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This report will outline the market analysis as basis information for developing the First Phase of Transjakarta electrification's Final Business Case Document

Building a Regulatory and Financial Basis for Transjakarta's First Phase E-bus Deployment

Task 3.1: Market Analysis Report

September 30, 2022

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List of Abbreviations

AC	Alternating Current
ACFTA	ASEAN-China Free Trade Area
ADB	Asian Development Bank
ADL	Alexander Dennis Limited
ADR	Australian Design Regulations
AIFTA	ASEAN-India Free Trade Area
APAC	Asia-Pacific
APM	*Agen Pemegang Merk* (Authorised OEM Distributors)
BaaS	Battery as a Service
BEB	Battery Electric Bus
BOM	Build, Own & Maintain
BPPBJ	*Badan Pelayanan Pengadaan Barang dan Jasa* (Jakarta Province Goods and Services Procurement Agency)
BRT	Bus Rapid Transit
CAGR	Compound Annual Growth Rate
CBU	Completely Built Up
CCS	Combined Charging System
CFF	Cities Finances Facility
DC	Direct Current
DNO	Distribution Network Operator
DSO	Distribution System Operators
e-Bus	Electric Bus
ETaaS	Electric Transport as a Service
EV	Electric Vehicle
GBP	British Pound Sterling
GVW	Gross vehicle weight
IBC	Indonesia Battery Corporation
ICE	Internal Combustion Engine
IRR	Internal Rate of Return
ITDP	Institute for Transportation and Development Policy
kg	kilogram
KUR	*Kredit Usaha Rakyat* (National Micro Credit Program)
kW	kilowatt
kWh	kilowatt per hour
m	meter
MABI	*Mobil Anak Bangsa Indonesia*
MoU	Memorandum of Understanding
OEM	Original Equipment Manufacturer
PRM	Persons of Reduced Mobility
PT	*Perseroan Terbatas* (Limited Company)
PTA	Public Transport Authority
PTO	Public Transport Operator

ROE	Regional-Owned Enterprise
RoI	Return of Investment
TCO	Total Cost Ownership
TJ	Transjakarta
UITP	International Association of Public Transport
UK DIT	UK Department for International Trade
UK PACT	UK Partnering for Accelerated Climate Transitions
UKEF	UK Export Finance
UN-ECE	United Nations Economic Commission for Europe
UNEP-CTCN	United Nation Environment Programme-Climate Technology Centre and Network
ZEB	Zero Emission Buses

Executive Summary

Following the government's mandate and vision, the intention is to electrify the Transjakarta fleet by 2030. To achieve this, significant investment and adaption to the existing contractual framework and regulations will be required to enable the implementation.

As part of this project deliverables, comprehensive research using qualitative and quantitative approaches was completed to better understand the requirements, gain insights from the market of current trends and lessons learned while providing more information to the market and allowing them the opportunity to provide initial advice on the requirements to be considered.

A framework matrix was developed to identify all the relevant key stakeholders across the important ecosystem of vehicle suppliers, charging equipment suppliers and financiers. A long list was developed from the initial research and through evaluating the key industry leaders through the evaluation framework, a shortlist was developed for further market engagement.

The preliminary market engagement meetings were held with vehicle OEMs, charging equipment suppliers and organisations involved in financing zero emissions projects in terms of both debt financing and leasing. Following on from previous studies, the objectives of the preliminary market consultations were to identify the potential industry players, to better understand more generically, the products and services available and to gather inputs on the procurement, financial, technical, legal, and other aspects to be able to shape the strategy and refine the working assumptions while increasing project attractiveness to the market by ensuring requests and requirements are feasible and appropriate.

The consultations were successful in that it confirmed the market is open to options and delivering the work packages and would welcome more detailed meetings with Transjakarta and ITDP to work together more collaboratively to develop the solutions. The market analysis has provided sufficient confidence that the market is interested in the project to supply vehicles, charging equipment with different options available for financing the transition. However, there are some uncertainties that remain and need to be resolved regarding contracting models and regulations.

To support the transition to zero emission transport, the industry is witnessing significant change. New entrants are moving into the market to provide solutions, while others are moving from their traditional market segments within the ecosystem to capitalise on the opportunities.

There are multiple operators across the Transjakarta transport network and many of the smaller operators would have challenges raising sufficient capital for procurement of electric buses and the required depot charging equipment. This is a challenge faced by many operators globally and creating the opportunity for alternative and innovative financing and ownership of buses fleets, especially in large markets with multiple operators.

Innovative financing and supply solutions are being developed to help reduce the risk exposure of the operator and authority, especially around battery life and performance. Options include the

ability to buy the bus while leasing the battery as well as business models provide Electric Transport as a Service (ETaaS) whereby the overall cost of the transition is fully financed and delivered by industry providers and the operator pays a mileage-based payment which is guaranteed by the authority.

Some of the depots are owned by private operators and are outside of Transjakarta's direct control which could affect the long-term financing and availability of charging equipment, especially if the operator does not complete or renew the operating contract. Having control over depots is an important factor and Transport Authorities in other markets have recognised the importance of depot ownership and have started to acquire depots from the private operators for service efficiency and availability of infrastructure.

The current technical regulations do not fully support the full-scale deployment of electric buses. Technical regulations need to be refined and aligned to the practicalities of operating electric vehicles. Batteries are heavy and increase the gross vehicle weight which exceeds the current technical regulations. In Europe and other international markets, the gross vehicle weight has been increased to consider the weight of the battery. Smaller and modular battery options are available from some suppliers although this would require more frequent charging and therefore, more charging infrastructure to be installed across the network as well as at the depots. The weight and cost saving of batteries are positive however, the overall Total Cost of Ownership (TCO) could be higher as more expensive fast or ultra-fast chargers would be required.

There is a price premium on European brand buses although these are fully produced (Completely Built Up) buses in Europe unlike the existing Transjakarta fleet which had a European chassis and locally manufactured body. This separate chassis-body approach has a lower import tax and through localising the manufacturing, reduces the overall cost and adds value to the local economy.

Through the market consultation, there was some interest in potentially establishing local production/assembly facilities. This would require investment and therefore, would only be viable with sufficient volume. Some OEM have already initiated discussions or agreements with local entities. Some of these manufacturers have experience in establishing overseas assembly plants including in Asia for their high-volume customers in Hong Kong and Singapore.

Framework agreements with the bus OEMs could provide the necessary volume assurance. This could achieve a lower vehicle unit rate through economies of scale and also ensure the OEM supports the vehicle as the procurement options would be dependent on the vehicle achieving the required performance standards.

OEMs expressed concern around the process to obtain permits for electric vehicle trials. The process is not entirely clear due to the technical regulations and the early stage of the introduction of electric vehicles in Indonesia. Significant time, effort and money is required by the OEMs to adapt their products for Indonesia. Having clarity on the process will enable the OEMs to develop

the vehicles to comply but also achieve the requirements and expectations of Transjakarta. Providing clarity will provide confidence to the OEMs to invest and be efficient in obtaining the necessary certification for homologation and other due diligence aspects.

The charging strategy is important for many reasons. Defining whether buses will be single use charged (depot-based), in service charged (on road opportunity) or combination of both will determine the bus specifications with regard to charging equipment but also define the type and quantity of equipment required. It will also directly impact the quantity and rate of electricity required and subsequent electrical infrastructure upgrades required. While slow charging takes longer, the equipment costs are lower and can be more easily scaled and combined with smart charging software. Conversely, fast charging allows for quick turnaround of vehicles with more expensive equipment but vehicles can be moved between charging stations to better utilise the equipment.

1. Introduction

1.1 Background

As part of the efforts to help accelerate electrification of Transjakarta fleets, there needs to be a robust implementation plan that can depict the steps and aspects that must be taken care of. Although there have been studies conducted around this topic, they are still not comprehensive. For instance, the phase 1 of this study was conducted to develop the electrification road map for micro bus only while the UNEP-CTCN study was revolving around BRT and non-BRT. There is also a study conducted as part of C40 CFF project but it was only to prepare for pilot phase only. The results of those studies are still useful, however, there have been changes on the target and progress of Transjakarta electrification where, as per the Governor Decree No. 1053 Year 2022, the target of electrification for Transjakarta fleets is 50% of operating buses by 2027 and 100% (equivalent to 10,047) by 2030. In the same decree, it is also stated that the financing and procurement of the said e-buses could be done with any alternative schemes within the corridor of regulations in Indonesia. When this report is being developed there have been 30 e-buses under the pilot basis that are operating on the streets of Jakarta as part of Transjakarta services.

Considering the development of the technology and progress of the electrification described above, it is necessary to also update the market research to either complement the market research that have been done by previous studies or update the information such as latest market price and trends. The market research on this study is also different in a way that there will be preliminary consultations with select industry players from e-bus and charger suppliers, bus operators and financing institutions as well as other companies that may take interests to be involved in the Transjakarta decarbonisation efforts. The purpose of this preliminary consultation is to gather inputs or challenges on the procurement, financial, technical, legal, and other aspects that may be relevant. Additionally, preliminary consultation could be used as an initial market sounding to increase the project attractiveness.

During a market research phase, the appetite of each player can also be identified whether they show interests to be involved or not later once the procurement starts. For instance, by conducting the preliminary consultation, the lead time of procuring e-bus and charger from a particular supplier can be obtained and whether they have enough capacity in the near future. There may be a case where a supplier is preferred by Transjakarta, however, they do not have the capacity to support the procurement.

All those information is obtained through having direct discussions with the players. The information will then be passed through to other teams who will be having further analysis. As an illustration, the market price will be used by technical team to calculate TCO analysis, the availability of certain products will be considered when developing the implementation phase.

Hence, market research is particularly imperative for the project team to develop the implementation phase for large-scale electrification of Transjakarta fleets.

Since the exact requirements are not defined yet (vehicle quantities, charging equipment etc) thus the preliminary engagements help to further develop these working hypotheses for range and operational performance to determine the fleet replacement plan, energy sizing requirements along with the development of the charging strategy which will guide the quantities and locations of charging equipment.

1.2 Objectives of the Report

This report largely aims to conduct research on the e-bus market around the globe to better understand the trend on the e-bus ecosystem and provide findings to help accelerate electrification efforts on Transjakarta fleets. It is also the intention to develop more comprehensive understanding of the technical and commercial aspects for the transition to zero emission fleet. In particular, the reports will:

1. Provide overview on the e-bus ecosystem that includes industry players of the e-bus, charger and fundings and financings to inform the next steps.
2. Present summary of findings from previous studies that have been conducted in relation to Transjakarta fleet electrification.
3. Discuss findings from preliminary consultation that were conducted with select industry players.

1.3 Scopes of the Report

This report is limited to discuss and describe the market research pertaining to Transjakarta electrification efforts. The market research includes desktop studies and consultations with select industry players. The report will also present a summary of findings from previous market analysis that have been conducted regarding electric bus including studies from UNEP-CTCN, UK PACT, World Bank and C40 CFF.

The preliminary market consultations were conducted mainly through video conference due to geographic location and pandemic situation. The key findings and results were then described and summarised in the report in as concise and useful as possible. It is also not the intention to consult all industry players available in the market, only those who satisfied the prescribed criteria that was developed through the analysis framework and those who had previous consultations with Transjakarta. Any further quantitative analysis such as financial and TCO analysis are to be discussed in separate reports of this study.

1.4 Outline of the Report

The report will start with a brief introduction that will give an overview of how the report will be structured and provide the objectives of the report. This is followed by methodology where it will

describe the analysis framework that will be used to conduct the market research as well as the approach to select the industry players to be consulted.

The following sections are an overview of e-bus ecosystem and technical consideration of Transjakarta electrification as well as findings from previous studies. The e-bus ecosystem will discuss an overview of the trends and products available in the global and domestic markets as well as the potential players through desktop research that could be engaged in Transjakarta electrification efforts. The desktop research will be complemented by technical consideration of Transjakarta fleets. This is particularly important so that the market research could be conducted on the relevant products and services only so as to maximise the efficiency of the study. The findings from previous studies that are related to Transjakarta electrification are not obsolete hence it will be summarised in the following section of this report. This is necessary so that to avoid any redundancy in the reports.

The report will be ended with findings from preliminary consultation with select industry players (e-bus and charger suppliers, financing institutions and other relevant stakeholders). The preliminary consultation aimed at gauging the market appetites about Transjakarta electrification and to understand what types of products are available in market and its process to bring to Indonesia. The overall findings and potential way forward will be reported in the last section.

2. Methodology

2.1. Market analysis framework

The purpose of the analysis framework was to provide a logical evaluation for shortlisting those for further engagement. The companies selected for the market engagement were selected from industry knowledge, qualitative and quantitative research and earlier engagement with Transjakarta. This included analysis of geographical coverage (international and domestic) and suitability of product of services to deliver the project objectives.

The methodology for the market analysis framework combined both qualitative and quantitative assessment. This was based on desktop research and industry knowledge and experience with the objective to attain updates and inputs from the key e-bus stakeholders involved in international projects as well as those developing in Indonesia. Both international and local stakeholders have the potential to be a significant participant in developing the e-bus ecosystem in Indonesia.

A key criterion for the selection of the suppliers was the potential to localise the production, whether in full or part, and transfer of skills for building national capability in the transition to zero emission. The true path to decarbonising is to minimise the supply chain footprint of zero emission buses while also contributing to the local economy.

When reviewing the company structures and profiles, it was important to consider the history of the organisations and assess the potential longevity of the organisation or previous successful implementation projects to be able to positively participate and supply solutions and support the project during the lifecycle.

The e-bus market is developing, and the research reached geographically from the Americas to UK & Europe to Asia to be able to assess the maturity of the e-bus ecosystem where vehicles, charging equipment and contracting and business structures are being deployed and provide valuable lessons and experiences.

The framework matrix developed for the evaluation included key requirements and metrics for scoring the suppliers.

From the initial desktop research, an initial long list was developed to identify the key suppliers in each sector. With the increasing interest in decarbonisation in the industry, many case studies and articles were available to help develop the initial long list of potential suitable suppliers. The assessment used a series of filters and metrics to identify and rank the suppliers in tiers.

The framework matrix applied a weighted score to enable a filtering process of both quantitative and qualitative metrics based on the suitability and applicability to the project needs such as interest or presence in Indonesia, appropriate products or services and necessary skills and experience to be a success partner. The evaluation also considered access to capital and potential

long-term viability based on historical performance delivering similar projects and a look ahead to provide and support the project and/or products

Types	Companies	Description	Request from TJ	Shows high interest on TJ electrification	Strategic role or position	Deliver wide-range variety of fleet models needed by TJ	Market presences
			All	All	All	OEM/ APM	OEM/APM
	Max points for weighted-scoring (max total points: 100)		10	30	20	10	10
torised distributors	Mobil Anak Bangsa		10	25	10	4	4
	BYD/ Bakrie Autoparts/ VKTR		10	30	20	10	10
	DFSK/ Sokonindo Automobile		8	20	10		
	TATA Motors/ TMDI		8	10	10		
	INKA		8	20	10	2	4
	Zhongtong		10	20	10	6	6
	Skywell/ Kendaraan Listrik Indonesia		10	20	10	4	6
	Golden Dragon						
	Higer/ HMI		10	20	10	6	6

Figure 1. Snapshot of evaluation matrix

Further analysis was completed and those identified from the long list were then evaluated based on their market share/size, product range and rated and positioned based on a 2x2 company evaluation quadrant matrix. The objective of this stage was to identify those within the segments to shortlist and conduct further analysis and participate in the preliminary market engagement meetings.

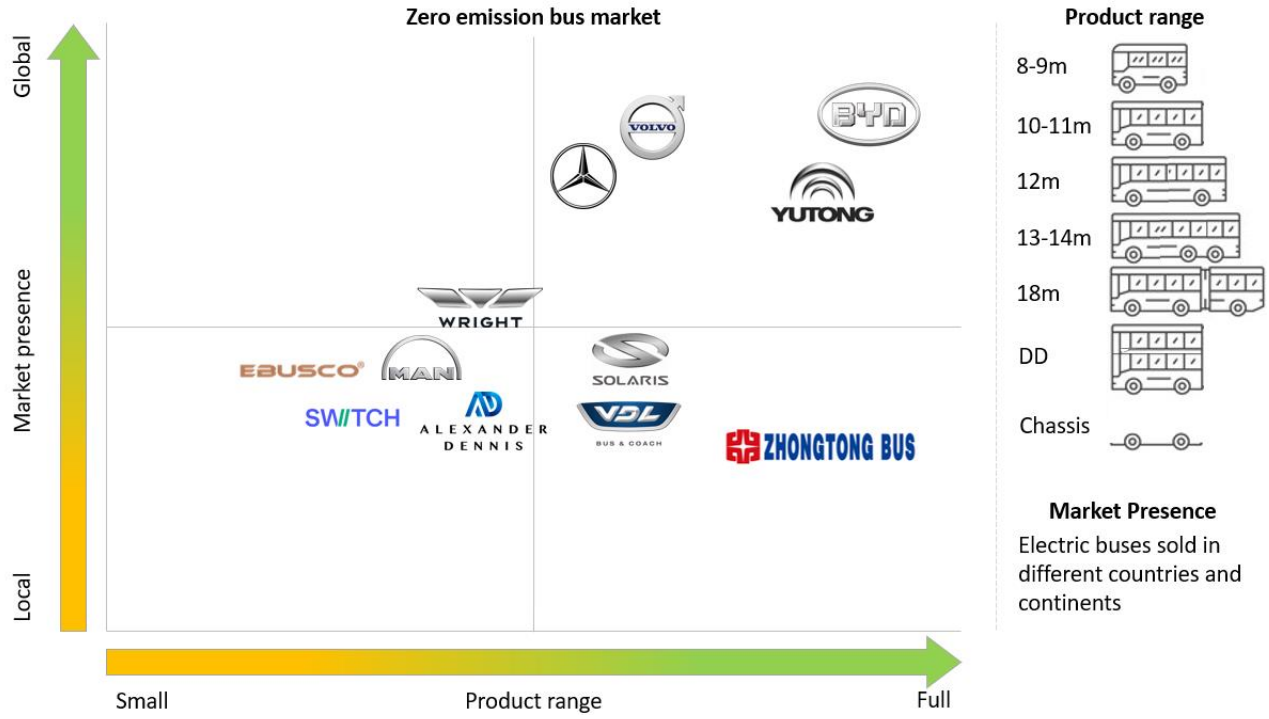

Figure 2. Company evaluation quadrant matrix (Source: Analysis)

For each OEM supplier, the overall product range was assessed along with those potentially suitability to meet the requirements of Transjakarta for both vehicles, associated infrastructure and the short and medium-long term operational plans. It is important to note that the

Transjakarta system combines two distinctly different system designs of low entry buses (non-BRT) and high floor BRT. High floor electric buses are a globally bespoke product and therefore, the product availability for these type of buses does not necessarily align with the replacement plans (2023-2024) and current regulation (gross vehicle weight). These would need to be developed specifically for Jakarta or right hand-drive high floor markets (South American BRT are High floor BRT but left-hand drive) but be sufficient in volume for the OEM to produce at an affordable price.

Sourcing investment, especially post pandemic, for assets is the key enabler of transition to zero emission transport. The evaluation framework was developed from initial desktop research with the matrix using a series of assessment metrics and dimensions to identify potential investors in all types of funding or acquisition models.

Following the final ranking and scoring, the shortlisted organisations were identified for the next stage of market consultations for the purpose to test our research hypothesis and to provide the suppliers more information of the status of the project, to review their product and services, technology options, production volumes and lead times, experience of previous projects and any other issues which could affect the project deliverables.

Transjakarta has been active in the market engagement with many suppliers in the e-bus market from power and utility companies, financiers, international and domestic suppliers of electric vehicle and aftermarket propulsion systems for retrofitting the existing vehicles.

The charging equipment market also has many players although has few large and dominant players. Through desktop, a list of suppliers was developed for further consultation as part of the market engagement. The key market leaders are Siemens and ABB-Hitachi. Other such as Heliox are growing their market share in Europe but do not currently consider Asia part of their growth strategy.

Equipment suppliers are now expanding their range of products in response to the requirements of operators for flexible and scalable solutions. Options include AC or DC charging and slow, fast and ultra-fast charging solutions. The key constraints for electrification are space and power availability within the network as off grid solutions (renewable energy) are not yet sufficient for large fleets and the suppliers are developing solutions to mitigate and manage these challenges.

2.2. Stakeholder Consultations with Transjakarta

During this project, there has been regular and extensive engagement with Transjakarta through formal and informal meetings and workshops, both online and in person. During these engagements, requirements have been defined, operational plans and constraints better understood and initial working hypothesis shared on the business and contracting models. Additionally, the findings and working assumptions have been presented and aligned. Guidance from Transjakarta has also been incorporated to explore specific concerns or areas of interest for further assessment, such as charging infrastructure as this will be critical to delivering an efficient

and cost-effective change program. Moreover, Transjakarta has also completed many market engagements to raise awareness and potential interest in the decarbonisation of public transport with support of ITDP and UK DIT.

The initial stage of the transition to decarbonise has been initiated with the plan to operate 100 battery electric buses. This initial pilot commenced in 2022 and uses BYD K9 12m low entry (non-BRT) buses provided by BYD through its local partner PT VKTR Teknologi Mobilitas (VKTR) and currently there are 30 e-buses running on the streets of Jakarta servicing passengers. These are the most standardised global product type aligned to those in the Transjakarta fleet. This makes this vehicle group the easiest to commence the transition and demonstrate the technology in Jakarta operating conditions with BYD able to offer the vehicle and charging system as an integrated package at a reasonable price as BYD is able to lever economies of scale pricing unlike European OEMs.

In addition to that, there were 4 e-bus models that have completed their trial runs for 3 months. Three of them were all low entry buses from 3 different OEMs namely Zhongtong, Golden Dragon and Skywell. The last one was from PT MABI (Mobil Anak Bangsa Indonesia) and it was a BRT bus (high entry high deck). There was also 1 electric micro bus that was supposed to conduct trial runs from DFSK Motor Indonesia that has 4.5 meter in length. However, until the report is written the trial run has not commenced yet.

Through this process and Transjakarta's own market engagement campaign, Transjakarta has raised interest and awareness from suppliers. It has signed Memorandum of Understandings (MoU) with other OEMs including Switch Mobility (formerly Optare UK and part of the Ashok Leyland Group) and Equipmake, also from the UK.

Switch Mobility are currently manufacturing the first pre-production 10m low entry non-BRT trial vehicle which should be delivered in early 2023 and once all necessary permits have been obtained, it will commence trials in Jakarta.

As an alternative to procuring new vehicles, Equipmake will assess the technical and commercial feasibility of retrofitting their self-developed electric propulsion system. This could shorten the procurement cycle although the TCO modelling is in progress to verify the commercial feasibility of this solution given the potential age constraint of the operating fleet. In preparation for the project, one of the leading retrofit companies (Equipmake, UK) has established an initial partnership with VKTR to develop a retrofit solution suitable for the Transjakarta fleet.

2.2.1. Charging infrastructure

The critical component and influencing factor on cost of fleet electrification is the infrastructure and the provision of adequate and reliable power to recharge the fleet.

The contractual model of Transjakarta includes depots owned by both Transjakarta as well as privately by the operators. The privately owned depots present another challenge to install the

equipment and who will design, own and finance the equipment with the current contracting model. Hence, Transjakarta have specifically requested to further investigate the alternative business models that may be suitable for Transjakarta considering all aspects.

Depot charging is essential for the fleet but due to the high duty cycles of the BRT fleet, charging strategy must be complemented with opportunity charging (on road or in terminus during operation) to provide continuous service without the need for significant fleet increase to provide the same service specification.

As part of this project, the network has been reviewed and sites identified where charging is possible. Local site surveys have been initiated to ascertain site ownership, evaluate the site conditions, potential provision of power and overall feasibility of installation of charging equipment. These assumptions have been included in the fleet sizing and implementation plan along with TCO modelling.

Two of the global leading charging infrastructure suppliers were engaged with to assess the available products and solutions. They were both aware of the project and provided information on charging solutions for the various sites (depot and stations/layover staging areas) which can be adapted to meet the site-specific requirements.

Preliminary consultations with Transjakarta could be summarised as follow:

1. Most of the Transjakarta existing fleet are from European brands such as Mercedes, Volvo and Scania. Some other brands such as Hino and Zhongtong have been introduced by other operators.
2. Most of the above brands have electric buses which could replace some of the fleets. None of these have been certified (homologated) for Indonesia although Volvo has confirmed it is working on a product to meet the technical and operational requirements.
3. Transjakarta do not have a preference for brands or country of origin of manufacture. However, the operational duty cycles and contract duration would require durable products to ensure robust reliability and therefore, proven products are required.
4. Initial pilot trials will help Transjakarta to evaluate the vehicles before large-scale procurement of the fleet. Engagement with OEMs continues to provide more trials of different vehicle types.
5. Transjakarta services will continue to require high-floor dual-side passenger doors to operate the BRT lines. Technical standards and specifications are defined but might need to be slightly refined for electric vehicles.
6. The charging infrastructure and charging systems should be interoperable. DC charging is more common as it offers the ability to slow or fast charge the vehicles.
7. Depot charging provides many advantages for large fleets and is the preferred method of charging although it is acknowledged that on-route charging will be required due to duty cycles.

8. Alternative financing and asset ownership to be considered as operators face challenges with access to sufficient capital but also, some depots are owned by private operators and are outside of Transjakarta's direct control.
9. There have been engagements with international financial institutions and have received positive interest. Thus, it is also important to consider fund channeling mechanisms to enable these funds to be utilised for Transjakarta electrification.

2.3. Desktop Research

2.3.1. E-Mobility market analysis

The e-bus market has developed significantly over the last 10 years. The interest and need for change to zero-emission vehicles has required industries to adapt to the changing landscape, especially post-COVID which saw a reduction in sales, shortage of inventory and slow-down in production.

The Asia-Pacific (APAC) region is the largest market for the electric bus and charging stations.[1] The dominance of the APAC market is attributed to the massive growth of China's electric bus market. China alone accounts for 99% of the total electric buses sold across the world, which creates a large demand for related infrastructure including charging stations. Although Asia leads in volume of electric vehicles, outside of China, the market lags behind many major countries. Indonesia has set a mandate to decarbonise public transport. As the industry transitions, the industry is witnessing a change in business model as new organisations enter the ecosystem.

Table 1. Emerging trends in E-bus ecosystem

	Existing	Emerging trends
Suppliers	• Traditional players (OEMs) • PTO or PTA purchase directly from OEM • Short term leasing available	• New alternative entrants to market providing solutions from other sectors e.g. power companies • Bus and battery purchased separately • Increase in leasing options including leasing battery
Contracting	• Shorter contracts (5+2 or 8-10-year contracts) • Operator procure all assets	• Extended contracts to align with new technology vehicle depreciation • More PTO procuring assets or introducing residual value mechanisms for key assets
Technology risk	• Operator has risk for technology and performance risk	• Battery provider or external providers absorb risk with performance guarantees
End of life risk	• Operator responsible for vehicle end of life • Operator performs life extension maintenance (engine change or	• Battery supplier or energy companies taking risk and providing second life for batteries

[1] UITP report 'National Framework for e-bus performance evaluation in India'

	fitting of exhaust equipment for enhanced emission standards)	

Source: ITDP Analysis

Bus OEMs across the world is developing more products (vehicles) to meet the growing demands and changes in operating practices as data provides more information to better plan and deliver the services. Most of these vehicles are developments of existing ICE vehicles while a few exceptions of new vehicle manufacturers are trying to enter the market with mixed success. UK based company, Arrival, commenced the design and development of a new light commercial van and 12m bus starting from scratch. Although they have achieved type certification for the bus, they have suspended the programme to develop the bus due to financial constraints.

From analysis of the Transjakarta operations and existing bus fleet, there are buses available in the market to replace the existing fleet for most of the fleet. OEMs are developing products which are electrified versions of their existing ICE range targeting existing customers and sales volumes to ensure they can sustainably recover their development and production costs. The 9-12m low-floor bus segment has the largest range of product options. These will be suitable for straight transition of the Transjakarta fleet with battery size options available to meet the operating requirements.

The high-floor BRT 18m articulated buses are not readily available although through market consultations, OEMs might be willing to adapt their existing products to suit the requirements. An alternative to new is the retrofitting an electric propulsion system which can help extend the life of the existing fleet until such new vehicles are available.

2.3.2. Market supply chains

New entrants to the market are disrupting the typical supply chains while consolidation and partnerships emerge to offer synergies for a simpler and more attractive market proposition.

Some large suppliers have adapted to market dynamics and either merged, been acquired or changed their strategic plans, resulting in an increase in collaboration. Examples included merger of ABB and Hitachi energy in 2020 for ~$7.8bn, while the bus manufacturer Solaris was acquired by train manufacturer CAF. BYD has created strategic partnerships with local body manufacturers in some territories and offer its chassis and technology such as with ADL (UK), Olectra (India) and Gemilang (Malaysia and Australia).

BYD and Yutong continue to lead the production and sales of electric buses with each manufacturer taking a different strategic approach. BYD offer a Completely Built Up (CBU) product as well as just a chassis to local body manufacture which can be more cost effective due to different rate of import duties while allowing operators to retain some consistency in fleets, while Yutong only offers its vehicles as CBU.

China has the lead in global production and achieved economies of scale with Yutong and BYD have delivered over 100,000 units between them, yet less than 3% of those were to Europe, about 1,800 vehicles. The major OEMs of Mercedes and MAN have been progressing at a slower rate

than other OEMs such as Solaris and VDL who have a larger market share in Europe, and in comparison, around 2,000 e-bus were sold in 2021 by European brand OEMs.

New vehicle manufacturers are also seeking to enter the market such as Arrival (UK), EURABUS (Germany) along with locally developed vehicles such as Inka (Indonesia). These are currently only producing small volumes but with plans to expand.

The availability of vehicles across the entire Transjakarta fleet are not as readily available as the ICE equivalent vehicles. Many options exist from the traditional tier one and two suppliers of the midi bus and low entry non-BRT fleet segment. However, the BRT Maxi bus and articulated bus types are less common as most global Public Transport Authority (PTA) and Public Transport Operator (PTO) opted for low entry products. This could present a challenge to find sufficient alternative vehicles or present an opportunity to modify (retrofit) these vehicle types with alternative zero emission propulsion systems. This approach has opportunities to localise some work as the vehicles will be retrofitted locally, while some of the propulsion system could be localised. There are also potential opportunity costs associated with the sale of the removed components such as engine, gearbox and other related components.

Outside of China, electric vehicles have not achieved price parity with ICE yet, both in terms of initial purchase price and Total Cost of Ownership (TCO). Consequently, finance and access to capital is the key enabler, or barrier, to full fleet adoption of zero emission fleets.

2.3.3. Charging equipment

An electric fleet charging solution consists of many different components from sub-stations, transformers, switch gear, and then the actual charging equipment itself. Back-office hardware and software allow PTO to track and monitor vehicles and their status for optimum service performance.

The charging solution will depend on the depot or station design constraints and operational requirements. These include the access and provision for sufficient power, available space to locate equipment, and the available time to charge the fleet. Local regulations and restrictions on consumption or tariffs are also potential constraints for fleet charging, especially large fleets.

Charging of vehicles can be through a plug-in, conductive (overhead) or inductive (surface mounted) and in either AC or DC current, with power ranging from 40-50kw for slow charging, 100-350kw for fast charging, and 350-800kw for ultrafast. The equipment to deliver the charging can be through wall-mounted ‘docking’ stations or free-standing charging units, which are typically fitted with one or two 40-50kw cable each with a CCS2 ‘gun’.

Figure 3. Types of charging equipment positioning: docking station, free-standing, overhead

Space availability in depots or stations are a key constraint. The size of equipment varies depending on the available space and vice versa, equipment needs to be fit into the available space. Compact wall mounted or free-standing charging docking stations/dispensers are common for small scale projects, while interconnected solutions are being deployed as PTO increase their electric fleets. Some large-scale electrification projects have seen a reduction of around 10-20% of parking spaces due to necessity of equipment positioning.

More innovative solutions are being developed for equipment and location of that equipment. These can include overhead gantry systems with either drop down plug in 'guns' or pantographs, either inverted pantographs down or bus pantograph up into charging hoods.

Safety protocols and requirements have been developed to limit the risk of human action for superfast while ultrafast has no manual handling of equipment and the vehicle and charging equipment communicate either automatically by Bluetooth or Wi-Fi to connect, or the driver manually activates the pantograph from a control in the cab of the bus.

Communication between the bus and equipment are also developing. Standardised communication protocols being developed with the intention of interoperability between different vehicles and equipment. The transfer of data between the vehicle and equipment, and managed through smart charging software, allows the equipment to determine which vehicle needs charging, how much is required and in what sequence the fleet should be charged based on program parameters.

Battery technology and vehicle supply are typically symbiotic, and the vehicle manufacturer leads. However, examples are emerging where PTO are tendering separately for the core vehicle (without battery) and the battery and charging equipment in different package. Second life for batteries are still relatively unknown and the market has not really matured or really established. Solutions are being developed for depot-based battery storage of second life battery packs.

Infrastructure provision is constraining the mass deployment of zero emission vehicles. Many existing depots and bus stations/staging areas have limited grid capacity and off-grid solutions (solar and wind) have yet to develop sufficiently to be efficient enough. Power generation and distribution network owners (DNO) are working to upgrade the networks, but this is a very long and capital-intensive process, especially as the power generation firms need to move away from

traditional fossil fuel to renewables. This long lead time will inhibit the mass adaption of electric vehicles. Installation of off-grid (local energy production), typically through solar is becoming more feasible in some locations. The use of solar reduces the need on grid-based power but requires batteries to store the energy during the day for when the fleet is charged at night.

Whilst solar is considered a relatively quick and sustainable solution for off-grid power, it still requires batteries to be able to store the energy generated during the day. In Australia, Tesla have provided 10 Tesla Powerwall batteries for 135kW storage capacity which is supplied by 250 solar panels that are able to produce a daily average of 438kWh. As part of the sustainability for zero emission, remote battery storage systems as part of a total solution while it is planned that the vehicle batteries could be used in depot storage as part of a second life.

2.3.4. Transjakarta procurement analysis and technical considerations

Transjakarta operates a combination of low floor city buses (non-BRT) and high floor (BRT) buses. This combination presents a different set of challenges to electrification of bus fleets in other major cities. High-floor BRT buses are not common and the procurement model might need to be adapted to provide the necessary assurance to the market as vehicle development might be required.

The current Transjakarta procurement process is appropriate for procuring existing bus technology for the contract. For new electric vehicles, a revision to the procurement process would be needed, especially if any other dimensions relating to the ownership model changes (buy or lease), the contracting model and whether alternative funding or financing models are implemented (Green funds etc).

The current Transjakarta procurement process is:

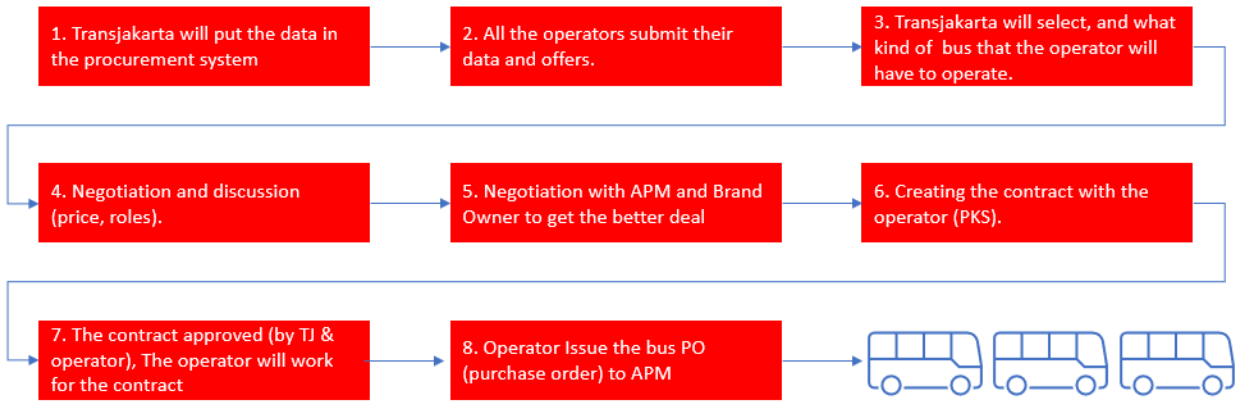

Figure 4 Transjakarta's procurement process

Large-scale fleet procurement is time and capital-intensive and this is further exacerbated when transitioning to zero-emission fleets due to the additional levels of technical and commercial requirements than traditional ICE vehicles.

For new technology vehicles, operational test data or experience is not available and the current approach might not be appropriate (excluding existing pre-trial vehicles). The ownership and procurement model needs to be defined; buy or leasing to enable appropriate TCO analysis to evaluate the best value proposition from the suppliers. The current procurement process allows any supplier to submit their technical and commercial proposals through the portal but without sufficient or adequate empirical data of acceptable operational performance such as certified independent performance data e.g. UITP SORT cycles or ZEMO partnership (UK), which may affect the actual performance of the services.

In some cities, the PTA establish approved fleet lists which operators choose from (London, Sydney). These are vehicles which have been proven or tested to comply with the operational requirements and reducing the risk for large scale procurement while also simplifying the evaluation process for procurement as a full and comprehensive assessment of multiple suppliers and brands is not required. Conversely, it also ensures sufficient response from bidders and/or compliant bids to the technical requirements, as experienced in some Indian e-bus tenders.

The cost of new vehicles and access to capital for local operators could delay the transition period. Standardising the technical specifications can provide some assurance to the market for volume of vehicles which could enable economies of scale to be achieved. Furthermore, Transjakarta could centralise the management of the procurement process with centralised funds/ available finance to provide further assurance which could be in the form of framework agreements. These would remove some of the challenges expressed by the incumbent operators.

2.3.5. Analysis of technical considerations of e-Bus fleet

The current fleet of vehicles consists of low-floor non-BRT and high-floor BRT buses and range in length from 9m to 18m. These are predominately based on a chassis and body configuration whereby the chassis is made by one supplier, typically European OEM and the body by another, typically, an Indonesian manufacturer.

The initial fleet of electric vehicles manufactured by BYD represent the common vehicle type in the global market (10-12m single deck low entry). These are manufactured as a Completely Built Up (CBU) product. This selection provides the opportunity to provide a readily deployable fleet as the chassis OEM and body manufacturers do not need to develop the final product and get it homologated for use.

The specification of these vehicles is based on common standards and specifications. Due to Indonesia technical regulations and requirements, special permits and initial homologation process has been prolonged but achieved by utilising vehicles which have similar specifications to

European standards. Initial certification was achieved through demonstrating alignment and compliance to European standards and specifications.

These vehicles do not operate on BRT routes and therefore, do not require passenger doors on both sides, again ensuring ease of implementation and provide all necessary accessibility features for Persons of Reduced Mobility (PRM).

The key technical consideration is going to be the balance of desire of range and compliance to technical regulations, mainly, the Gross vehicle weight unless exemptions or a change to the regulations and legislation is made.

Additionally, the high duty cycles and requirement for heating and air conditioning for the fleet will have a considerable impact on the energy consumption across the year. This will require careful consideration to the charging strategy which in turn will be a key influence on the battery size.

For new vehicles and to enable a quick deployment, it might be more time efficient to initially specify the initial vehicles as CBU rather than with local body to allow time for design, development and approval from the chassis manufacturer. All new vehicles should be designed to comply with high industry standards (UN-ECE) which should help ensure longevity of assets if built to international standards, especially regarding fire safety.

2.4. Preliminary Market Consultations

Preliminary market engagement meetings were held with vehicle OEMs, charging equipment and organisations involved in financing zero emissions projects in terms of both debt financing and leasing.

Transjakarta is required to follow strict tendering and procurement rules. The initial market engagement consultations are intended as preliminary to engage with potential suppliers on the market before launching the public procurement procedure.

The objectives of the preliminary market consultations were to identify the potential industry players, to better understand more generically, the products and services available and to gather inputs on the procurement, financial, technical, legal, and other aspects to be able to shape the strategy and refine the working assumptions while increasing project attractiveness to the market by ensuring requests and requirements are feasible and appropriate.

The exact requirements are not defined yet (vehicle quantities, charging equipment etc) and therefore, the preliminary engagements help to further develop these working hypotheses for range and operational performance to determine the fleet replacement plan, energy sizing requirements along with the development of the charging strategy which will guide the quantities and locations of charging equipment.

The principles of the preliminary market consultations were for initial information gathering as the specific requirements of the project are not yet known. The process for public projects is fairness and transparency and the initial engagement will not distort level of competition. No agreements or contracts were made or entered into during the engagements, nor commercial details shared.

Funding of new vehicles can be through either direct funding by local supplier (VKTR or Indotruck (Volvo) or other players) or through external funding by banks of their choice. The local vehicle suppliers have some capacity to fund the fleets and as large organisations, they have experience of financial services although VKTR has ceased trading in financial services and unlikely to recommence due to time for licensing etc.

Access to sufficient capital is sometimes difficult due to either ability to obtain loans or due to high interest rates. Some operators do not have sufficient access to capital and need support from external funding. Interest rates are sometimes high at ~12-14% making financing vehicles expensive. As per local financing regulations, the PTO are required to make some down payments (ranging from 20% - 30%) to spread the payments rather than all upon delivery. While some OEMs are able to fund or support fleet procurement, in some cases, they too are facing challenges accessing sufficient capital to provide the initial down payments, especially the Cooperative operators.

3. Electric Bus Market Ecosystem

3.1. Overview of Electric Bus Industry

3.1.1. The electric bus industry

Zero Emission Buses (ZEB) and in particular BEB sector has seen significant interest and increased rate of deployment compared to alternative zero emission technology such as Hydrogen fuel cell. This is primarily due to easier to deploy, more readily available products and support more mature despite the operational challenges of range anxiety and scalability.

The electric bus industry shares many synergies with the rail industry and as the e-bus industry develops and matures, some players are moving into or expanding their e-mobility solutions. At the primary level, the ecosystem consists of suppliers, infrastructure, finance and consumers. Within each segment of the ecosystem are sub-levels which require aligned strategies and develop synergies.

The vehicle supplier market consists of more than 100 manufacturers globally. These manufactures either a complete bus (Completely Built Up (CBU)) or just the chassis or body. The complete vehicle market consists of the traditional global OEMs (Mercedes, MAN, Volvo and Scania) while smaller tier two OEMs have adapted or developed their products to be zero emission. Small and bespoke companies are trying to enter and disrupt the market and with mixed success for example Arrival, a UK based company, is a new start up with a fresh approach to electric vehicles but recently scaled back its development.

China leads global production and has achieved economies of scale with Yutong and BYD having delivered over 100,000 units between them, yet <3% of those were to Europe. The major OEMs of Mercedes and MAN have been progressing at a slower rate than other OEMs such as Solaris (CAF) and VDL who have a larger market share in Europe, and in comparison, ~2000 eBus were sold in 2021 by European brand OEMs.

In addition to the core bus manufacturers, the industry also includes companies specialising in the propulsion and energy storage systems. This are either supplied directly to chassis manufacturers (e.g. Voith) or can be offered as retrofit to existing vehicles to convert them from conventional fuel to zero emission (e.g. Equipmake for BEB and Riccardo for hydrogen fuel cell).

3.1.2. Power and charging infrastructure providers

Availability of power, especially green energy, is a key requisite to ensure low/no emissions of the ‘well to wheel’ cycle. Otherwise, the vehicles may be zero emission at the tailpipe but essentially, they remain fossil fuelled due to the power generation. This requires involvement and coordination at the macro ecosystem level. Power generation and provision of charging

equipment are typically operated by different companies although the equipment provided for generation, distribution and charging are often from the same OEM, such as but not limited to, Siemens, GE and ABB-Hitachi etc. In some countries, power generation companies are entering the e-bus market as a vertical supplier or through consortiums to deliver solutions to operators, including moving towards more localised production and distribution of power for grid and off-grid based power meaning a shift in market dynamics in the supply and value chain.

On the other hand, battery technology is evolving with achievements in higher energy density. Different types of batteries exist but with mixed results and market adaption. The key parameter for any electric vehicle is energy consumption measured in kWh/km. It is predominantly connected to the vehicle's weight which is the key concern due to existing regulation. The race to reduce the total mass of the batteries to gain the highest energy density is high with OEMs offering modular battery configurations as well as the rate of development being advancing.

The charging market is large and diverse between AC and DC charging equipment and from slow to ultra-fast charging (50->500kWh) and in all formats from plug-in CCS dispensers to pantograph hoods and pantograph masts.

Figure 5. Types of charging equipment (Source: ABB-Hitachi Grid e-Motion fleet presentation)

Despite the large market size and value, the market in developed markets is dominated by a limited number of companies. Siemens and ABB-Hitachi are two of these and were selected for preliminary market engagement. The approach by vehicle OEMs varies with some partnering with specific charging equipment suppliers, others agnostic while some vehicle OEMs produce their own. This slightly distorts the market for analysis of volume and sales as BYD is one of the leaders in sales and prefers to supply its own chargers.

The need for charging and the potential for a larger market of private operators outside of public transport is generating interest outside of the mainstream charging equipment providers. Traditional fossil fuel companies (BP and Shell etc) are joining the effort to decarbonise and move into electrical charging systems and infrastructure.

Additionally, power generation companies have diversified into providing more downstream services. This ensures the retain of market share but also able to develop their core expertise as well as opportunities in the value chain to generate, distribute and manage to charge equipment as part of the new business models emerging.

As part of the roadmap to decarbonisation, more renewable and off-grid power generation is required to provide the necessary 'green' power required for charging BEB. This opportunity is also stimulating interest for clean and renewable energy with new suppliers emerging.

In order to maximise the opportunity and value chain, a UK based bus manufacturer (Wrightbus) includes a power and hydrogen producer in its parent company portfolio along with a finance company in order to offer the Electric Transport as a Service (ETaaS) solution.

3.1.3. Financing

Funding is often the most critical element as most segments can be managed or mitigated to adapt the service or manage power yet, without adequate funding, full fleet adaption will not be possible due to the price premium and operation disparity compared to conventional fuel vehicles.

Financial institutions are keen to invest in renewable energy and green transportation as they seek to diversify their portfolio. Finance and funding for new vehicles and the associated charging systems are being provided by a range of sources. Governments have created dedicated initiatives and funds for supporting procurement of zero emission buses (FAME II (India), ZEBRA (UK), FTA Low-No grants (USA) etc). Banks and private financiers are keen to be involved and support the development as they transition towards more sustainable developments and are developing more innovative business models which seek to replicate those of the rail and aviation industry through establishing longer financing packages and leasing business.

Banks including HSBC and Natwest (UK) along with Commonwealth bank and Macquarie bank (Australia) are just some which are actively seeking investments in electric public transportation. HSBC has recently just agreed funding of up to £60mn to the UK Yutong dealership to allow them to support PTO/PTAs transition to electric vehicles. [2]

The charging equipment suppliers have access to capital and in some cases are willing or able to explore financing projects such as Siemens Financial Services. These new business models and the change in the paradigm of the ecosystem with key players moving from their traditional and core competencies or markets into other market areas, enable them to capture more of the value chain. These have been done through acquisition or through developing synergies and partnerships to offer new products or services. Examples include power generation and Distribution System Operators (DSO) entering the marketing to provide their generated power as well as the necessary equipment; bus, the battery and charging equipment either individually or collectively as a turnkey package. One such example is Enel X who are gaining some success in the market.

In Indonesia, there has been an increase in interest from local companies getting involved through partnerships with international firms. This includes companies attempting to design and build

[2] https://www.sustainable-bus.com/news/pelican-funding-hsbc-yutong/

their own electric vehicles while others collaborate with existing bus OEMs. BYD and PT VKTR Teknologi Mobilitas (VKTR) have signed an agreement for developing the electric vehicle industry ecosystem in Indonesia.

3.2. E-Bus Market Ecosystem – Worldwide

3.2.1. E-Bus industry overview

The e-bus industry is estimated to be worth $40bn with the e-bus charging infrastructure market valued at USD 1.68 Billion in 2021, and it is expected to reach USD 6.63 Billion by 2027, registering a CAGR of around 16.4% during the forecast period (2022–2027).

Despite the global pandemic, the global Electric Bus Market was around 170,000 units in 2020. The global market size is expected to gain momentum by reaching around 544,000 units by 2028, exhibiting a CAGR of 16% during the forecast period from 2021-2028.[3] Asia Pacific remains the largest e-bus market in the world and comprises some of the fastest developing and developed economies in the world. The growth in the region can be attributed to the dominance of the Chinese market and presence of leading OEMs such as BYD, Yutong and Zhongtong in the country, resulting in exponential growth of the market while exports of BYD and Yutong to the UK, Europe, Americas and Australia continue through more partnerships and confidence by Operators. European and American OEMs are slowly growing their sales volumes but are significantly smaller and more cautious in their product development.

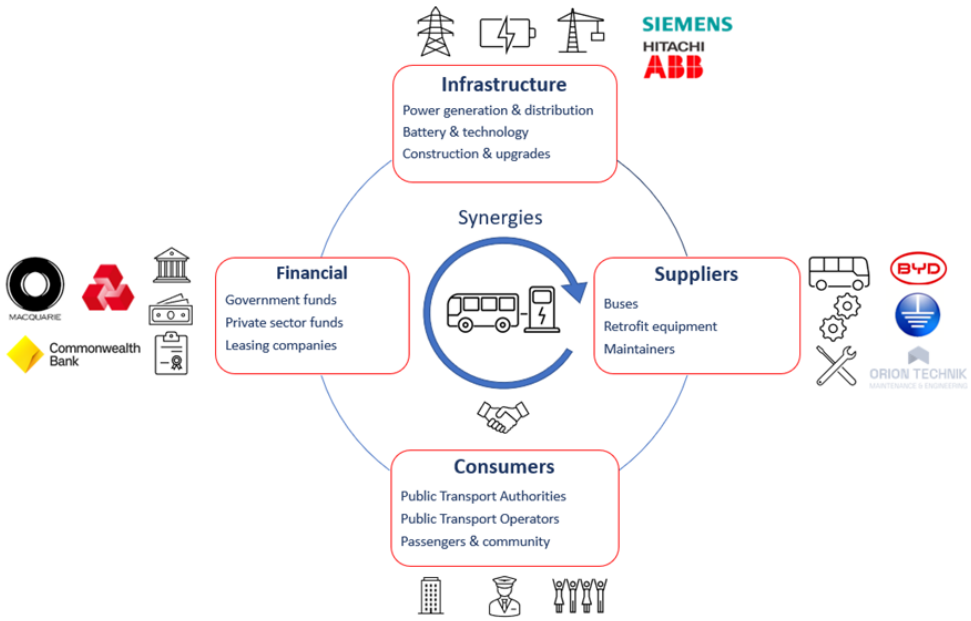

Figure 6. E-bus market ecosystem

[3] https://www.fortunebusinessinsights.com/electric-bus-market-102021

China leads the way for the volume of electric vehicles deployed. Subsequently, Chinese brands have developed more products and gained more experience in designing and building battery electric buses. Yutong and BYD are the leading OEMs with the latter, having first established itself as a battery manufacturer.

Table 2. E-bus market share globally

OEM	E-Bus registration 2021	E-Bus registration 2020	Trend registration 2021-2020 (%)	Market share 2021 (%)	Market share 2020 (%)	Trend market share 2021-20 (%)
Solaris	390	415	-6.3	11.9	18.8	-6.9
BYD-ADL	375	190	+97.4	11.4	8.6	-2.8
Mercedes	333	99	+236.4	10.1	4.5	+5.6
Yutong	303	164	+84.4	9.2	7.4	+1.8
Iveco Bus	274	114	+140.4	8.3	5.2	+3.1
BYD	257	424	-39.4	7.8	19.2	-11.4
Volvo Buses	211	217	-2.8	6.4	9.8	-3.4
Irizar	201	24	+737.5	6.1	1.1	+5
VDL	178	127	+40.2	5.4	5.7	-0.3
MAN	134	25	+43.6	4.1	1.1	+3
EBusco	132	109	+21.1	4	4.9	-0.9

Source: : https://www.sustainable-bus.com/news/eu-electric-bus-market-2021/

BYD and Yutong lead with overall volumes. They offer products of different quality standards for the intended market. These are defined as either 'The China standard' or 'The European standard'. Those built to the 'China standard' use all Chinese products for the batteries, motors, and control systems and are not certified to European homologations standards. Due to this they are more economical and normally exported to developing countries or those with less rigorous standards for vehicle technical regulations. Those built to the 'European standard' are largely intended to the European market as well as other developed markets including Australia and parts of Asia such as Hong Kong and Singapore. These use major OEM systems and sub-systems for the steering, suspension as well as batteries, motors, and control systems. Consequently, these are more expensive. A 12m low floor city bus ranges between £350,000-400,000 (subject to specifications) compared to the China standard vehicle which can be £100,000-150,000 cheaper.

In comparison, a purpose-built 8-9m bus (not a van conversion) cost £250,000-300,000 and have a much smaller battery and potential operating range of 100-150km. Electric minibusses adapted from vans e.g. Mercedes Sprinter have a lower initial purchase price with 100-115kWh battery packs. Other markets outside of Europe produce 8-9m more economically such as Karsan and

Temsa. The price for all vehicles is subject to specifications and battery size, of which the battery typically costs up to 50% of the purchase price.

European OEM 18m articulated low floor electric buses cost between €600,000-800,000 due to the additional battery size but also, due to the low volume compared to other types (10-12m). High floor BRT 18m buses are available in the market from a limited number of suppliers predominantly Chinese and due to the lack of demand in European and other developed target markets, these are all only built to Chinese standard.

BYD are utilising their experience of a proven chassis and electric propulsion system and partnering with bodybuilders in some territories which allows them to tailor their products for the intended markets, whether UK, Europe, India or Australia providing appropriately priced products and access to established aftersales support. In the UK, they are the leading e-bus OEM with their partnership with Alexander Dennis Limited (ADL). Other OEMs include VDL, Solaris and Volvo who have good market share in their respective core markets. The traditional tier one OEMs of Mercedes and MAN have been slow to market with their products but are now gaining sales in 2022 and as they are all built in Europe, are comparably priced with no real competitive advantage to BYD or Yutong.

Smaller and more niche OEMs include Wrightbus, eBusco and Irizar manufacture products in smaller volumes. These have growing market share in home markets, while also venturing into new markets. Additionally, others include Switch (formerly Optare) and Caetano with lower production volumes of their smaller range of core products.

In addition to the above, more economical models are being introduced by Karsan and Temsa from Turkey providing a lower entry price for some European and developing nations.

In Russia, Kamaz had deployed Europe's largest fleet with about 800 in operation in Moscow. Kamaz has low export sales outside of Russia except to some neighboring countries.

In the US, the market uptake has been slow per capita/fleet size. Proterra with other major OEM subsidiaries i.e., Nova (Volvo) has strong domestic sales due to regulatory requirements for localisation and being able to achieve strict performance requirements specifically for the North America market which differ from European and other global markets.

3.2.2. Retrofitting

Retrofitting is seen as a technically feasible solution to contribute to transition to zero emission as an alternative to purchasing new electric vehicles which whilst being higher capital cost, there are also long lead times for some suppliers. With finances being strained during post-covid recovery, retrofitting could potentially offer a cost-effective solution for some PTO/ PTA, especially those which allow vehicles to operate for longer lifecycle and for lower duty cycles as the battery size can be smaller and therefore more economical making the whole transition more cost and time effective. However, there are limitations and a detailed analysis of the business case is being

performed as part of this study. The price of the retrofit solution depends primarily on the size of the battery pack. Prices vary and range between £150,000-250,000 depending on battery and motors. The technology is relatively comparable to the electrical system on a new vehicle but the overall price difference is with the bus itself and whether the operator has sufficient financial resources to replace a traditional vehicle with an electric vehicle earlier than initially planned.

Companies specialising in the battery electric propulsion and energy storage systems vary in size from global players (e.g., Voith) to more bespoke Engineering companies that have developed their own solutions such as Equipmake (UK), Magtec (UK) Kleanbus (UK) and Pepper Motion (e-trofit (Germany)).

In some countries, regulation has yet to be amended to allow retrofitted vehicles to be eligible for the same financial incentives to new vehicles. Adaption has also been slower due to potential concern from some operators regarding overall warranty and comparable performance to ensure sufficient return on investment.

One significant advantage of retrofitting over a full electric vehicle is the ability to localise quicker. Components can be transported more efficiently than a whole vehicle or even assembled and fitted to vehicles in-country reducing the overall cost of transportation and carbon footprint, the latter being the overall objective of true decarbonisation.

In addition to battery electric, hydrogen fuel cell electric retrofit solutions are being developed for heavy duty cycle vehicles by Riccardo (UK).

3.2.3. Market penetration and deployment

Many major cities are transitioning their fleet to zero emission. The general approach are small scale trials to evaluate technology and products. Once proven, or the level of confidence is sufficient, operators are transitioning routes one by one or introducing ZEB in parallel to existing ICE fleets for service resilience. Many of the decisions are risk-based approach, especially when the commercial risk of farebox revenue is with the operator.

Initial trials are often small scale with less than 5 vehicles. As technology matures and confidence grows with operators, albeit political pressures and objectives, serial introduction of vehicles has commenced. Many major cities or PTA's have implemented policies for new vehicle procurement. Growth is being driven by key policies. One of the leaders is the Scandinavian region where 75% of all new vehicles registered to date in 2022 have been zero emission (308 of 408 registered).[4]

Framework agreements based on performance specifications are becoming increasingly popular. There are two recent examples of frameworks for zero emission buses (JIVE 2 in Europe) although this is not a new concept as examples exist in Australia whereby the PTA consolidates the operator's requirements to secure volume purchase discounts. Recently in Germany, a PTO/PTA

[4] https://www.sustainable-bus.com/news/denmark-three-quarters-buses-electric/

(Deutsche Bahn Bus) has created their own framework agreements with OEMs to procure a fixed number of buses initially with options for more later. This approach could work for Indonesia with Transjakarta or another body acting as the procurement authority.

Scaling up is still constrained by available grid-based power but in most cases, is commercially driven decisions. The initial purchase price of an electric vehicles is still significantly more although the TCO is becoming more comparable. To reduce the initial capex of the vehicles, battery leasing or whole vehicle leasing options are becoming more widely available. Batteries can be leased for up to 15 years to reduce the depreciation costs of the vehicle and thus lower the operating costs with examples in the UK from leading groups such as FirstGroup.

Battery performance, the end of life of the battery and how to best manage the environmental impacts are still relatively unknown elements of decarbonisation of vehicles. As existing vehicles approach the first life of the batteries of 5-8 years (depending on battery chemistry), operators are now preparing for the challenge. The replacement point is relatively unknown due to lack of empirical data due to varying duty cycles and other environmental factors, state of charge defines the replacement milestone limiting detailed planning for replacement. Managing the end of life of the battery is becoming an important decision factor during fleet procurement. Some bus suppliers (Switch and Alexander Dennis) have included options to offer the battery as a separate component of the bus or the battery as a service (BaaS) whereby the vehicle is not retired from service with just the battery changed, like with current ICE vehicle major units (engine, gearbox etc). These firms redeploy the battery either for alternative purposes and low demand or back-up power supplies or can use them for depot-based energy storage when renewable energy is used for charging the fleet which needs to be stored before being able to be utilised for charging the fleet.

3.2.4. Green funding

Within the ecosystem, funds are being created from Governments and International development banks. In these, private investors are willing to also participate to fund zero emission assets as they seek to develop more sustainable portfolios. In some cases, this can include transitional vehicles such as low-no emission and retrofit technology vehicles.

Operators with low access to capital sometime rely on financiers who can provide options such as Build Own & Maintain (BOM) models or infrastructure leasing at a $/kW cost. In very few markets, OEMs form consortiums but due to the risk of operations, they prefer to sell and maintain rather than directly operate. Many of the financiers in the market are evolving into turnkey solution providers to provide operators with a seamless service. As the interest and rate of adoption of zero emission transport increases, the number of players in this market is increasing as investors seek to develop financing and/or leasing companies as a sort of Rolling stock leasing company which is popular with other long-life transport assets such as planes and trains.

Those who have shown an interest in investing in green technology and establishing green funds include large institutional investors such as Standard Chartered, Macquarie and Commonwealth Bank while other banks in other global markets (Natwest, UK) have provided funding for fleet and depot equipment.

For foreign investment, there is an interest from the initial market engagement. These new 'cleantech' organisations (for example VEMO Mexico) seek to invest in new initiatives to support the decarbonisation of large fleets. In order to provide the necessary assurances for investors, appropriate controls and mechanisms would need to be in place to protect the investment and stimulate further interest in the project due to the level of subsidy required as a result of low farebox revenue, such as an escrow account from Transjakarta to the finance company.

Some of the local players have initiated discussions with financing institutes. VKTR has commenced engagement with 3-4 financing institutions (one of them is Standard Chartered), the financing institution still needs a partner to distribute the fund, they need a multi-finance and leasing company.

3.3. E-Bus Market Ecosystem – Indonesia & Jakarta

3.3.1. Domestic Players in E-Bus Ecosystem

E-bus industry has started to gain momentum in Indonesia to support Government's vision to reduce climate change impacts and achieve net zero emission by 2060. There are already players identified in this industry both as OEMs or Authorised OEM Distributor.

PT. Mobil Anak Bangsa Indonesia (MABI) has already produced electric bus for mainly mining companies ranging from 8m – 12m buses. The demand for electric bus quite high in mining industry because those companies already understand the carbon trading impact on the operation. MABI's products have also been operated on trial basis in Jakarta as well as in Semarang. The production capacity is still limited and would need financing support for bulk orders. The products available are 12m bus with 315kWh battery and 8m bus with 137.7 kWh battery capacity.

The capability to develop products locally can be demonstrated although the technical standards build quality would need to be enhanced and the financial capability developed, especially if the power and propulsion systems are to use European components and control systems for compliance to the international standards as this will required the local company to purchase the equipment in advance to the sale of the end product to the operator. They would also need considerable Research and Development to ensure reliability and durability of the products, especially with Finite Analysis of the vehicle superstructure when heavy loads such as batteries are located in high centre of gravity positions such as on the roof.

VKTR is the sole local partner/authorised distributor (APM) of BYD e-buses in Indonesia, which means bus operators cannot purchase BYD products directly but only through VKTR. Similarly, VKTR can only sell BYD products and cannot sell any e-buses from other OEMs. Additionally, VKTR has also signed an agreement with other players namely Equipmake from UK for retrofitting ICE buses, GAC Group and APM Group for e-bus components and also an agreement with the current charging company. Furthermore, VKTR has the flexibility to source to other OEMs for products that are not available in BYD such as Switch Mobility for 10m bus and GAC Group for microbus. As for high-deck single e-bus, it is still in the process where BYD will be manufacturing the e-bus and the body will be produced by Laksana, which will be the first high-deck e-bus in the world. Due to this model, VKTR can offer a wide range of products that would suit Transjakarta requirements.

PT Indotruck Utama is the sole local partner/authorised distributor (APM) of Volvo trucks, buses and coaches and construction equipment in Indonesia. They are a subsidiary of Indomobil Group, one of the largest automotive distributor and manufacturer in Indonesia. Volvo are currently assessing the feasibility to adapt the Volvo BZL product for Indonesia and to be competitive with other e-bus manufacturers, initially plan to import the chassis and partner with a local body manufacturer to complete the product such as Laksana or Gemilang. This would be available in 10 and 12m variants and Volvo are working on a e-coach chassis which could be designed for high-floor BRT bus body and again available in 10 and 12m variants.

In terms of financing, VKTR also has same barrier where it does not have the capacity to procure in bulks order without funding support. A discussion with financing institution has also been held and a multi-finance or leasing company is required to distribute the funds.

Since battery is the biggest part of an e-bus, a battery holding company, Indonesia Battery Corporation (IBC), has been set up by the government that consists of SOE companies such as Mining Industry Indonesia (Mind ID), Aneka Tambang (Antam), Pertamina and PLN. The role of this holding company is mainly to produce and streamline the EV battery ecosystem in order to make it more accessible and affordable for the consumers.

3.3.2. Transjakarta Electrification Procurement Process

In order to identify the role, influence, and interest of each industry player on the procurement process of the Transjakarta electrification, the analysis of the procurement process related to the electrification of Transjakarta needs to be performed. Transjakarta is a Regional-Owned Enterprise (ROE), hence the procurement process regarding assets operated under Transjakarta services is regulated under a set of regulations namely Governor Regulation 50/2019 on the guidance for goods/services procurement for Regional Owned Enterprises (ROE, "*Badan Usaha Milik Daerah*"/ BUMD). Furthermore, The Governor of Jakarta delegates the Jakarta Province Goods/ Services Procurement Service Agency (*Badan Pelayanan Pengadaan Barang dan Jasa*/ BPPBJ) to manage local e-catalogue for bus operator procurement purposes under the OK-OTRIP programme (now Jak Lingko) through the Governor Regulation 98/2018.

Currently, Transjakarta still perform a gross-cost contract scheme with the bus operators through a quota system. This shows the high interest and influence of bus operators on the current procurement process because they have direct involvement with Transjakarta. Jakarta Transport Agency establishes the quota for the bus operators through a certain process. Accordingly, only operators that have quota could bid the services through the e-catalogue. In order to place a bid for Transjakarta services, private bus operators should obtain support/proof from bank (financing institutions) for purchasing the fleets; get support from APMs (“*Agen Pemegang Merk*”/ authorised OEM distributors) & carrosserie (the carriage body of the fleets); and provide performance bond (*jaminan pelaksanaan*). Since the current electric bus run under the Transjakarta services imported in completely built-up (CBU), the support from e-bus body’s companies (carrosserie) is not needed. After operators bidding the tenders, BPPBJ, Jakarta Transport Agency, and Transjakarta will select the operators and negotiate the cost per kilometre proposed by the operators.

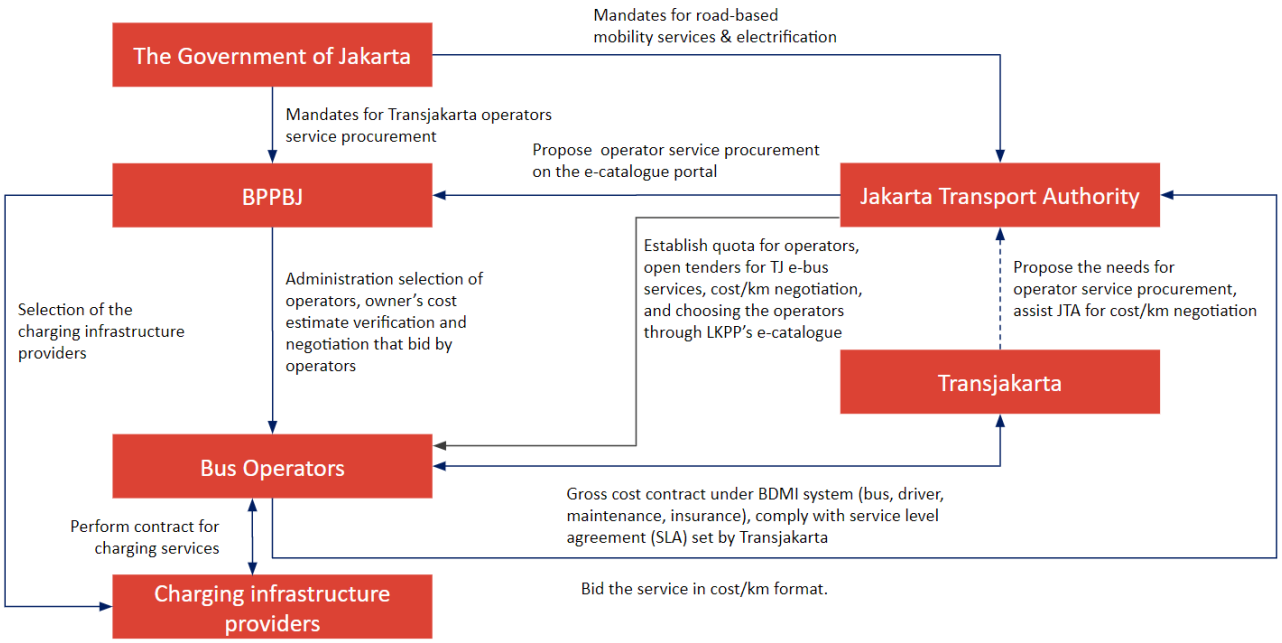

Figure 7. Public procurement process for Transjakarta electrification

The difference in procurement process between conventional bus and electric bus is that the latter requires additional contract between the bus operators and charging infrastructure providers for the overnight charging at the depots owned by the operators. The selection of charging infrastructure providers is also organised by BPPBJ through the e-catalogue. It is to be noted that Transjakarta do not have direct involvement on the charging infrastructure providers.

Based on the analysis of the current procurement process related to Transjakarta electrification, there are four industry sectors that have high involvement or influence on the electrification: bus operators, financing institutions, OEMs/APMs, and charging infrastructure providers. For the electrification, the bus operators perform two types of contracts simultaneously; with Transjakarta and with charging infrastructure providers.

In Indonesia, the level of funding and programs in operation are small. This is in part due to the low level of implementation of zero emission buses but also around the structure and framework of the management of funds and provision of finance for funds. Whilst green funding in other countries is starting to gain momentum due to pressure of climate change, the same practice is in very initial stage in Indonesia. According to market consultation with some local financing institutions, green funding is not preferred yet for public transport electrification since the regulations and expected benefits (lower interest rate) are still minimal. In fact, it would require more efforts to satisfy the due diligence requirements yet the interest rate is the same as conventional funding mechanism.

In terms of inclusivity, it is evident that the procurement process of Transjakarta is open to all, which means it is transparent and everyone from every background can participate. The procurement process is merit based hence there is no discrimination of any kind and it is based on the performance of the tenderers only.

4. Technical Considerations of Transjakarta Electrification

When developing the technical specifications, there needs to be a holistic view of the technical requirements and possible constraints. Assessing a vehicle individually for TCO and comparing to an ICE equivalent is not appropriate. The overall cost comparison should be performed on a route level basis. This is because the bus might be able to achieve a certain service performance but if the charging intervals are long, more vehicles might be required to deliver the same level of service and thus, the route costs might be significantly more.

The implementation profile for transition considers both fleet replacement as well as fleet refurbishment through retrofitting e-Bus technology solutions to the existing fleet.

The key technical considerations are to define the charging strategy (depot, terminal to terminal or combination of depot and opportunity), battery sizing and charging method (plug-in or pantograph). These three all have equal weighting and importance and varying one dimension has a direct impact on the other i.e., change the charging strategy from depot to opportunity can allow smaller batteries but requires more charging equipment. In comparison, depot based only would require larger batteries and could require a higher replacement fleet ratio if longer charging is required.

The roadmap for implementation should consider the timing of fleet replacement to align with the installation and commissioning of equipment.

Additionally, if retrofitting is considered as part of the strategy, the operators will need to ensure uptime of the fleet while retrofitting the existing fleet i.e., maintaining a float fleet for operational cover. The purpose of the extensive desktop research and preliminary market engagement were to develop more comprehensive understanding of the technical and commercial aspects for the transition to zero emission fleet.

The initial preliminary analysis of the network and feasibility of electrification is assuming a combination of depot based and opportunity charging. This combination is required to provide the current service design.

The study has included an assessment of the year one potential operational range based on battery condition and depth of discharge while also assuming the battery performance at later year to assess the suitability of the vehicle types for the service specification. The analysis is based on desktop analysis and considers a constant performance and has not been modelled for seasonal variations nor route specific for other potential factors such as topography and other factors.

The energy modelling considers overnight and some opportunity charging. Detailed site-specific energy modelling has not been completed to assess the peak and average local requirements. Preliminary assessments identify that there is sufficient on-grid charging capacity.

Other dependences and considerations are facilities upgrades while ensuring uninterrupted services delivery and the training/capability building and knowledge transfer of staff. This can range from operational planning (bus and staff rostering) to engineering inspections and repairs.

Furthermore, the technical considerations for the market research include:

- The procurement lead time is long and complex with the various stakeholders against a mandate to electrify by 2030. The definition of technical specifications will need to consider these challenges and focus on readily available vehicles and features by 2030.
- Program planning needs to ensure all risks, issues and assumptions are clear to enable the work plans to be developed to the necessary technical detail.
- The standards and specifications need to be defined at the early outset to ensure compatibility and interoperability of the fleet, data systems and charging equipment communication protocols. The fleet specifications and tendering requirements will need to consider legal and regulatory compliance (where applicable) but defining a common standard for compliance that does not restrict the product availability needs to be considered.
- Operational duty cycles to ensure the bus is able to operate the service specification. An assessment of the battery performance and seasonal variations along with the likely depth of discharge later in the vehicle life is essential to ensure that whilst the vehicle might have the theoretical range in year 1, it might not have the same range in later years. This might require a change to the service design or fleet utilisation.
- Battery size versus range is a common dilemma. Electric buses need high battery capacity to perform like their ICE counterpart buses but batteries are heavy and buses are governed by maximum axle weights. The dilemma is more batteries (more weight) and less passengers (revenue) or where to find the ideal compromise.
- The battery technology varies between OEMs and have different characteristics but also risks. A single type of battery technology can be specified but could limit the availability of products.
- Charging power can be provided as either AC or DC and for range of power options with some vehicles able to utilise higher charging than others. This has a direct impact on the type of chargers (DC are typically larger), while faster charging can, in some cases, contribute towards fewer charging stations
- Charging strategy will help manage and mitigate some of the risks associated with range anxiety and battery degradation, as well as form the basis for the fleet procurement, and contribute towards minimising the fleet replacement to as close to 1:1 (electric bus to ICE). Utilising a mix of depot and network-based charging equipment can extend the operational duty of a vehicles. Depot based charging strategies can also consider and prioritise vehicles such as first in/first out or vehicles requiring longer charging time are considered. Likewise, charging strategies can also manage depot power consumption and energy cost to ensure lower operating costs.

- Location of equipment will be important to ensure sufficient access to land for installation and operation of charging equipment. Moreover, the facilities may need additional power which could be from grid or off-grid based power but the ability to install needs to be assessed (planning/development restrictions).
- Service resilience needs to be considered along with the preferred methodology to ensure service continuity in the event of grid- based power interruptions. This can include energy storage systems (batteries) and/or portable power generation which can be powered by conventional fuels or low/no emission technology options.

An integral part of the technical considerations as part of the business plan are energy costs and tariffs. While opportunity charging can reduce the battery size, it can lead to more expensive fast charging equipment which will charge the vehicles during the day, which could be a peak tariff rates compared to overnight depot-based charging. This whole strategy development can be compared to a Rubik cube, where changing one aspect has a direct impact on another. Hence, the market analysis can help the project team to gather the latest trends and information around e-bus industry so that it can be utilised to develop the implementation plan.

5. Findings from Previous Studies on Market Analysis

There have been several studies conducted related to Transjakarta electrification. ITDP completed a study to develop the road map for implementation for BRT and non-BRT e-bus in 2021. The study also included engagements with a few industry players through meetings and workshops. The main goal of market research in that study was to prepare Transjakarta to conduct pilot for 100 e-buses.

Additionally, ITDP also completed a study in developing road map for implementation specifically for electric microbus under the phase 1 of this project (UK PACT) in early 2022. The study was very specific to microbus hence the market research was also revolving around understanding the operations of the microbus and market availability that suits the operations.

Another study that is related to Transjakarta electrification is a study completed by GIZ under C40-CFF where it was specifically aimed at developing a technical feasibility study for piloting e-bus service. Accordingly, the study also did market analysis especially with operators to understand their operation needs against available products in the market and calculating the TCO at route level.

The initial pilot commenced in 2022 and uses BYD K9 12m low entry (non-BRT) buses provided by PT VKTR Teknologi Mobilitas (VKTR) and currently there are 30 e-buses running on the streets of Jakarta servicing passengers. These are the most standardised global product type aligned to those in the Transjakarta fleet.

To fit the gap in the market with available products, there were also 4 e-bus models that have completed their trial runs for 3 months. Three of them were all low entry buses from 3 different OEMs namely Zhongtong, Golden Dragon and Skywell. The last one was from PT MABI (Mobil Anak Bangsa Indonesia) and it was a BRT bus (high entry high deck). There was also 1 electric micro bus that was supposed to conduct trial runs from DFSK Motor Indonesia that has 4.5 meter in length. However, until the report is written the trial run has not commenced yet.

5.1. Findings

The research performed previously identified potential suppliers and partners, provided an assessment of the existing contracting model and regulation and an implementation roadmap including gap analysis of the policy and regulatory requirements to enable cost effective electrification.

Many of the key findings from previous studies remain valid. The policy gaps identified and issues on commercial feasibility of e-bus in Indonesia have yet to be finally resolved, as does the capability of the local operators, both technically and financially to deliver this program of change. Regulation can provide the key enablers to success. Current regulation determines the maximum age, the gross vehicle weight, creates challenges with importing new zero emission vehicles due to

the afore mentioned issues along with taxes and duties which currently do not stimulate the market.

Technically, the major challenges relating to the availability of suitable vehicles, charging infrastructure and the battery capacity remain. The e-bus market remains low in Indonesia, despite Asia being the largest global e-bus market. The knowledge and capability of the Operators is still low to lead the program although the pilot projects are providing real-life tangible lessons which before were not available. Since the pilot phase has only been running for nearly 1 year now, the operators are still learning

Financially, price parity has yet to be demonstrated. Battery Electric Bus (BEB) have a higher initial purchase price compared to Internal Combustion Engine (ICE) equivalent vehicles and Operators have a low availability or access to funding to deliver the transition requirements. Additionally, technical challenges of the operational capability of BEB (operational range and sometimes reduction in passenger carrying capacity due to the extra weight of the bus) compared to the existing ICE fleet means the overall cost per route is significantly higher due to the replacement ratio required which exceeds 1:1 in addition to the premium price over ICE.

Previous studies have combined high level assessments and summary bottom-up assessment through early market engagement to identify the requirements rather than detailed design and solution development.

The initial pilot trials are providing tangible data demonstrating proof of concept and technology. The e-bus pilots that are currently in operation are providing tangible data that should ideally be acquired and analysed further to support the study and decision-making process of implementing large scale e-bus operation under Transjakarta.

The previous studies considered the types of vehicles and types of routes deployed on. The research assessed the vehicles available and the technical specifications. The routes were assessed and grouped, and terminals/ staging areas assessed for feasibility of charging from an operational perspective.

To verify the technology through proof of concept, pre-trial buses were deployed in service for two years and studied with the performance data used to form the basis of the potential capability for the feasibility of the transition.

To transition the full fleet will require a change to the service design and operational deployment. The scheduling of buses to consider battery start of charge and where necessary recharging intervals has not been completed. The planning and scheduling of services considering the new scheduling parameters (duty cycle, vehicle range and state of charge) needs to be completed for optimum efficiency which to date, has been a desktop simulation of calculation and fixed assumptions to provide a perspective on the feasibility as part of the business case.

Previous studies included desktop research and engagement meetings. The engagements enabled more information to be gained on issues and opportunities. OEMs (BYD and MABI) found that whilst the industry was ready, the demand from operators was not sufficient. This was in part due to financial requirements, uncertainties around the contracts while also other regulatory restrictions. Today, the same challenges remain.

The Mikrotrans will be more challenging as the previous study identified that most vehicles are stored at the drivers home due to the absence of depots. This will make charging difficult from an infrastructure installation and operational deployment perspectives.

To summarise, the key points from previous studies are:

1. Regulation regarding gross vehicle weight identified that the current limits of vehicle types, 8,000kg for midi buses and 16,000kg for large buses will restrict the design capabilities of the future fleet. Batteries increase the weight of the bus and therefore to comply with the technical regulations, the batteries either need to be smaller or the passenger carrying capacity needs to be reduced. Neither are practical and regulation needs to be adapted to align with current industry standards and provide the balance of desire of range and capacity. As a comparison, in Europe, to achieve this balance of desire, the maximum gross vehicle weight for buses has been increased by 1,000kg to consider the additional weight of the battery pack.
2. License and permits have not been developed to consider the implementation of zero emission vehicles. The requirements and regulations for importing and registering electric buses is not clearly defined nor easily interpreted. Due to the gap in technical standards aligned to other mature markets, extensive documentation and physical inspections are required to obtain initial certifications. In some cases, the permits are for temporary import licenses and use of the vehicles.
3. Current regulations are based in ICE fleet and traditional modes of operation and contracting model and can impede transition to zero emission fleet. Operator contracting model is fixed and aligned to the age profile of the vehicles and there are issues around the details of the contracting model to implement new technology vehicles alongside existing ICE as well as vehicle ownership/transfer if not aligned to contract (end of contract novation of assets)
4. Indonesia only allows the use of public transport vehicles up to 10 years old. The life expectancy of vehicles is increasing. Accessibility requirements have necessitated that all vehicles have accessibility features and with the introduction of alternative zero emission propulsion systems, along with enhanced manufacturing capabilities which extend the durability and reliability of the vehicle, the economic life of a vehicle is being extended beyond traditional lifecycles. Some countries such as Australia still allow vehicles up to 25 years old to operate as long as necessary structural integrity checks are performed.
5. The current business model relies heavily on subsidy to the farebox revenue which impacts the business case but can also increase risk on securing financial assistance for project funding.

6. Vehicle pricing is premium compared to ICE equivalent. There is a need to develop the business model that overcomes high initial prices to ensure Return on Investment (RoI) and acceptable Internal Rate of Return (IRR)
7. Technology choices are limited with just plug-in charging used without smart charging software to study optimisation. There is a need for development of charging infrastructure across the city with network of opportunity charging essential to complement depot based and enable more efficient operations

5.2. Gap Analysis

The desktop study enabled the collection of data and information for vehicle options, battery sizes and operational performance. Engagement with stakeholders, both operators and manufacturers, provided further detail on the level of interest and perceived barriers to implementation.

The key gaps included:

- Policy and regulation around supporting introduction of electric vehicles, especially for Transjakarta electrification, is not clear. There needs to be a comprehensive and holistic analysis to enable a smooth transition to zero emission buses.
- Availability of actual power or provision of power at key locations which can only be verified by onsite assessments and coordination with relevant stakeholders
- Fleet options and availability within the required implementation timeframe. Leadtime is assumed to be 6-9 months. The actual availability of build slots, delivery, local registration and operational readiness is likely to be longer. There will need to be an intense communication with the OEMs to obtain the latest information on the lead time and their production capacity once Transjakarta has come to a decision.
- The actual number of vehicles is assumed based on desktop exercise rather than detailed scheduling. Without confirmation of charging strategy and availability of opportunity charging, the assumed fleet requirements will be higher to deliver the same level of service to allow for split shifts to enable charging due to lack of range. An alignment with planning and scheduling will need to be performed to allow a more accurate estimation.
- Funding and financing will need to be further detailed along with alignment to the contracting model to determine the commercial feasibility and to what level the funding gap needs to be increased
- Design of depots and implementation of depot charging equipment. Site surveys will need to be completed and options for charging scenarios developed. The same will need to be conducted for terminals and other additional locations where charging equipment are planned to be located.

6. Preliminary Market Consultations

6.1. Preliminary Market Consultations Framework

The objective of the preliminary market engagement was to further test the working assumptions and hypotheses for the feasibility of the fleet transition. It sought to further detail the information gained from the desktop research into the ecosystem, regulations and identify the key stakeholders.

The selection of industry players to engage with was derived from triangulation of industry knowledge of the team, primary information sources (e.g. Transjakarta) and secondary research through desktop research.

The framework developed evaluated the identified suppliers across a multi-dimensional criteria of market position, willingness to participate and available products and services.

The e-bus ecosystem consists of too many suppliers to engage with all of them. The purpose of the framework was to shortlist the leading players per sector as well as those either already involved with Transjakarta or those whom might be willing to participate. Not all the suppliers identified in the framework were willing to participate as Asia or Indonesia is not part of their current strategic plans (for example Heliox, a provider of charging equipment).

From the framework, a set of questions was prepared and meeting held. Most were online for the international suppliers while domestic suppliers were met in person by the ITDP team.

Initial online meetings were held and all who participated stated a desire to continue the engagement process as more information became available through the study so they could internally review their products and services while also better prepare for the project initiation stages, especially given the ambitious timelines to complete the project.

Funding of the vehicles and charging equipment is key concern, especially with smaller operators. Defining who will procure and how the funding mechanism will be developed and managed is essential to stimulate the necessary demand. Hence, engagements with financiers both local and international were also held to understand the trends and challenges. These inputs were then be utilised by the project team to formulate alternative business models and financing schemes in order to help accelerate the transition to zero emission buses.

6.2. Industry Players Being Consulted

There were many industry players that were engaged during this phase and were categorised as below:

1. **Vehicles OEMs**
    a. Volvo (KB) - Existing ICE supplier, interested to develop eBus product
    b. PT Mobil Anak Bangsa Indonesia (MABI)

c. Yutong (KB) - Possible new supplier for eBus
d. Alexander Dennis (KB) - Interested to explore possible eBus development
e. Switch (KB) - Providing trial eBus
f. PT VKTR Teknologi Mobilitas (VKTR)

2. **Charging equipment OEMs**
   a. ABB-Hitachi (KB)
   b. Siemens (KB)

3. **Bus Operators**
   a. Kopaja (Medium Bus Operator)
   b. KWK (Micro Bus Operator)

4. **Financing Institutions**
   a. UK Export Finance (UKEF)
   b. Bank BNI
   c. Bank BSI
   d. Bank Mandiri
   e. PT. SMI
   f. Asian Development Bank (ADB)

5. **Retrofitting Companies**
   a. Spora EV

6. **Others**
   a. Electromotiv

All the industry players were consulted either through online or physical meeting where it allows.

6.3. Results from Preliminary Market Consultations

The preliminary market consultations provided a good opportunity to engage with the key players in the respective segments of the ecosystem to provide more information on the project and for all stakeholders to better understand the priorities and objectives, to enable the market to prepare for involvement and interest in the future procurement process and review the technical considerations. Additionally, the engagements would also explore the willingness to participate in further development within Indonesia to enhance the localisation of content.

Overall, the **market is generally interested** and welcomed the engagement program to provide information on the status and for them to explain their products and services.

6.3.1. Vehicles

The eBus market is growing as demand levels increase. Yutong and BYD are the global leaders in sales of electric buses while the European OEMs are observing more interest.

Yutong and BYD have managed to achieve economies of scale from about 10 years of production and European certification which allows them to gradually grow their international customers. BYD first introduced electric buses in Europe in 2013 in Amsterdam and in 2016 in London and are more competitive on pricing compared to European OEMs in Europe.

As demand grow, so has the lead times for deliveries. This will have an impact on achieving the implementation profile. OEMs which have multiple manufacturing locations can take advantage of managing supply and demand. Moreover, International Trade Agreements such as AIFTA (Asean-India) can lower the vehicle unit cost as the **import tax is lower** at 5% compared to ACFTA (ASEAN-China) where the tax rate is 40%. VKTR/BYD have been able to take advantage of this and import electric chassis from India more competitively than from Chinese or European factories.

The fleet requirements are defined by low floor non-BRT and high floor BRT as well as micro bus. Through market awareness, desktop research and market engagement, it was confirmed that the low floor non-BRT vehicle market has many potential vehicle products for the majority of the requirements (9-12m) with more options and shorter lead times.

However, the options for high-floor [electric] BRT buses are limited as most European OEM build low-floor design configuration vehicles based on market demand. There are some early examples of high-floor BRT being delivered by Yutong and BYD for the South America market. These include the BYD K12A specifically developed for Bogota's TransMilenio BRT system as well as another example built in partnership with Brazilian body manufacturer Marcopolo.

BYD's strategy is to develop a product to replace the existing 18m and 24m ICE buses and these could be suitable for Transjakarta. This vehicle only has a range of up to 240km which does not provide sufficient range for the Transjakarta network as a direct replacement but could be feasible. Yutong has also developed a bespoke high floor electric 18m BRT bus for Mexico BRT which they claim can operate up to 330km.

Both of these vehicles have been developed for the specific South American BRT markets which have high volumes of vehicles. It was suggested that there **could be interest to further develop** these products specifically for Jakarta which is a righthand drive (RHD) country if there was **sufficient demand for units. Other manufacturers are interested in the project (Volvo) but are less** willing to develop new products, while the design and development of a locally produced body on a European chassis would impact delivery timelines. However, they are **evaluating how to value engineer** their electric BZL chassis for Indonesian market to meet the technical regulations and be more competitive on pricing.

Partnership with a local body manufacturer is a preferred approach to allow the cost of the vehicle to be more competitive, allow for local content and after sales. VKTR/BYD have an existing partnership with Trisakti for the low-floor but they do not have a design for high floor and they

would look to work with Laksana. Other OEMs have **expressed an interest in local production** or assembly if there was sufficient demand for the products (ADL & Switch).

Bus manufacturers plan for a **lifecycle of 7-8 years for the initial battery pack** and whole vehicle should last significantly longer with good level of maintenance. The OEMs acknowledge the current lifecycle constraints will make business case difficult even with lower priced Chinese vehicles. Volvo are assessing to how adapt their product range to be more competitive.

Retrofitting would require a technical assessment of the bus to prepare the detailed design. As part of the design development, the existing powertrain and associated components would need to be removed, weighed then the design developed. **Weight distribution is important** to ensure structural integrity, comply with vehicle axle mass regulations and the potential battery sizing. The initial vehicle would be custom adapted with all necessary new fixtures and fittings design, fabricated and installed. This is typically time consuming and can take 4-6 weeks although once designed and installed, the subsequent vehicle retrofits would be quicker as the parts would be pre-fabricated and installation guides prepared.

6.3.2. Charging equipment

The market engagement for the charging equipment included the global leaders of ABB-Hitachi and Siemens along with Heliox, another leading European equipment supplier. Heliox have no strategic plans to expand into Indonesia and provided some information but did not want to engage in the full consultation.

The business model of the charging equipment suppliers varies. Yutong are agnostic to suppliers and partner with equipment suppliers (ABB in Qatar and Phihong in UK and Scandanavia) whereas BYD prefer to deploy their own equipment. ABB-Hitachi and Siemens have some good market penetration as the European bus OEM partner with them rather than developing their own chargers like BYD.

ABB-Hitachi merged in 2020 but by the end of 2022, they will separate and form separate companies again. At the time of the consultation, the team involved were Hitachi and provided detailed information on their products and services and case studies which included electrification of large bus depots in Glasgow, Scotland as well as a new BRT system in Brisbane, Australia.

Siemens were also very proactive and interested and their UC range of equipment fulfils all Transjakarta's potential requirements with equipment from 40kw to 800kw ultrafast chargers. They have a portfolio of project case studies including Hamburg, Germany to create the largest electric bus depot in Europe.

The charging OEM prefer packing of equipment and civil works to provide a solution which is commercially competitive and lower risk, i.e. only involves supply of charging equipment and installation upgrade works within the depot rather than outside the boundary.

Both suppliers have developed charging communication protocols and management software to provide operational and asset data to help operators improve management of the fleet and utilise the data for future planning and optimisation.

Depot based CCS plug-in chargers are currently the most common type used. This is due to a number of factors but primarily due to installation is within the confines of the depot and therefore scope of responsibility without extensive involvement with external stakeholders for ease of implementation, they use low power (typically 40-50kWh) to maximise number of vehicles within the permitted peak power allowances by the DNO as well as consuming power at the lower tariff rates, and the operating range are within the battery capability meaning daily single charge is feasible. Slow charging equipment is also the lowest cost equipment solution and can be utilised to charge 2-3 vehicles per night without the need to move the vehicle helping to reduce the TCO. In some parts of Europe though, operators are deploying opportunity charging too with a blend of terminal charging and on-route opportunity charging, although the latter is the less common. As technology and confidence matures, as well as operators increasing the fleet transition, more examples of both depot and terminal fast charging are being trailed and deployed. The cost premium of the vehicle and charging equipment compared to ICE is a key constraint to mass deployment but as volumes increase, prices should reduce further to contribute towards overall TCO parity with traditional fleets

Charging equipment costs of many different elements from the transformer, rectifiers, high-low voltage switchgear, cabling and then the actual charging interface equipment (dispenser/pantograph etc).

Generally, the largest cost is for grid connections and upgrades, the transformer and other modifications to enable the installation. The price of charging equipment can be small in comparison and is reducing as the market mature and more options become available. The different business models emerging also bundle the cost of the charging equipment into an overall operating cost which help reduce the initial upfront costs although may end up costing more overall. Depot based CCS plug-in chargers are the most cost effective. AC chargers cost less than DC as the power inverter is on the vehicle and now in the charging infrastructure with prices ranging from £5,000-15,000 for AC and £25,000-40,000 for DC chargers. The power rating and volume of chargers directly affect the costs and these prices can vary dependent on brand and whether additional software and cables are required etc. In comparison, a pantograph mast with associated equipment can be £150,000-300,000 depending on power rating and type of interface connections. The charging hood (pantograph up) can be much lower at £3,000-5000 although additional infrastructure is required but can be distributed to more charging points enabling a lower price per charging point.

6.3.3. Bus Operators

Public bus operators in Jakarta have vary depending upon bus size, which includes microbus, medium bus, and large bus. In Jakarta, cooperatives become bus operators, for instance Koperasi Wahana Kalpika as one of microbus operators and Koperasi Angkutan Jakarta is one of the operators for medium buses.

The nature of bus operators poses a major challenge to the financial sector since it is based on a cooperative system, not a company, which requires them to follow cooperative regulations. As per financial regulation, there needs to be some down payment especially for financing the purchase of vehicles and normally up to 30%. For microbus, it is usually required to pay 30% of the vehicle price while for medium bus it is less than 20% and most banks avoid cooperatives due to many considerations, particularly the level of loan risk with quite a small success rate.

The current challenges for microbus operators are financial capacity of the owner to fulfil the down payment regulation if they were to shift to electric microbus. The microbus owners are currently eligible to take advantage of KUR (Kredit Usaha Rakyat), which is a facility provided by government where it is intended to help small and medium enterprises/individuals to access financing relatively easily and with low interest rate. It is essentially a capital credit where the target demand is those who have feasible business but not bankable. The maximum credit limit of KUR is currently IDR 500 million, while the price range of electric microbus is currently around IDR 600 million.

Similarly, medium bus operators also face challenges due to high up-front cost that they need to prepare. Another issue raised during the engagement was the low profits that they earn even in existing condition due to high wasted kilometres, which is reduced to IDR 2.6 million per unit per month. This is largely due to bus operations that is highly dynamic. The operators may be required to run the buses that are quite far from their depots resulting in high dead kilometres (up to 50km) yet they only get compensated up to 20kms or as per negotiation in the contract. Apparently, during contract negotiations, there routes to be operated are not determined hence it depends on the daily operational plan, which makes all the risk of dead kilometres to be borne by the operator.

They also face difficulties in accessing loan directly from the bank since the members of the cooperatives are mainly low to medium income individuals. Thus, they face barrier in providing the required down payment.

However, both bus operators that were engaged show interest in shifting to electric bus so long as the level of profit that is earned is the same as existing condition. Additionally, financing mechanism to help access the capital cost is also required by all operators since the financial capacities of the bus operators do not allow access to business as usual (direct bank loan).

6.3.4. Financing Institutions

The market has many different types of investors willing to participate. Funding and support for sourcing the fleet and depot upgrades can be from a range of options from outright purchase to leasing. Flexible business models and financing plans are available and new business models are emerging while more suppliers are providing finance to deliver 'Electric Transport as a Service' (ETaaS)

The key to securing financing is the requirement to have the necessary assurances in place, especially for the smaller operators due to the level of subsidy which is required due to the low farebox revenue which is considered insufficient to cover financial obligations. One option would be for direct payment by Transjakarta or Government of Jakarta.

Leasing options could be available through a rolling stock leasing model which could include fleet maintenance and management too. Financial packages could be developed so operators could choose which package they would like. There are several market financing institutions, there are UK Export Finance (UKEF) and the Asian Development Bank (ADB) at the global level, while local institutions are PT. SMI and several commercial local banks (BNI, BSI, and Mandiri). UKEF is the UK's export credit agency and a government department, working alongside the Department for International Trade as an integral part of its strategy and operations. UKEF also works with over 100 private credit insurers and lenders to help companies access export finance (loans and bank guarantees that enable international trade to take place as securely as possible). UKEF can only provide working capital to exporters, not buyers (TJ), by submitting exporters and borrowers to banks that are included in the UKEF cooperation list. Currently, UKEF's maximum transaction size is GBP 500 million, with no Indonesian banks on the list (never made a transaction).

In addition to UKEF, ADB is another global institution that provides social and economic development by giving loans, grants, technical assistance, and equity investments. Different loan kinds are available from ADB through the Sovereign and ASEAN Catalytic Green Finance Facility (ACGF) and also in the private sector. In the Transjakarta case, ADB makes it possible to support the private sector loan scheme by considering due diligence (DD), market reports, technical reports, legal reports, and environmental insurance reports. ADB can provide up to a maximum of USD 300 million, or 25% of the total project cost to be implemented.

UK Export Finance (UKEF) and the Asian Development Bank (ADB) use additional financing due to intermediaries and currency risks. Each agency has a different repayment period: UKEF has up to 14 years for electric buses, while ADB has up to 50 years through Sovereign and ACGF facilities and 20 years through a private sector scheme. Collaboration with SOE is very important for the structure of UKEF and ADB to conduct transactions through financial intermediaries in the form of foreign banks and PT. SMI for additional financing. The eligibility criteria are based on credit risk, due diligence assessment, and social environment. The several market financing institutions at global and local levels require national government guarantees from the Ministry of Finance and regional governments.

At the local level, PT SMI is a state-owned company engaged in financing operational sector infrastructure, including transportation, that supports sustainable development goals (SDGs) in Indonesia. The projects that have been carried out by PT SMI from the financing division represent commercial financing with a maximum tenor of up to 25 years at the rupiah exchange rate. PT SMI suggests the need for approval from the local government and DPRD (Regional House of Representatives) if the scheme uses Pinda (Regional Loan), and considering sponsors and tariffs for SPV if through the private sector. It is important to pay attention to commercial feasibility if the scheme is using green financing. It is also recommended to utilise ballooning payment rather than bullet payment since the refinancing risk is quite high for bullet payment.

Commercial local banks have almost the same criteria because banks are required to comply with OJK financial regulations with the operator's financial capacity to provide up to 30% down payment for fleets with two years of operational profit. The consulted local banks (BNI, BSI and Mandiri) already have portfolio in the transport sector especially for Transjakarta ICE buses. Commercial local banks generally do not have an issue with the differences between electric and conventional buses as long as the credit period is covered at the time of the contract (payment period in contract period). Local banks may also consider using bullet payments, depending on the contract and financing scheme.

6.3.5. Retrofitting Companies

The market for retrofitting is increasing along with the demand for the transformation of the use of motorized vehicles towards electricity-based vehicles around the world. In Indonesia itself, there is Spora EV, which is a start-up engaged in vehicles retrofitting. They are often involved in the accommodation of public transportation conversions, including policy making at the national and regional level for technical aspects; however, they do not have experience of implementing it yet. The conversion supply chain is still reliant on outside sources such as China, Europe, and the United States. However, there are several parts that can be localized to be more cost-efficient. Spora EV already has conversion standards and certifications, even though the national regulatory basis for technical matters is not yet available. Spora EV has only retrofitted small vehicles and motorcycles currently.

Challenges in retrofitting buses in the form of trust and financing that have not been supported by the government or Transjakarta. Spora EV is not only vehicle conversion but also problem solving on routes, charging consultations, and use cases. Conversion is a good solution for the energy transition because providing a new fleet is still expensive. Spora EV is still at the product development stage and still needs partners due to limited resources. The estimation of retrofit financing still depends on global market prices because many goods are imported. There are difficulties with spare parts from Europe and America because they have not yet entered the Asia-Pacific market and do not have a team for retrofit.

Others

In addition to focusing on a technical perspective, bus electrification also requires a view of the resulting emission output to follow sustainable development. Electromotiv is engaged in heavy transportation with the aim of being green, reliable, and low-cost. Provide an end-to-end solution called Depot in a Box, including funding, battery management systems, vehicle systems, and renewable energy. Essentially, Electromotiv provides the advisory and consulting services but do not do any manufacture or sell any products.

Project Sydney is one of the programs carried out under the 15-year Monterey contract. This project employs pantograph charging to save space, reduce costs, and optimize the batteries. It is important to have a contract from the government to ensure finance and operations. The current challenge is that the municipalities have an old contractual scheme and used for e-bus, hence it needs to be ensured that the product matches the operator's needs.

Equipmake is the UK's leading battery electric driveline retrofit company with solutions for light and heavy vehicles. They designed a modular system enabling them to develop the propulsion system to be optimum for the intended use case which can reduce the battery size and therefore cost. Equipmake have recently designed and developed a solution for Transport for London. Equipmake is currently working with Brazilian bus manufacturer Agrale and Argentinian coachbuilder Todo Bus to develop the electric version of their buses and recently completed the prototype for testing in Argentina

Equipmake's solution also has the potential to be assembled locally in Indonesia and have signed an MoU with PT VKTR Teknologi Mobilitas (VKTR) and Transjakarta to develop a retrofit solution as an initial trial could eventually be rolled out to more buses in the Transjakarta fleet as an alternative to new vehicles.

6.4. GESI and Inclusivity Issues

Through the preliminary consultations, even though the regulations and policies are not robust yet, it is found that the market has equal opportunities to all and open lots of opportunities for stakeholders from different background to participate in the electrification program. For example, due to it being a new technology, the electrification program will create new job opportunities for the public especially local job market. It would require specialised personnel to operate the charging facilities as well as for the maintenance of e-buses. Hence, it is an open market for all to learn and be part of the e-bus industry including staff of existing operators, maintenance companies, etc.

Furthermore, the market consultation also suggests that there should be incentive to the industry, particularly for the e-buses in the local market to nurture and initiate market boost. This is especially important to level the playing field, as currently the local market still has limited financial capacity to be able to compete with international suppliers.

Even though there is already TKDN (Tingkat Komponen Dalam Negeri), which is a regulation that regulates the minimum level of local components in a particular product, the e-bus industry is still an exception due to it being a new technology. It is suggested that the government should also encourage the production of e-bus locally by enforcing the TKDN regulation gradually.

7. Conclusions & Next Steps

Preliminary market engagement meetings were held with vehicle OEMs, charging equipment suppliers and organisations involved in financing zero emissions projects in terms of both debt financing and leasing. Following on from previous studies, the objectives of the preliminary market consultations were to identify the potential industry players, to better understand more generically, the products and services available and to gather inputs on the procurement, financial, technical, legal, and other aspects to be able to shape the strategy and refine the working assumptions while increasing project attractiveness to the market by ensuring requests and requirements are feasible and appropriate.

Transjakarta is required to follow strict tendering and procurement rules. The initial market engagement consultations are intended as preliminary to engage with potential suppliers on the market before launching the public procurement procedure. There were no agreements made nor information which could provide a competitive advantage shared. The consultations provided guidance on initiatives as well as potential strategies for more cost effective and time efficient procurement.

The exact requirements are not defined yet (vehicle quantities, charging equipment and so forth) and therefore, the preliminary engagements help to further develop these working hypotheses for range and operational performance to determine the fleet replacement plan, energy sizing requirements along with the development of the charging strategy which will guide the quantities and locations of charging equipment. The market is open to options and delivering the work packages and would welcome more detailed meetings with Transjakarta and ITDP to work together more collaboratively to develop the solutions.

The market analysis has provided sufficient confidence that the market is interested in the project to supply vehicles, charging equipment with different options available for financing the transition. However, there are some uncertainties that need to be resolved regarding contracting models and regulations.

To support the transition to zero emission transport, the industry is witnessing significant change. New entrants are moving into the market to provide solutions, while others are moving from their traditional market segments within the ecosystem to capitalise on the opportunities.

Innovative financing and supply solutions are being developed to help reduce the risk exposure of the operator and authority, especially around battery life and performance. Options include the ability to buy the bus while leasing the battery as well as business models provide Electric Transport as a Service (ETaaS) whereby the overall cost of the transition is fully financed and delivered by industry providers and the operator pays a mileage-based payment which is guaranteed by the authority.

There are multiple operators across the Transjakarta transport network and many of the smaller operators would have challenges raising sufficient capital for procurement of electric buses and the required depot charging equipment. This is a challenge facing many operators globally and creating the opportunity for alternative and innovative financing and ownership of buses fleets, especially in large markets with multiple operators.

In other global markets, the contracting model is being evolved to allow for the introduction of electric vehicles alongside traditional ICE. Due to level of investment in vehicles and infrastructure and operating costs, a different mechanism is required. Moreover, if the operator procures the fleet, they require more certainty for use of vehicles after contract term (residual agreed value or purchase agreements) or extension to the current contract to allow for the full depreciation of the vehicle.

Technical regulations need be to refined and aligned to the practicalities of operating electric vehicles. Indonesia or Transjakarta should also which electric vehicle specific regulations should be adopted, such as charging communication protocols. Charging communication protocols are essential for the bus and charging equipment to communicate for the transfer of data on state of charge amongst other operational data. Having a common protocol will enable different vehicle types and makes to use the same charging infrastructure seamlessly

Additionally, the technical standards and regulations should define whether the vehicles should comply to European standards (e.g., UN-ECE R107) or its equivalent in other markets such as Australian Design Regulations (ADR) or Chinese standards. The effect of this decision is potentially two-fold. Ensuring a consistent standard will ensure quality vehicles with reliable and durable propulsion systems and components for asset longevity although this will come at a cost premium. A 12m low floor city bus range between £350,000-400,000 (subject to specifications) compared to the China standard vehicle which can be £100,000-150,000 cheaper. Although there is a significant price premium on European buses, this rate might not apply to Transjakarta fleet as these are fully produced (Completely Built Up) buses in Europe unlike the ICE fleet which had a European chassis and locally manufactured body. This separate chassis-body approach has a lower import tax and through localising the manufacturing, reduces the overall cost and adds value to the local economy.

Through the market consultation, there was some interest in potentially establishing local production/assembly facilities. This would require investment and therefore, would only be viable with sufficient volume. Some OEM have already initiated discussions or agreements with local entities. Some of these manufacturers have experience in establishing overseas assembly plants including in Asia for their high-volume customers in Hong Kong and Singapore.

Framework agreements with the bus OEMs could provide the necessary volume assurance. This could achieve a lower vehicle unit rate through economies of scale and also ensure the OEM supports the vehicle as the procurement options would be dependent on the vehicle achieving the required performance standards.

Electric vehicles are still new to Indonesia and therefore, the vehicle regulations have not been adapted as necessary. The current Gross vehicle weight (GVW) in Indonesia is lower than many other markets and significantly lower than the European standard. Moreover, these markets have allowed a further extension of the GVW to facilitate electric vehicles which weigh more due to the inclusion of large heavy battery packs. Regulations such as this need to be considered to allow the introduction of Battery Electric Buses (BEB) with sufficient operating capability when using depot-based charging. Some bus OEM (Volvo & Equipmake) offer a modular battery system whereby the number of battery modules is customised for the vehicle design, size and operating requirements. Smaller batteries weight less and can work within existing regulatory frameworks; however, they would require more frequent charging. This charging would need to be either terminal charging at the end of each route or in-service opportunity charging at periodic bus stops. The weight and cost saving of batteries are positive however, the overall Total Cost of Ownership (TCO) could be higher as more expensive fast or ultra-fast chargers would be required.

OEMs expressed concern around the process to obtain permits for electric vehicle trials. The process is not entirely clear due to the technical regulations and the early stage of the introduction of electric vehicles in Indonesia. Significant time, effort and money is required by the OEMs to adapt their products for Indonesia. Having clarity on the process will enable the OEMs to develop the vehicles to comply but also achieve the requirements and expectations of Transjakarta. Providing clarity will provide confidence to the OEMs to invest and be efficient in obtaining the necessary certification for homologation etc.

The charging strategy is important for many reasons. Defining whether buses will be single use charged (depot-based), in service charged (on road opportunity) or combination of both will determine the bus technical specifications but also define the type and quantity of equipment required. It will also directly impact the quantity and rate of electricity required and subsequent electrical infrastructure upgrades required. Depot based charging is typically at a lower rate (50 - 80 kWh) compared to fast (100 - 300kWh) and ultra-fast charging (> 350kWh). The higher the rate of charging, the potential peak power consumption could be higher requiring more power from the network which also needs to be stable. This would require more depot or route-based power transformer and other equipment. The depot-based slow charge though takes longer and would need to be compatible with the duty cycles and if only depot-based charging is deployed, more buses could be required as some of the Transjakarta fleet have long operating days which is not possible to complete on a single charge. When considering the charging time and size of batteries, if buses with bigger batteries and slower charging are chosen, the replacement ratio to opportunity charged BEB will be higher which will increase the route specific TCO, which will already be more than the ICE equivalent fleet.

The current contracting model is for an operating contracting of up to 10 years which the vehicles are procured and operated for up to the same duration. Implementing electric vehicles, especially the initial implementation, is very capital intensive as the depots need to be modified and charging infrastructure implemented. Additionally, price parity between electric buses and ICE is

still not possible with the current contract. The enhancements in build quality and to provide a longer-term return on investment, many markets are increasing the contracting duration and/or increasing the operating life of the vehicles to reduce the overall TCO. This is an important factor when a high subsidy is required above the farebox revenue.

To progress technical trials and enable the full implementation of the transition to decarbonisation can include the following actions to develop a more detailed roadmap:

1. Establish working group with relevant Government agencies and industry players or industry representative groups to develop technical standards for electric buses, to mitigate any potential risks or issues and to monitor the performance and progress of the electrification.
2. The current regulations and contracting model are a barrier to transition. These need to be jointly reviewed and adapted to enable the seamless transition. Principally, the key amendments are;
    a. Refine regulations of vehicle lifecycle and align to industry standards reflecting the developments in technology and build quality. Other cities and authorities have extended to up to 15 years with half-life (7 years) refurbishment which would align to battery lifecycle
    b. Allow increase in gross vehicle weight in consideration for additional weight due to batteries without needing to reduce passenger carrying capability
    c. Simplify the process for homologation/certification for vehicles with clear guidance on how to achieve the necessary documentation for new buses for trials and tests
    d. Funding and financing of contracts and level of subsidies to be reviewed and/or restructured
3. Develop strategies for charging and infrastructure to enable modelling of energy requirements for electrical infrastructure upgrades along with further refinement of fleet replacement strategy (vehicle quantities and battery specifications etc). Further detailed analysis of route planning, vehicle scheduling and charging strategies to be evaluated. The technical bottom-up planning will contribute to defining the requirements for on-route charging. This will require Transjakarta, and possibly private operators, to procure more advanced computerised planning and scheduling systems to develop the operational scenarios.
4. Evaluate feasibility of Transjakarta taking control of overall procurement process including defining the technical specifications, fleet procurement and roll out program, which would enable large order to achieve economies of scale. Detailed common technical standards for vehicles and charging communication protocols to be established to allow interoperability across the network. Transjakarta and the operators can jointly evaluate and decide on the routes to be electrified as part of the roll out strategy with Transjakarta acting as single point for procurement to achieve economies of scale in procurement.
5. Through a single point of procurement, developing framework agreements with OEMs based on performance metrics to ensure OEMs ‘buy-in’ to the process. Larger potential orders could

achieve lower purchase price by providing certainty to OEMs (potential to reduce unit rate ~5-10% reduction (BYD/VKTR)) and they would need to commit to performance targets.

6. Further evaluate financing and ownership models for fleet and infrastructure assets to reduce the risk for operators who often struggle for access to significant capital. This could include third party ownership (rolling stock companies leasing to operators) which might be secured by Transjakarta.
7. Ensuring adequate power across the network and charging infrastructure is essential, especially continuity of power. Power generation, distribution system operators and charging equipment suppliers to work together to develop more detailed solutions.

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