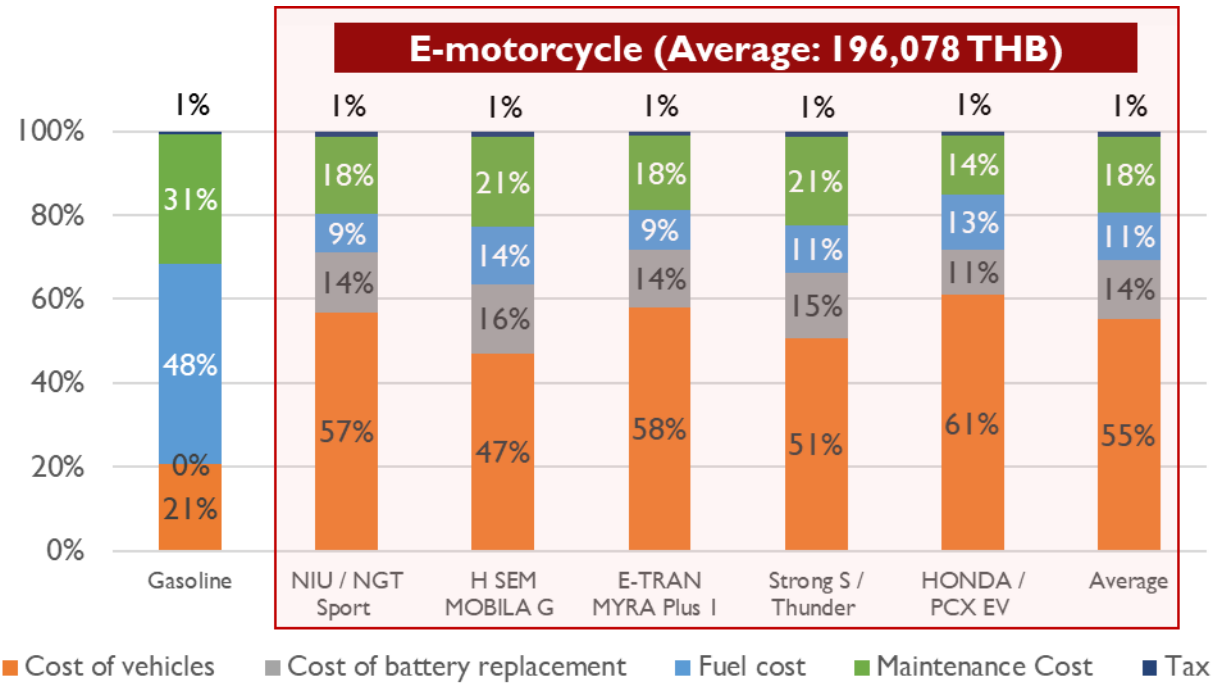
Capital Expenses (CAPEX) is the total cost of motorcycle acquisition. For a gasoline motorcycle, the CAPEX will be the cost of a motorcycle invested in Year 0 while the CAPEX of the electric motorcycle will cover the cost of the motorcycle at Year 0 and the cost of battery replacement 3

years after the start of operation. As shown in Table 42, the CAPEX of a gasoline motorcycle is about 54,500 THB while the average capital cost of a e-motorcycle including the cost of battery replacement at the end of year 3 is 135,795 THB, therefore 2.49 times of the CAPEX of a conventional motorcycle. The CAPEX of a gasoline motorcycle has a share of 21% of the total cost over the lifetime of the motorcycle while the CAPEX of an electric motorcycle has the share of 51% - 61% of the total cost over the motorcycle lifetime (Figure 62).

Table 42: CAPEX and OPEX of gasoline motorcycles and electric motorcycles over 6-year lifetime

Model / Cost	Gasoline motorcycle	Electric motorcycle					
		NIU / NGT Sport	H SEM MOBILA G	E-TRAN MYRA Plus I	Strong S / Thunder	HONDA / PCX EV	Average
CAPEX (THB)	54,500	136,181	105,181	142,741	116,181	178,692	135,795
OPEX (THB)	209,546	55,553	60,394	56,195	59,284	69,991	60,283
Total (THB)	264,046	191,733	165,575	198,935	175,465	248,684	196,078

Figure 62: Shares of CAPEX and OPEX of gasoline motorcycles and electric motorcycles over 6-year lifetime



Operating Expenses (OPEX) of both a gasoline motorcycle and an electric motorcycle covers fuel costs, maintenance cost, and tax. The total NPV of the OPEX of a gasoline motorcycle over its 6-year lifetime is at 209,546 THB while that of an e-motorcycle is an average of 60,283 THB, or approximately 71% less than that of a gasoline motorcycle. Figure 62 shows the shares of CAPEX and OPEX of a gasoline motorcycle and an electric motorcycle over their 6-year lifetime. The share

of the fuel cost of a gasoline motorcycle is about 48% of the total cost while the cost of electricity consumption of an e-motorcycle is about 9% - 13% of the total cost.

b) Total cost of ownership of motorcycle taxi operation and maintenance

Total cost of ownership (TCO) is estimated by the following formula**:**

$$\text{TCO} = \frac{\text{NPV of (CAPEX + OPEX over its lifetime)}}{\text{Total distance in service over its lifetime}}$$

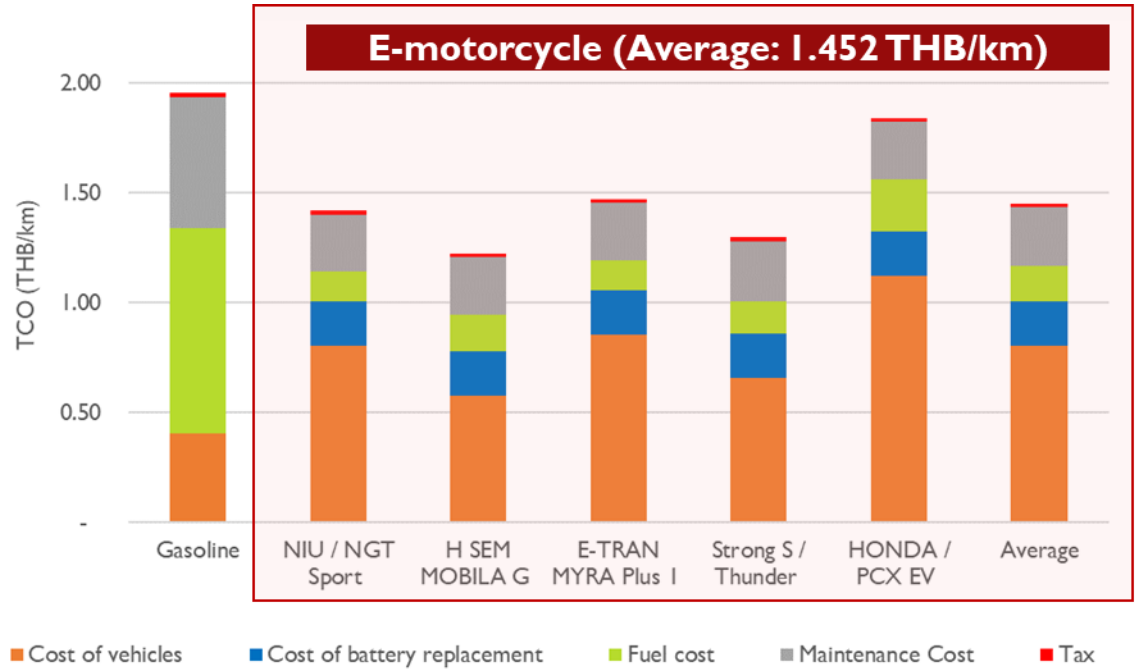
Results of the TCO analysis are shown in Figure 63. It is found from the analysis that the TCO of an e-motorcycle is about 1.473 THB/km which is lower than that of a gasoline motorcycle (1.924 THB/km). It can be concluded that the TCO of an e-motorcycle is competitive, comparing to that of a gasoline motorcycle.

Table 43: TCO of a gasoline motorcycle and an electric motorcycle

Model / Cost	Gasoline motorcycle	Electric motorcycle model					
		NIU / NGT Sport	H SEM MOBILA G	E-TRAN MYRA Plus I	Strong S / Thunder	HONDA / PCX EV	Average
TCO (THB/km)	1.956	1.420	1.226	1.474	1.300	1.842	1.452

Remark: From the field survey, the total distance in service of a motorcycle taxi is about 75 km/day or 135,000 km over its 6-year lifetime.

Figure 63: TCO of a gasoline motorcycle and an electric motorcycle



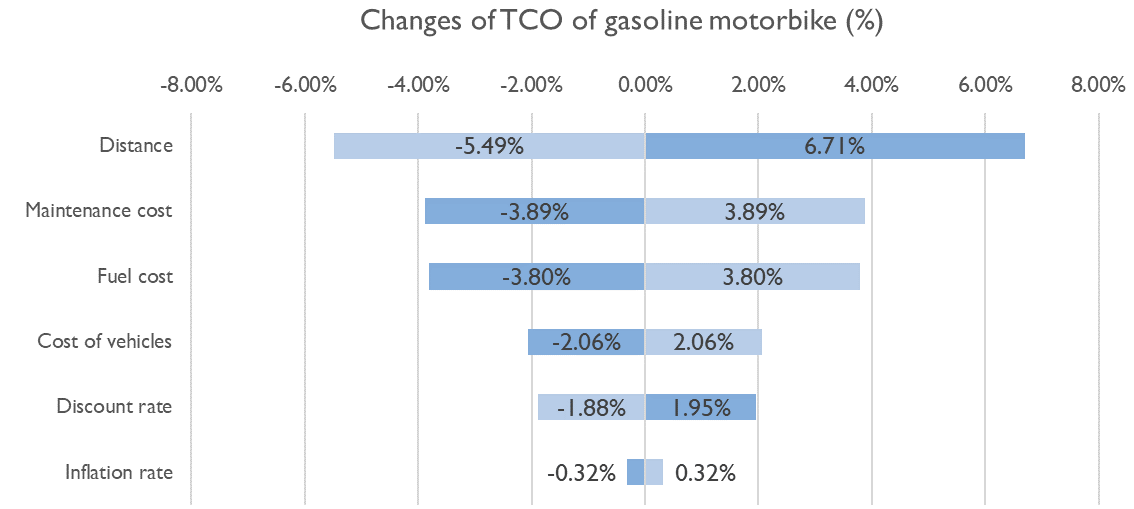
c) Sensitivity analysis on TCO of motorcycles

The sensitivity analysis helps assess the impact of parameters on the TCO of the motorcycle. When adjusting the value of each parameter by 10%, the changes of TCO are as shown in Figure 64. Key findings are:

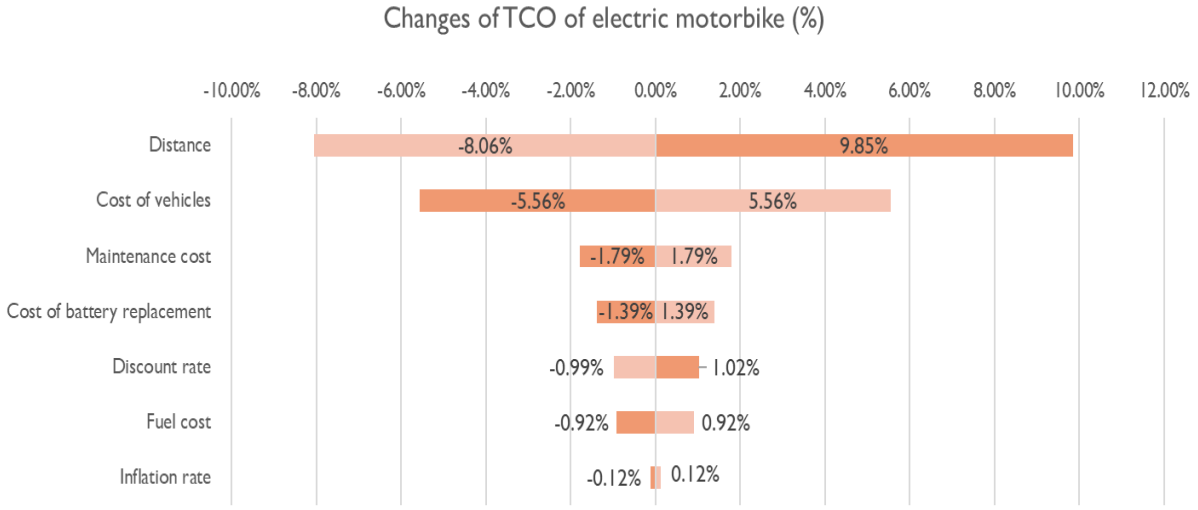
- The change distance driven will have the greatest impact on TCO, especially for an electric motorbike (9.85%).
- The change in cost of the vehicle affects the TCO of an electric motorcycle by approximately 5.56%, whereas the impact of the TCO of a gasoline motorcycle is 2.06%.
- The change in fuel costs affects the TCO of a gasoline motorcycle by approximately 3.80% compared to that of an electric motorcycle at 0.92%.
- The change in the maintenance cost affects the TCO of a gasoline motorcycle by approximately 3.89%, whereas the impact on the TCO of an electric motorcycle is 1.79%.

Figure 64: Sensitivity analysis on TCO of motorcycles

a) Sensitivity analysis on TCO of a gasoline motorcycle



b) Sensitivity analysis on TCO of an electric motorcycle



6.3.2 Financial and technical challenges of motorcycle taxi electrification

Through interviews of various stakeholders from both the public and private sectors as well as stakeholder consultation workshops discussing the results from the desk research and analysis, the financial and technical challenges of electric motorcycle taxi operation and maintenance were addressed. Considering the existing business model of motorcycle taxis and the ecosystem required for electric motorcycles there are three key stakeholders for public motorcycle electrification: e-motorcycle manufacturers as motorcycle suppliers, public motorcycle operators as motorcycle owners, and battery swapping service providers as electricity suppliers. Thus, the financial and technical challenges are divided by the three stakeholder groups, covering the technical, and the financial dimensions as shown in Table 44.

Table 44: Regulatory, financial, and technical challenges of motorcycle taxi electrification

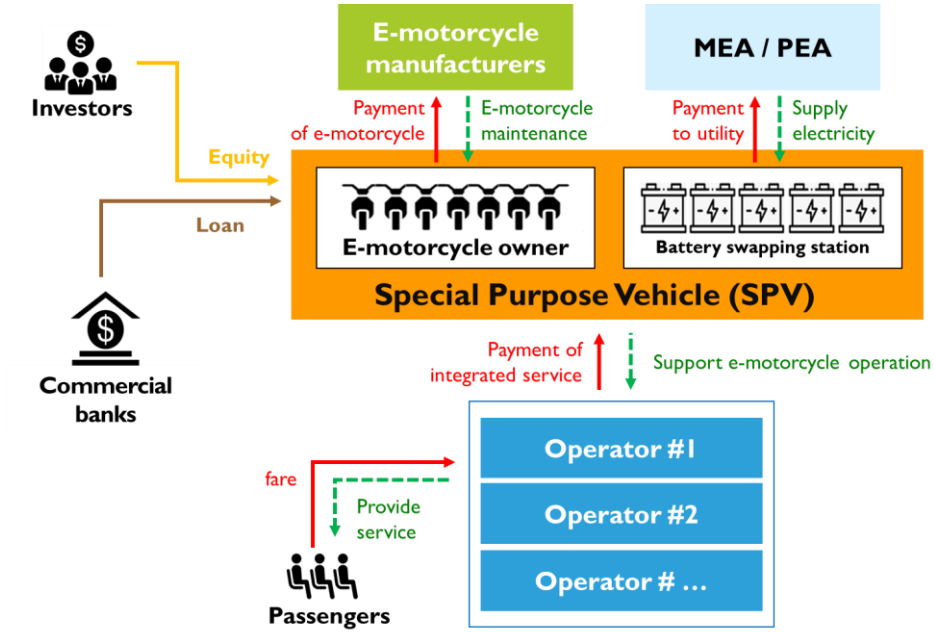
	Technical	Financial
E- Motorcycle and battery manufacturer	• Uncertain demand of electric motorcycles • Need for electric motorcycle model of which a battery capacity covering 100 – 160 km/day • Existing models of e-motorcycle in the market (small size& low speed) do not match with the needs of motorcycle taxi drivers • Timely process for local certification of new e-motorcycle models by the manufacturers • Lack of operators' awareness on safety of electric motorcycles	• Limited access to financing and lack of confidence from financial institutions on EV manufacturers • Higher production cost of local manufacturers compared to import cost (especially exemption of import tax) • No reference for residual value of EV, especially public EV that commercial banks can apply for assessing project financing
Motorcycle operator	• No universal batteries for all models • Timely and complicated process for DLT's registration of e-motorcycles • Limited technical capacity to maintain and repair of e-motorcycles • Lack of confidence on the capacity of batteries and the limited availability of charging stations or battery swapping stations	• Relatively high investment cost of e-motorcycle acquisition • Limited credits of operators to access financing • Lack of confidence from financial institutions and insurance sector • Lack of confidence in sufficient charging stations and unstable electricity price
Battery swapping station	• Relatively high investment cost of battery swapping stations • Volatile electricity price	• Uncertain demand due to small number of e-motorcycle • No clear standard and in-charge public sector on battery swapping stations in Thailand leading to difficulties for battery swapping businesses in accessing financial support from the government • Timely and complicated permission process

6.4 Proposed business models and financial mechanisms for motorcycle taxi electrification in Thailand

6.4.1 Conceptual framework for the proposed business model

As described in Section 5.3, various financial options have been developed all over the world to promote public transport electrification. Considering the context of Thailand, **the current business model applied for electric motorcycles is the integrated end-to-end financing** (Table 45).

Table 45: Integrated end-to-end financing model

Integrated end-to-end financing model
Diagram:  Source: Own design
Description: This model aims to bundle all services/ products required for motorcycle taxi electrification (mainly vehicle, battery, charging infrastructure) to provide an integrated solution. Key players in this model include: • ***An integrated end-to-end service SPV:*** Owning all assets required for motorcycle taxi electrification through long-term contracts with e-motorcycle manufacturers as well as charging infrastructure suppliers and providing integrated end-to-end service to the motorcycle taxi operators under monthly or yearly contracts, • ***A motorcycle taxi operator (driver):*** Providing service to passengers, operators by renting electric motorcycles together with maintenance and charging services through the SPV. Operators will be charged for integrated services on a monthly basis while the revenue comes from collection of fares. The key advantage of this model is that the operator does not need to pay any upfront costs. Additionally, the operator can engage with only one entity, which is potentially cost saving with less time and effort needed. The SPV can be bundled up by potential investors from the manufacturing, component provider, financing institution, or power company side. This model relies heavily on the capacity of the SPV which must be highly mature and able to assure the availability and the quality of the services provided to the motorcycle taxi operator.

6.4.2 Case study of Gogoro in Taiwan[75]

The case of Gogoro in Taiwan is well recognized as one of the most successful models in promoting electric scooters. The key success factor is the coverage of battery swapping stations, called GoStations, all over the country.

Figure 10 shows the expansion of the battery swapping network of Gogoro in Taiwan.

Gogoro was found in 2011 as an electric scooter manufacturer. In 2015, there were only 30 GoStations. From Gogoro's own funding together with strong financial support from the Taiwanese government, over 500 GoStations were installed in 2017. At the end of 2021, Gogoro counted a total of 2,215 GoStations nationwide. Currently, there are 2,280 GoStations with 839,000 batteries while the number of gas stations was barely higher at 2,487 stations in total (Figure 65).

Figure 65: Expansion of battery swapping network of Gogoro in Taiwan

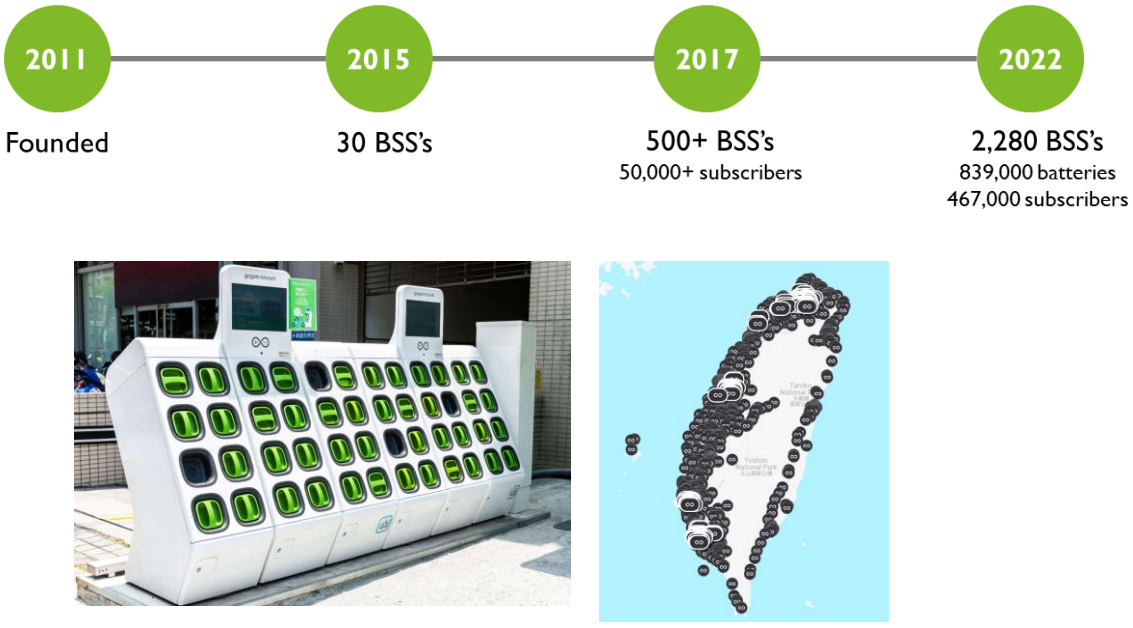
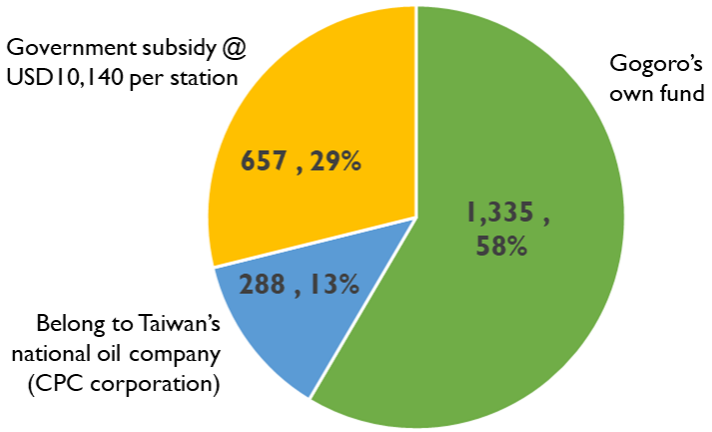


Figure 66 illustrates the contribution of the Taiwanese government and Gogoro in expanding the network of batter swapping stations. The financial support from the government include:

- 30 million USD investment in Gogoro through a National Development fund in 2015,
- Subsidy for BSS at 10,140 USD/station in 2018,
- Subsidy to purchase of electric motorcycle taxis, and
- Investment of CPC corporation (Taiwan's state-owned company) in 288 BSS outside the Taipei area.

[75] https://www.gogoro.com & https://meet-global.bnext.com.tw/articles/view/47488 & https://nspp.mofa.gov.tw/nsppe/news.php?post=127546&unit=379 & https://energy.asia/gogoro-battery-swapping-revolution-in-taiwan-how-it-happened/ & https://cdn.gogoro.com/resources/pages/about/investors/attachments/Gogoro_Poema_Presentation_210916_DELIVER_S.pdf

Figure 66: Contribution of Taiwanese Government and Gogoro in expanding the network of battery swapping stations



It can be drawn from the successful case of Gogoro that the coverage of battery swapping stations or charging facilities is the most crucial strategy to promote the deployment of e-motorcycles nationwide. This strengthens the confidence of users in changing to electric vehicles. Moreover, the support from the government especially through subsidies on the investment in BSS is the most essential factor stimulating the expansion of the network.

6.4.3 Detailed assessment of the proposed business model

To conduct a detailed assessment of the proposed models, the net present value (NPV), internal rate of return (IRR), and payback period of both models were estimated using discounted cash flow (DCF) analysis.

For the integrated end-to-end financing model, a DCF model was developed to assess the return of investment of the integrated end-to-end service SPV while the benefit of the motorcycle taxi operator is estimated at 10% discount of the current operating cost. The analysis was conducted for three scenarios with different assumptions on the expansion of e-motorcycle taxis and battery swapping stations. Table 46 illustrates key details of each scenario while Table 47 provides the key assumptions for the financial assessment of an integrated end-to-end financing model for motorcycle taxi electrification.

Table 46: Three scenarios for financial assessment of integrated end-to-end financing model for motorcycle taxi electrification

Items	Unit	Scenario I	Scenario II	Scenario III
Targets of e-motorcycle in 2030	units	10,000	85,000	650,000
Total batteries in 2030	pieces	15,000	127,500	975,000
Total modules of batteries in 2030	modules	750	6,375	48,750

whereas,

Scenario I: Assumed that 1,000 e-motorcycles are deployed each year

Scenario II: All motorcycle taxis in Bangkok changes to e-motorcycle

Scenario III: Targets of national plan (30@30)

Table 47: Assumptions for financial assessment of integrated end-to-end financing model for motorcycle taxi electrification

Assumptions	Unit	Amount
Operating days	days/year	300
Distance per day	km/day	75
Project lifetime	years	6
Inflation rate	%	1.8%
Discount rate	%	8.0%
CAPEX		
Cost per BSS (20 Batteries per module)	THB/module	80,000
Cost per battery	THB	20,373 – 24,738
Cost per e-motorcycle	THB	79,510
OPEX		
O&M of motorcycle & swapping stations	% of total investments	2.5%
Tax of motorcycle	THB/year	500
Land rental fee	THB/month	1,500
Buying Electricity price (peak)	THB/kWh	4.50
Buying Electricity price (off-peak)	THB/kWh	2.60
Shares of peak	%	35%
Average cost of electricity	THB/kWh	3.27
Fuel consumption	kWh/km	0.031
Battery size	Ah	40
Battery voltage	V	60
Battery Efficiency	%	95%
Charging Efficiency	%	90%
Corporate income tax	%	20%

The goal of the initial assessment is to find the rate of charge for end-to-end service in THB/year that allows an attractive return of investment to an integrated service SPV, i.e., the IRR of the investment is not less than 10%. Key results from the initial assessment are:

- It is feasible for integrated service SPV to invest in both e-motorcycles and BSS. Also, the operator can save monthly operating cost. The net savings for the operators range between 33,300 – 35,800 THB/year (Table 48).
- However, it requires high investment cost for BSS in the early years and the SPV is facing risks on uncertain demand. Therefore, support is needed to promote the expansion of BSS network.

Table 48: Key results from the initial assessment of an integrated end-to-end financing model

Items	Unit	Scenario I	Scenario II	Scenario III
Targets of e-motorcycle in 2030	units	10,000	85,000	650,000
Total batteries in 2030	pieces	15,000	127,500	975,000
Total modules of batteries in 2030	modules	750	6,375	48,750

Items	Unit	Scenario I	Scenario II	Scenario III
Operating cost of operators				
Baseline operating cost of operator	THB/year		75,300	
Service fee	THB/year	42,000	40,500	39,500
Net savings for the operators	THB/year	33,300	34,800	35,800
Return on investment: Integrated service SPV				
· NPV	MB	126.52	744.92	5,655.38
· IRR	%	10.50%	10.15%	10.56%
· Payback Period	years	9.55	9.83	9.60

6.4.4 Scenario analysis on support needed for an integrated end-to-end financing model

Although it is feasible for integrated service SPV to invest in both e-motorcycles and BSS and the operator can save monthly operating cost, the growth of motorcycle taxi electrification is limited by the high investment if BSS network and uncertain demand of e-motorcycle. Therefore, an intervention is needed to promote the expansion of BSS network at the early stage. In this section, the assessment has been made to find the level of subsidy for the investment of BSS that can attract funding for the integrated service SPV (IRR at 10%) as well as attract the operators to adopt electric motorcycles.

Scenario III aims for the deployment of 650,000 electric motorcycles in 2030. The investment subsidy at 10% of the total investment cost of BSS amounting to 4,419 MB allows 50% reduction in operating costs of motorcycle taxis. With this level of subsidy, the SPV will obtain 10% return on its investment. The support needed for a 10% investment subsidy to BSS network per the amount of GHG abatement is about 36.78 USD/tCO_2.

Table 49 describes key findings which can be described as follows:

- Scenario I aims for the deployment of 10,000 electric motorcycles in 2030. The investment subsidy at 30% of the total investment cost of BSS amounting to 288 MB allows 50% reduction in operating costs of motorcycle taxis. With this level of subsidy, the SPV will obtain 10.03% return on its investment. The support needed for a 30% investment subsidy to BSS network per the amount of GHG abatement is about 118.27 USD/tCO_2.
- Scenario II aims for the deployment of 85,000 electric motorcycles in 2030. The investment subsidy at 20% of the total investment cost of BSS amounting to 1,215 MB allows 50% reduction in operating costs of motorcycle taxis. With this level of subsidy, the SPV will obtain 10.06% return on its investment. The support needed for a 20% investment subsidy to BSS network per the amount of GHG abatement is about 71.04 USD/tCO_2.
- Scenario III aims for the deployment of 650,000 electric motorcycles in 2030. The investment subsidy at 10% of the total investment cost of BSS amounting to 4,419 MB allows 50% reduction in operating costs of motorcycle taxis. With this level of subsidy, the SPV will obtain 10% return on its investment. The support needed for a 10% investment subsidy to BSS network per the amount of GHG abatement is about 36.78 USD/tCO_2.

Table 49: Scenario analysis on support needed for integrated end-to-end financing model

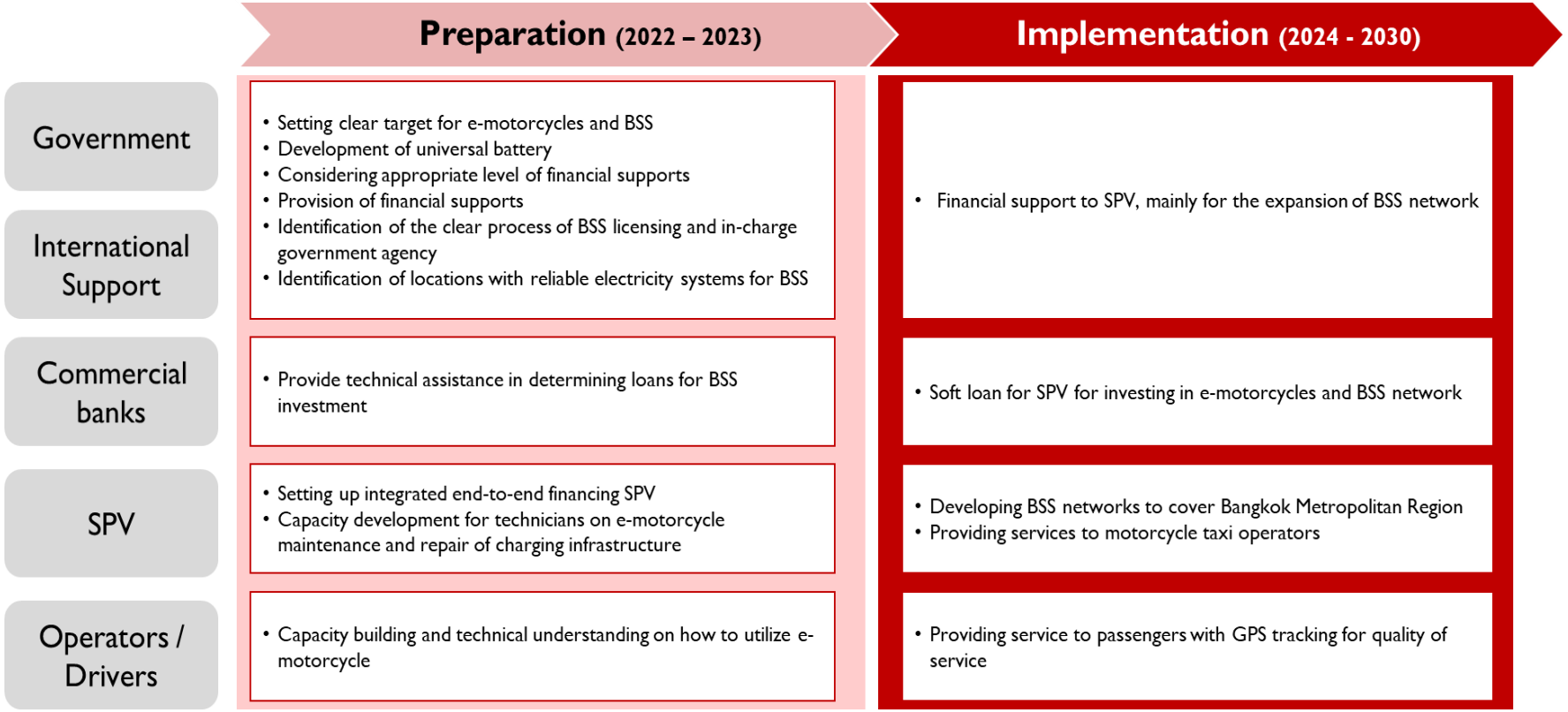
Items	Unit	Scenario I	Scenario II	Scenario III
Targets of e-motorcycle in 2030	units	10,000	85,000	650,000
Total batteries in 2030	pieces	15,000	127,500	975,000
Total modules of batteries in 2030	modules	750	6,375	48,750
Operating cost of operators				
Baseline operating cost of operator	THB/month	6,275.00		
Service fee charged to operators (50% savings)	THB/month	3,137.50		
Investment subsidy needed				
• Total investment (e-motorcycle + BSS)	MB	1,463	10,353	70,621
• Total investment (BSS only)	MB	960	6,077	44,189
• % of total investment (BSS only)	%	30%	20%	10%
• NPV of subsidy	MB	288	1,215	4,419
• Subsidy per module	THB	72,500	57,500	32,500
Return on investment: Integrated service SPV				
• NPV	MB	87.29	631.47	4,092.31
• IRR	%	10.03%	10.06%	10.00%
• Payback Period	years	9.6	9.8	9.7
Provision cost of subsidy per				
• Total CO2 reduction	tCO_2	72,217	507,242	3,561,681
• Support per tCO_2 abated	THB/tCO_2	3,989.13	2,396.13	1,240.67
• Support per tCO_2 abated	USD/tCO_2	118.27	71.04	36.78

6.5 Roadmap of financial mechanisms for motorcycle taxi electrification in Thailand

The proposed business models and the financial supports from the government or from the international climate fund on the investment in BSS expansion can remove the key financial and technical barriers for motorcycle taxi electrification in Thailand along with building confidence in the technology. Only some barriers on regulations, e.g., the timely process for local certification of e-motorcycle, the unclear standard and in-charge public sector representative for battery swapping stations needs further actions from government agencies.

The roadmap below is developed to operationalise financial mechanisms for motorcycle taxi electrification in Thailand. The roadmap is divided into two phases, i.e., the preparation phase and the full implementation phase. During the preparation phase, the clear target setting as well as the detailed design of financial support together with the capacity building programs for relevant stakeholders, mainly commercial banks and technicians will be conducted. During the implementation phase, the BSS network will be expanded with the financial support from the government or international sources. The coverage of BSS network will enhance the confidence of the operators to deploy e-motorcycles. The actions needed by primary stakeholder group in each phase are highlighted in Figure 67.

Figure 67: Roadmap of financial mechanisms for motorcycle taxi electrification in Thailand



6.6 Recommendation for motorcycle taxi electrification in Thailand

The analysis of TCO concludes that the TCO of an e-motorcycle is competitive with that of a gasoline motorcycle, being almost 0.5 THB/km lower. The key challenges for promotion of motorcycle taxi electrification in Thailand are the relatively high investment cost of motorcycle acquisition together with the limited credits of motorcycle taxi operators to access financing.

The current business model run by most of e-motorcycle suppliers is an integrated end-to-end financing model whereas an integrated end-to-end service SPV bundles all services/ products required for motorcycle taxi electrification (mainly vehicle, battery, charging infrastructure). An integrated solution is provided to operators, who are being charged for the service package on a monthly basis. This model removes the financial barriers mentioned earlier; however, the expansion of e-motorcycle is still limited. This results from the motorcycle taxi operators' concern on the capacity of batteries together with the limited availability of charging stations or battery swapping stations (BSS).

The review of a successful model of Gogoro in Taiwan proves that the coverage of battery swapping stations or charging facilities citywide or nationwide can strengthen the confidence of the users in changing to electric vehicles. To accelerate the expansion of BSS network, the financial support especially through subsidies on the investment to BSS is needed. Since motorcycle taxi operators or drivers in Thailand are classified as independent workers that have unstable incomes, the financial support for motorcycle taxi electrification will not only help Thailand to foster climate-friendly transport but also to improve the quality of life for those operators with unstable incomes.

7. Conclusion

Road transport is the highest emitter of all sub-sectors in transport in Thailand. While there are many components within the road transport sector, this study is focused on the public vehicles of three selected modes of transport, including public bus, van, and motorcycle taxi. The reasons of such prioritisation are not only because they are the main modes of public transport in Thai cities, but also because EV products are available in these segments.

Moreover, since public transport markets generally differ from one city to another, it would not be practical to study all the markets within the country. The study is therefore specifically focused on the largest metropolitan area, namely the Bangkok Metropolitan Region (BMR), as its road transport sector is most developed and presumably most carbon intensified. Therefore, the results of this study will serve to provide a financing blueprint for large-scale electrification of public transport fleets in the country.

Through the process of desk reviews, field surveys, stakeholder interviews and focus group consultations, as well as technical and financial assessment, it is recommended that public buses and motorcycle taxis are prioritised for electrification, while the electrification of public vans requires technical and regulatory reform which is under way.

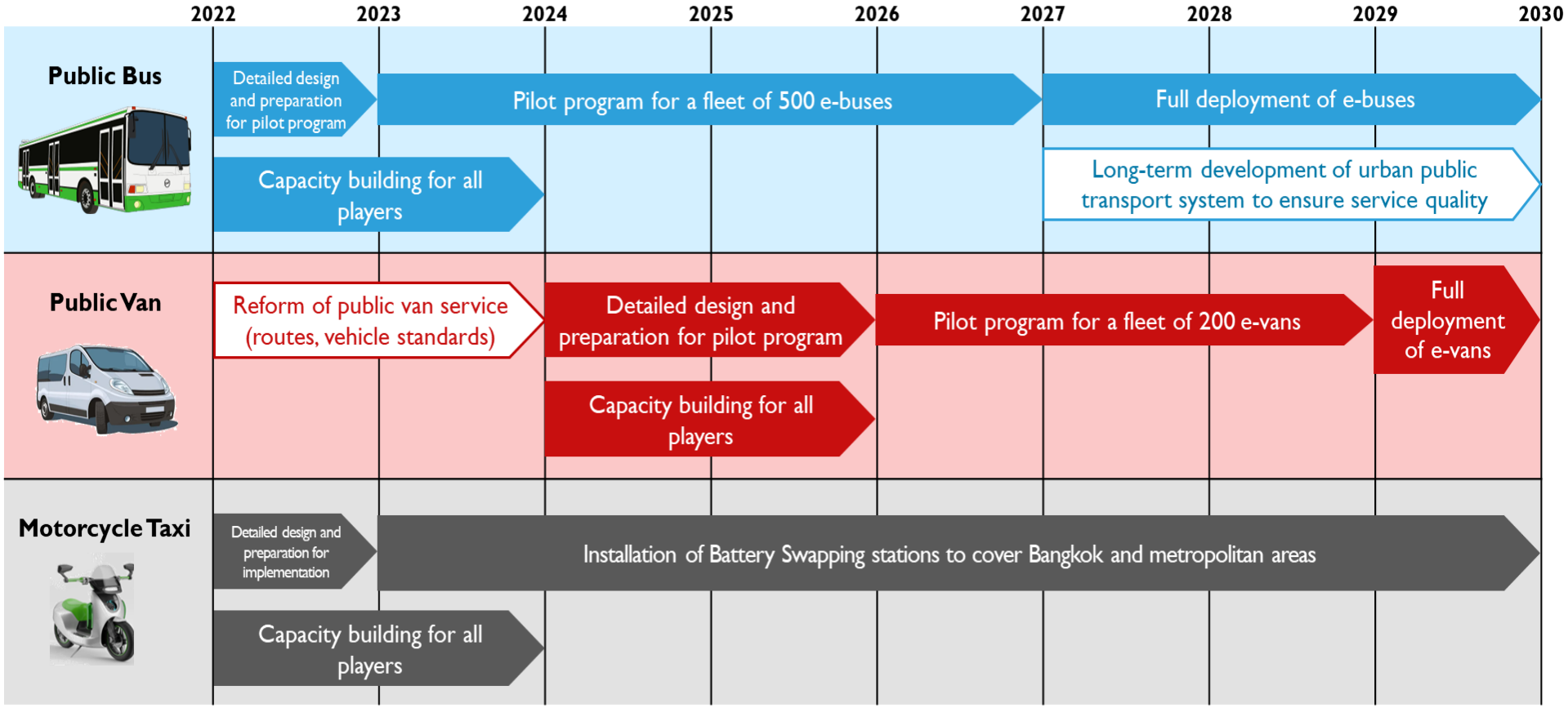
Due to the decreasing cost of EV, the total cost of ownership of an e-bus as well as an e-motorcycle is competitive, compared to that of a diesel bus and a gasoline motorcycle. However, key barriers to electrification of public fleets include the high upfront cost, cross-chain risk, and lack of confidence from financial institutions. The operating lease model and the integrated end-to-end financing model are considered as potential business models to overcome the existing barriers to public bus electrification in Thailand while the integrated end-to-end financing model is applicable for motorcycle electrification.

To initiate the electrification of public buses, investment subsidy is needed to modernized public bus service over the next 15-year lifetime. The long-term development of public transport to remove overlapping routes and improve service quality especially the adoption of new models for bus operators and fair adjustment of bus fares are crucial for the sustainability of public bus service. The electrification of 500 public buses leads to 43,091 tCO_2/year GHG emission reductions and the number of beneficiaries is up to 1,140 million passenger-trips.

For motorcycle taxi electrification, an integrated end-to-end financing model is preferred by most e-motorcycle suppliers; however, the expansion of e-motorcycle is still limited. This results from the motorcycle taxi operators' concern on the capacity of batteries together with the limited availability of charging stations or battery swapping stations (BSS). To accelerate the expansion of BSS network, financial support especially through subsidies to the investment of BSS is needed. The financial support for motorcycle taxi electrification will not only help Thailand to foster climate-friendly transport but also to improve the quality of life for those operators with unstable incomes. The promotion of 10,000 e-motorcycles will lead to an annual GHG emission reduction of 12,032 tCO_2 with about 10,000 motorcycle taxi drivers or operators benefitting from the program.

Figure 68 summarizes the overall roadmap for development of public land transport electrification.

Figure 68: Roadmap for development on public land transport electrification



Annex A: Key assumptions for financial assessment of public bus electrification

1. General assumptions		
Assumptions	**Unit**	**Amount**
Operating days	days/year	300
Distance per trip	km/trip	30
Number of trips	trip/day	8.0
Project lifetime	years	15.0
Inflation rate	%	1.8%
Discount rate	%	8.0%
Debt - equity ratio	-	70 : 30
Interest rate	%	4.0%
No. of years for debt reimbursement	years	7
Corporate income tax rate	%	20%
Depreciation		
- Bus	years	15
- Battery	years	8
- Charging infrastructure	years	10
Cost of Selling, General, and Administrative (SG&A)	% of revenue	5%
Exchange rate	THB/USD	33.73

2. Assumptions on capital expenses (CAPEX) of public buses				
Assumptions	**Unit**	**Diesel**	**NGV**	**Electric**
Cost of acquisition	THB	4,900,000	3,549,000	6,650,000
Size of battery	kWh	-	-	350
Cost of battery	THB/kWh	-	-	10,000
Lifetime of battery	cycles	-	-	2,000
Year for battery replacement	years after start of operation	-	-	7

3. Assumptions on operating expenses (OPEX) of public buses				
Assumptions	**Unit**	**Diesel**	**NGV**	**Electric**
Fuel consumption	(litre, kg, or kWh) /km	0.65	0.60	1.00
Fuel price	THB/litre or kWh	31.54	15.59	6.85
Bus driver and assistant	THB/month	50,000	50,000	50,000
Maintenance cost	THB/day	2,046.91	1,720.00	1,023.46
GPS & insurance	THB/year	144,000	144,000	144,000
Bus tax and license fee	THB/year	8,440	8,440	8,440

4. Assumptions on CAPEX and OPEX of charging infrastructures		
Assumptions	**Unit**	**Amount**
CAPEX: charging sockets & stations		
- Cost of charging socket	THB/socket	1,000,000
- Cost of charging station	THB/station	500,000
- Number of hour electricity charged	hr/day	6
- Capacity of socket	kW	100
- % spare of socket	%	40%
CAPEX: transformer upgrade		
- Power factor	%	80%
- Contingency	%	20%
- Size of transformer in market	kVA	1,250
- Total cost of transformer	THB/1250 kVA	1,200,000
OPEX		
- O&M Cost (% of charging sockets)	%	7.0%
- Overhaul @ Year8 (% of charging sockets)	%	40%
- Buying Electricity price (peak)	THB/kWh	4.50

Assumptions	Unit	Amount
- Buying Electricity price (off-peak)	THB/kWh	2.60
- Shares of peak	%	70%
- Charging efficiency	%	90%
- Share of revenue to land host	%	3.5%
5. Assumptions on GHG emission reductions		
Assumptions	**Unit**	**Amount**
Net Calorific Value of diesel (DEDE, 2020)	MJ/litre	36.42
Emission Factor of diesel (IPCC, 2006)	kgCO2/TJ	74,100
Emission Factor of NGV (TGO, 2022)	kgCO2/kg	2.26090
Emission Factor of grid electricity (TGO, 2022)	tCO2/MWh	0.4999

Annex B: Key assumptions for financial assessment of public van electrification

1. General assumptions		
Assumptions	**Unit**	**Amount**
Operating days	days/year	300
Distance per trip	km/trip	30
Number of trips	trip/day	6.0
Project lifetime	years	10.0
Inflation rate	%	1.8%
Discount rate	%	8.0%
Debt - equity ratio	-	70 : 30
Interest rate	%	4.0%
No. of years for debt reimbursement	years	7
Corporate income tax rate	%	20%
Depreciation - Van - Battery - Charging infrastructure	 years years years	 10 8 10
Cost of Selling, General, and Administrative (SG&A)	% of revenue	5%
Exchange rate	THB/USD	33.73

2. Assumptions on capital expenses (CAPEX) of public vans				
Assumptions	**Unit**	**Diesel (13 seats)**	**Skywell Shodai (11 seats)**	**Skywell Pandai (20 seats)**
Cost of acquisition	THB	1,269,000	2,300,000	2,500,000
Size of battery	kWh	-	88	104
Cost of battery	THB/kWh	-	10,000	10,000
Lifetime of battery	cycles	-	2,000	2,000
Year for battery replacement	years after start of operation	-	7	7

3. Assumptions on operating expenses (OPEX) of public vans				
Assumptions	**Unit**	**Diesel (13 seats)**	**Skywell Shodai (11 seats)**	**Skywell Pandai (20 seats)**
Fuel consumption	(litre, kg, or kWh) /km	0.13	0.31	0.64
Fuel price	THB/litre or kWh	26.80	6.60	6.60
Cost of driver	THB/month	20,000	20,000	20,000
O&M cost	THB/month	11,000	4,000	6,000
Insurance & Tax	THB/month	3,388	3,388	3,388
Route fee	THB/month	1,070	1,070	1,070

4. Assumptions on CAPEX and OPEX of charging infrastructures		
Assumptions	**Unit**	**Amount**
CAPEX: charging sockets & stations		
- Cost of charging socket	THB/socket	700,000
- Cost of charging station	THB/station	350,000
- Number of hour electricity charged	hr/day	6
- Capacity of socket	kW	70
- % spare of socket	%	40%
CAPEX: transformer upgrade		
- Power factor	%	80%
- Contingency	%	20%
- Size of transformer in market	kVA	1,250
- Total cost of transformer	THB/1250 kVA	1,200,000

Assumptions	Unit	Amount
OPEX		
- O&M Cost (% of charging sockets)	%	7.0%
- Buying Electricity price (peak)	THB/kWh	4.50
- Buying Electricity price (off-peak)	THB/kWh	2.60
- Shares of peak	%	70%
- Charging efficiency	%	90%
- Share of revenue to land host	%	3.5%
5. Assumptions on GHG emission reductions		
Assumptions	**Unit**	**Amount**
Net Calorific Value of diesel (DEDE, 2020)	MJ/litre	36.42
Emission Factor of diesel (IPCC, 2006)	kgCO2/TJ	74,100
Emission Factor of grid electricity (TGO, 2022)	tCO2/MWh	0.4999

Annex C: Key assumptions for financial assessment of motorcycle taxi electrification

1. General assumptions				
Assumptions	**Unit**	**Amount**		
Operating days	days/year	300		
Total distance per day	km/day	75		
Project lifetime	years	6.0		
Inflation rate	%	1.8%		
Discount rate	%	8.0%		
Debt - equity ratio	-	70 : 30		
Interest rate	%	4.0%		
No. of years for debt reimbursement	years	7		
Corporate income tax rate	%	20%		
Depreciation - Motorcycle - Battery - Charging infrastructure	 years years years	 6 6 6		
Exchange rate	THB/USD	33.73		
2. Assumptions on capital expenses (CAPEX) of e-motorcycles and battery swapping station (BSS)				
Assumptions	**Unit**	**Amount**		
E-motorcycle	THB/motorcycle	79,510		
Battery swapping station	THB/station	80,000		
Battery	THB/piece	29,104		
Number of batteries per station	pieces/station	20		
Assumptions	**Unit**	**Scenario I**	**Scenario II**	**Scenario III**
Cost reduction of battery due to economies of scales	%	15%	20%	30%
Total no. of e-motorcycles in 2030	motorcycles	10,000	85,000	65,000
Total no. of BSS's in 2030	stations	750	6,375	48,750
Total no. of batteries in 2030	Pieces	15,000	127,500	975,000
3. Assumptions on operating expenses (OPEX) of e-motorcycles				
Assumptions	**Unit**	**Amount**		
O&M of motorcycle & swapping stations	% of total investments	2.5%		
Tax of motorcycle	THB/year	500.00		
Land rental fee	THB/month/station	1,500.00		
4. Assumptions on OPEX of BSS				
Assumptions	**Unit**	**Amount**		
- Buying Electricity price (peak)	THB/kWh	4.50		
- Buying Electricity price (off-peak)	THB/kWh	2.60		
- Shares of peak	%	35%		
- Fuel consumption	kWh/km	0.031		
- Battery size	Ah	40		
- Battery voltage	V	60		
- Battery Efficiency	%	95%		
- Charging Efficiency	%	90%		
5. Assumptions on GHG emission reductions				
Assumptions	**Unit**	**Amount**		
Net Calorific Value of gasoline (DEDE, 2020)	MJ/litre	31.48		
Emission Factor of gasoline (IPCC, 2006)	kgCO2/TJ	69,300		
Emission Factor of grid electricity (TGO, 2022)	tCO2/MWh	0.4999		

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