ARUP

NUS National University of Singapore

The future of petrol stations in an electric vehicle world

Foreword

Transport represents a significant percentage of global carbon emissions – decarbonising this sector is critical for climate action. However, with ambitious targets planned for the transition to electric vehicles (EVs), Southeast Asian cities have much to do to maximise their transition. The move to a zero-emission vehicle future will require new thinking and infrastructure. So, what will this future hold for petrol stations?

Research aim

In response to a lack of research into the detailed planning and design for repurposing petrol stations, we partnered with the National University of Singapore (NUS) to investigate how the shift to EVs might affect current transport assets and how they could be repurposed. Our key research questions were:

1. What is the future of petrol stations in Southeast Asia (SEA) in an EV world?
2. How can cities in SEA analyse, re-evaluate and repurpose their petrol stations?

Our research investigated the options available to transition petrol stations using three case studies across Southeast Asian cities namely Singapore, Jakarta and Kuala Lumpur.

Our team assessed over 800 petrol stations across the three cities. We then deployed the clustering method to a city's petrol stations portfolio to identify typologies. Our research then went a step further and developed three repurposing design options. These options spanned the full range of transport and land use focuses, including a transport-focused EV charging hub, a mixed-use hub with EV charging, and an option where the transport function is no longer required and land can be re-purposed. We then applied the design options to real case study locations in clusters in each city to explain how transition options can be deployed practically.

Project team
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"This research collaboration with NUS can help guide cities in analysing, re-evaluating, and repurposing their existing assets in their EV transition."

Michael Chadney
Transport Planning Lead, Singapore
Arup

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"Working with Arup has been a pleasure. The forward-looking yet practical findings on EV transition in Southeast Asia provide valuable insights for cities to explore and collaborate on."

Dr Ghim Ping Ong
Deputy Head (Research), Department of Civil and Environmental Engineering
National University of Singapore (NUS)

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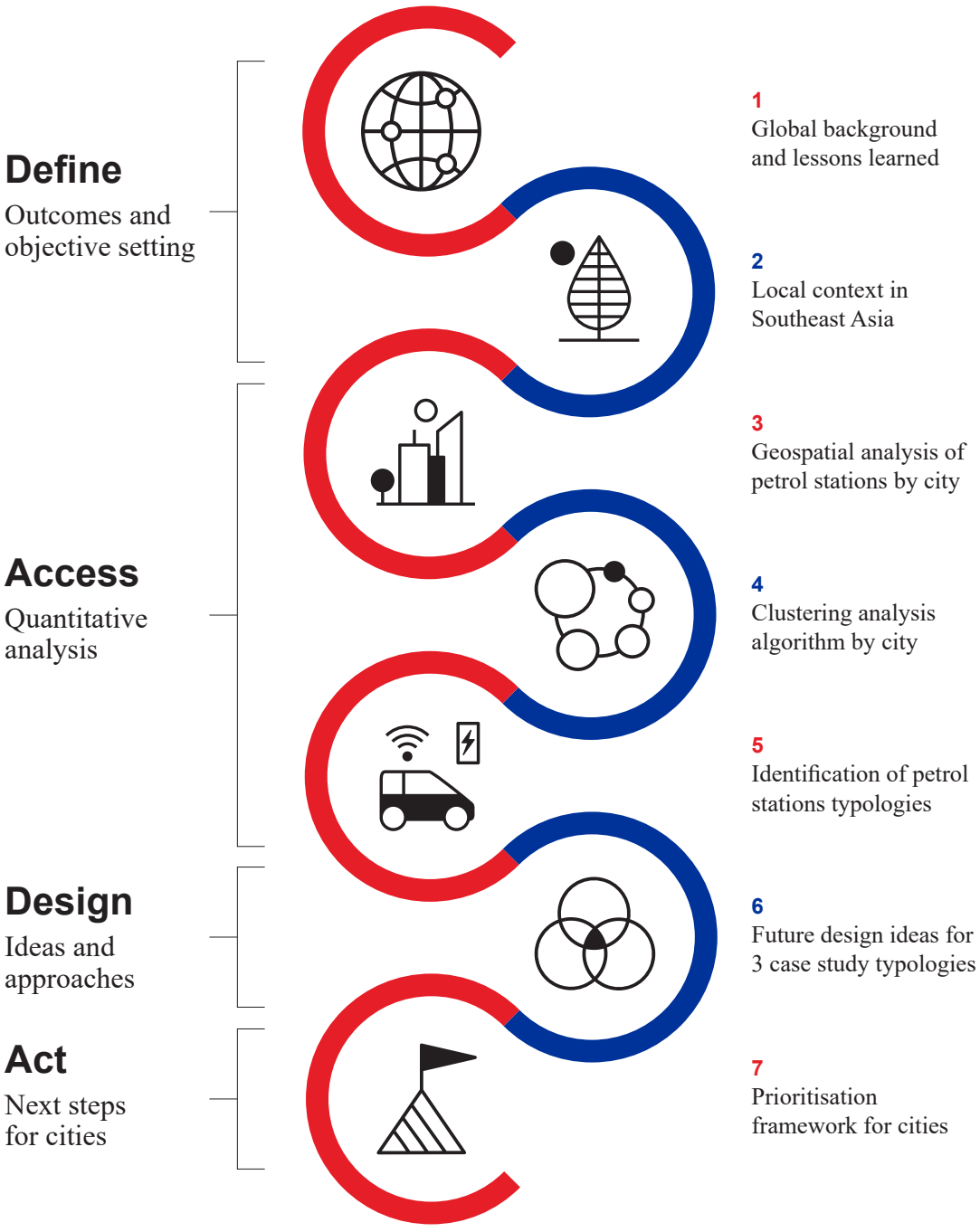
The research framework

Our research approach has several key stages. We performed a comprehensive desktop review to identify where each city is at along its EV journey, the local petrol station context, and a detailed clustering analysis to identify typologies of petrol stations for cities to apply a targeted approach. Thereafter, we identified solution options and design ideas for different typologies, including how these can be deployed in example use cases in each of the three Southeast Asian case study.

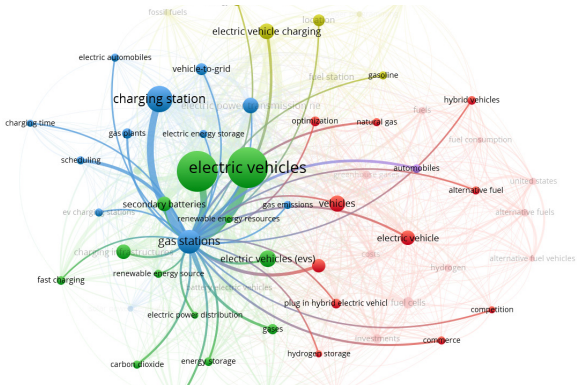


Part 1: Define

Global examples and lessons learned

Local context in Southeast Asia

Global examples and lessons learned



Global research trends and gaps

The research undertook a comprehensive global literature review. As part of these works, bibliometric analyses were undertaken to ascertain the state of play globally for similar academic research. We found there was an increasing trend of papers and growing interest in the topic of EVs and EV hubs with key centres of research activity from USA, China, Germany and Japan. However, much of the research has been focused on the technology side of charging batteries and electric vehicles, with the retrofit of petrol stations or hub planning and design being much less researched.

New typologies and designs

Around the world new typologies and design ideas are emerging for the design of EV charging hubs. Our firm is already highly active in this space. For example, the Electric Forecourt®, a new generation of filling station, was conceived out of extensive research undertaken by our architects in collaboration with GRIDSERVE, into the limitations and frustrations with existing charging infrastructure. It represents a new typology and the radical evolution of the fuel station. Servicing the public and fleet vehicle operators, the design will offer reliable, ultra-rapid EV charging supported by a range of ancillary services, mitigating range and charge anxiety and providing a unique user experience never seen before.

Repurposing examples in cities

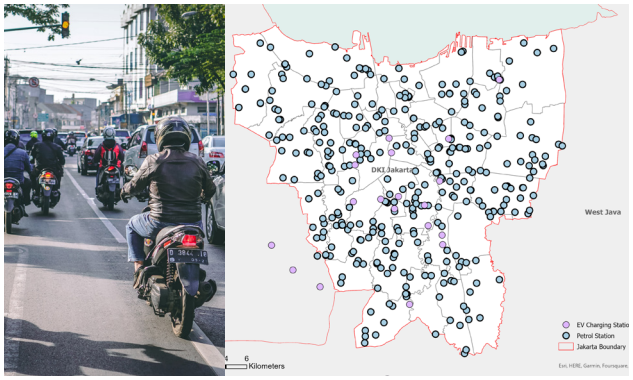
Zooming in to more specific global case studies for the retrofit of petrol stations to EV charging hubs, small pockets of global examples were found. One key example in the United Kingdom is the Shell EV Charging Hub, Fulham. Shell's EV charging hub in London has facilities for drivers to relax while charging their car and a solar canopy as an alternative energy source for the station. All pumps and tanks were removed and completely replaced with EV charging infrastructure. Cost of installing EV charging points was reduced and simplified by a redesign of the internal electric feed cabling.

Local context in Southeast Asia

SEA countries are at different stages of their EV transition and have specific local needs

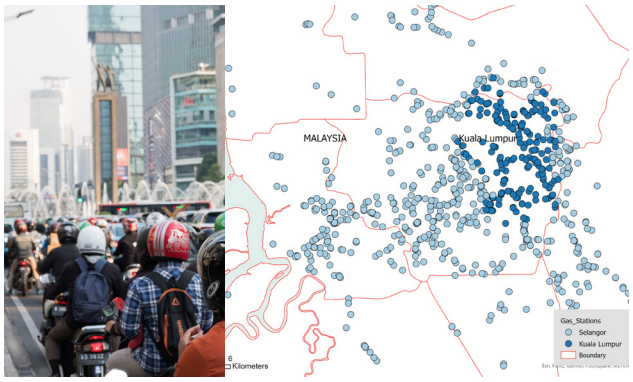
Singapore

Singapore aims to reduce carbon emissions from land transport by 80% by around 2050. To achieve this, the government has made a comprehensive EV Roadmap to boost EV adoption [1]. This roadmap includes the deployment of 60,000 EV charging points (40,000 public chargers and 20,000 private chargers) by 2030 and a target of 100% clean energy vehicles by 2040. Whilst Singapore is a leader in the EV transition in the region, it is still in early stages of the process. EVs comprise just 1.2% of the total car population and its registration rate was around 18.1% in 2023 [2]. As of July 2023, there are over 3,600 charging points islandwide [3].



Indonesia

Indonesia has committed to reaching net-zero emissions by 2060 or earlier. The national government claims to promote two-wheeled and four-wheeled EVs to reach 1.8 and 0.4 million respectively by 2025, and to reach 13 and 2 million by 2030. Jakarta, being the capital and largest city of Indonesia, is at an initial stage, with a low EV adoption rate of 0.1% in 2021 in addition to insufficient and unevenly distributed charging infrastructure [4]. To encourage EV adoption and cater to the rapidly increasing charging demand, the Indonesian government aims to construct 6,300 charging stations and 17,000 battery swapping stations by 2025, which would increase it to 32,000 and 67,000 respectively by 2030.



Malaysia

EV development in Malaysia it at a relatively similar stage to Indonesia, with a 0.3% EV adoption rate [4] and 550 charging stations. Like other countries in the region, Malaysia also seeks transportation electrification to help the country achieve its ambition of net-zero emissions. The lack of public chargers is also the greatest concern of Malaysian consumers purchasing EVs [5]. To promote EV sales, Malaysia has pledged to install 10,000 chargers by 2025.

Part 2: Assess

Geospatial analysis of petrol stations by city

Clustering analysis algorithm by city

Identification of petrol stations typologies

Assessment methodology

A bespoke geospatial analysis and clustering algorithm to identify petrol station typologies

Clustering analysis is a data analysis technique that explores the naturally occurring groups within a data set known as clusters [6]. The key objective of the clustering analysis was to analyse the typical geospatial characteristics of petrol stations in a city to identify 'clusters' of similar types. The clustering analysis workflow deployed for determining the petrol station typologies is summarised in the diagram below.

The approach draws on four criteria, two of which are land use focused, and two which are transport focused.

The land use focused criteria are:

i) Residential urban form; and

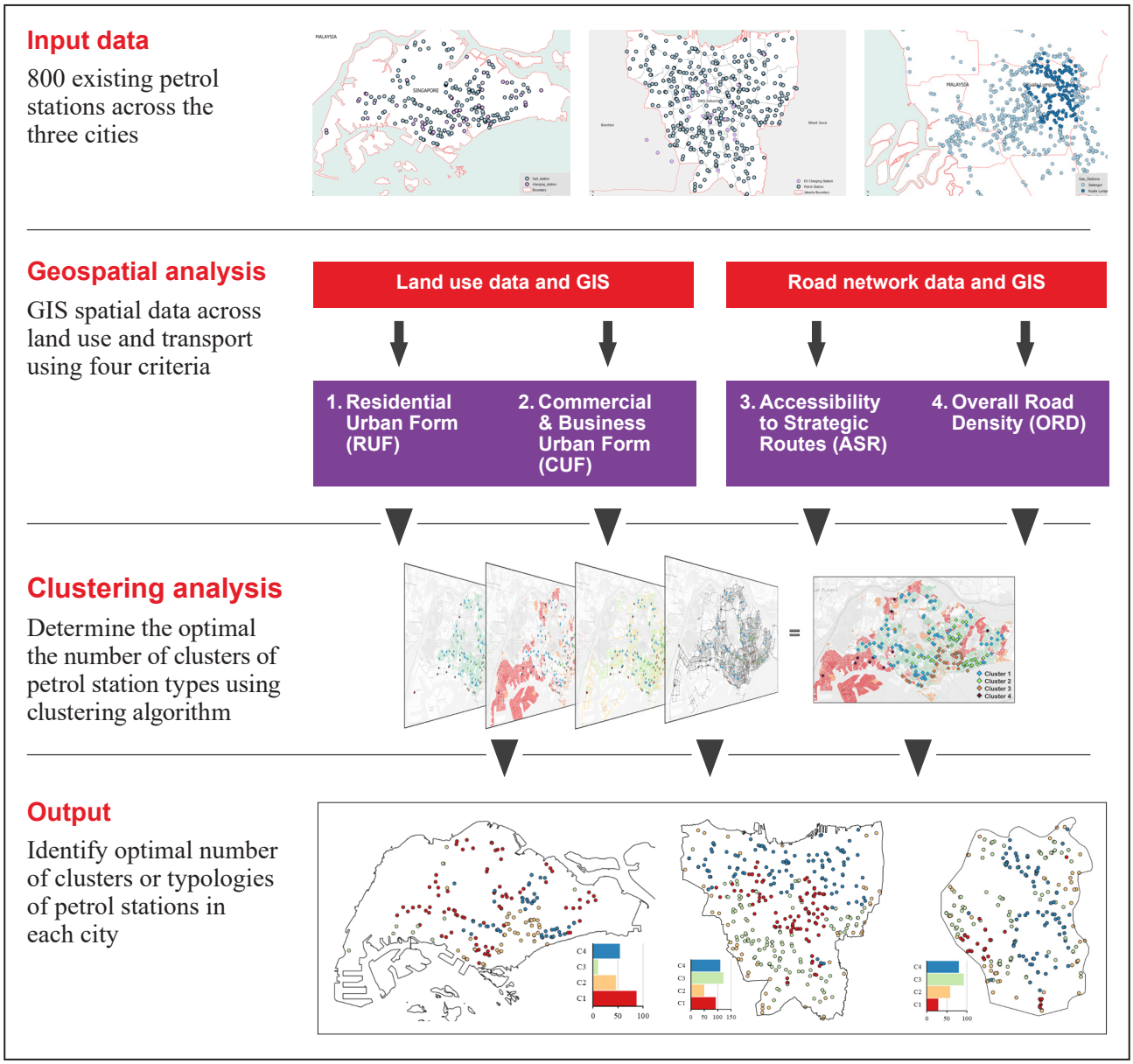
ii) Commercial and business urban form

The transport focused criteria are:

iii) Accessibility to strategic routes; and

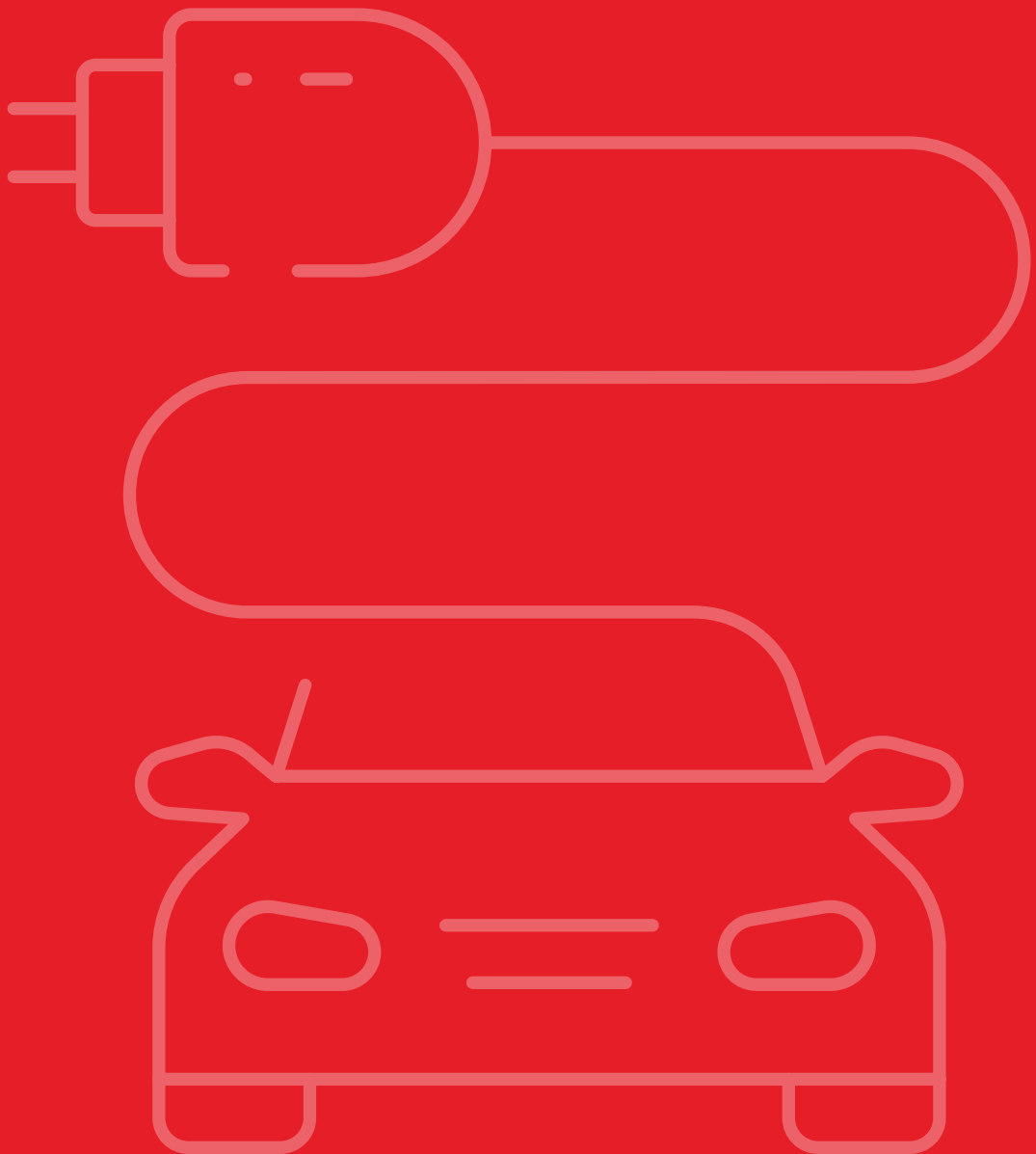
iv) Road density

GIS spatial data analysis for each provides the basis inputs into the algorithm to identify the clusters.



Part 3: Design

Future design ideas for three case study typologies



Design ideas for different repurposing options

We identified future typologies based on global and local best practice review, transport and land use strategies of cities, and the learnings gained in understanding existing petrol stations' characteristics. They provide a selection of repurposing options that range from a greater transport function to a greater land use function, to inform design ideas. After identifying the typologies, our research then explores the specific design ideas and how they could be deployed at real case study petrol stations in each city.

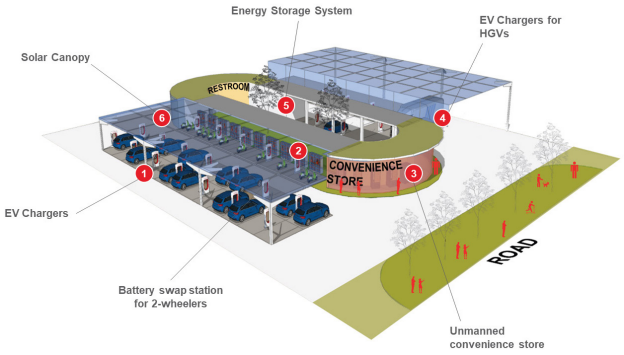
Greater transport function

Greater land use function

Option 1

Petrol station converted to EV charging hub

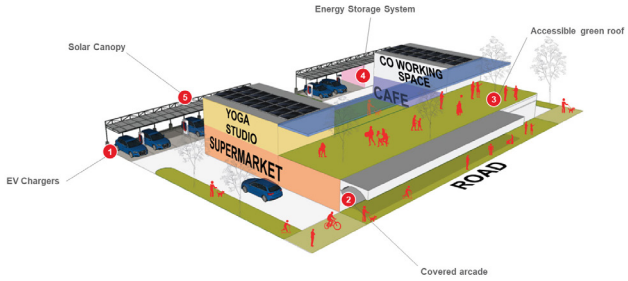
- Helps address an EV charging gap for the city.
- Primary demand is from transport users.
- Important on strategic routes / corridors to support longer trips.
- More suitable for Indonesian and Malaysian cities compared to Singapore.



Option 2

Petrol station becomes more mixed-use with EV charging

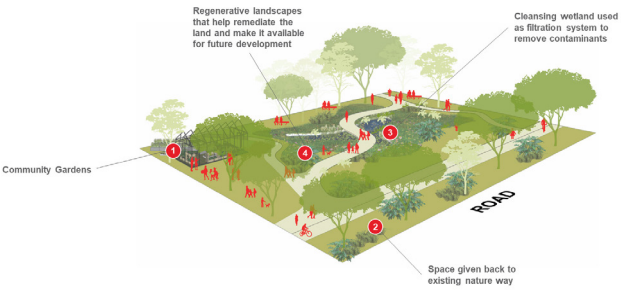
- Helps encourage on-route charging. Travel diary not impacted.
- Helps encourage integrated transport and land use planning.
- Improves urban character.
- More suitable for collectors and local roads in mixed-use areas.
- Potential use case in all three countries.



Option 3

Land given back, transport function no longer needed

- Good option when charging demand is met by either destination charging or other charging stations.
- Leverages opportunities to give back to land to nature or other community uses.
- Potentially very suitable for Singapore due to shorter average travel distances and potential for charging elsewhere including within public housing estates.

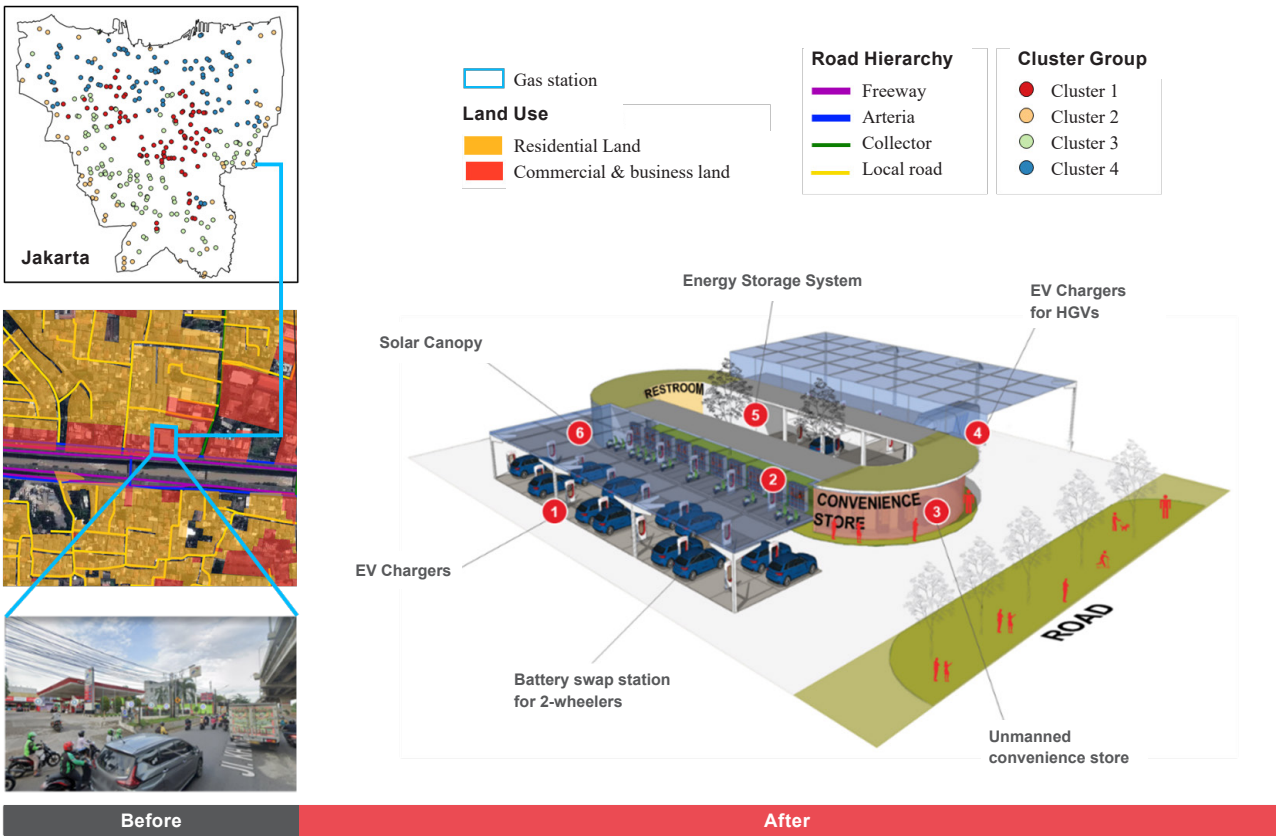


Case study application

Option 1: Petrol station converted to EV charging station (pure transport function)

This option proposes to convert a petrol station into an EV charging hub. It serves as a pure transport function option and helps address an EV charging gap for the city. Primary demand of the EV charging hub would be from transport users and would be important on strategic routes or corridors to support longer trips. We developed design ideas for application at a petrol station case study in Pertamina, Jakarta, as shown in the image below. This petrol station selected falls within the typology of Jakarta Cluster 2 and has the geospatial features of low RUF, CUF, ORD, and median ASR. The selected petrol station is near a strategic arterial road connecting Jakarta to the Bekasi area and is a good match for Option 1. It serves as a key transport focus and used by mixed type of vehicles.

In this design option, the new EV charging hub serves a prominent transport function in addressing EV charging capacity for the city on a strategic route. A key theme is efficiency and automation (i.e. no or few staff required). As a modern and comprehensive charging hub, it is expected to service various types of EVs and various charging types such as DC rapid charge and battery swap. Additionally, renewable energy systems such as solar panels and energy storage systems are planned to be deployed to save electricity and shift overdemand during peak hours. This design option of the charging hub is proposed to address the charging capacity, especially in dense road network areas or near strategic roads.



Part 4: Act

Next steps / multi-criteria evaluation framework

Next steps: Our evaluation framework

We are helping guide cities in analysing, re-evaluating, and repurposing their existing assets to respond to the EV transition.

Evaluation framework

As part of the research project, we developed a multi-criteria evaluation framework to help guide the future use of petrol stations so that cities can deploy a more detailed transition strategy as a next step. It includes six key criteria covering aspects of strategy and policy, demand and deliverability.

The framework has been developed to be:

- Holistic and comprehensive
- Consistent and a guiding tool for cities
- Adaptable to different context
- Respond to different criteria at different levels of detail
- Flexible to different indicative scoring techniques
- Used to inform implementation plans

Conclusion

Whilst many studies in the EV space have focused on vehicle and charging technology, the Arup and NUS research study has unpacked the built environment implications and specific design ideas for repurposing existing assets as part of holistic city planning. It provides a framework of varied options from transport-focused EV hubs to fully repurposing the land where the transport function is no longer needed.

Moving forward the evaluation framework can by applied by city planners when analysing, re-evaluating, and repurposing their existing assets to respond to the EV transition. It allows for a targeted approach to help prioritise design decisions for different locations. The evaluation framework allows for a full suite of appraisal criteria to be utilised – from EV infrastructure policy, impact on electricity grids, revenue and profit, technical complexity and cost, to implementation complexity. These criteria can be integrated to build a comprehensive assessment system to evaluate the transition opportunity of existing petrol stations.

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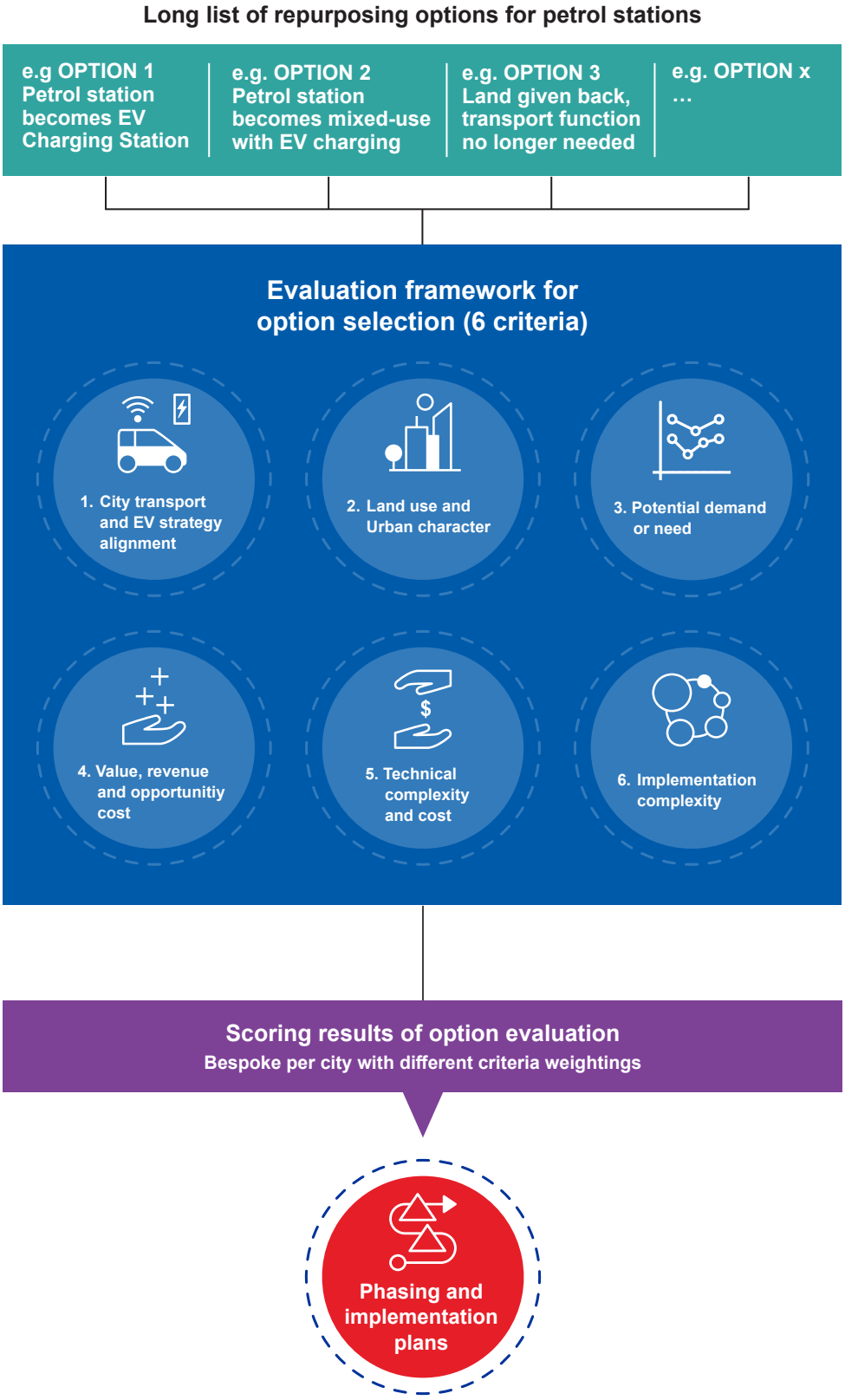
Long list of repurposing options for petrol stations
e.g OPTION 1
Petrol station becomes EV Charging Station
e.g. OPTION 2
Petrol station becomes mixed-use with EV charging
e.g. OPTION 3
Land given back, transport function no longer needed
e.g. OPTION x
…
Evaluation framework for option selection (6 criteria)
1. City transport and EV strategy alignment
2. Land use and Urban character
3. Potential demand or need
4. Value, revenue and opportunitiy cost
5. Technical complexity and cost
6. Implementation complexity
Scoring results of option evaluation
Bespoke per city with different criteria weightings
Phasing and implementation plans

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