Barriers and Strategies Analysis For E-motorcycle Battery Swap Technology Diffusion In Indonesia

A Circular TIS-ISM Integrated Approach

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Preface

These last 2 years have been an incredible journey for me as I pursued my master's degree in Sustainable Energy Technology at TU Delft. Combining study with raising my little daughter, representing Indonesia Power and PLN, and being supported by LPDP as a scholarship source added a new level of challenge to my life as a student, a professional, a dad, and a husband. First and foremost, I want to express my deepest gratitude to my wife, Indah Puspita. Her unwavering support, love, and sacrifice made it possible for me to pursue my master's degree. I am also immensely grateful to my daughter, Maryam Dzakiyya Sabilarrusyda, for being a constant source of strength and joy. I appreciate her understanding and acceptance of my absence during important family moments due to my studies. I owe a debt of gratitude to my extended family, especially my parents, for their endless prayers and support throughout my journey. Their teachings have instilled in me the values of ambition, hard work, and perseverance.

To my graduation committees, I am profoundly thankful for your guidance and flexibility in accommodating my needs. Dr. Linda, in particular, deserves special recognition for her patience, quick responses, and invaluable guidance throughout my research. Dr. Hanieh's feedback was instrumental in enhancing my report. I knew them both since the first year as my favorite lecturers in the subject of Sustainable Energy Innovation and Entrepreneurship insight, and I am very grateful to find that both become my supervisors in this thesis.

Lastly, I want to extend my gratitude to everyone I have met during my time at TU Delft, especially PPI Delft (Persatuan Pelajar Indonesia di Delft) and Energy for Refugee (EFR). Being surrounded by intelligent, ambitious, and energetic individuals has enriched my experience and shaped me in profound ways. To all my friends, near and far, thank you for your companionship and support. I hope this thesis becomes beneficial for stakeholders to recognize the challenges within the attempt to diffuse battery swap technology in Indonesia, and for readers to raise awareness about the importance of transitioning to a more sustainable and cleaner form of transportation.

Okto Fenno
Delft, June 2024

Executive Summary

The global transportation sector faces significant environmental challenges due to its heavy reliance on fossil fuels. In response, many countries are exploring sustainable alternatives, such as electric vehicles (EVs). Indonesia, with its abundant nickel reserves, is actively pursuing the adoption of EVs to reduce greenhouse gas emissions. Initiatives like the Battery-Based Electric Vehicle Acceleration Program aim to promote EVs, particularly electric motorcycles. The Indonesian government has set ambitious targets, aiming for 2.5 million electric motorcycles by 2025 and 13 million by 2030 (DEN, 2016). However, according to the Directorate General of Land Transportation, Ministry of Transportation, as of January 22, 2024, at 15:23 GMT +7, the total population of electric motorcycles equipped with the Type Test Registration Certificate (SRUT), one of the requirements for the vehicle registration certificate (STNK), is 99,594 units, which is far from the target. Despite these efforts, challenges related to charging infrastructure and higher costs hinder widespread adoption. Battery swapping systems for electric motorcycles have emerged as a potential solution to these issues. This thesis aims to explore the development and implementation of the e-motorcycle battery swap business in Indonesia. It utilizes Raghav's Circular Technological Innovation System (TIS) Framework to understand the industry's dynamics and employs Interpretive Structural Modeling (ISM) to identify and prioritize causes of barriers identified from circular TIS framework. The study seeks to propose effective strategies to address these barriers and facilitate the e-motorcycle battery swap industry growth in Indonesia. The complete flowchart of the combined Circular TIS-ISM framework is shown as follows:

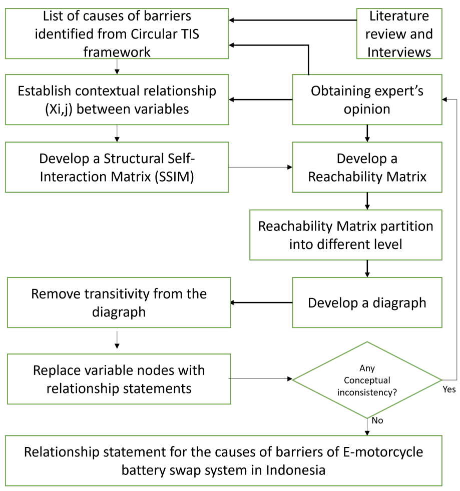

Figure 1: Circular TIS-ISM Flow Diagram

The incorporation of Interpretive Structural Modeling (ISM) within the Combined TIS-ISM Framework significantly enhances comprehension of the relationships among identified causes of barriers in Raghav's TIS framework. Coupled with a thorough understanding of the status of building blocks, it provides a hierarchical perspective on the complex dynamics within the Circular TIS framework. ISM serves as a complementary tool for Raghav's TIS framework to offer a holistic view before introducing a suitable and effective strategy to address the prioritised causes of barriers before others. Figure 2 encapsulates the findings from the first half of the Circular TIS-ISM framework. Most of the building blocks and influencing conditions status are partially complete and some of them are totally incomplete. Only a few of the blocks are considered complete.

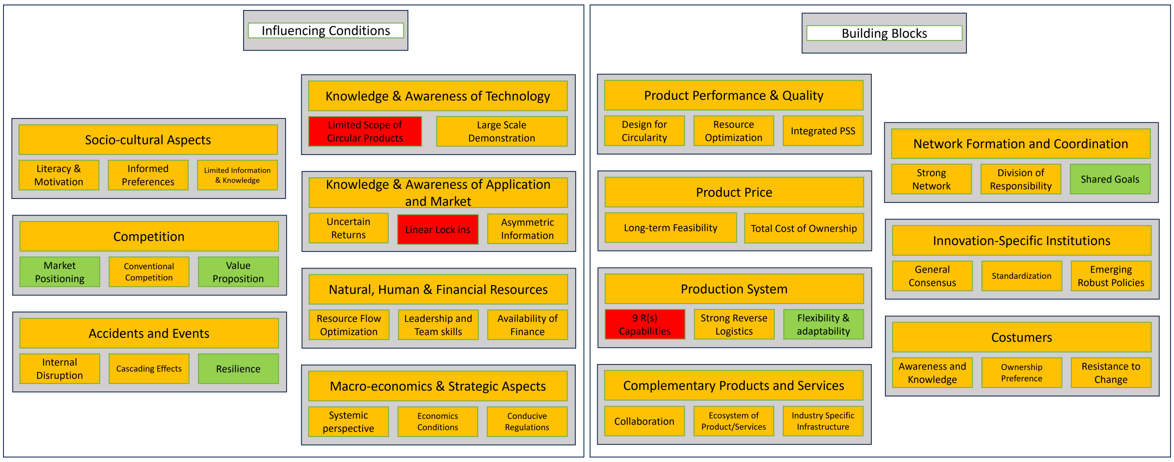

Figure 2: Current Status of Building Blocks and Influencing Conditions

Using the finding from the first half of the framework, the 33 identified causes of barriers from the explanation of incomplete and partially complete influencing condition blocks that hinder the completeness of the building blocks are listed and later be used as a basis to build 33x33 Self Structural Intersection Matrix (SSIM), involving three experts in a brainstorming session, which become the input of the ISM to generate the hierarchy among identified causes of barriers. Next, the final reachability matrix is constructed using the rule of transitivity as the basis on doing the final step, which is the level partition in several iterations. The result of the complete procedure of the last half of the framework is shown in Figure 3.

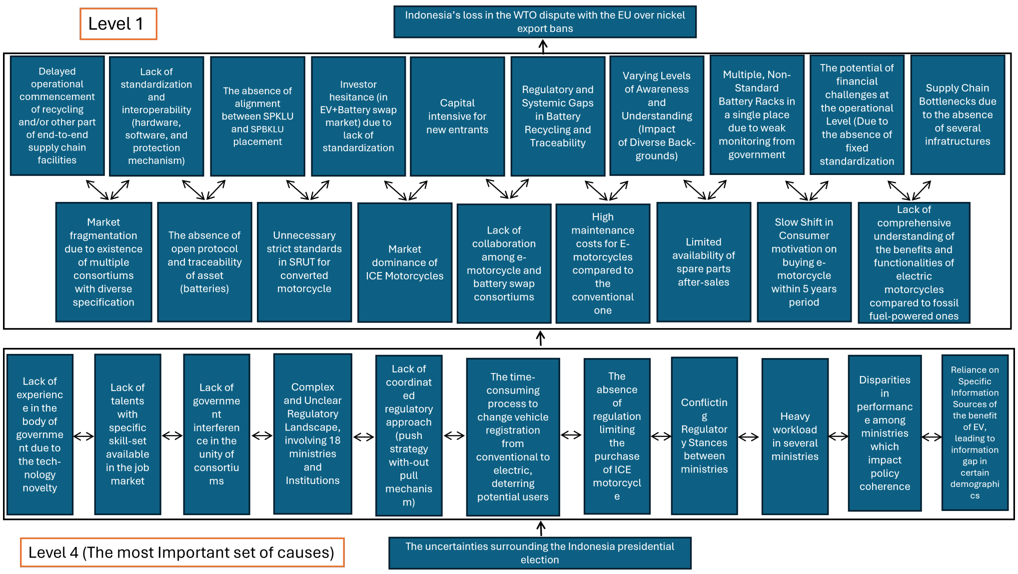

Figure 3: Hierarchical Relationship Between Causes of Barriers of Battery Swap Technology Diffusion in Indonesia

The result of ISM provides the insight that solving the lowest level (level 4) is crucial to alleviate the challenges posed by the upper levels of causes (Level 3 and beyond). Considering that elements at the same level cannot have one-way arrows, as they mutually influence each other, it was essential to eliminate them at the same time.

In addition, the indirect relation represented by the transitivity rule is removed from the final result. Based on the result above, the strategy on each level is derived. The ISM results reveal a four-level hierarchy of 33 causes of barriers identified using the Circular TIS framework: Level 4 features one cause related to uncertainty during presidential election periods; Level 3 includes eleven causes mostly related to government performance; Level 2 encompasses nineteen causes mainly associated with market fragmentation, standardization issues, infrastructure delays, competition with conventional vehicles, and collaboration challenges among new technology players; and Level 1 highlights one cause stemming from Indonesia's loss in the WTO dispute with the EU over nickel export bans. Using this hierarchical model, strategies are defined to address and alleviate the causes of barriers that hinder the large scale diffusion of battery swap system for e-motorcycle in Indonesia at each level.

Specific strategies proposed to effectively tackle the identified causes of barriers at each hierarchical level are stated as follows: • Level 4 - Engaging businesses during the presidential transition phase can influence policy through channels like KADIN via existing consortiums or associations. If interventions do not work, stakeholders may opt to wait and see before deploying programs or strategies, reflecting a cautious approach in uncertain political and regulatory environments • Level 3 - The strategy involves forming a unified consortium of battery manufacturers and e-motorcycle providers to influence ministry programs, using social media influencers to communicate with potential customers effectively, and addressing workforce shortages by collaborating with KADIN (KADINDA in the re- gional level) for TVET programs and LPDP for recruiting master's graduates (with internship experiences in the technology-leading company overseas), as well as partnering with Markija for vocational training aligned with MBKM program. • Level 2 - The strategy involves partnering with ICE-based motorcycle companies to reduce maintenance costs and improve parts availability, collaborating with software interoperability firms to standardize com- ponents like plugs, sockets, and EVCC (as an enabler for serving battery charging stations (SPKLU) as a complementary part of the overall charging system alongside with the unevenly distributed battery swap stations (SPBKLU)), advocating for removing strict "SRUT" standards in motorcycle conversions to increase the e-motorcycle population, and utilizing social media influencers to raise customer awareness. For new entrants, seeking guidance from larger firms to develop market specifications or doing a "wait and see" strategy on the government maneuver and the emergence of a unified consortium that applies the new standard in their latest products. • Level 1 - The strategy involves coordinated efforts led by the government to mitigate the consequences, as companies cannot directly tackle this complex international legal and trade matter. Progress in addressing barriers at lower levels can contribute to creating a more favourable environment for addressing this challenge

At the end of the report, these findings were validated by four experts, confirming the logical structure of the hierarchy and the relevance of the proposed strategies. However, two findings were considered less relevant: the barrier at Level 1 concerning Indonesia's export ban disputes in the WTO due to the broad potential for battery technology development in Indonesia, despite the fact that nickel-based batteries have the highest value in the recycling process compared to lithium-based batteries; and one proposed strategy related to collaboration with internal combustion engine (ICE) providers, which was deemed less relevant based on evidence provided by one validator.

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Abbreviations

Abbreviation	Definition
AEML	Asosiasi Ekosistem Mobilitas Listrik
AISMOLI	Asosiasi Industri Sepeda Motor Indonesia
BLDC	Brushless DC motor
BBNKB	Bea Balik Nama Kendaraan Bermotor
CBU	Completely Build Up
CAPEX	Capital Expenditure
CE	Circular Economy
CKD	Completely Knocked Down
Dirjen EBTKE	Directorate-General of New and Renewable Energy and Energy Conservation
DoC	Depth of Charge
E-motorcycle	Electric motorcycle
E2W	Electric Two Wheelers
EVs	Electric Vehicles
GDP	Gross Domestic Product
GIAMM	Gabungan Industri Alat-Alat Mobil dan Motor
GHG	Greenhouse Gas
HREC	Human Research Ethics Committee
HR	Human Resources
ICE	Internal Combustion Engine
IBC	Indonesia Battery Corporation
IKD	Incompletely Knocked Down
ISM	Interpretative Structural Modelling
KBLBB	Kendaraan Bermotor Listrik Berbasis Baterai (Battery based EV)
Kemenperin	Kementrian Perindustrian (Ministry of Industry)
Kemendagri	Kementrian Dalam Negeri (Ministry of Internal Affairs)
KLHK	Kementrian Lingkungan Hidup dan Kehutanan (Ministry of Living Environment and Forestry)
LFP	Lithium Ferro Phospate
LCR	Local Content Requirement

Abbreviation	Definition
LPDP	Lembaga Pengelola Dana Pendidikan (Education Endowment Fund Management)
MEMR	Ministry of Energy and Mineral Resource
MoU	Memorandum of Understanding
NBR	National Battery Research Institution
NMC	Nickle Manganese Cobalt
OEM	Original Equipment Manufacturer
OTR	On The Road
Permenperin	Peraturan Menteri Perindustrian (Minister of Industry Regulation)
Perpres Peraturan Menteri Keuangan (Minister of Finance Regulation)	Peraturan President (Presidential Regulation) PMK
PLN	Perusahaan Listrik Negara (State Electricity Company)
PSS	Production-Service System
PPnBM	Pajak Penjualan Atas Barang Mewah (Luxury Goods Sales Tax)
PKB	Pajak Kendaraan Bermotor (Vehicle Tax)
SBBMC	Swappable Batteries Motorcycle Consorsium
SBMC	Swappable Batteries Motorcycle Consortium
SLO	Surat Laik Operasi (Operational Clearance)
SNI	Standar Nasional Indonesia (Indonesian National Standard)
SRUT	Sertifikat Registrasi Uji Tipe (Type Test Registration Certificate)
SSIM	Structural Self Interaction Matrix
SPBKLU	Stasiun Penukaran Baterai Kendaraan Listrik Umum (Public Electric Vehicle Battery Swap Stations)
SPKLU	Stasiun Pengisian Kendaraan Listrik Umum (Public Electric Vehicle Battery Charging Station)
TIS	Technological Innovation System
TCO	Total Cost of Ownership
TKDN	Tingkat Komponen Dalam Negeri (Local Content Requirement)
VAT	Value Added Tax

1 Introduction

The global transportation sector, while essential for today's fast-paced life, poses significant challenges due to environmental issues and inefficient management practices. The rampant increase in vehicles, primarily powered by non-renewable sources, has exacerbated these challenges, making it imperative to explore sustainable alternatives for public transportation. The dependence on fossil fuels not only harms the environment but also renders transportation unsustainable in the long run. Indonesia, possessing abundant nickel reserves, seeks to revolutionize its automobile sector by embracing EVs (electric vehicles) as a viable solution, aligning with global efforts to reduce Greenhouse gas emission (GHG) (F. Ahmad, Alam, and Asaad, 2017).

In Indonesia, the urgent need to address the environmental impact of conventional vehicles has led to the introduction of initiatives such as the Battery-Based Electric Vehicle Acceleration Program (PERPRES-RI, 2019). Despite the positive reception of any electric vehicles (EVs), challenges remain, especially concerning the charging infrastructure. Indonesia stands as the third-largest motorcycle market worldwide, yet the integration of electric motorcycles remains limited (F. Ahmad, Alam, Alsaidan, et al., 2020). The Indonesian government has set ambitious targets, aiming for 2.5 million electric motorcycles by 2025 and 13 million by 2030 (DEN, 2016). However, the government encounters several hurdles in promoting electric motorcycle adoption. One obstacle is the higher price of electric motorcycles compared to their non-electric counterparts, attributed to the inclusion of batteries (Rubens, 2019). Additionally, the extended duration required for battery charging poses another significant challenge. To address these issues, implementing a battery swapping system emerges as a viable alternative (F. Ahmad, Alam, Alsaidan, et al., 2020).

Despite the benefits offered by battery swapping for electric motorcycles, challenges persist in the development of the battery-swapping industry in Indonesia, particularly in terms of its services. Operating a battery swapping station is notably more intricate compared to a charging station. Demand management proves to be particularly challenging; unlike charging stations, battery swapping stations have an inventory of batteries, and these batteries must be fully charged to maintain their service level, incurring costs even when not in use (F. Ahmad, Alam, Alsaidan, et al., 2020). Additionally, ensuring standardized batteries and regular maintenance is crucial to guarantee good battery quality, a responsibility that falls on service providers (W. Sutopo et al., 2018). Another obstacle lies in the demand for affordable installation and operating infrastructure, a challenge recognized in the industry (Jain, 2018).

The situation is complicated further by a classic chicken-and-egg dilemma. Prospective users are hesitant to embrace electric motorcycles if a well-established infrastructure is lacking. Conversely, providers are reluctant to invest in battery swapping services if the business lacks profitability due to insufficient market demand, creating a challenging scenario (Mak et al., 2013). These persistent issues highlight the necessity for extensive research to explore innovative solutions to address these complex challenges.

The primary objective of this thesis proposal is to shed light on the development and implementation of the e-motorcycle battery swap business in Indonesia. The study will leverage the Circular Technological Innovation System (TIS) Framework (Shankar, 2023) to offer a comprehensive understanding of the dynamics within the electric motorcycle battery swap industry in the context of circularity. Additionally, the study will employ Interpretive Structural Modeling (ISM) to identify and prioritize the existing causes of barriers, establishing hierarchies among them. This in-depth analysis, along with the insight from building blocks and influencing condition status, will pave the way for the proposal to introduce precise and effective strategies specifically tailored to address the prioritized causes of barriers within the hierarchical model (Attri et al., 2013). Through this approach, the proposal strives to contribute valuable insights to facilitate the successful establishment and sustainable growth of Indonesia's e-motorcycle battery swap industry.

1.1. Literature Selection

To perform a comprehensive and efficient literature review, various combinations of specific keywords were employed to identify relevant papers. These keywords included terms such as battery swap, electric vehicles, Indonesia, Electric motorcycle, Socio-technical, Niche, Niche Strategies, Barriers, Challenges, Technological Innovation System, ”Interpretative structural modeling, policy, strategies, and innovation policy. The first five keywords were utilized to pinpoint knowledge gaps related to battery swap technology in the context of Indonesia, while the last ten aimed to identify gaps concerning the theoretical framework. The literature review primarily relied on Scopus, the Elsevier website, and the TU Delft repository. Some of the searches made include the following combinations:

- ”Battery swap” AND ”Indonesia” yielded 12 results. However, several focused on sustainable supply chain planning, some of them focused on lessons learned for commercialization, technology preferences, technology readiness, and national battery standardization. Only one paper was related to the challenge of upscaling the battery swap operation in Indonesia.
- ”Battery swap” AND ”Indonesia” AND ”Challenges” yielded one result that focused on addressing the infrastructure challenge.
- ”Battery swap” AND ”Indonesia” AND ”Policy” yielded two results which focused on sensitivity analysis on policy associated with battery swap utilization in Indonesia and policy related to renewable energy utilization for battery charging stations in the new capital city (IKN).
- ”Battery swap” AND ”Niche” yielded one result, which only compared the options to electrify heavy-duty vehicles (Finding of Germans pilot project).

- ”Technological Innovation System” or ”TIS” AND ”Strategy” yielded 52 results. None of them focused on battery swap innovation systems in a certain country. However, one particular paper focused on technology diffusion for companies, which can be used as a primary reference for building the TIS framework on this topic. However, TIS alone does not provide sufficient insight into the hierarchical relationships between barriers and does not indicate which one should be prioritized for resolution first. Another paper is related to the modified TIS which has the adjusted building blocks and influencing conditions that are related to the circularity and high technology.
- Several combinations of all mentioned keywords AND ”electric motorcycle” yielded four results: 1 case focused on the impacts of battery swap stations in Africa, 1 case focused on the preference for a specific city in Indonesia (Bandung), 1 case focused on persuasive design of battery swap, and another one focused on the personal sustainable benefit from electric motorcycle, in which implies there are is a big opportunity to deep in the socio-technical study on e-motorcycle battery swap technology, both globally or specifically for Indonesia.

Based on the relevance to the topic, 20 papers were selected as the references for further analysis. The following table shows the essential information on each selected paper.

Table 1.1: Overview of selected papers

Publication	Author(s)	Title	Related Topic(s)			
			Battery swap	Indonesia	Technology development	Upscaling /Transition
2023	Suwignjo, P., Yuniarto, M.N., Nugraha, Y.U., Desanti, A.F.,	Benefits of Electric Motorcycle in Improving Personal Sustainable Economy: A View from Indonesia Online Ride-Hailing Rider	Yes	Yes	No	No
2023	Shankar, R.	Exploring the role of Niche Strategies in overcoming Barriers to Circular Innovation	No	No	yes	Yes
2023	Chandra, B., Simon, S., Romain, C.D.S., Muhammad, F. et al	Preferences for electric motorcycle adoption in Bandung, Indonesia	Yes	Yes	yes	No
2023	Setyawan, A.D., Zahari, T.N., Anderson, K.	Examining the effectiveness of policies for developing battery swapping service industry	Yes	Yes	No	Yes
2023	Heryana, N., Iskandar, H.R., Furqani, J.	Utilization of Renewable Energy for Charging Station in Indonesia New Appointed Capital City, Nusantara	Yes	Yes	Yes	No
2023	Romdlony, M.Z., Khayr, R.A., Muharam, A., Amin, Fachri, R.K.	LSTM-based forecasting on electric vehicles battery swapping demand: Addressing infrastructure challenge in Indonesia	Yes	Yes	Yes	No
2023	Balijepalli, C., Shepherd, S., Crastes Dit Sourd, R., Praesha, T., Lubis, H.A.-R.	Preferences for electric motorcycle adoption in Bandung, Indonesia	Yes	Yes	Yes	No
2023	Suwignjo, P., Yuniarto, M.N., Nugraha, Y.U., Wiratno, S.E., Yuwono, T.	Benefits of Electric Motorcycle in Improving Personal Sustainable Economy: A View from Indonesia Online Ride-Hailing Rider	Yes	Yes	Yes	No
2022	Ortt, R.L., Kamp, L.M.	A technological innovation system framework to formulate niche introduction strategies for companies prior to large-scale diffusion	Yes	No	No	Yes
2022	Aqidawati, E.F., Sutopo, W., Pujiyanto, E., Fahma, F., Ma'aram, A.	Technology Readiness and Economic Benefits of Swappable Battery Standard: Its Implication for Open Innovation	Yes	Yes	Yes	No
2022	Questera, N., Aziz, M.V.G., Purwadi, A.	Preliminary Design to Overcome Range Anxiety in Indonesia Using the Quest Motors Electric Vehicles Ecosystem	Yes	Yes	Yes	No
2021	Shih, L., Chien, Y	Persuasive design for improving battery swap service systems of electric scooters	Yes	No	No	Yes
2021	Sheehan, C.S., Green, T.C., Daina, N.	A simulation approach to analyze the impacts of battery swap stations for e-motorcycles in Africa	Yes	No	No	No

Continued on next page

Table 1.1 – Continued from previous page

Publication	Author(s)	Title	Related topic(s)			
			Battery swap	Indonesia	Technology development	Upscaling /Transition
2021	Anggundari, W.C., Dewantoro, A., Bendjamin, B.L., Yopi, Darmayanti, N.T.E.	Analysis of the quality parameter requirements of national standard development for battery swap in electric vehicles	Yes	Yes	No	No
2020	Furkan, A., Alam, M.S., Shariff, S.M.	Battery swapping station for electric vehicles: opportunities and challenges	Yes	No	No	Yes
2020	Habibie, A., Sutopo, W., Budijanto, M.	Comparative analysis of developing innovation products on electric motorcycle conversion: Lesson learned to commercialization	Yes	Yes	No	No
2019	Prianjani, D., Sutopo, W., Hisjam, M., Pujiyanto, E.	Sustainable supply chain planning for swap battery system: Case study electric motorcycle applications in Indonesia	Yes	Yes	No	No
2018	Rahmanullah, E.S., Nurjanah, S.	Influence of product quality, price and supporting infrastructure to perceived value and interest in buying of electric motorcycle	no	Yes	No	No
2018	Prianjani, D., Sutopo, W., Hisjam, M., Pujiyanto, E.	Designing framework for standardization and testing requirements of battery swap for electric motorcycle application in Indonesia	Yes	Yes	No	Yes
2018	Sutopo, W., Nizam, M., Rahmawatie, B., Fahma, F.	A review of electric vehicles charging standard development: Study case in Indonesia	Yes	Yes	No	No

1.2. Research Gap

The selected literature review reveals critical gaps in the research landscape concerning battery swap technology for electric motorcycles (e-motorcycles) in Indonesia. Firstly, there is a scarcity of studies focusing on niche introduction strategies for e-motorcycle battery swaps toward large-scale diffusion, creating a significant knowledge gap. This indicates an opportunity for the thesis to explore and formulate effective niche introduction strategies for e-motorcycle battery swap, adapting successful approaches from other technologies to the unique context of battery swap for e-motorcycle. Secondly, the research highlights the limited attention given to the socio-technical aspects of battery swap technology, both globally and specifically within Indonesia. An in-depth analysis of the social, cultural, economic, and technological factors influencing the adoption and diffusion of battery swap technology for e-motorcycles is necessary. This analysis could offer valuable insights into the challenges and opportunities in implementing battery systems for e-motorcycles, addressing the existing gap in the literature. Moreover, within Indonesia's context, there are few comprehensive studies on battery swap development for e-motorcycles. While some literature focused on technological optimization (Romdlony et al., 2023), policy sensitivity analysis (Setiawan et al., 2023), personal sustainable benefit as in Suwignjo's paper (Suwignjo et al., 2023), and battery standardization as in Prianjani's paper (Prianjani et al., 2019) and Sutopo's paper (W. Sutopo et al., 2018), there is a lack of research on what drives and hinders e-motorcycle battery swap technology within the socio-technical framework of Indonesia. Additionally, there is a limited exploration of upscaling strategies for e-motorcycle battery swap technology beyond the fleet market. One of the papers related to the Indonesian market, written by Chandra et al. (Balijepalli et al., 2023), has a narrow view of a particular city In Indonesia and lacks of upscaling study.

One research paper was identified regarding battery swap technology in electric vehicles in general, not limited exclusively to e-motorcycles, and without a specific focus on Indonesia as the research subject (F. Ahmad, Alam, Alsaidan, et al., 2020). At this rate, conducting case studies, interviews, or surveys with stakeholders involved in battery swap implementation in Indonesia could provide crucial insights into the specific challenges within the Indonesian market. In addition, A comparative analysis of battery swap technology development for e-motorcycles in Indonesia with other countries or regions such as Africa (Sheehan et al., 2021) could yield valuable comparative insights. By understanding successful adoption models elsewhere, Indonesia can potentially learn from international best practices, contributing to a more comprehensive understanding of e-motorcycle battery swap technology adoption globally.

The literature review also reveals a notable absence of policy recommendations for the adoption of battery swap technology for e-motorcycles, such as Setiawan's paper (Setiawan et al., 2023). This research integrates Walker's policy analysis framework (Walker, 2000) with Forrester's system dynamics approach (Forrester, 1994) to assess the implementation of battery swapping technology. This literature does not derive policy strategy recommendations directly from the framework; it only analyzes the effectiveness of the ongoing policy. It does not delve into non-policy barrier analysis crucial for the widespread adoption of E-Motorcycle Battery Swap systems in Indonesia.

The TIS framework for companies (J. R. Ortt and Kamp, 2022), although instrumental in devising strategies to mitigate identified barriers, both lack a specific mechanism for prioritizing these barriers. Furthermore, the original TIS building blocks and influencing conditions may be implicitly suitable for the battery swap business context in Indonesia. Still, it can be further fit by using another type of TIS with modified building blocks and influencing conditions related to the circularity (Shankar, 2023).In addition, unlike TIS (and the modified version), the integration of ISM provides a method to map barriers and hierarchical interrelation. This integration ensures that the resulting output includes a hierarchical relationship among the barriers, enabling a clear prioritization of which barriers should be addressed first as a root of the problem. Therefore, the addition of ISM adds a crucial layer of insight that TIS (or the modified one) alone does not provide, facilitating informed decision-making regarding barrier resolution strategies.

1.3. Suitability of TIS Frameworks

In assessing various frameworks for their applicability to analyzing barriers and influencing conditions to circular innovations, particularly focusing on the adoption of battery swap systems for motorcycles in Indonesia, a detailed comparison was conducted. The comparison matrix highlighted distinct features and approaches within the reports authored by Raghav Shankar, Jules, and Ruben. The original 2022 Technological Innovation Systems (TIS) framework is less suited for analyzing barriers to circular innovations, such as the adoption of battery swap systems for Indonesian motorcycles. It lacks the tailored elements needed to comprehend the complexities specific to circular innovations in this context. Additionally, its limited adaptability may hinder addressing the unique challenges posed by circular economy principles in relation to the battery swap system. Furthermore, the framework's inadequate emphasis on circular economy principles might overlook crucial aspects inherent to circular innovations like battery swaps. Lastly, adapting the original TIS framework might necessitate substantial alterations or the creation of entirely new blocks, deviating from the preference observed in preferred methods, like highlighted approaches, Raghav's, Jules's, and Ruben's, which integrate new elements within an existing framework rather than introducing entirely new structures. The comparison matrix highlighted distinct features and approaches within the reports authored by Raghav, Jules, and Ruben. The matrix of comparison between all three modified approaches is shown below.

Table 1.2: Comparison of TIS Frameworks

No	Author	Reference	Change in Building Blocks	Change in Influencing Conditions	Type of Firm	Circularity	Keywords /Notes
1	Raghav Shankar (2023)	"Exploring the role of Niche Strategies in overcoming barriers to Circular Innovation Exploratory Case Studies of Circular High-Tech firms in The Netherlands"	Consist of 7 regular building blocks and seven influencing conditions introduced in Ortt & Kamp's Paper, but with the sub-blocks and modified keywords associating circular innovation context in each of them	Consist of 7 regular influencing factors introduced in Ortt & Kamp's Paper, but with modified keywords	High tech Company	Yes	Additional 2-3 sub-blocks on each Building blocks and Influencing condition blocks. Important keyword: Collaboration standardization, competition between old and new technology.
2	Julius Engelen (2023)	Overcoming barriers to Circular Innovations: exploring niche strategies for successful introduction	Additional building blocks: Reverse Logistics Adjusted building blocks: Production system, Complementary products and services, Network formation and coordination	Additional influencing condition: Data Infrastructure Adjusted influencing conditions: Knowledge and awareness of technology, Natural human and financial resources	General (companies with circular innovations)	Yes	Suggested separation of reverse logistics and data infrastructure, Important keywords: competition between linear and circular business in a same technology (ex: beverages and apparel Industry)
3	Ruben Warns (2023)	"Niche strategies for reuse innovations Niche introduction strategies for large-scale diffusion of reuse innovations in the European domestic soft drinks industry"	Adjusted building blocks: Performance and the quality of the Circular Product-Service System, Pricing of the Circular Product-Service System, Circular production system	Adjusted influencing conditions: Knowledge and awareness of CE technology and practices, Environmental and strategic aspects	Soft drinks industry	Yes	Emphasis on 'Re-use Innovation models for soft drink industry and efficiency in handling return streams
4	Ortt, J. R., & Kamp, L. M. (2022)	"A Technological Innovation System Framework to Formulate Niche Introduction Strategies for Companies Prior to Large-scale Diffusion."	None	None	High tech Company	Not explicitly specified	Emphasized the development of high-tech product/technology in TIS context, a potential link to circular innovations

Jules' method suggested the separation of reverse logistics and data infrastructure, providing more specificity in new blocks and conditions, which is beneficial. However, concerning competition blocks, Jules emphasized that Circular Economy (CE) is in its early stages, facing primary competition from the dominant linear technologies, which often hold advantages in performance, price, and legislation. Despite this, competition within circular innovation systems arises from the pursuit of adequate secondary resources, with potential conflicts between recycling-focused systems and those emphasizing product lifespan extension, like repair-oriented approaches. This approach may be less suitable for the context of the battery swap system for e-motorcycles, which faces intense competition with traditional ICE motorcycles, which both have completely different business models although still in the same buyer's pool. It is important to note that there are no changes identified in the other building blocks except the two additional blocks related to the circularity, as they are quite similar to the original TIS frameworks and can be effectively implemented in a general context.

Raghav's building blocks and influencing condition blocks broke down into 2-3 sub-elements of building blocks and influencing condition blocks, providing more detail than other methods. Raghav's approach offers an influencing condition block to capture diverse competition statuses, such as conventional competition (competition between future and old technology), which is suitable for the context of competition between battery swap systems for e-motorcycles and the sales of traditional ICE motorcycles. Raghav's building blocks and influencing condition blocks also depict consensus, conducive regulation, collaboration, and standardization among new players. Standardization must be developed before the technology can be mass-produced and used as a driving force (Wahyudi Sutopo et al., 2022), and collaboration is needed to alleviate the bottleneck of the market expansion.

Ruben's method focused on the reuse innovation in the soft drink industry. It also included adjusted blocks and conditions related to circular product-service systems with the absence of standardization building blocks, which would not align well with the context of the battery swap system and e-motorcycle technology that need standardization as building blocks (Wahyudi Sutopo et al., 2022).

Jules' method shows suitability for the context. However, it does not explicitly address standardization as a building block, which is important for battery swap systems (Wahyudi Sutopo et al., 2022). In addition to the various influencing conditions outlined by Jules, the significance of "data infrastructure", as defined by Jules, cannot be ignored. While this element proves to be valuable, it can be effectively addressed within the "systemic perspective" framework proposed by Raghav. According to this perspective, data infrastructure transforms into a systemic enabler meticulously crafted by governmental entities. This holds particular relevance in the context of the battery swap ecosystem, where it assumes the role of an open protocol for battery identification. Through this, it establishes traceability mechanisms, thereby facilitating waste monitoring and encouraging the implementation of reverse logistics. .

Additionally, when comparing Raghav's framework with Rubens', there are no significant differences in the main blocks. However, Raghav stands out with its advantages in the details, manifested in the form of "sub-blocks." This nuanced approach makes Raghav's framework more conducive to studying the intricacies of battery swap technology in the context of Indonesia.

It is noteworthy that all three methods, including Jules, Raghav, and Ruben, lack emphasis on geographical location-related block adjustments. While they provide insights into understanding the dynamics of technology and general customer behaviors, none of these methodologies specifically address the need for adjustments tailored to the geographical context, which means that all three methods can be applied to the proposed study located in Indonesia.

In conclusion, Raghav's approach emerges as the most suitable and holistic framework for the analysis of the battery swap system technology for e-motorcycles. Raghav's method breaks down these components into 2-3 sub-blocks, providing a level of detail that is essential for understanding the complexities of the battery swap system. The method captures nuances such as the competition between new and old technologies (is suitable for the context of e-motorcycle vs ICE motorcycle), collaboration among new players or consortiums, and special blocks for understanding standardization processes—factors crucial to alleviate the bottleneck of the market expansion.

1.4. Research Question

Based on section 1.2, the literature review indicates a predominant emphasis on the technical feasibility of e-motorcycle battery swap technology and the broader category of electric vehicle infrastructure in Indonesia. However, there exists a substantial academic knowledge gap concerning the specific development of e-motorcycle battery swap systems in the country. Particularly, strategies for their introduction and scaling within the Indonesian market remain underexplored. This thesis aims to enhance the existing understanding of this technology and intends to fill, at least partially, the academic void in this area. The main research question guiding this study is as follows:

What prioritized strategies can be implemented to overcome the identified causes of barriers and facilitate the successful large-scale diffusion of E-Motorcycle Battery Swap systems in Indonesia?

An in-depth investigation is indeed required to answer the main question driving this research. Beyond simple identification, the goal of this research is to rank these obstacles and provide politicians and business professionals with a strategic road map. This plan will outline which challenges need to be tackled first in order to make the biggest headway. An organized method is necessary to navigate this investigation, which generates a number of focused sub-questions:

1. What are the key stakeholders in the various e-motorcycle battery swap-related sectors within Indonesia, and what are their interconnections?
2. What is the current status of government policies, incentives, and the regulatory framework in Indonesia concerning E-Motorcycle Battery Swap systems?
3. What is the current state of each building block and influencing condition blocks in the Technological Innovation System (TIS) in terms of e-motorcycle battery swap system development in Indonesia? Which one is considered a complete, partially complete, or incomplete building block?
4. How are identified barriers and their causes interconnected?
5. What is the level of importance or priority to each of the identified causes of barriers in order to focus efforts and resources on those that are deemed most critical or time-sensitive?

1.5. Research Approach

The exploration of groundbreaking technological innovations from a socio-technical perspective often involves employing structured methodologies like the Technological Innovation System (TIS) for companies before large-scale diffusion. This thesis aims to enhance the framework by using the modified version of TIS (which is more suitable for the battery swap business context in Indonesia), including strategies for policymakers, and analyzing the interconnections between building blocks and influencing conditions of such technology. However, modified TIS alone falls short of providing comprehensive insights into the hierarchical relationships among barriers and does not specify which barriers should take priority for resolution. This is where ISM proves invaluable when coupled with the modified TIS frameworks. Integrating ISM allows for a clearer understanding of strategy formulation based on the hierarchical relationship between barriers. In this study, the conceptual TIS framework developed by Ortt and Kamp (J. R. Ortt and Kamp, 2022), and with the modification created by Raghav (Shankar, 2023) will be utilized, along with a data-collection strategy, Interpretative Structural Modelling (ISM). This integrated modified TIS-ISM approach provides a dynamic view of the challenges, enabling us to develop tailored strategies for overcoming barriers effectively, ultimately facilitating the widespread adoption of E-Motorcycle Battery Swap systems in Indonesia while considering the complex system dynamics.

The research report will commence with an exploration of pertinent literature frameworks detailed in Chapter 2. Subsequent chapters, starting from Chapter 3 onwards, will systematically outline the methodology to address each sub-question. Since most of the research sub-questions are exploratory in nature, desk research is also an excellent place to start for each one. Nevertheless, each research sub-question requires a distinct approach to be addressed.

The first sub-question, **What are the key stakeholders in the various e-motorcycle battery swap-related sectors within Indonesia, and what are their interconnections?**, is set on examining the key players who could affect the adoption of e-motorcycle battery swap system in Indonesia. Comprehending the identities and interplay of these players is vital for multiple stages that follow, such as ascertaining which influencing factors correspond with which regime and formulating policy approaches. Extensive desk research in academic and informal sources should be sufficient to provide the best answer to this sub-question. However, the responses to interviews conducted in later phases may also serve as an additional way of verifying the answers discovered during the research stage due to the limited series of related literature.

The second sub-question, **What is the current status of government policies, incentives, and the regulatory framework in Indonesia concerning E-Motorcycle Battery Swap systems?** is set on exploring what the government policies applied to the Indonesia E-Motorcycle Battery Swap systems. Answering this question should be similar to the first sub-question by combining literature reviews and interviews due to limited sources of related academic papers. The answers for the first and second sub-questions will be addressed in Chapter 3 of the reports. For Chapter 3, the Indonesia National Battery Research Institute has been selected as the primary respondent. This institution offers an initial viewpoint on the Indonesian stakeholder map and ongoing policy as its interests align across the entire spectrum, from upstream to downstream. This choice is strategic, allowing insights from this initial discussion to guide the identification of other involved stakeholders. Subsequent interviews with diverse stakeholders will culminate in a comprehensive stakeholder map.

The third sub-question, **What is the current state of each building block and influencing condition block. In the Technological Innovation System (TIS) in terms of e-motorcycle battery swap system development in Indonesia? Which one is considered as complete, partially complete, or incomplete building blocks**, emphasizing exploring the changing circumstances of the e-motorcycle battery swap system? The goal is to understand what is the status of each of the seven main building blocks and which building blocks act as a barrier to large scale diffusion on the battery swap technology for e-motorcycles in Indonesia.

The research involves a thorough analysis of academic and industry literature, forming the foundation for understanding the background and development of key elements. This exploration provides essential insights, shaping relevant interview questions. Direct discussions with industry experts offer current, firsthand insights that are challenging to obtain otherwise, enriching the research with authentic perspectives. The semi-structured framework of the interviews will serve two important goals. First of all, this method ensures that significant research issues within the discipline are methodically addressed. Second, it gives interviewees sufficient room to cover subjects they believe are most important to the technology. All these related answers will later be discussed in Chapter 4.

The fourth sub-question, **How are identified barriers and their causes interconnected**, explores the intricate relationships between barriers (incomplete or partially complete building blocks) and the corresponding causes identified in Raghav's TIS framework. Each of the seven main influencing factors contributes to or inhibits this system's adoption on each main building block. Desk research and interviews with industry professionals will be used in tandem to explore these questions.

The fifth question, **What is the level of importance or priority to each of the identified causes of barriers in order to focus efforts and resources on those that are deemed most critical or time-sensitive?** necessitates a strategic analysis within the framework of ISM. By utilising ISM analysis, this inquiry seeks to identify and prioritise the essential causes of barriers that became factors that can hinder the completion of building blocks of E-Motorcycle Battery Swap systems adoption in Indonesia. ISM allows for a systematic evaluation. Addressing these most crucial causes of barriers can catalyse a chain reaction, which is important in terms of formulating effective strategies to alleviate all the causes of barriers.

After all barriers are identified from the first wave of interviews (and literature review) within the TIS framework, a questionnaire regarding the relationship between identified barriers will be delivered to the expert on the respective stakeholders to gather initial input of ISM in the form of a structural self-interaction matrix (SSIM), which illustrates the direction of contextual relationships between element as a first step of ISM which will be completely explained in the Section 2.4. A full explanation related to the context of Indonesia's battery swap system within the frameworks of ISM will be delivered in Chapter 5.

Finally, using the finding from Chapter 6, the main question, **What prioritised strategies can be implemented to overcome the identified causes of barriers and facilitate the successful large-scale diffusion of E-Motorcycle Battery Swap systems in Indonesia?**, can be answered.

1.6. List of Interviewees

Table 1.3 provides a comprehensive list of interviewees who will play a pivotal role in this research, especially for chapters 4,5, 6 and 7 in the validation section. Each participant represents a key stakeholder within the battery swap ecosystem development in Indonesia. These stakeholders include a local battery manufacturer that has met 40% of the local content requirement (TKDN), PLN as the singular entity responsible for electricity provision to battery swap stations; ministries actively engaged in regulatory matters concerning battery swap technology and internal combustion engine (ICE) motorcycle conversion, an emerging e-motorcycle startup, and a researcher possessing valuable insights into customer knowledge and ownership preferences. It is worth noting that, in accordance with requests for confidentiality, some participants have been anonymised to protect their identities.

No.	Name of Respondent	Position	Name of Organization	Type of Organization	Date	Involvement
1	Interviewee 1	Researcher of Technology and Regulation	National Battery Research Institute	Independent Battery Research Institute and Its Ecosystem	21/11/2023	Chapter 4 and 5
2	Interviewee 2	Supervisor Marketing and After Sales Support	Anonymous	Local battery manufacturer	20/12/2023	Chapter 4
3	Interviewee 3	Research and Development Officer	PLN	Single entity of electricity provider	4/12/2023	Chapter 4
4	Interviewee 4	Assistant Deputy of Maritime and Transportation	Kementrian Maritim dan Investasi	Ministry (government)	6/12/2023	Chapter 4
5	Interviewee 5	Coordinator of Electrical Power Testing	Kementrian ESDM	Ministry (government)	25/11/2023	Chapter 4
6	Interviewee 6	Policy Analyst	Kementrian ESDM	Ministry (government)	23/11/2023	Chapter 4 and 5
7	Interviewee 7	Officer of Directorate of Waste Handling	Kementrian KLHK	Ministry (government)	7/12/2023	Chapter 4
8	Interviewee 8	Senior Legal of E-mobility Ecosystem	Anonymous	Local E-motorcycle + battery swap provider	14/12/2023	Chapter 4 and 5
9	Interviewee 9	CTO & Co-founder	Anonymous	Local Interoperability roaming technology provider	15/12/2023	Chapter 4
10	Interviewee 10	Researcher/ University Lecturer	Sepuluh Nopember Institute of Technology	University	31/1/2024	Chapter 4
11	Interviewee 11	Member of Political Party	Anonymous	Political Party	14/3/2024	Chapter 4 and 6
12	Interviewee 12	Project Manager	Anonymous	Mining Company	24/3/2024	Chapter 4
13	Interviewee 13	Battery and Power Electronics Researcher	BRIN	Indonesia Research Institute	22/4/2024	Chapter 4 and 6
14	Validator 1	Marketing Director	ABC	Battery Packer Company	24/4/2024	Validation of Results (Ch. 5 and 6)
15	Validator 2	Senior Officer of Technology Innovation	PLN	Grid Owner and Regulator	27/4/2024	Validation of Results (Ch. 5 and 6)

No.	Interviewee	Position	Name of Organization	Type of Organization	Date (DD/MM/YYYY)	Involvement
16	Validator 3	Battery Swap Ecosystem Researcher	BRIN	Research Institution	30/4/2024	Validation of Results (Ch. 5 and 6)
17	Validator 4	SVP of Corporate Strategy and Business Development	IBC	Battery Corporation	1/5/2024	Validation of Results (Ch. 5 and 6)

Table 1.3: List of Interviewees

All interviews for this research will be conducted strictly per TU Delft's human research ethics guidelines. After recording each interview, the subsequent step involves manual transcription of the video content, which is particularly necessary since the interviews are conducted in Indonesian and are not supported by automated transcription features in Microsoft Teams. Next, the coding process will be implemented using ATLAS TI 23, aligning closely with the specific questions addressing sub-building blocks and influencing condition blocks tailored for each interviewee. To deepen the exploration of key topics, improvised questions may also be introduced during the interviews.

1.7. Research Flow Diagram

The proposed research flow diagram is depicted in Figure 1.1 below. Every stage of the project is displayed, together with the necessary inputs, the corresponding research approach, and the section to which it will be connected. Each step's relevant research question or questions are also displayed.

1.8. Research Ethics

This research strictly adheres to ethical guidelines set by the Human Research Ethics Committee (HREC) as shown in Appendix D, and a detailed Data Management Plan as shown in Appendix E. The HREC oversees the writer's commitment to high ethical standards throughout the research process. In conducting interviews, respecting participants' rights and privacy is prioritized. Each interview is carried out with participants' informed consent, secured through an HREC-approved consent letter as shown in Appendix F.

1.9. Data Analysis Tools

Other than search engines like Google, TU Delft repository, Scopus for academic literature and Google for grey literature, no particular tools will be employed for desk research. Also, for the interview session, the record feature in TU Delft Microsoft Teams will be utilized for recording purposes, followed by coding the transcription using ATLAS TI 23. Finally, a quantitative data analysis tool like MATLAB will be used to code the matrix of interrelation between causes of barriers as input for ISM acquired from the brainstorming.

1.10. Deliverables

This research aims to deliver three major artifacts: (1) Raghav's TIS frameworks that introduce the adjusted building blocks and influencing conditions that fit the proposed context (2) an ISM framework that produces the hierarchical relationship between causes of barriers located in Raghav's TIS frameworks, and (3) suitable strategies

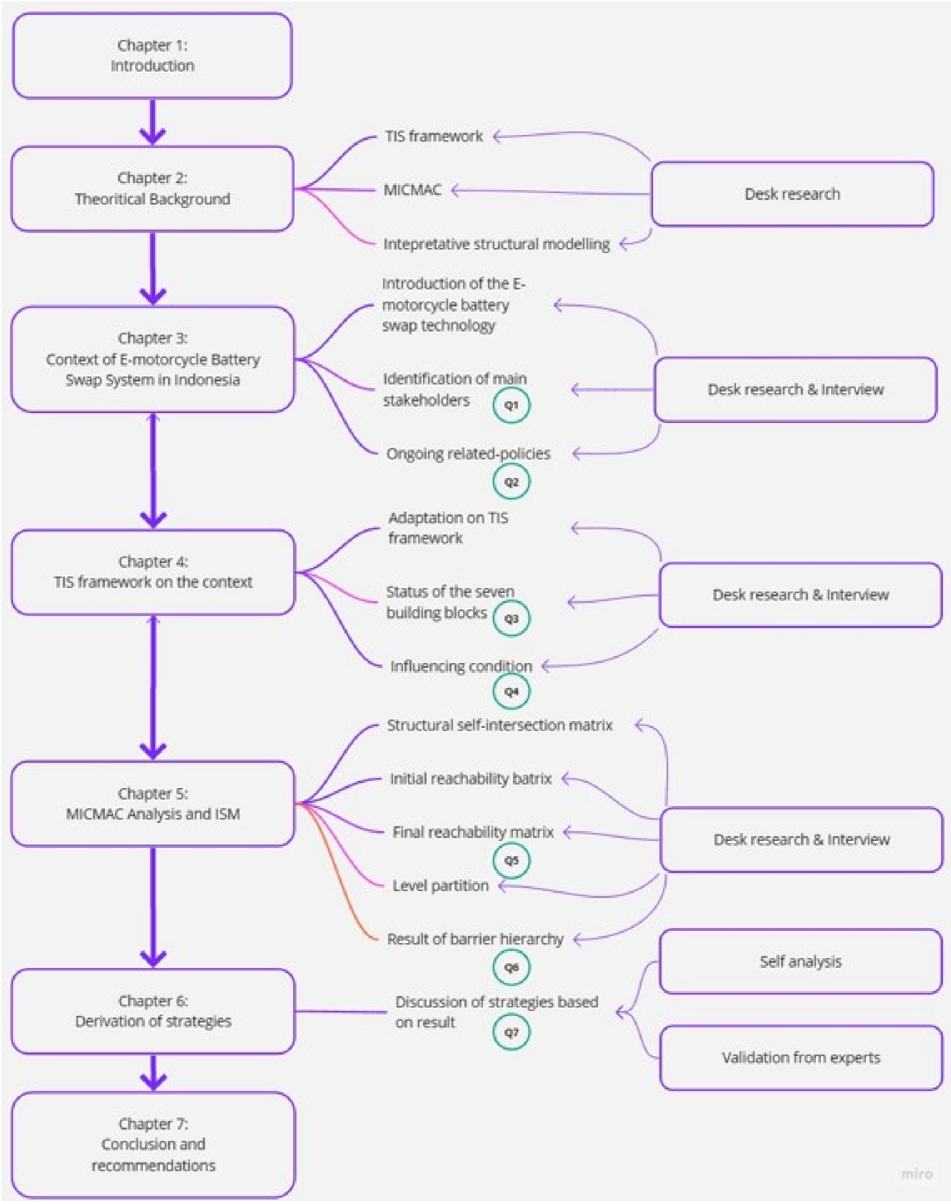

Figure 1.1: Research flow diagram

to resolve the barriers based on the finding from modified TIS-ISM frameworks. In addition, due to the dynamic nature of the regulations in Indonesia, this research only incorporates updates of regulation changes up to the end of the year 2023.

By delivering above mentioned artifacts, this research brings several scientific contributions as The following: (1) the combination of TIS-ISM approach to identify hierarchical relationships between barriers of a certain technology, (2) the identification of potential strategies that could circumvent the niche development barriers that hinder the large-scale diffusion of e-motorcycle battery swap technology in Indonesia, (3) the recommendation of the strategy for Indonesia's government to diffuse its battery swap system for e-motorcycle in Indonesia, and lastly (4) this research act as novel literature of TIS-ISM frameworks for e-motorcycle battery swap system in Indonesia.

1.11. Alignment to Sustainable Energy Technology Program

This research holds significant potential to serve as a cornerstone and valuable resource in shaping Indonesia's energy strategies, particularly concerning the implementation of a battery swap system for e-motorcycles. It offers a comprehensive reference for key stakeholders within the energy industry in Indonesia. Moreover, the research aligns with the objectives of the SET program by addressing the integration of innovative solutions, such as the battery swap system, within the context of economic and societal profiles. Additionally, academically, this research contributes by addressing identified gaps, specifically regarding the technical and economic potential of deploying the battery swap system for e-motorcycles at a national scale. It aims to provide comprehensive insights and recommendations to facilitate its implementation and impact within the Indonesian context.

1.12. Report Structure

As shown in the figure 1.1, the report is structured as the following. Relevant theories are explained in Chapter 2 as the basis of the research, followed by a context of e-motorcycle battery swap in Chapter 3, along with the identification of the main stakeholder of it and ongoing related policy in Indonesia. Subsequently, Chapter 4 elaborates on the identification of building blocks and influencing conditions within Raghav's TIS framework, which leads to Chapter 5, which elaborates on the hierarchical relationship between causes of barriers using the ISM method. In Chapter 6, the strategy will be derived from the building blocks status from TIS and the hierarchical inter-relation between causes of barriers as the output of ISM; this chapter is also associated with the validation of the hierarchical relationship between causes of obstacles from the TIS framework and the proposed strategies. Then, Chapter 7 elaborates on the conclusion of relevant topics, reflecting on the research, its relevance, and its limitations, what goes wrong during the research progress, as well as providing recommendations to several relevant stakeholders and recommendations for potential research topics.

2

Theoretical Background

2.1. Ortt and Kamp's TIS Framework

In 2022, Ortt and Kamp introduced an original TIS framework tailored to assess innovation readiness for large-scale diffusion or the need for a small-scale niche introduction strategy. This framework specifically targets innovations in their adaptation phase, possessing functional prototypes but lacking widespread commercialization (J. R. Ortt and Kamp, 2022).

The framework comprises three key components: TIS building blocks (previously termed core factors), influencing conditions (previously referred to as influencing factors), and niche strategies. The TIS building blocks not only highlight critical aspects of the technological and market system necessary for large-scale diffusion but also indicate the timing and scale of introduction strategies. The presence or absence of these building blocks determines the feasibility of widespread innovation adoption. The lack or absence of these blocks can directly stop a lot of people from adopting them widely. If most building blocks are absent or incomplete, it is recommended that the innovation producer postpone introduction strategies until these elements are more established. Alternatively, if only certain blocks are missing or incomplete, the innovation can undergo an adaptation phase, introducing itself to a niche market via tailored strategies to navigate barriers. Each TIS building block is detailed in the Appendix A.

Before all the building blocks are ready and the innovation can be adopted on a large scale, there might be an opportunity to introduce a specific version of the innovation in a smaller, specialized market. This is explained using examples like Poly-ethylene fibre and Photovoltaic cells in the paper. Ortt and Kamp illustrate how the timing and scope of introducing strategies can be determined when a building block is inadequate, missing, or incompatible, signalling a barrier to large-scale adoption. When such a barrier exists, a small-scale niche introduction strategy might be necessary. Sometimes, the nature of the barrier does not provide enough information to assess the type of niche introduction needed. Investigating the root cause of the barrier might offer more details to create a specific niche introduction strategy. Therefore, Understanding influencing conditions can help pinpoint the cause of a barrier, which in turn can guide the development of a niche introduction strategy. Essentially, influencing factors provide valuable information for devising niche introduction tactics. Each of the influencing conditions is explained in Appendix A.

This research later utilizes the modified version of Ortt and Kamp framework to capture the circularity aspect, which will be explained in Section 2.2. This framework becomes a starting point to assess the feasibility of introducing a battery swap system for e-motorcycles on a large scale in Indonesia. The aim is to identify potential barriers to technology diffusion and propose strategies to overcome them. However, while the framework offers valuable insights, it lacks specificity in showcasing the hierarchy and relative power of identified barriers. Therefore, the additional framework is necessary to understand how these barriers interact within the complex system comprehensively.

2.2. Circular Innovation Building Blocks

To advance this research, the upcoming phase involves a thorough examination of building blocks within each facet of Raghav's TIS framework, which is modified from the original one. This tailored investigation centres on the context of circular innovation and its implications for the integration of battery swap systems for e-motorcycles in Indonesia. Raghav's approach stands out as the most fitting structure for scrutinizing the technology of battery swap systems in e-motorcycles. Raghav's technique not only incorporates additional elements into the existing framework of building blocks and influencing conditions but also dissects these components into 2-3 sub-blocks, offering a level of intricacy essential for comprehending the complexities of the battery swap system. The approach captures subtleties such as the competition between emerging and traditional technologies (suitable for the e-motorcycle vs. ICE motorcycle context), collaboration among novel players or consortiums, and dedicated blocks for consensus and standardization processes, which become critical factors for alleviating the bottleneck in market expansion. The analysis aims to illuminate how each component contributes to the comprehensive functionality of the TIS and its impact on nurturing circular innovation, particularly within the distinctive landscape of e-motorcycle battery swap systems in Indonesia. More explanation of each building block is provided in the Appendix **??**.

2.2.1. Product Performance and Quality

As previously discussed, the concept of 'Product performance and quality' holds a distinct significance within the sphere of circular innovation. Beyond adhering to conventional standards, circular high-tech products aim to align with circular principles. This goes beyond typical performance metrics, focusing on maximizing resource efficiency, reducing waste, and promoting prolonged product usage and reusability.

Circular high-tech innovation places considerable emphasis not only on delivering superior performance and quality but also on integrating circular principles throughout the product lifecycle. This involves reimagining every stage, from sourcing sustainable materials and utilizing eco-friendly manufacturing processes to designing for durability, reparability, and recyclability. Prioritizing circularity enables high-tech companies to craft products that not only excel in functionality but also embody sustainability, contributing to the shift towards a more resource-efficient and regenerative economy.

Strategies like material recycling, remanufacturing, and product-as-a-service models are integrated into circular high-tech products to optimize resource use, minimize environmental impact, and foster a more sustainable, circular economy (Shankar, 2023). Therefore, in the realm of Circular Innovation, components such as 'Design for Circularity' and resource optimization hold pivotal importance under this building block.

2.2.2. Product Price

In the realm of circular innovation, the pricing aspect encompasses crucial distinguishing factors. Unlike traditional approaches, circular high-tech innovation considers not only the upfront product cost but also factors in long-term feasibility and the total cost of ownership. Several authors have underscored this point. While circular economy principles aim to create value and reduce waste, implementing circular practices may entail additional expenses, such as integrating recycled materials or adopting re-manufacturing processes. Striking a balance between the economic feasibility of circular products and their environmental benefits is pivotal. This involves assessing life cycle costs, exploring potential cost savings through prolonged product lifespans, and identifying opportunities for innovative business models like leasing or sharing. By meticulously considering the price factor and aligning economic viability with circular principles, this building block can be effectively implemented (Shankar, 2023).

2.2.3. Production System

In the realm of circular innovation, the production system and technical expertise serve as pivotal distinguishing factors. Circular high-tech innovation necessitates a transformation in production processes towards optimizing resources, reducing waste, and integrating circular practices. Key elements encompass the adoption of cutting-edge technologies enabling efficient resource utilization, the implementation of remanufacturing and recycling processes, and fostering collaboration throughout the value chain.

Technical expertise becomes indispensable in designing products for disassembly, establishing reverse logistics systems, and ensuring the quality and performance of recycled materials. Additionally, the production system must exhibit flexibility and adaptability to accommodate changes in product design, materials, and processes, facilitating the shift toward circularity.

Emphasizing technical expertise and continuously enhancing production systems are imperative for successful circular high-tech innovation (Shankar, 2023). The production system remains a critical component in Circular Innovation, especially concerning the 9R capabilities and Scalability.

2.2.4. Complementary Products and Services

In the realm of circular innovation, the presence of complementary products and services assumes a pivotal role. Companies necessitate access to a supportive ecosystem comprising various complementary goods and services, encompassing infrastructure, network support, and efficient communication channels. Collaboration among industrial players stands as a critical factor in operationalizing circular innovation. Coordinated efforts, shared visions for technical innovation, and mutual cooperation are highlighted as essential for the widespread adoption of circular practices. However, challenges may surface due to a lack of participating actors or inadequate collaboration between them.

To surmount these hurdles, fostering robust partnerships and cultivating a shared understanding of circular principles within the industry hold paramount importance. Collaborative efforts among stakeholders and the availability of complementary products and services significantly contribute to the effective implementation and diffusion of circular innovation (Shankar, 2023). It's important to note that while some circular products/services may not rely on existing complementary products and services, they may necessitate the establishment of a novel ecosystem.

2.2.5. Network Formation and Coordination

In the landscape of circular innovation, network formation and coordination emerge as pivotal factors. Effectively implementing circular practices demands seamless collaboration and coordination among stakeholders across the value chain. This involves establishing robust networks and nurturing relationships among various entities, including producers, suppliers, distributors, and consumers.

Efficient coordination ensures the smooth functioning and uninterrupted flow of materials and products within the circular economy. However, challenges may arise concerning communication, delineation of responsibilities, and infrastructure. Addressing these hurdles necessitates proactive engagement, open communication channels, and a unified vision to accomplish circular objectives (Shankar, 2023). Due to the inherent nature of Circular Innovation, this building block assumes critical importance, emphasizing factors like Strong Network and division of responsibility.

2.2.6. Innovation-Specific Institution

These institutions encompass regulatory frameworks, environmental laws, waste disposal regulations, and the overarching legal system. Their effectiveness and alignment with circular economy principles significantly impact the feasibility and success of circular innovation initiatives. The absence or misalignment of supportive regulations, coupled with limited adoption of circular procurement methods, pose formidable barriers.

Furthermore, the global perspective and coordination of innovation-specific institutions play a pivotal role in circular innovation. The lack of a worldwide consensus on Circular Economy principles and the limited utilization of circular procurement methods present significant challenges for global-scale circular innovation. In contrast, conventional innovation may be less reliant on global coordination and agreements.

Regrettably, the lack of robust legal enforcement mechanisms, complex government structures, and policy frameworks hinder the transition towards circularity. Misaligned incentives, legal system deficiencies, and institutional shortcomings further impede progress toward realizing a truly circular economy. A thorough assessment and proactive mitigation of these institutional factors are crucial to drive the transformative shift towards circular innovation (Shankar, 2023).

2.2.7. Customers

Customers wield significant influence in propelling the success of circular innovation. Studies in cognitive sciences and preferences have highlighted that enhancing social awareness among customers regarding sustainability issues and improving their environmental literacy notably impacts their decision-making process. Additionally, the trend towards service-based models and shared ownership significantly shapes customer preferences.

However, various barriers can impede customers' adoption of circular innovation, including limited consumer perception, inadequate involvement and support from consumers and suppliers, and resistance to changes in consumer behaviour and business practices. Overcoming these barriers necessitates a profound understanding of customer behaviour and effective communication strategies.

It's critical to identify potential customers with a genuine need for the innovation and ensure they comprehend its advantages compared to other products. Addressing hurdles like limited resources, knowledge gaps, and uncertainties about the product is crucial in converting potential customers into actual customers (Shankar, 2023). This aspect holds a pivotal role within the TIS. Literature suggests a shift in customers' mindsets, which, for various reasons, can quickly turn into a barrier.

2.3. Circular Innovation Influencing Conditions

As highlighted by Ortt and Kamp, a comprehensive comprehension of the barriers' nature holds significant importance. Rooted in insights from the literature review, this effort strives to identify and comprehend the pivotal elements within each influencing condition unique to Circular Innovation. By meticulously considering these influencing conditions, this study endeavours to offer valuable insights into the barriers encountered and intends to steer the development of effective strategies aimed at overcoming obstacles to achieving widespread diffusion. More explanation of each building block is provided in the Appendix **??**.

2.3.1. Knowledge and Awareness of Technology

When examining the influencing condition of 'Knowledge and awareness of technology' in the domain of circular innovation as opposed to other innovation forms, several distinct differences surface. Within the context of circular innovation, technology expertise plays a pivotal role within the Technological Innovation System (TIS). However, a significant divergence lies in the constrained scope of circular designs, limiting their potential impact.

As highlighted by Ritzén and Sandström, integrating circular products into existing production processes can present challenges. This underscores the need for a deeper comprehension of the intricacies involved in transitioning traditional production systems toward circularity. By fostering knowledge and awareness of technology specific to circular innovation, these initiatives contribute to surmounting barriers and facilitating the shift towards a more circular economy (Shankar, 2023).

2.3.2. Knowledge and Awareness of Application and Market

In the realm of circular innovation, comprehending the practical application and market dynamics holds paramount importance. Understanding how the innovation can be applied and being aware of the market structure and key stakeholders are indispensable. However, challenges such as information asymmetry, uncertain returns, and economic viability can impede progress.

Overcoming these hurdles is crucial for fostering transparency, predictability, and economic success. Moreover, competition prevails among various technologies and product versions, exerting influence on factors like pricing and performance. Therefore, knowledge and awareness of the application and market landscape play a pivotal role in navigating these challenges and achieving success in circular innovation. Circular firms not only compete with conventional products and services but also contend with other circular offerings, shaping the overall success of the firm (Shankar, 2023).

2.3.3. Natural, Human and Financial Resources

Scholarly literature underscores the distinct approach required for resource utilization in Circular Innovation. It involves optimizing resource efficiency, minimizing waste generation, and fostering resource regeneration. This mandates a comprehensive grasp of the involved natural resources, their availability, and sustainable utilization.

Human resources play a pivotal role in circular innovation, demanding specialized knowledge and expertise in circular design, resource management, and sustainable practices. Financial resources also hold a unique position in circular innovation, supporting not only the development of innovative technologies and processes but also establishing infrastructure for resource recycling, remanufacturing, and implementing circular business models. Efficient allocation and coordination of these resources are fundamental for successful circular innovation, setting it apart from other innovation forms with differing resource requirements and management approaches (Shankar, 2023).

2.3.4. Macro-economic and Strategic Aspects

In the domain of circular innovation, macro-economic and strategic aspects are highlighted as pivotal influencing conditions. Uniquely, circular innovation demands a reorientation of macroeconomic policies and strategic perspectives. It necessitates a holistic understanding of the circular economy's potential impact on sectors, industries, and broader economies.

Macroeconomic factors such as resource availability, market demand, and regulatory frameworks must align with circular principles, facilitating the transition to a circular economy. Strategic considerations entail reimagining business models, reconfiguring supply chains, and revising value propositions to align with circular objectives. Organizations need to evaluate the economic viability and long-term sustainability of circular practices, factoring in potential costs, benefits, and returns on investment. Achieving this requires strategic foresight, innovative thinking, and cross-sector collaboration to address systemic challenges and fully unlock the potential of circular innovation (Shankar, 2023).

2.3.5. Socio-cultural Aspects

Socio-cultural aspects hold a significant sway as influencing conditions within the realm of circular innovation, showcasing distinct differences compared to other innovation forms. The success of circular innovation heavily relies on aligning social and cultural norms, values, and beliefs with the tenets of the circular economy.

Environmental consciousness and the burgeoning interest in sustainable lifestyles and consumption patterns have emerged as driving forces for circular innovation. However, barriers such as limited knowledge, resistance to change, and cultural preferences favouring traditional ownership models can hinder the widespread adoption of circular practices. Furthermore, customer perceptions and attitudes toward circular products and business models significantly impact their acceptance and market penetration (Shankar, 2023).

2.3.6. Competition

Competition emerges as a pivotal influencing condition within the sphere of circular innovation, showcasing distinct differences. In circular innovation, competition extends beyond conventional product-based rivalry to encompass diverse versions of products employing new technologies, varying components, production systems, and complementary goods and services. Circular enterprises not only vie against other circular offerings but also face formidable competition from traditional products and services. This distinctive competitive landscape significantly influences the success of circular innovation. Moreover, competition shapes factors such as relative pricing and the performance of innovative solutions.

Unlike conventional innovation, circular firms must navigate the competition between established and emerging technologies, as well as among various circular solutions. This underscores the significance of differentiation, value proposition, and market positioning within the realm of circular innovation. Effectively addressing competition and strategically positioning circular solutions in the market stand as pivotal considerations for successful circular innovation (Shankar, 2023).

2.3.7. Accidents and Events

Occurrences and unforeseen events stand as significant influencing factors within the domain of circular innovation, delineating notable distinctions from other innovation forms. The inherently unpredictable nature of incidents, whether arising internally within a company or externally as unforeseen events, holds the potential to impact the processes of circular innovation substantially.

Internal occurrences such as manufacturing errors or product failures can disrupt the progression and execution of circular practices. Conversely, external factors like wars or natural calamities possess the capacity to disrupt supply chains—an integral component of a circular economy—resulting in substantial consequences. These incidents underscore the criticality of resilience and adaptability within the milieu of circular innovation. The capacity to promptly respond to and recuperate from such incidents and events becomes imperative to ensure the unhindered advancement of circular innovation while mitigating potential disruptions (Shankar, 2023).

2.4. Interpretative Structural Modelling

Interpretative Structural Modelling (ISM) was Initially proposed by Warfield in 1973; ISM has proven effective in determining connections between specific elements, defining related problems or issues, and modelling strategies for examining how one variable influences another (Attri et al., 2013; Agarwal et al., 2007).

The relevance of ISM to this research lies in its ability to locate structural connections between variables unique to a system, providing a method to resolve complex multi-factor issues. In this research, ISM offers insights into the hierarchy and interdependencies of causes of barriers generated from influencing conditions that hinder the completeness of building blocks in the Circular TIS Framework. By providing the ISM, the level of importance or priority to each of the identified causes of barriers to focus efforts and resources on those that are deemed most critical or time-sensitive can be introduced, which will later be useful to formulate the strategy to alleviate all the barriers based on the level of importance among the causes. As depicted in Figure 2.17, the flowchart of the ISM framework showcases its interpretive nature, where relationships between variables are determined by evaluating the chosen study group and their interrelations.

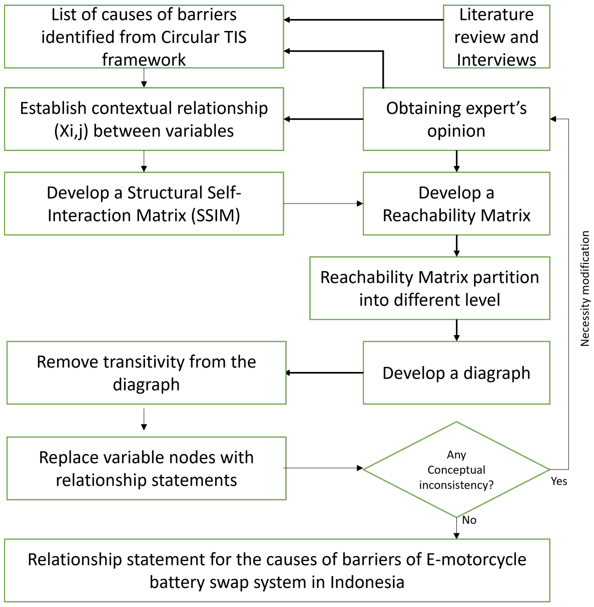

Figure 2.1: Interpretative Structural Modelling Flow Diagram

Following the application of the Technological Innovation System (TIS) framework shown in Figure 2.1, a comprehensive list of causes of barriers, encompassing factors hindering the completeness of building blocks, is obtained. This exhaustive list becomes a foundational component for the subsequent stages of analysis. To establish contextual relationships between these causes, expert opinions are leveraged through a collaborative brainstorming session, resulting in the creation of a Structural Self-Interaction Matrix (SSIM).

The SSIM forms the basis for further quantitative analysis. Utilizing this matrix, a Reachability Matrix is constructed to transform the alphabetical values representing relationships between causes into numerical values (0 and 1). Subsequently, the transitivity principle is applied to generate the final Reachability Matrix. This matrix, in turn, serves as a crucial input for the next step, known as level partition.

The final step, level partition, proves to be instrumental in providing insights into the relative importance of all causes of barriers. This segmentation into levels offers a nuanced understanding of the hierarchy among these causes. This crucial information, derived from the Level Partition, plays a pivotal role in the subsequent stages of structural modelling for the causes of barriers. By providing a systematic and data-driven approach, this analytical process enhances our ability to prioritize and address the identified barriers effectively within the research framework. The complete and more detailed steps are given as follows:

- **Identification of parameters**. The components that needed to be taken into account for the relationship identification were gathered by literature surveyors by surveying the literature and conducting interviews with related experts. In this project, these components are all represented by the barriers detected in the TIS framework.
- **Creation of Structural Self Interaction Matrix(SSIM)**. Building a structural self-interaction matrix derived from the expert's opinion, which illustrates the direction of contextual relationships between identified causes of barriers, is the first step in developing the interpretive structural model. Shown in Table 2.1, the relationship between two constraints, Ei and Ej, has been represented by the four symbols in the development of SSIM.

Ei represents the causes of barriers in the row of the SSIM, and Ej represents the causes of barriers in the column of the SSIM.

Symbol	Relationship Between Element Row i (Ei) and Column j (Ej)
V	Ei element influences Ej element, but it is not the other way around.
A	Ej element influences the Ei element, but it is not the other way around.
X	There is a reciprocal contextual relationship between Ei elements and Ej elements.
O	There is no reciprocal contextual relationship between element Ei and element Ej.

Table 2.1: Rules of SSIM Symbol

The example of SSIM generated from the experts' brainstorming session, which consists of 15 identified elements, is shown as follows:

No.	Barrier	15	14	13	12	11	10	9	8	7	6	5	4	3	2
1	Lack of R&D culture	O	A	O	X	V	V	O	V	O	O	O	O	A	O
2	Lack of supporting policy and poor execution	V	V	O	V	V	O	V	V	V	V	V	V	X	
3	Lack of skilled personnel and training institutes	O	O	O	O	A	V	O	O	O	A	V	O		
4	Grid issues/Energy access	A	A	A	O	O	V	O	O	O	A	A			
5	Regulatory issues	V	V	V	A	V	O	V	O	V	A				
6	Lack of awareness/understanding of technology	O	O	O	O	V	O	V	O	V					
7	Lack of financing institutions and incentives	A	A	O	O	X	O	O	V						
8	High initial investment cost	O	A	A	O	A	A	O							
9	Lack of coordination between agencies/stakeholders	V	O	O	V	O	O								
10	Poor reliability and low efficiency	O	A	O	A	O									
11	Poor market infrastructure	A	A	A	A										
12	Lack of information	O	O	O											
13	Lack of local infrastructure (land and resources)	A	O												
14	Lack of subsidies/incentives inadequacy	A													
15	Multi-tired govt. approvals and documentation														

Table 2.2: Examples of barriers in a certain technology diffusion (Dhawale, 2019)

- **The Initial Reachability Matrix**. Substituting the four symbols of SSIM (V, A, X, or O) with 1s or 0s in the initial reachability matrix is the next step in creating an initial reachability matrix from SSIM. The example is shown in Table 2.3. The guidelines for substituting are:
  - If (i, j) the value in SSIM is V, (i, j) the value in the reachability matrix will be 1, and (j, i) the value will be 0.
  - If (i, j) the value in SSIM is A, (i, j) the value in the reachability matrix will be 0, and (j, i) the value will be 1.
  - If (i, j) the value in SSIM is X, (i, j) the value in the reachability matrix will be 1, and (j, i) the value will also be 1.
  - If (i, j) the value in SSIM is the value of O, (i, j) in the reachability matrix will be 0, and (j, i) will also be 0.

Bariers	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15
E1	1	0	0	0	0	0	0	1	0	1	1	1	0	0	0
E2	0	1	1	1	1	1	1	0	1	0	1	1	0	1	1
E3	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0
E4	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
E5	0	0	0	1	1	0	1	0	1	0	1	0	1	1	1
E6	0	0	1	1	1	1	1	0	1	0	1	0	0	0	0
E7	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0
E8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
E9	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1
E10	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
E11	0	0	1	0	0	0	1	1	0	0	1	0	0	0	0
E12	1	0	0	0	1	0	0	0	0	1	1	1	0	0	0
E13	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0
E14	1	0	0	1	0	0	1	1	0	1	1	0	0	1	0
E15	0	0	0	1	0	0	1	0	0	0	1	0	1	1	1

Table 2.3: Example of Initial Reachability Matrix (Dhawale, 2019)

- **The Final Reachability Matrix**. Once the first reachability matrix is constructed, 1* entries are added to any location where transitivity links are identified during SSIM brainstorming and discussions, for instance, 'i leads to j' and 'j leads to k', so 'i leads to k' (shown at Figure 2.2). Shown also in Table 2.4, the final reachability matrix is obtained by adding transitive relationships (Attri et al., 2013).

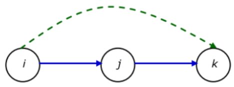

Figure 2.2: Transitivity Between Barriers

Bariers	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15
E1	1	0	1*	0	1*	0	1*	1	0	1	1	1	0	0	0
E2	1*	1	1	1	1	1	1	1*	1	1*	1	1	1*	1	1
E3	1	1	1	1*	1	1*	1*	1*	1*	1	1*	1*	1*	1*	1*
E4	0	0	0	1	0	0	0	1*	0	1	0	0	0	0	0
E5	1*	0	1*	1	1	0	1	1*	1	1*	1	1*	1	1	1
E6	1*	1*	1	1	1	1	1	1*	1	1*	1	1*	1*	1*	1*
E7	0	0	1*	0	0	0	1	1	0	0	1	0	0	0	0
E8	0	0	0	0	0	0	0	1	0	0	0	0	0	0 ,	0
E9	1*	0	0	1*	1*	0	1*	0	1	1*	1*	1	1*	1*	1
E10	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
E11	1*	1*	1	1*	1*	1*	1	1	1*	1*	1	1*	1*	1*	1*
E12	1	1*	1*	1*	1	1*	1*	1*	1*	1	1	1	1*	1*	1*
E13	1*	1*	1*	1	1*	1*	1*	1	1*	1*	1	1*	1	1*	1*
E14	1	1*	1*	1	1*	1*	1	1	1*	1	1	1*	1*	1	1*
E15	1*	1*	1*	1	1*	1*	1	1*	1*	1*	1	1*	1	1	1

Table 2.4: Example of Final Reachability Matrix (Dhawale, 2019)

- **Partition Level**. In this step, the updated reachability matrix is used to obtain the reachability set, antecedent set and intersection set, segregating the barriers into different levels. The reachability set for barrier 'i' shows which barriers are influenced by barrier 'i'. Similarly, the antecedent set for barrier 'i' outlines barriers that influence barrier 'i'. The intersection set is simply the intersection of these two sets. A level is assigned to the barrier when the reachability and the intersection sets are the same for a barrier. Shown below is an example of the first iteration of the level partition.

Barriers Sr. No.	Reachability Set	Antecedent Set	Intersection Set	Level
E1	1 3 5 7 8 10 11 12	1 2 3 5 6 9 11 12 13 14 15	1 3 5 11 12	
E2	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	2 3 6 11 12 13 14 15	2 3 6 11 12 13 14 15	
E3	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	1 2 3 5 6 7 11 12 13 14 15	1 2 3 5 6 7 11 12 13 14 15	
E4	4 8 10	2 3 4 5 6 9 11 12 13 14 15	4	
E5	1 3 4 5 7 8 9 10 11 12 13 14 15	1 2 3 5 6 9 11 12 13 14 15	1 3 5 9 11 12 13 14 15	
E6	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	2 3 6 11 12 13 14 15	2 3 6 11 12 13 14 15	
E7	3 7 8 11	1 2 3 5 6 7 9 11 12 13 14 15	3 7 11	
E8	8	1 2 3 4 5 6 7 8 10 11 12 13 14 15	8	1st
E9	1 4 5 7 9 10 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	5 9 11 12 13 14 15	
E10	8 10	1 2 3 4 5 6 9 10 11 12 13 14 15	10	
E11	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	1 2 3 5 6 7 9 11 12 13 14 15	1 2 3 5 6 7 9 11 12 13 14 15	
E12	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	1 2 3 5 6 9 11 12 13 14 15	1 2 3 5 6 9 11 12 13 14 15	
E13	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	
E14	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	
E15	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	

Table 2.5: Example of Level Partition in The First Iteration (Dhawale, 2019)

At the top of the ISM hierarchy are the factors for which the intersection sets and reachability are equal. The top-level factors (level 1st) do not influence the other factors above their own level in the hierarchy (2nd, 3rd, and so on). The top-level factor is eliminated from consideration once it has been established. The example table of the second iteration of level partition is shown in Table 2.6. As Element 8 (E8) has the same set of Reachability set and Intersection set (set =8) in the first iteration, "8" will be removed from the process in iteration two in all sets for whole elements(E1-E15), E8 also will be not taken into account during the second iteration. The second iteration achieves two Elements (E7 and E10) with the same sets of Reachability and Intersection, making them both considered elements located at level two of the hierarchy (Level 2nd). The elements in the next level are then determined by repeating the same process. This process keeps going until every factor's level is determined. The hierarchical digraph can be constructed with the aid of these levels (Dhawale, 2019).

Barriers Sr. No.	Reachability Set	Antecedent Set	Intersection Set	Level
E1	1 3 5 7 10 11 12	1 2 3 5 6 9 11 12 13 14 15	1 3 5 11 12	
E2	1 2 3 4 5 6 7 9 10 11 12 13 14 15	2 3 6 11 12 13 14 15	2 3 6 11 12 13 14 15	
E3	1 2 3 4 5 6 7 9 10 11 12 13 14 15	1 2 3 5 6 7 11 12 13 14 15	1 2 3 5 6 7 11 12 13 14 15	
E4	4 10	2 3 4 5 6 9 11 12 13 14 15	4	
E5	1 3 4 5 7 9 10 11 12 13 14 15	1 2 3 5 6 9 11 12 13 14 15	1 3 5 9 11 12 13 14 15	
E6	1 2 3 4 5 6 7 9 10 11 12 13 14 15	2 3 6 11 12 13 14 15	2 3 6 11 12 13 14 15	
E7	3 7 11	1 2 3 5 6 7 9 11 12 13 14 15	3 7 11	2nd
E8				1st
E9	1 4 5 7 9 10 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	5 9 11 12 13 14 15	
E10	10	1 2 3 4 5 6 9 10 11 12 13 14 15	10	2nd
E11	1 2 3 4 5 6 7 9 10 11 12 13 14 15	1 2 3 5 6 7 9 11 12 13 14 15	1 2 3 5 6 7 9 11 12 13 14 15	
E12	1 2 3 4 5 6 7 9 10 11 12 13 14 15	1 2 3 5 6 9 11 12 13 14 15	1 2 3 5 6 9 11 12 13 14 15	
E13	1 2 3 4 5 6 7 9 10 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	
E14	1 2 3 4 5 6 7 9 10 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	
E15	1 2 3 4 5 6 7 9 10 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	2 3 5 6 9 11 12 13 14 15	

Table 2.6: Example of Level Partition in The Second Iteration (Dhawale, 2019)

The table below shows the result of the level partitioning step after the final iteration.

Level No.	Barriers to the diffusion of Solar PV and Wind in India
1st	High initial investment cost(8)
2nd	Lack of financing institutions and incentives(7)
	Poor reliability and low efficiency(10)
3rd	Lack of R&D culture(1)
	Grid issues/Energy access(4)
4th	Regulatory issues(5)
	Lack of coordination between agencies/stakeholders(9)
	Poor market infrastructure(11)
	Lack of information(12)
	Lack of local infrastructure (land and resources)(13)
	Lack of subsidies/incentives inadequacy(14)
	Multi-tired govt. approvals and documentation(15)
5th	Lack of supporting policy and poor execution(2)
	Lack of skilled personnel and training institutes(3)
	Lack of awareness/understanding of technology(6)

Figure 2.3: example of Various levels of barriers in India (Dhawale, 2019)

- **Draw digraph based on the final iteration of level partition** An illustration of the elements and their interdependence is called a digraph, which is created using a level partition as a guide. The relationship between nodes in the different levels of the hierarchy is represented as lines of arrows directed to the higher level. The top-level factor goes at the top of the digraph, followed by the second-level factor at the second position, and so on. The lowest level of the digraph, in this case, level 5th, will become the most prioritized element to solve to alleviate the elements above its level. Two elements on the same level can never have a one-way link. The example of a digraph is shown in Figure 2.4

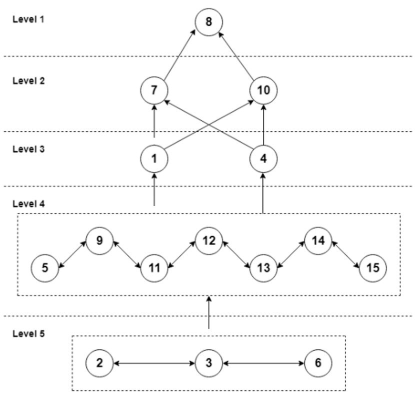

Figure 2.4: Nodes and Links in Final Digraph (Dhawale, 2019)

- **Constructing interpretive structural modelling (ISM)**. To transform the digraph into an ISM model, statement nodes (real names of barriers) are used in place of element nodes. As a result, the ISM model provides a detailed elemental hierarchy and aids the user in foreseeing how changes to one element may affect other components. The example product of Final ISM is shown in Figure 2.5.

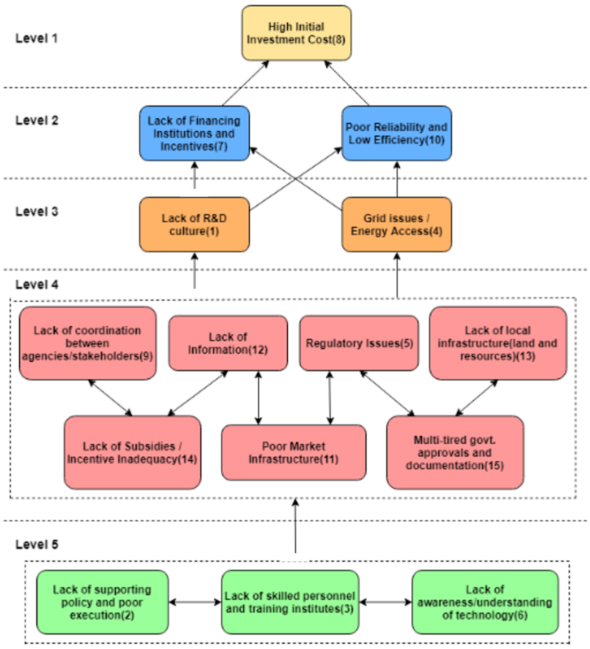

Figure 2.5: Example of ISM final result (Dhawale, 2019)

Understanding an Interpretive Structural Modeling (ISM) diagram involves a vertical hierarchy, much like a pyramid. The foundation comprises the bottom-level nodes, representing the root causes or fundamental elements, which feed into the higher-level nodes. These higher nodes encapsulate more complex issues or barriers resulting from the interactions of the underlying components. To mitigate or address the barriers at the upper levels, attention must first be directed toward resolving or minimizing the issues at the lower levels. It is important to address the foundational causes to impact the larger problems effectively. Consequently, by strategizing solutions at the elemental level, one can foresee how changes in these elements may cascade upwards, affecting and potentially mitigating the higher-level factors in the ISM structure.

2.5. Niches Strategies

According to prevalent literature, niche strategies are effective methods for introducing radically new innovations to the market when large-scale diffusion is not feasible. In high-tech environments, niche market strategies have been found to be relatively successful (J. R. Ortt and Kamp, 2022).

In this thesis, niche strategies refer to targeted approaches used to introduce new products or services within a specific market segment. These strategies aim to address barriers to large-scale diffusion by initially launching the product in a smaller market segment characterized by a distinct group of consumers with specific needs and preferences. By focusing on this niche market, companies can potentially overcome barriers to large-scale diffusion. The paper by (J. Roland Ortt et al., 2013) identifies ten niche strategies that can be employed by high-tech startups involved in circular innovation. These strategies are detailed in Appendix B, along with related work on niche strategies.

However, instead of introducing niche strategies based solely on the statuses of the building blocks and influencing conditions, this thesis proposes introducing niche strategies hierarchically at each level of the priority of identified causes of barriers. This hierarchical approach is the final output of the combined Circular TIS-ISM framework.

2.6. A Combined TIS-ISM Framework

The incorporation of Interpretive Structural Modeling (ISM) within the Combined Circular TIS-ISM Framework significantly enhances comprehension of the relationships among identified causes of barriers in the Circular TIS framework. Coupled with a thorough understanding of the status of building blocks, it provides a more holistic perspective on the complex dynamics within the Circular TIS framework. ISM serves as a complementary tool for the Circular TIS framework to offer a holistic view before introducing a suitable and effective strategy to address the causes of barriers within the hierarchy of prioritization. Figure 2.6 encapsulates this complete framework.

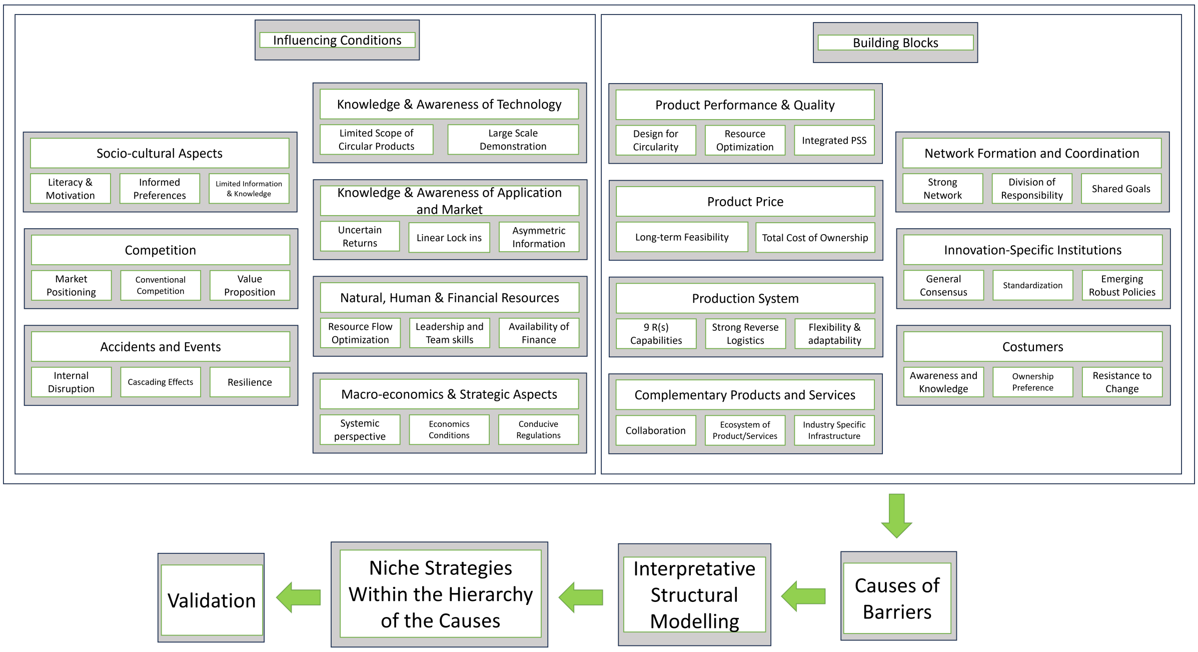

Figure 2.6: Combined Circular TIS-ISM framework

3

Battery Swap System for E-Motorcycle in Indonesia

Chapter 3 investigates an in-depth examination of the existing technology, complex network of stakeholders, and regulations influencing the e-motorcycle battery swap systems in Indonesia. The exploration begins by elaborating on the existing technology of battery swap and e-motorcycles in Indonesia, followed by unravelling the roles, connections, and impact of key players in this ecosystem, drawing insights from academic studies and diverse sources to illuminate the web of individuals and entities shaping the adoption and trajectory of these systems.

Simultaneously, the chapter investigates the complex web of governmental policies, incentives, and regulatory frameworks shaping the landscape. This investigation, blending literature synthesis with insightful interviews, reveals the current situation in Indonesia. Regulations and evolving policies converge to define this landscape, with discussions anchored by insights from a researcher at the Indonesia National Battery Research Institute and extensive literature reviews.

This chapter serves as a reader's compass, guided by initial perspectives from the Institute to chart a course toward a comprehensive understanding. These foundational insights pave the way for a broader stakeholder map and a nuanced discourse on policy formation, directly addressing the pivotal research sub-questions 1 (SQ1):**What are the key stakeholders in the various e-motorcycle battery swap-related sectors within Indonesia, and what are their interconnections?**, and sub-question 2 (SQ2):**What is the current status of government policies, incentives, and the regulatory framework in Indonesia concerning E-Motorcycle Battery Swap systems?** .

3.1. E-motorcycle Technology in Indonesia

Electric vehicles encompass a wide array of transportation modes entirely reliant on electricity for power (ADB, 2022). Within this category, electric two-wheelers, including electric bikes, scooters, and motorcycles, operate solely on electrical energy. However, this report concentrates solely on the electric motorcycle (e-motorcycle).

Figure 3.1: An e-motorcycle manufactured by GESITS in Indonesia (Gesitmotors, 2023)

The design and structure of e-motorcycles bear resemblance to traditional motorcycles but operate using an electric motor. They boast larger frames and wheels compared to bikes and electric scooters. In terms of motor power and speed, e-motorcycles typically feature substantially more powerful motors (often exceeding 10kW). They can achieve higher top speeds comparable to fuel-powered motorcycles, exceeding 100km/h. In Indonesia, operating an e-motorcycle necessitates possession of a regular motorcycle license, registration, and strict adherence to safety standards akin to those for fuel-powered motorcycles.

One of the primary distinctions lies in the power train: e-motorcycles utilize electric motors, while fuel-based bikes rely on internal combustion engines (ICE). This fundamental difference sets the foundation for various contrasting features. Emissions represent another differentiating factor: e-motorcycles produce no tailpipe pollutants, while fuel bikes release carbon monoxide, nitrogen oxides, and hydrocarbons, contributing to environmental pollution. In terms of noise levels, e-motorcycles operate more quietly compared to their fuel-based counterparts. This characteristic contributes to reduced environmental noise pollution, enhancing overall urban tranquility. Moreover, the maintenance requirements for e-motorcycles are notably lower due to their simpler design and fewer moving parts. This inherent advantage translates to reduced upkeep costs and potentially greater reliability compared to traditional fuel-based bikes. The table presented below outlines the core components of an e-motorcycle, detailing their production origins—whether locally manufactured or imported (Shahab, 2023). Approximately 60% to 80% of the overall expense is sourced from imports, contributing to the higher pricing of e-motorcycles in Indonesia compared to internal combustion engine (ICE) counterparts offering similar performance levels.

Additionally, alongside the introduction of new e-motorcycles, the government actively advocates for the transition of conventional internal combustion engine (ICE) motorcycles into e-motorcycles. Despite these efforts, the adoption rate remains low, primarily due to the steep cost of converting ICE motorcycles. The conversion process is governed by Permen ESDM 65/2020. Despite this regulatory framework, the Institute for Essential Services Reform (IESR) notes the limited uptake of e-motorcycles, even those that undergo conversion, attributed to their perceived high costs. The public's willingness to pay for converted e-motorcycles ranges around IDR 5 - 8 million.

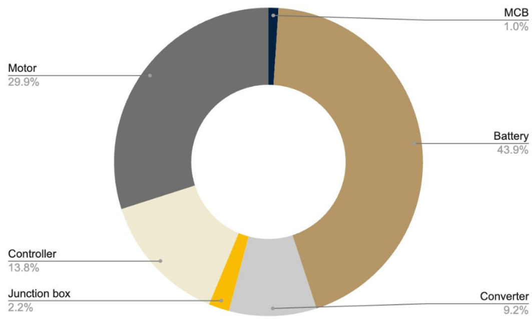

Figure 3.2: Cost of components (Shahab, 2023)

Table 3.1: Components of an E-Motorcycle and Production Origins

Component	Production Origin	Description
Converter	Import	Converts DC voltage levels within the battery, facilitating adaptation to various components.
Junction Box	Local	Sealed enclosure housing electrical connections, ensuring safe containment of electrical flow.
Controller	Import	Regulates electricity flow from the battery to the motor, monitoring multiple vehicle parameters.
Electric Motor	Import	Transforms electrical energy into mechanical energy, propelling the vehicle forward.
MCB	Local	Electrical safety device that disconnects circuits upon detecting overload or short circuit situations.

Current Population of E-motorcycles In Indonesia (based on SRUT Record)

According to the Directorate General of Land Transportation, Ministry of Transportation, as of January 22, 2024, at 15:23 GMT +7, the total population of electric motorcycles equipped with the Type Test Registration Certificate (SRUT), one of the requirements for the vehicle registration certificate (STNK), is 99,594 units. This falls significantly short of the target mentioned on the social media account of the Ministry of Energy and Mineral Resources (MEMR, 2023c), which aims for 2,000,000 electric motorcycles by 2025.

Conversion from ICE to Electric

In addition to the option of acquiring a new e-motorcycle, customers have the flexibility to convert their existing internal combustion engine (ICE) motorcycles into electric motorcycles. The government has officially declared a subsidy for the conversion of gasoline-based motorcycles to electric motorcycles, amounting to Rp 10 million per unit. This incentive represents an increase from the previous Rp 7 million per unit. The upward adjustment of the electric motorcycle conversion incentive value is outlined in the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 13 of 2023. This policy was signed by Minister of Energy and Mineral Resources Arifin Tasrif on December 12, 2023, and officially published on December 15, 2023. Article 3 specifies that the maximum conversion cost is set at Rp 17 million, covering components such as the battery pack, brushless DC (BLDC) motor, and controller. This conversion cost will then be offset by the government incentive of Rp 10 million per unit (MEMR, 2023b).

”The value of the conversion cost deduction as referred to in paragraph (1) is granted in the amount of Rp 10,000,000 for each converted motorcycle,” states the regulation. The incentive aims to benefit 50,000 converted motorcycles in 2023 and 150,000 converted motorcycles in 2024. However, the conversion targets may be subject to change based on program evaluations. Notably, a new aspect introduced in Ministerial Regulation 13 of 2023 is that the recipients of the electric motorcycle conversion incentive are no longer limited to individuals but also include community groups, government institutions, and non-governmental organizations. This means that businesses and government agencies can now receive the incentive if they choose to convert their gasoline-based fleet to electric motorcycles.

3.1.1. Comparison of Features: New Electric Motorcycle vs. Converted Electric Motorcycle

To elaborate on the comparison between new electric motorcycles and converted electric motorcycles, a table could be created to showcase the distinguishing features of each type. This table, denoted as Table 3.2 in the previous paragraph, would aim to highlight the differences in various aspects such as price, warranty, technology, performance, customization, regulatory compliance, and resale value between these two categories of motorcycles. This comparative analysis assists in illustrating the trade-offs and considerations associated with choosing between a new electric motorcycle and one that has undergone conversion from a traditional internal combustion engine (ICE) motorcycle to an electric variant (Shahab, 2023).

Table 3.2: Comparison of Features: New Electric Motorcycle vs. Converted Electric Motorcycle (Shahab, 2023)

Feature	New Electric Motorcycle	Converted Electric Motorcycle
Powertrain	Equipped with a dedicated electric powertrain	Converted from an ICE powertrain
Battery Pack	Includes an integrated battery pack	May utilize off-the-shelf batteries
Chassis	Designed and optimized for electric performance	Adapted from a modified ICE chassis
Performance	Tailored for optimal electric performance	Potentially less efficient due to motor not originally intended for electric two-wheelers
Efficiency	Designed for optimum electric efficiency	May not achieve the efficiency of a new electric motorcycle
Technology	Able to leverage the latest electric vehicle technology	Limited implementation based on the ICE platform
Cost	Priced in the range of IDR 15 - 40 million	Cost of conversion ranges between IDR 15 - 23 million (excluding incentives from the government)

3.2. Battery Swap Technology in Indonesia

E-motorcycle users in Indonesia have three primary choices for recharging their batteries: home charging, destination charging, or utilizing Public Electric Vehicle Battery Swap Stations (SPBKLU) for battery swaps. SPBKLU is specifically designed for users with high-intensity needs, such as ride-hailing or logistic drivers, who might have limited time for conventional charging methods. Conversely, private users covering shorter distances prefer the convenience of charging at home or their destinations, such as their workplace.

While the expansion of SPBKLU significantly reduces range anxiety, it has not notably changed the charging behavior of private users. In 2022, there was a fivefold increase in SPBKLU stations compared to the previous year. Interestingly, from an investment standpoint, the cost per unit of SPBKLU is considerably lower than Public Electric Vehicle Battery Charging Station (SPKLU).

Most SPBKLUs are owned by e-motorcycle brands, especially those collaborating with ride-hailing companies and businesses that provide on-demand transportation services through mobile apps. Collectively, they possess around 700 SPBKLUs, facilitating approximately 180 thousand swaps over 1.5 years. However, this averages about 330 swaps per day or one swap every two days per station, significantly below the expected utilization rate of 100 swaps per day per station according to ADB (IESR, 2023).

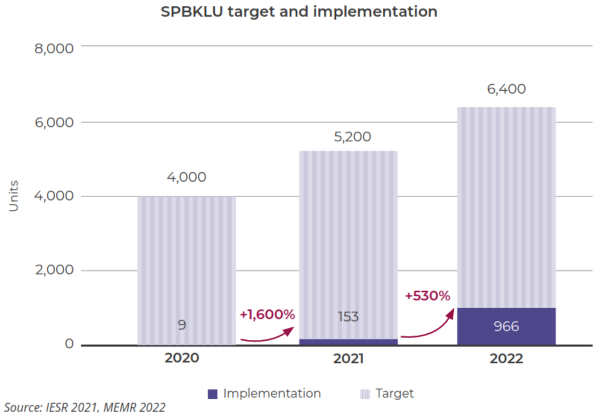

Figure 3.3: SPBKLU target and implementation 2020-2022 (IESR, 2023)

As of November 17, 2022, Indonesia showcased a robust infrastructure with 439 charging stations (SPKLUs) spanning 328 locations, complemented by 961 battery swap stations (SPBKLU) situated across 961 different areas throughout the archipelago. The envisioned goal for battery swap stations stands at an ambitious 15,625 by 2030 (MEMR, 2023c) according to the official Social Media of MEMR (Ministry of Energy and Mineral Resource). At present, the prevailing distribution predominantly centers around Java, showcasing a concentrated network. This study encompasses five identified brands within the EV landscape; however, a significant hurdle lies in the absence of standardization among these brands. Each brand presents unique dimensions, voltage specifications, and capacities, elaborated in Figure 3.4 to facilitate comparative analysis among select brands. It is worth noting that these charging swap stations are broadly categorized into two types: bottom connector and top connector, each catering to distinct technical requirements and user needs within the electric vehicle ecosystem.

Brand Name	Dimension (mm)	Capacity & Voltage	Battery Pack	BSS	2W-EV	Connector Position
SWAP	177 x 177 x 330	64V 22,5Ah			Minerva Electron SMOOT Tempur SMOOT Zuzu	Bottom
OYIKA	170 x 120 x 340	60V 20Ah			Tailg Warrior Smoto Y1S NIU Gova 03 Rakata S9	Bottom
VOLTA SGB (*Sistem Ganti Baterai*)	240 x 150 x 200	60V 23Ah			Volta 401 Volta Virgo	Top
KYMCO IONEX	N/A	N/A			Kymco Ionex Many 110	Bottom
EZYFAST	N/A	N/A			Viar Q1 Selis Kymco	Top
GOGORO	N/A	N/A			Gogoro SuperSport All New Gogoro Delight Gogoro S Performance Gogoro 1 Series Gogoro 2 Series Gogoro 3 Series Gogoro VIVA MIX Gogoro VIVA XL Gogoro VIVA	Bottom

Figure 3.4: Comparation between some battery swap service providers (Mubarok, 2023)

In addition, from the field observation of a researcher from the National Battery Research Institution (NBRI), it was revealed that there is a prohibition from ride-hailing users against disclosing product specifications. Some of the data cannot be obtained due to restrictions imposed by the brand. Additionally, concerning the battery cathode, the variation among providers was noted based on data collected in 2023. For instance, SWAP utilizes LFP (Lithium-Ferro-Phospate), Oyika uses NMC (Nickel-Manganese-Cobalt), Volta opts for LFP, Kymco employs LFP, and Gesits utilizes NMC. Furthermore, it is worth noting that the choice of battery cathode, whether NMC or LFP, significantly influences performance. The higher density and smaller size of NMC battery packs allow for a storage capacity and voltage that can be larger than LFP. However, due to its lower working voltage compared to NMC, LFP is more suitable for city cars, as its range is not ideal for long journeys, and its acceleration may not be as smooth as an NMC battery pack.

3.3. Related Stakeholders in Indonesia

The landscape of Indonesia's e-motorcycle industry is predominantly shaped by startup entities that have secured financing through equity and debt from institutional investors, including venture capital and private equities. This dynamic is particularly evident as original equipment manufacturers (OEM) maintain a cautious "wait and see" approach toward Electric Vehicles (EVs). Notably, companies like SWAP and Smoot fall under the umbrella of "SWAP Energi," while Volta and SGB ("Sistem Ganti Baterai") are operated by "Volta Indonesia."

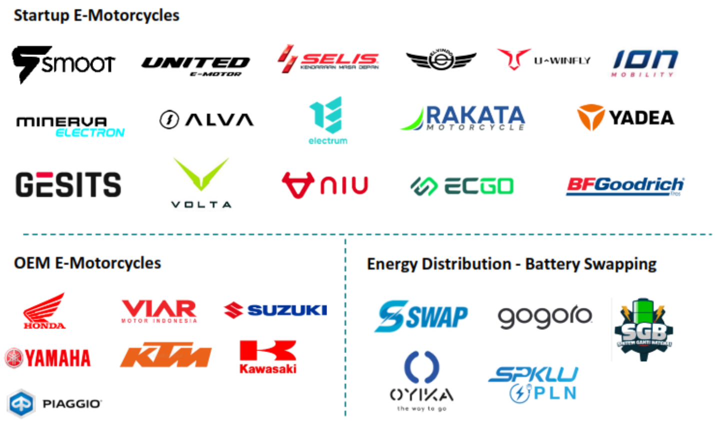

Figure 3.5: Startups of E-motorcycle, OEM, and Battery Swap (Shahab, 2023)

In terms of stakeholders of motorcycle conversion, as of 6 November 2023, the list of government-verified conversion workshops, according to the Ministry of Land Transportation, with a total of only 194 units of converted motorcycles (proven with the issued type test registration certification) is as follows (Kemenhub, 2023) :

- Balai Besar Survei dan Pengujian Ketenagalistrikan, EBT, dan Konversi Energi - DKI Jakarta
- PT. Braja Elektrik Motor - ITS Surabaya
- Elders Garage (Roda Elektrik Asia) - Jakarta
- PT. Juara Bike - Tangerang
- PT. Nagara Sains Konversi- Jakarta
- DIKST ITS - Surabaya
- PT. Handhika Garda Parama - Jakarta
- Percik Daya Nusantara - Bali
- PT. Tri Mentari Niaga/ BRT - Bogor

- PT. Cogindo Daya Bersama - Cirebon
- PT. Spora EV - Jakarta
- PT. Sarana Makmur Sejahtera- Mojokerto
- PT Roda Elektrik Gemilang - Bali
- PT. Strum Technology Asia - Jakarta
- PT. Mitra Metal Perkasa - Karawang
- PT. Ide Inovatif Bangsa - Bandung
- CV. Karya Kartanagari Group - Bogor
- Politeknik Negeri Jakarta - Jakarta
- PTDI - STTD - Bekasi
- PT. Electric Vehicle Trimotorindo - Tangerang
- PT. Ekoelektrik Konversi Mandiri
- SMKN 2 Jember - Jember
- SMK Muhammadiyah Kartasura - Solo
- PT. Solusi Intek Indonesia - Bekasi
- Saikono Otoparts Indonesia - Bekasi
- Blu Politeknik Transportasi Darat - Bali
- PT Semesta Motor Indonesia - DKI Jakarta
- DYVOLT EV Shop - Bekasi
- SMKN 1 Seyegan - Yogyakarta

Based on the interviews conducted by Deloitte in May 2023, the distribution of swapping stations among the top four private players, as of an interview conducted in May 2023 and illustrated in Figure 3.6, delineates the market share: ”SWAP” holds 1,100 swapping stations (70.92%), ”Volta” maintains 295 swapping stations (19.02%), ”OYIKA” operates 150 swapping stations (9.67%), and ”Gogoro” possesses six swapping stations (0.39%). These key players cater to various e-motorcycle brands and are often associated with either ride-hailing giants or third-party logistics (3PL) companies, shaping their adoption (Deloitte, 2023).

- **SWAP** serves as the system for e-motorcycle brands such as SMOOT, MINERVA, and ELECTRON and is utilized by key users like GRAB, TIKI, BLIBLI, and LAZADA LOGISTICS.
- **GOGORO** supports e-motorcycle brands like ELECTRUM and is predominantly used by GOJEK.
- **SGB operators** is employed by motorcycle brands owned by themselves: VOLTA, and are favoured by key users such as GOJEK and SICEPAT.
- **OYIKA** supports SELIS Brand.

Battery swapping offers compelling advantages, enabling a 75% reduction in battery replacement costs compared to conventional charging models for electric motorcycles. This innovative approach also saves a significant hour per single journey. Riders benefit from a staggering 3,600x faster charging time, minimizing opportunity costs and idle time as they can charge on the go. Moreover, the longevity of swapping batteries decreases vehicle maintenance expenses, extending the life cycle of the batteries to up to 2 years. The distribution network of over 1,500 one-off battery swapping stations effectively eradicates range anxiety for users. These insights are predicated on various assumptions, including a 10-year e-motorcycle lifespan, an average On-The-Road (OTR) price of $1,300, 50km range per cycle for charging models, 60km range per cycle for swapping models, a year of battery life equating to 500 cycles, and an average battery replacement cost of $730 (Deloitte, 2023).

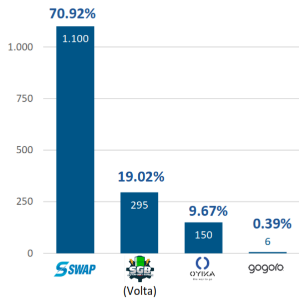

Figure 3.6: Market Share of swapping stations by the top 3 private players (Deloitte, 2023)

3.3.1. The Complete Map of Identified Stakeholder

Figure 3.7 offers a comprehensive overview of Indonesia's battery swap ecosystem, depicting its involvement chain from regulatory oversight to end-user interactions. The diagram employs colour-coded rectangles to symbolize different stakeholders and processes within the ecosystem.

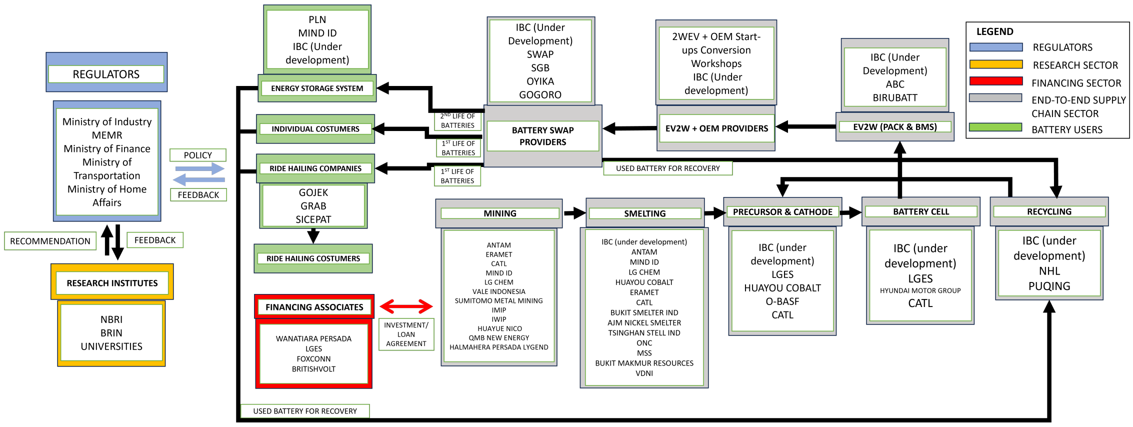

Figure 3.7: Identified Stakeholders of battery swap system for e-motorcycle in Indonesia (combined from multiple sources)

Boxes with blue colour indicate the regulators, consisting of related ministries, responsible for overseeing the entire supply chain from mining to consumers. The yellow colour represents stakeholders conducting research, providing recommendations to regulators, and receiving feedback. These stakeholders collaborate within the ecosystem, assisting regulators in policy formation and contributing to market dynamics. The grey colour signifies the upstream-to-downstream battery swap-e-motorcycle ecosystem, encompassing mining, smelting, precursor+cathode production, battery cell manufacturing, battery packing, E-motorcycle providers, battery swap providers, and recycling facilities. The green colour indicates customers, including those involved in the first lifecycle of batteries and those utilizing batteries for a second lifecycle. For example, batteries with a state of charge (SoC) above 80% may be reused by electricity providers for energy storage purposes. The red colour represents associates that provide financing for all components within the grey-coloured boxes, supporting the financial aspects of the ecosystem. The ecosystem's complexity is evident in distinct streams such as mining, smelting, precursor and cathode production, battery cell manufacturing, battery packer, and battery management systems. Mining extracts raw materials for batteries, while smelting refines them. The precursor and cathode production stage converts refined materials into battery components. Battery cell manufacturing produces functional units for deployment. Battery packers assemble these units into battery packs, and the battery management system ensures their efficient operation.

The distinction between battery life cycles is crucial, as customers utilize batteries in either their first or second life cycles. The visualization of the first life cycle emphasizes individual users and major fleet management entities like GOJEK, GRAB, and SICEPAT (Deloitte, 2023). These entities play a significant role in the initial deployment and utilization of batteries within the electric vehicle ecosystem. Conversely, batteries in the second life cycle, with Depth of Charge (DoC) below conventional thresholds but still functional for energy storage, are directed towards power generation companies like PLN and MIND ID IBC. This repurposing of batteries for energy storage highlights the importance of sustainability and the integration of battery technology into broader energy systems, ensuring their continued usefulness beyond their initial applications in transportation.

The concentration of nickel mining concessions in Indonesia is particularly in Sulawesi. This is notable due to the island's significant nickel reserves. Central Sulawesi Province is a key location, housing the Indonesia Morowali Industrial Park (IMIP). Additionally, Halmahera Island in North Maluku Province hosts the Indonesia Weda Bay Industrial Park (IWIP). In South East Sulawesi Province, there is the Konawe Industrial Park operated by PT VDNI (Huber, 2021). Additionally, China, which has led the EV race until now, is well aware of the likely future battery-grade nickel shortage. Chinese companies have been ahead of the investment in several new HPAL facilities that are under construction in Indonesia (Ribeiro et al., 2021).

In March 2021, the Indonesia Battery Corporation (IBC) was established, bringing together four state-owned companies in the mining and energy sector: MIND ID (mining industry holding company), Aneka Tambang (Antam, a nickel miner), PLN (electric utility), and Pertamina (oil and gas company). An interesting development is the requirement for foreign electric vehicle (EV) battery companies investing in Indonesia to collaborate with IBC. It is worth noting that none of the companies within IBC have prior experience in manufacturing EV batteries. This requirement may be a strategic move aimed at facilitating technology transfer and promoting job creation (Huber, 2022).

3.3.2. Battery Swap Business Process

As per insights from Deloitte's report (Deloitte, 2023), understanding the landscape of business processes, charging dynamics, and station partnerships in Indonesia's ride-sharing industry becomes clearer:

- Riders in this ecosystem predominantly fall within the middle to low-income bracket, with Indonesia's GDP per capita averaging USD 4,332.7 in 2021. They exhibit high mobility, spending between 30 to 120 minutes daily commuting and relying heavily on motorcycles as their primary income source, especially within the logistics and ride-hailing sectors.
- When their batteries run low, riders turn to swap stations provided by companies like SWAP, GOGORO, OYIKA, and SGB, among others. These stations offer a rapid swapping process, taking anywhere from 10 seconds to 2 minutes, depending on the service provider.
- Strategic partnerships for swap stations are established with various retail outlets, including modern-trade retail chains, gas stations, malls, and other convenient locations. This setup aims to save time for drivers, with potential savings of up to 4 hours, and the swapping process itself taking a mere 9 seconds.
- This mode of battery swapping proves to be cost-effective, with savings of USD 0.03 per mile and estimated to be 50% cheaper compared to traditional petrol motorcycles.

Figure 3.8: Insights from Business Processes, Charging Models, and Rider Profiles

Regarding pricing and business models, two predominant strategies emerge (Deloitte, 2023):

1. Charge per Kilometer: Adopted by players like SWAP, this model allows users to swap batteries at any time, with an average cost of USD 0.01 per kilometer. Users have unlimited swapping quotas, resulting in a varying total monthly cost depending on the users' driving distance. According to the NBRI (National Battery Research Institute) study, the travel range for ride-hailing drivers and couriers typically falls within the range of 50 to 120 kilometers per working day. Meanwhile, for users commuting from home to work, such as myself, the daily travel range is generally around 20 to 30 kilometers on workdays
2. Monthly Subscription and Fixed Fee: Companies like GOGORO, SGB, OYIKA, and VOLTA operate on a subscription-based model, charging around USD 0.7 per month. Users pay a fixed fee per swap when their battery range is low, resulting in varied total monthly costs.

3.4. Ongoing Policies in Indonesia

In Indonesia, the landscape surrounding electric vehicles (EVs) is continually evolving, driven by ongoing policies and regulations formulated by key governing bodies. This section aims to delve into the realm of EV policies, shedding light on the entities responsible for shaping these regulations, the current policies in force, and the anticipated regulations poised to impact the electric vehicle sector. By exploring the organizational frameworks behind policy formulation and highlighting the existing and forthcoming regulations, a comprehensive understanding of the evolving EV landscape in Indonesia will be provided. Beginning this subsection, the following table provides an outline detailing the roles and responsibilities of central government agencies concerning the transport sector (Imran, 2019).

Table 3.3: Responsibility of Involved Ministries (Imran, 2019)

Organization	Roles and Responsibilities
Ministry of National Development Planning (BAPPENAS)	Formulate and develop national development planning as a guideline for central, provincial, and city governments Control and review regional development planning Coordinate and control national and international programs Decide budget allocations for programs, together with the MoF
Ministry of Transport	Prepare national transport policy that provides guidelines to provincial and city governments Manage the operation of public transport facilities and infrastructure
Ministry of Public Works and Housing	Formulate national policy for public works infrastructure, including roads and bridges Develop and construct public works infrastructure
Ministry of State-Owned Enterprise	Develop a national policy for the operation of transport infrastructure

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Table 3.3 – continued from previous page

Organization	Roles and Responsibilities
	Manage the operation of national transport infrastructure and public transport services
Ministry for the Environment and Forestry	Develop national policy and guidelines for environmental management and control of pollution Control and review environmental problems Provide guidelines on climate change in Indonesia Coordinate and negotiate with international agencies dealing with climate change
Ministry of Home Affairs	Coordinate national, provincial, and city government programs and activities for development Supervise national and regional government to improve development practices
Coordinating Ministry for Economic Affairs	Formulate national economic policy, planning, and implementation procedures Coordinate and create synergy in economic policy related to urban transport policy among line ministries
Ministry of Finance (MoF)	Formulate national policy on economic growth Allocate a budget for road and public transport infrastructure projects, together with BAPPE-NAS

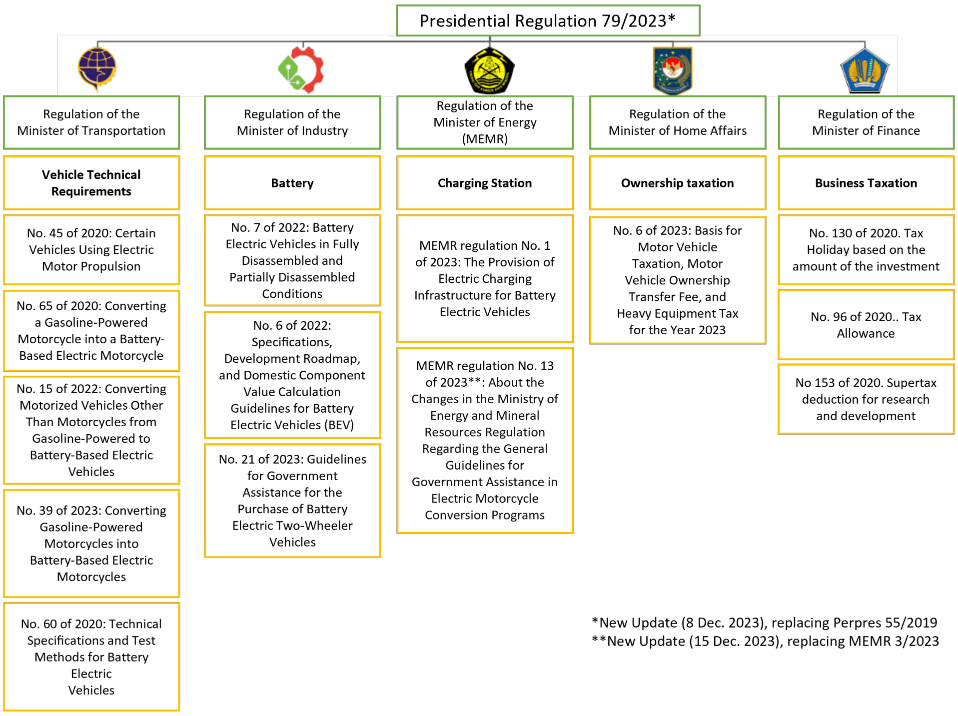

Figure 3.9: Regulatory Mapping of Indonesia EV

3.4.1. Deep Dive into PERPRES (Presidential Regulation) 55/2019

The foundation for all regulations concerning electric vehicles in Indonesia stems from Presidential Regulation 55/2019 (PERPRES 55/2019). This overarching directive subsequently unfolds into more detailed guidelines distributed across five key ministries within the country. These ministries include the Ministry of Transportation, the Ministry of Industry, the Ministry of Energy and Mineral Resources (MEMR), regulations from the Ministry of Home Affairs, and regulations outlined by the Ministry of Finance. Each of these entities plays a pivotal role in delineating and implementing specific aspects of the regulations about electric vehicles within their respective domains

(PERPRES-RI, 2019). For a comprehensive view of the ongoing regulations within each ministry and their specific mandates regarding electric vehicles, the detailed breakdown depicted in figure 3.9 is given.

The regulatory landscape governing Electric Two-Wheelers (E2W) and Electric Vehicles (EVs) in general is underpinned by the pivotal Presidential Regulation 55/2019, focusing on the Acceleration of the Battery-Powered Electric Motor Vehicles for Road Transportation Program. This regulation meticulously outlines various facets that span the types of vehicles, industrial obligations, company classifications, charging infrastructure requirements, and specific import provisions (PERPRES-RI, 2019).

Industrial Requirements

Under the auspices of Presidential Regulation 55/2019, the types of vehicles are categorized into three segments: Type 1 includes E2W and E3W, while Type 2 comprises E4W. Industries engaging in the production of these vehicles must have outlined plans for establishing local Electric Vehicle manufacturing facilities. These encompass two-wheeled motor-vehicle industries, four or more wheeled motor-vehicle industries, and motor-vehicle component industries. Furthermore, specific company classifications are mandated and delineated into Vehicle Companies, Component Companies, and National-brand EV Companies. The charging infrastructure aspect necessitates the provision of charging facilities, either private or SPKLU (Public Electric Vehicle Charging Stations), along with battery-swap facilities to support the burgeoning electric vehicle market (PERPRES-RI, 2019).

For both Vehicle and Component companies, stringent industrial prerequisites are enforced. These include the compulsory establishment of local Electric Vehicle manufacturing facilities based on Indonesian laws, operation strictly within Indonesian territories, and possession of Industrial Business Permits (IUI). Vehicle companies need IUI for the assembly or production of Electric Vehicles. In contrast, component companies require IUI for the assembly or production of primary and supporting components for Electric Vehicles (PERPRES-RI, 2019).

Import Provisions

Regarding Import Provisions, a table effectively summarizes the prerequisites for different company types and the specifics regarding imported products:

Company type	Import Prerequisites	Imported products
Vehicle Companies	Must have plans to establish local Electric-Vehicle manufacturing facilities	Imports of Electric Vehicles that take the Completely Built-Up (CBU) form but in limited amounts and for limited periods
Component Companies	Must not yet be capable of producing primary and supporting Electric-Vehicle components	Two types of components may be imported, specifically: • Incompletely Knocked Down (IKD) components; and • Completely Knocked Down (CKD) components

Table 3.4: Import Provisions for Vehicle and Component Companies (PERPRES-RI, 2019)

Local Content Requirements

The evolution of local content requirements for Electric Vehicles (EVs) in Indonesia delineates a strategic trajectory aimed at fostering indigenous production and bolstering the domestic Electric Vehicle industry. For the smaller EV variants encompassing E2W and E3W, the stipulated local content requirements have exhibited a progressive rise over time. Beginning in 2019 at 40%, these requirements surged to 60% by 2026, further escalating to a substantial 80% between 2026 and 2030. This gradual augmentation reflects a concerted effort to cultivate local manufacturing capabilities and enhance the indigenous contribution to the EV production chain (PERPRES-RI, 2019).

Conversely, for the larger EV categories typified as E4W and beyond, the local content prerequisites have followed a similar upward trajectory, albeit with divergent timelines. Commencing at 35% in 2019, these requirements escalated to 40% by 2022. The subsequent years witnessed a more rapid ascent, reaching 60% between 2024 and 2026, culminating in an ambitious target of 80% local content by 2030. This phased approach encapsulates a strategic roadmap aimed at fortifying the local manufacturing ecosystem for larger EV models, aiming to achieve higher localization rates over the coming years (PERPRES-RI, 2019).

Incentives (Fiscal and Non-Fiscal)

Indonesia has laid out a comprehensive set of incentives to promote Electric Vehicles (EVs), aiming to boost their adoption and production. These incentives cover both financial and non-financial aspects, strategically designed to spur growth and innovation in the electric mobility sector. Financial incentives include specific cuts in import duties for EV-related products, encouraging the import of essential components crucial for EV manufacturing. Alongside these fiscal perks, non-financial incentives are diverse, aiming to stimulate EV adoption and local production. Exemptions from road-usage limitations ease logistical challenges, facilitating smoother mobility for EVs throughout the country. Tax incentives, particularly regarding Luxury-Goods Sales Tax (PPnBM), aim to alleviate financial burdens and enhance affordability for consumers.

However, it is notable that the regulations under PERPRES 55/2019 do not explicitly emphasize the consequences for Firms that cannot fulfil commitments to improve the national market, such as meeting specific local content targets after receiving these incentives. Additionally, PERPRES 55/2019 only emphasizes the Public Charging Station (SPKLU) development. Battery Swap Stations (SPBKLU) are not incorporated into the incentive clauses outlined in PERPRES 55/2019. This signifies a gap in the regulation, as it doesn't highlight the importance of market enhancement commitments or the inclusion of SPBKLU in the incentive framework. These areas have evolved in subsequent updates. The detail of incentives incorporated in the PERPRES 55/2019 is shown as follows (PERPRES-RI, 2019):

1. Import duty incentives for imported EVs in completely knocked down (CKD) or incompletely knocked down (IKD) states or main components for a specified quantity and duration.
2. Luxury-Goods Sales Tax incentives.
3. Central and regional tax exemptions or reductions.
4. Import duty incentives for machinery, goods, and materials for investment purposes.
5. Duty suspension for export purposes.
6. Government-covered import duty incentives for raw materials and auxiliary materials used in the production process.
7. Incentives for establishing public charging Station (SPKLU) equipment.
8. Export financing incentives.
9. Fiscal incentives for research, development, and technological innovation activities, as well as vocational training in battery-based electric vehicle (KBL) component industries.
10. Parking tariffs at locations designated by regional governments.
11. Reduced charging costs at public charging Stations (SPKLU).

12. Financing support for SPKLU infrastructure development.
13. Professional competence certification for EV industry human resources.
14. Product certification and technical standards for EV companies and EV component industries.

3.4.2. Deep Dive into New Update: Presidential Regulation (PERPRES) 79/2023

While many sections remain unchanged, notable adjustments include the inclusion of 'SPBKLU' in certain clauses, a downward adjustment in the TKDN targets, a detailed definition of incentives, and the introduction of consequences for those unable to fulfil their commitments post-receiving incentives. These modifications significantly reshape the regulatory landscape governing the electric vehicle industry, emphasizing a nuanced but substantial shift in key aspects of compliance, incentives, and consequences for non-compliance. The detail of the change from PERPRES 55/2019 to PERPRES 79/2023 is elaborated as follows (PERPRES-RI, 2023):

1. In Articles 1, 2, and 7, the revisions primarily involve the inclusion of the term "SPBKLU" and a more focused definition of motorcycle conversion within existing parameters.
2. Article 8 delineates a shift in TKDN standards, with a decrease from 40% until 2023 to an extended timeline until 2026 and a further revision to 60% between 2027-2029. The aim is to reach an 80% TKDN target beyond 2030, but exemptions apply for converted motorcycles done by specialized workshops.
3. Article 12 significantly broadens import permissions for battery-based electric vehicles with completely built-up (CBU). Initially restricted to the EV industry establishing domestic battery-based eV manufacturing facilities, the revised regulation now includes those who invest in these facilities to introduce new products or increase production capacities. This CBU import allowance extends until 2025 after ministerial investment approval.
4. In Article 17, a notable addition involves expanding the eligible recipients of government incentives, particularly emphasizing companies engaged in SPBKLU (battery swap station).
5. Article 18 underscores heightened incentives for battery-based EV industries importing CBUs and those expediting domestic assembly processes for CBUs until the end of 2025, aligning with the allowances set in Article 12.
6. The introduction of Article 19 signifies a significant expansion of fiscal incentives for two-wheeled battery-based EVs and Battery Swap Stations (SPBKLU). This updated article also incorporates government programs for purchase assistance and e-motorcycle conversion aid for a specified duration.
7. Moreover, the insertion of Article 19A elaborates on the details of Article 18. It covers incentives such as government-covered import duties for CBUs, luxury tax incentives for domestically produced EVs, reduced or exempted regional taxes for domestically produced Completely Knock Down (CKD) EVs, import duty incentives for machinery and materials related to investments, and raw material import duty or auxiliary material duty incentives used in the production process.
8. Article 19A introduces new clauses, stipulating that incentives apply only if the relevant industries commit to producing a specified quantity of domestically manufactured battery-based EVs within a specific timeframe (details pending). These industries must provide collateral equivalent to the incentives received, facing proportional fines if production commitments are not met.

3.4.3. Deep Dive into Regulations from Ministers

The regulatory landscape governing Electric Vehicles (EVs) in Indonesia is a comprehensive framework encompassing various governmental assistance and incentives to bolster their adoption and production. Regulation from the Ministry of Industry (Permenperin 21/2023) outlines government assistance for E2W purchases, delineating stringent criteria for companies seeking this support. E2Ws must be registered in the Information System of The Aid from The Ministry of Industry (Sistem Informasi Program Bantuan Kemenperin) and meet the minimum 40% local content requirement. Moreover, participating companies are prohibited from increasing the selling price of Electric Motorcycles once enlisted for assistance, and any alterations in production components resulting in reducing the 40% local content threshold are disallowed (Kemenperin, 2023). This regulation further details the verification process conducted by Independent Verification Institutions, ultimately offering a discounted price of IDR 10 million per E2W, fostering their accessibility and affordability (MEMR, 2023b).

As depicted on the official government website https://landing.sisapira.id/, designed to facilitate citizen engagement, the PROGRAM BANTUAN PEMERINTAH UNTUK PEMBELIAN KENDARAAN BERMOTOR LISTRIK BERBASIS BATERAI RODA DUA stands as a testament to the government's commitment to promoting electric two-wheeler adoption. In the fiscal year 2024, a total of 8,826 applications have been submitted by citizens seeking the financial incentives provided by the program. Notably, the rigorous verification process has successfully validated 7,294 of these applications. With a generous quota of 583,880 aids earmarked for distribution, a significant number of eligible citizens still have the opportunity to access the incentive, contributing to the broader goal of encouraging the widespread adoption of battery-based electric motorbikes in the country (SurveyorIndonesia, 2024).

Simultaneously, Regulation from the Ministry of Energy and Mineral Resources (Permen ESDM 1/2023) focuses on the provision of charging infrastructure for Battery Electric Vehicles (BEVs), delineating the types, locations, and charging technology. Recharging facilities and Swap - Public electric vehicle battery exchange stations (SPBKLU) are designated infrastructures strategically situated across various settings. Medium-duration charging units (7-22 kW) are mandated in settlements, offices, malls, and parking lots while fast-charging units (22-50 kW) are allocated for arterial roads, highway rest areas, and gas stations. PLN establishes tariffs for these services, contingent upon allocation, ensuring accessibility and uniformity in charging services (MEMR, 2023a).

Furthermore, Regulation from the Ministry of Internal Affairs (Permendagri No. 6 of 2023) contributes to the incentivization of EV adoption. The former exempts all-electric vehicles—whether private or public, used for people or goods—from PKB (Pajak Kendaraan Bermotor) and BBNKB (Bea Balik Nama Kendaraan Bermotor) rates (Kemendagri, 2023). These initiatives are complemented by various tax incentives aimed at fostering the EV industry's growth, including Tax Holiday based on the amount of the investment (Minister of Finance Regulation no. 130 of 2020), Tax Allowance (Minister of Finance Regulation no. 96 of 2020) for investment in EV ecosystem, and Super Tax Deduction for Research and Development within EV Production Company with highest deduction of gross income by 300% (Minister of Finance Regulation no. 153 of 2020).

3.4.4. Chapter's Conclusion (Answers for SQ1 and SQ2)

In response to SQ1, **'What are the key stakeholders in the various e-motorcycle battery swap-related sectors within Indonesia, and what are their interconnections?'**, There are 7 Involved Ministries with specific roles, on

5 out of 7 produced relevant regulations based on its umbrella regulation (Presidential Regulation 79/2023). 16 existing EV manufacturers, 6 OEM e-motorcycles, 29 conversion workshops, and five battery swap providers exist in Indonesia. The top private players, namely SWAP, Volta, OYIKA, and Gogoro, dominate the market share, shaping adoption through collaborations with ride-hailing giants and third-party logistics companies. The complete diagram of stakeholders, ranging from mining industries, recycling facilities, all-round players (IBC), and customers in the second-life cycle of the battery, is depicted in Figure 3.7.

In response to SQ2, **'What is the current status of government policies, incentives, and the regulatory framework in Indonesia concerning E-Motorcycle Battery Swap systems?'**, the regulatory landscape in Indonesia is shaped by the concerted efforts of various ministries. There are five key ministries actively involved in the regulation of battery swap systems for e-motorcycles, each contributing to the comprehensive framework. The initial cornerstone of this regulatory landscape was laid in 2019 through Presidential Regulation (PERPRES) No. 55, which later manifested in five sets of regulations under different ministries.

Local content requirements for Electric Vehicles (EVs) in Indonesia aim to boost indigenous production and support the domestic EV industry. Initially set at 40% in 2019, these requirements progressively increased to 60% by 2024, further rising to a significant 80% between 2026 and 2030. However, a notable revision occurred with the issuance of PERPRES 79 in 2024, extending the initial 40% target until 2026, followed by a subsequent revision to 60% between 2027-2029. The ultimate goal is to achieve an 80% TKDN target beyond 2030, with exemptions applied to converted motorcycles done by specialized workshops.

The regulatory framework for Electric Vehicles (EVs) in Indonesia includes substantial government assistance and incentives:

- Ministry of Industry's Regulation (Permenperin 21/2023) guides assistance for E2W purchases with stringent criteria, including 40% local content maintenance and restrictions on price alterations.
- The Ministry of Energy and Mineral Resources Regulation (Permen ESDM 1/2023) focuses on charging infrastructure for Battery Electric Vehicles (BEVs), including device specifications, business permits, monitoring, and sanctions.
- Regulation from the Ministry of Internal Affairs (Permendagri No. 6 of 2023) exempts all EVs from PKB and BBNKB rates to enhance ownership preference.
- incentives (Ministry of Finances) include Tax Holiday (PMK 130/2020), Tax Allowance (PMK 96/2020), and Super Tax Deduction for research and development (PMK 153/2020), aiming to encourage EV development and utilization.

4 Case Study Analysis

In this chapter, the spotlight is on analyzing Indonesia's e-motorcycle battery swap system. The goal has three distinct aspects: first, to assess the completeness of the system's building blocks to recognize the barriers in the technology diffusion; second, to uncover the influencing conditions contributing to any observed incompleteness, and third, to observe the relationship between barriers and the causes of barriers. This inquiry aligns with the fundamental questions laid out in Sub question 3 (SQ3), **'What is the current state of each building block and influencing condition block in the Technical Innovation System (TIS) in terms of e-motorcycle battery swap system development in Indonesia? Which one is considered as complete, partially complete, or incomplete building blocks ?'**, and Sub-question 4 (SQ4), **'How are identified barriers and their causes interconnected?'**, of the study.

SQ3 directs an examination of the current state of each building block within the Technical Innovation System (TIS), particularly in the context of advancing the e-motorcycle battery swap system in Indonesia. This involves categorizing these blocks as complete, partially complete, or incomplete. Meanwhile, SQ4 delves into exploring the various conditions of building blocks, discerning their roles as drivers if a certain block status is complete or barriers if a certain block status is incomplete or partially complete, in shaping the development of the battery swap system for e-motorcycles in Indonesia. In addition, SQ4 explores the relationship between barriers (incomplete or partially complete building blocks) and their causes (influencing conditions), providing the cause-and-effect relationships between incomplete or partially complete building blocks and the underlying influencing conditions that give rise to these barriers.

As shown in Table 1.3, the stakeholders engaged in this investigation span a spectrum of expertise, encompassing governmental ministries (Kementrian ESDM, Kementrian KLHK, and Kementrian Maritim dan Investasi), research institution (N-BRI), the single entity responsible for electricity provision in Indonesia (PLN), a key player in battery swap and e-motorcycle sector, third-party technology supporter, and representatives from the battery manufacturing domain. Apart from interviews, literature studies and questionnaires are also involved in this section.

4.1. Building Blocks for Circular Innovation

4.1.1. Product Performance and Quality

The table below provides a comprehensive comparison between targeted Electric and Gasoline Motorcycles specifically tailored for private and commercial urban usage (ADB, 2022). It details various parameters encompassing the engines, batteries, driving range, popular brands, capital expenditure (CAPEX), operational expenses (OPEX) for both private and commercial users, and the overall Total Cost of Ownership (TCO). Notably, the comparison highlights distinctive features such as engine specifications, battery technology, range, costs, and brand preferences pertinent to the Indonesian market. This analysis serves as a valuable resource to understand the nuanced differences and considerations between these two types of motorcycles, aiding potential buyers and industry stakeholders in making informed decisions about urban mobility options.

Table 4.1: Targeted Electric versus Gasoline Motorcycles for Private and Commercial Urban Usage (ADB, 2022)

Parameter	Gasoline Motorcycle	Electric Motorcycle	Comment
Engine	110–125 cc engine with 6 to 9 kW power	1,800–2,500 W engine with peak power of 5–7 kW and speeds of 50–70 km/h	Lower powered e-scooters are not considered to be comparable and are thus not included; higher powered e-motorcycles such as the Niu NGT are not included due to having triple investment cost of a fossil-fuel-based motorcycle.
Batteries	—	Lithium-ion of 1.2–1.5 kWh with a lifespan of 2–3 years (1,000 cycles)	Electric motorcycles are offered in general with the option of one or two batteries; 2–3 hours are required for a full charge at home
Driving range	150 km	40–70 km with one battery; 80–140 km with two batteries	Average distance per day for an urban Jakarta private user: 40–50 km; Average distance per day for a commercial user: 80–100 km
Popular Brands	Honda, Yamaha, Suzuki	Gesits, Swag Type X, United T1800	Brands as sold in Indonesia currently
CAPEX	Rp17–21 million	Rp24–28 million with one battery	Battery cost around Rp 7-15 million. The battery cost is declining annually 5%–10%
OPEX Private User	Rp3.4 million per year or Rp240 per km	Rp1.0 million per year or Rp70 per km	Based on annual mileage of 14,000 km; includes maintenance and energy cost; excludes finance cost
OPEX Commercial User	Rp5.9 million per year or Rp250 per km	Rp1.6 million per year or Rp70 per km	Based on annual mileage of 24,000 km; includes maintenance and energy cost; excludes finance cost
Total Cost of Ownership	Private: Rp550 per km Commercial: Rp470 per km	Private: Rp556 per km Commercial: Rp520 per km	Includes CAPEX (including battery replacement), OPEX and finance cost; 5-year lifespan of motorcycle private and 4-year commercial usage

The detailed comparison provided in the table offers valuable insights into the nuances of electric and gasoline motorcycles tailored for private and commercial urban usage in Indonesia. It shows crucial parameters such as engine specifications, battery technology, driving range, costs, and brand preferences, facilitating informed decision-making for potential buyers and industry stakeholders. This analysis sets the stage for further exploration into the sub-blocks related to ”Product Performance and Quality,” specifically focusing on aspects such as Design for Circularity, Resource Optimization, and Integrated Product-Service Systems (PSS).

Design for Circularity

The evaluation of the battery swap system’s ”product performance and quality” in Indonesia encompasses three essential measures: Design for Circularity, Resource Optimization, and Integrated Product-Service Systems(PSS). Design for Circularity involves the design of products and services aimed at facilitating reuse, repair, or recycling at the end of their life cycles. An interview with **interviewee 1** reveals a growing interest in circularity, notably depicted in Figure 3.7, with only a handful of existing MoUs with overseas players such as NHL and PUQING, which will be commissioned by 2025. While limited, this marks a positive initiation, categorizing this block as partially complete and urging the integration of new players to enrich the ecosystem.

According to a senior legal employee of an e-mobility ecosystem within a battery swap company, who opted to remain anonymous (interviewee 8), the estimated lifespan of batteries ranges from 7 to 10 years. However, de- Despite internal discussions mentioning potential reuse or recycling processes for these batteries, the absence of malfunctioned batteries at this early stage become the reason for the unnecessity of clear protocols at the business level regarding- ing recycling and reusing the old battery for other purposes.

Resource Optimization

In terms of resource optimization, the presence of non-interoperable racks from different brands contributes to unnecessary budget allocation. At a single location, multiple battery racks from various brands coexist, highlighting the lack of resource optimization. This scenario underscores the inefficiency of utilizing racks equipped with expensive power electronics due to their non-interoperable nature. The result is an increased expenditure attributed to the need for multiple systems that cannot seamlessly integrate, leading to a suboptimal utilization of resources.

Another issue of resource optimization is in terms of repurposing batteries in their second life phase. Insights from an interview with **interviewee 1** highlight the potential for reusing a second life of batteries into Energy Storage Systems for variable renewable energy sources, underscoring an avenue for optimizing resources effectively. However, based on the information from IESR, such facilities will exist after late 2025 (IESR, 2023).

Integrated Product-Service Systems (PSS)

In the realm of Integrated Product-Service Systems (PSS), the prevailing business model within the battery swap system entails renting batteries alongside motorcycle sales. Notably, major users comprise ride-hailing company operators like GOJEK, engaging in agreements to purchase motorcycles from providers like Gogoro(and Electrum) while concurrently renting motorcycles (including batteries) to motorcycle taxi drivers (Gojek). This model facilitates the return of batteries to the manufacturer for reuse or remanufacturing, which may align with the integrated PSS concept aimed at minimizing waste and maximizing environmental efficiency, as the ownership of e-motorcycles, including batteries, is in the company, not the customers.

4.1.2. Product Price

Analyzing the ”product price” aspect of the battery swap system in Indonesia involves understanding its Long Term Feasibility and Total Cost of Ownership. Long Term Feasibility examines the economic viability over time, considering factors like technology development costs and market demand potential. Interviews with industry experts emphasize the importance of addressing interoperability concerns and ensuring robust after-sales support to sustain operations. Furthermore, the Total Cost of Ownership is a crucial consideration, particularly in a market where more than 70% of potential e-motorcycle users belong to lower socio-economic strata according to a Kompas Litbang survey (Dananjaya and Maulana, 2023). Price plays a pivotal role in purchasing decisions, with conventional motorcycles priced competitively. According to the IESR, cost reduction incentives for motorcycles are more effective since they make E2W prices much cheaper (IESR, 2023); however, the aftersales cost remains expensive compared with the ICE market according to Interviewee 9. Further information on both crucial sub-blocks is explained below.

Long Term Feasibility

Analyzing the ”product price” aspect of the battery swap system in Indonesia involves two pivotal measures: Long Term Feasibility and Total Cost of Ownership. Long Term Feasibility emphasizes the economic viability of circular innovation in the long run, encompassing aspects like technology development costs, financing availability, and market demand potential. Based on the interviews with **Interviewee 3** and **interviewee 9**, the development and implementation costs of new technologies are important, especially considering the projected shift towards open protocols and regulated voltage among various providers to address interoperability concerns.

Moreover, insights gleaned from the interview with **interviewee 9** provide an expanded perspective on Long Term Feasibility. The **Interviewee 9** stressed the crucial connections between long-term viability and after-sales support, emphasizing how robust after-sales services are integral for customer satisfaction and sustained operation. Additionally, the discussion highlighted the importance of interoperability, spanning both software and hardware domains. The mention of interoperability roaming technology enabling multiple software bridges underscores the necessity for seamless communication between disparate platforms.

Furthermore, the interview underscored potential hurdles regarding hardware standardization. Variations in port designs, voltage levels, and rack sizes established by different consortiums pose a significant challenge. This absence of uniform hardware specifications could impede the large-scale diffusion of the battery swap system over time. The lack of standardization may result in increased implementation costs, hindered interoperability, and operational inefficiencies, potentially jeopardizing the long-term feasibility of the system.

Total Cost of Ownership

According to a Kompas Litbang survey, more than 70% of potential e-motorcycle users in Indonesia belong to the lower and mid-lower socio-economic strata (Shahab, 2023). Price stands as a pivotal determinant in motorcycle sales, with the leading motorcycle priced at approximately IDR 18 million. This trend carries over to electric motorcycles, exemplified by models like the Viar Q1, initially priced at Rp21 million, emerging as a top-selling e-motorcycle in 2022-2023. To capitalize on this substantial user base, electric motorcycles must bridge the price disparity with conventional motorcycles. This strategy aims to render them more accessible and affordable for the predominant lower and mid-lower socio-economic classes, thereby expanding their market reach.

Table 4.2: Top-Selling Motorcycles: Conventional vs. E-Motorcycles (OTR Prices) (Shahab, 2023)

Rank	Top Selling Motorcycle	OTR Price (in IDR)
1	Honda Beat	IDR 18,050,000
2	Honda Vario	IDR 22,550,000
3	Yamaha Mio	IDR 17,700,000
Rank	**Top Selling e-Motorcycle before IDR 7 million subsidy**	**OTR Price (in IDR)**
1	Viar Q1	IDR 21,000,000
2	Gesits G1	IDR 28,970,000
3	Selis E-Max	IDR 22,000,000

Examining the battery swap pricing strategies adopted by various industry players provides insights into diverse user-centric approaches. For instance, Company SWAP employs a per-kilometer charging system that allows users to swap batteries at USD 0.01 (IDR 200) per kilometer, ensuring flexibility and unlimited swapping but totalling an estimated USD 10.6 (IDR 160,000) per month. Conversely, Companies GOGORO, OYIKA, SGB, and VOLTA utilize a subscription-based model charging approximately USD 0.7 (IDR 10,000) per swapping, with users opting for swaps when battery range decreases. The fixed fees per swap range between USD 10 (IDR 150,000)and 20.5 (IDR 300,000) per month, resulting in varied monthly costs based on swapping frequency (Deloitte, 2023). While these pricing models may offer better value than gasoline usage, they pose a substantial challenge to low- and middle-income workers due to the capital expenditure involved in purchasing e-motorcycles, even with subsidies in place. This economic burden affects their adoption rates despite the competitive pricing offered by battery swap systems.

In addition, **Interviewee 9** gave insights on a critical aspect often overlooked in the discussion of battery swap systems: the maintenance and after-sales costs of e-motorcycles. The **Interviewee 9** highlighted that despite the competitive pricing models of battery swap systems, the maintenance costs for e-motorcycles remain relatively high. This factor significantly impacts the total cost of ownership for users, especially for low- and middle-income workers. Even with potential subsidies for purchasing e-motorcycles, the ongoing expenses related to maintenance and after-sales support pose a substantial economic burden.

4.1.3. Production System

To understand deeper into Indonesia's battery swap ecosystem, it is essential to analyze the dynamics of its production system. This system encompasses various stages, starting from the extraction of raw materials to the deployment and recycling of batteries. At its heart lies the complex process of nickel mining, primarily concentrated in Sulawesi. With significant nickel reserves, Indonesia plays a pivotal role in the global electric vehicle (EV) battery market. Numbers of the stakeholders exist already in the related sectors, which can be seen in Section 3.3.1. Within the system, individual consumers and ride-hailing strategic partnerships like Gogoro-Gojek engage with battery swap providers (Gogoro, 2021), creating a complex stakeholder network. The system also allows for the reduction of the total cost ownership of ownership to the user by battery leasing business model and integration of the system into public facilities such as gas stations, minimart, PLN offices, etc.

However, the landscape of Indonesia's battery supply chain reveals a gap in the nation's midstream and circular aspect industry. Despite substantial investments across the entire supply chain, critical components such as battery producers and recycling facilities are not expected to operate until at least 2025 (IESR, 2023). This delay underscores the need for efforts to bridge existing gaps in infrastructure and regulatory frameworks. Additionally, the level of Adaptability and Flexibility in adopting circularity and the absence of detailed regulations around reverse logistics poses a significant challenge discussed in the sections below.

9 R(s) Capabilities

Based on the interviews with **Interviewee 1** and **Interviewee 5**, the establishment of Indonesia Battery Corporation (IBC) and the engagement of overseas companies like Puqing and NHL indeed mark a proactive step toward enhancing 9R(s) capabilities and strong reverse logistics in battery management and resource optimization. Yet, the absence of detailed regulations around reverse logistics and waste management poses a significant gap in ensuring effective execution. Robust regulatory frameworks are vital to guide and enforce proper reverse logistics practices, ensuring the efficient collection and disposal of end-of-life materials. These regulations would play a crucial role in minimizing environmental impact, promoting responsible waste handling, and augmenting the effectiveness of recycling initiatives within the battery industry. Without comprehensive guidelines, the full potential of these collaborative efforts to enhance 9R(s) capabilities may remain unrealized.

According to a senior legal employee of the e-mobility ecosystem within a battery swap company, who opted to remain anonymous (**interviewee 8**), the estimated lifespan of batteries ranges around seven years. However, despite internal discussions mentioning potential reuse or recycling processes for these batteries, the absence of malfunctioned batteries at this early stage becomes the reason for the unnecessity of clear business protocols regarding recycling and reusing the old battery for other purposes. This perspective aligns with insights from **Interviewee 9**, who highlighted similar concerns. In addition, Interviewee 9 provides insights into the concept of circular economy, expressing concerns about its implementation in Indonesia. According to the interviewee, the approach towards achieving zero waste lacks scientific rigour, as it should ideally involve the core competencies of scientists and engineers. Despite efforts to emulate strategies from other countries, the interviewee suggests that the current approach in Indonesia remains predominantly linear, with superficial attempts at incorporating green practices without addressing the underlying scientific principles.

Strong Reverse Logistics

Delving deeper into Indonesia's battery supply chain reveals a significant gap in the nation's midstream industry. Despite improvements made in various sectors, the country lags in establishing itself as a comprehensive, end-to-end producer of nickel-based EV batteries. Many critical components within this sector are either absent or, at best, exist in relatively diminutive scales (IESR, 2023), including the reuse and recycling sector. The true status of a complete end-to-end producer of these batteries is vividly depicted in Figure 4.1, shedding light on the stark contrast between the existing infrastructure and the envisioned comprehensive ecosystem. Based on the IESR (IESR, 2023), the landscape of financing within Indonesia's electric vehicle (EV) industry reflects a significant investment of around USD 20 billion across the entire supply chain, yet critical components such as battery producers and recycling facilities are not slated for operation until at least 2025.

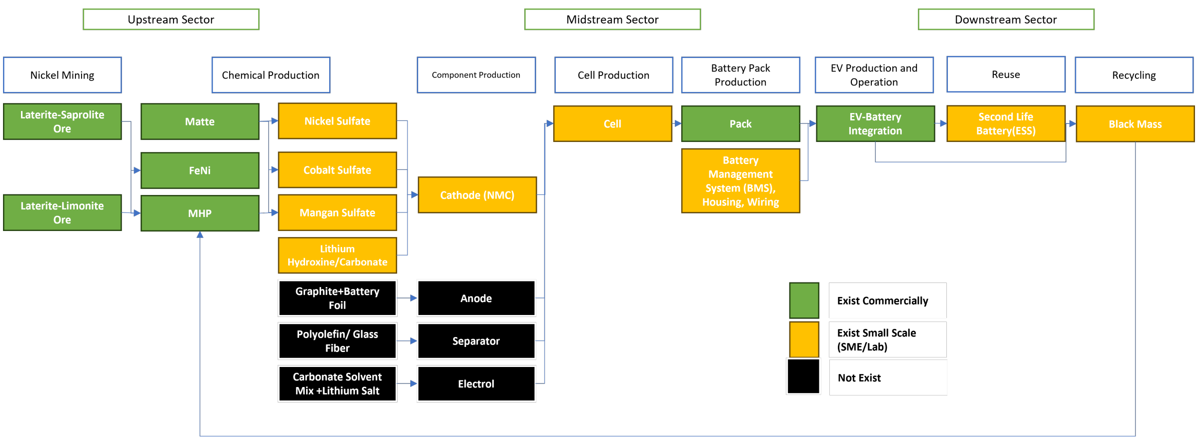

Figure 4.1: Indonesia Battery Supply Chain Status ((IESR, 2023))

Adaptability and Flexibility

In terms of adaptability and flexibility, the evaluation of stakeholder awareness and readiness plays a pivotal role in the successful implementation of the Indonesia National Standard (SNI). The awareness level among stakeholders and the public regarding the significance of adhering to a swappable battery standard is a key determinant in gauging the preparedness of human resources. Notably, stakeholders involved in implementing these standards exhibit a high level of awareness regarding the importance of adhering to the swappable battery standard in SNI

(Aqidawati et al., 2022).

This analysis was conducted to gauge the capacity of Indonesian stakeholders to embrace and comply with the SB standard upon its implementation. This assessment aimed to measure the readiness of stakeholders and their ability to align with the standards through various means, including financial investments to meet standard criteria, intrinsic motivation, and a proactive willingness to adhere to prescribed norms. Encouragingly, the survey outcomes affirm that stakeholders in Indonesia demonstrate commendable adaptability to comply with standards, reflecting a strong inclination and capability to align with and thrive under the swappable battery standard once it is put into effect. This resilience and adaptability among stakeholders bode well for the successful implementation and widespread adoption of the swappable battery standard within the Indonesian context.

4.1.4. Complementary Products and Services

In addition to purchasing new electric motorcycles, converting existing internal combustion engine (ICE) motorcycles into electric motorcycles can complement the latest products to boost the population of battery swap users. This program is supported by a government subsidy of Rp 10 million per unit, increased from Rp 7 million per unit initially. This incentive, outlined in Regulation Number 13 of 2023 by the Minister of Energy and Mineral Resources, Arifin Tasrif, covers a maximum conversion cost of Rp 17 million, including components such as the battery pack, brushless DC (BLDC) motor, and controller (MEMR, 2023b). Apart from the high upfront cost, there are other factors contributing to the slow adoption of converted e-motorcycles. The converted e-motorcycle has a shorter warranty period, ranging from 6 months to 1 year, and some even have no warranty period. As a comparison, spare parts for new e-motorcycles usually come with a 2-year warranty. In addition to the short warranty period, lack of knowledge about the conversion program and lack of experience in trying a converted motorcycle lead to low consumer confidence in the conversion program (IESR, 2023).

Other complementary products and services supporting the development, production, distribution, adoption, use, repair, maintenance and disposal of the innovation are explained deeper in the form of collaboration between e-motorcycle industries, the creation of a product/service ecosystem, and the establishment of industry-specific infrastructure as follows.

Collaboration

As an example of solid collaboration, the Swappable Batteries Motorcycle Consortium (SBMC) has remarkably expanded its membership, boasting a commendable count of 32 renowned brands by the close of 2023 (Dananjaya and Maulana, 2023). This concerted effort signifies SBMC's proactive approach in both augmenting its membership and meticulously delineating technical specifications for upcoming endeavours. Notably, the consortium has achieved a pivotal milestone by crafting initial prototypes of exchangeable batteries through selected suppliers, an integral step in the validation and fine-tuning of technical specifications. SBMC's strategic roadmap delineates a phased approach in prototype creation, with the initial rounds serving as crucial testing phases for specifications. Subsequent phases, scheduled for 2024, aim to refine prototypes for field trials in collaboration with battery manufacturers, exchange station providers, and OEMs. Beyond tangible actions, SBMC actively engages in high-level discussions with European and international standardization bodies, driving discussions and advancements in swappable battery development for motorcycles.

Encompassing 32 member companies, including industry titans like Honda, Piaggio Group, Yamaha, and

Forsee Power, SBMC epitomizes a diverse and influential assembly, fostering a collaborative environment. The consortium's forthcoming participation at EICMA 2023 underscores its commitment to exploring organizational progress and future objectives. The planned meetings during this event will delve into SBMC's strides and future trajectory, reflecting the consortium's proactive stance. Moreover, SBMC's global engagements are poised to continue, with technical specification discussions slated for Tokyo in October 2023 and subsequent meet-ups planned for April 2024 in Turin, Italy. These proactive endeavours reinforce SBMC's steadfast dedication to cultivating a robust network and nurturing collaboration among industry leaders, propelling advancements in swappable battery technology within the motorcycle sector.

Furthermore, based on a second interview with **Interviewee 1**, consortia such as Asosiasi Ekosistem Mobilitas Listrik(AEML), Asosiasi Industri Sepeda Motor Listrik Indonesia (AISMOLI), Gabungan Industri Alat-alat Mobil dan Motor (GIAMM), and others significantly augment collaborative efforts, potentially shaping industry standards and fostering innovation in Indonesia's EV realm. Another example, partnerships with entities like Infiniti Energy Indonesia, Birubatt, ABC Battery, and Gotion, advocated by NBRI, indicate a widening network focused on battery tech, infrastructure enhancement, and market penetration strategies within the Indonesian EV sector.

However, based on the Article ”Open Innovation in Developing an Early Standardization of Battery Swapping According to the Indonesian National Standard for Electric Motorcycle Applications”, related to the standardization and the emergence of consortia, during the maturity phase, when a technology has become mature and relatively stable, with competitive implementations in the market, it becomes critical to prioritize compatibility. Failure to ensure compatibility among providers could lead to a loss of market share. This lack of compatibility, in turn, can act as a bottleneck in the expansion of the market, impacting the adoption and further growth of the technology (Wahyudi Sutopo et al., 2022).

Industry-specific infrastructure

In the context of industry-specific infrastructure, the nation's abundant reserve of 21 Mt of nickel, a primary raw material for EV batteries, positions it uniquely among EV manufacturing countries, attracting automakers keen on establishing production sites. However, depicted also in Figure 4.1, despite substantial investments exceeding USD 20 billion across the entire supply chain, the full integration of domestic EV supply chains awaits further realization, with several battery cathode/cell producers do not exist, and recycling facilities slated for operational commencement post-2025 (IESR, 2023). This underscores the ongoing imperative to fortify Indonesia's circular infrastructure for a seamless transition toward an integrated and sustainable EV ecosystem.

Ecosystem of Product/Service

Furthermore, concerning the ecosystem of products and services, the emergence of thousands of swap stations across Indonesia, strategically positioned in places like minimarts, gas stations, e-commerce hubs (like Lazada and Blibli), state-owned logistics hubs (like POS), and collaboration with ride-hailing companies, represents a significant step in accommodating EV users (Deloitte, 2023). However, despite this expansive network, a critical incompleteness persists due to the disparity in each dimension and voltage levels according to the **Interviewee 1** leading to the potential issue in the interoperability.

4.1.5. Network Formation and Coordination

In Indonesia's e-motorcycle and battery swap sectors, coordination is crucial, guided by dedicated teams mandated by Presidential Regulations (PERPRES-RI, 2023). However, progress towards goals outlined in the "Grand Strategy Energy" falls short, as the data are shown by the official social media of MEMR (Ministry of Energy and Mineral Resource) (MEMR, 2023c). Meanwhile, in supply chain networks, entities are identified from the local and overseas players, as shown in the section 3.3.1. The main building block, "Network Formation and Coordination," is further elaborated in the sections below.

Division of Responsibility

Regarding division of responsibility, Indonesia's regulatory landscape under Presidential Regulation (PERPRES) No. 55-2019 (in transition to the more recent update, PERPRES No.79, 2023) has established a coordination team chaired by the Ministry overseeing governmental business in maritime affairs, with the Ministry coordinating economic affairs serving as the vice-chair. This team comprises key stakeholders such as the Ministers of Finance, Research and Technology, Industry, Commerce, Energy and Mineral Resources, Transportation, Environment, Internal Affairs, and the Head of the Police Department. This coordinated effort delineates the regulatory framework via ministerial regulations (Permen), encompassing five pivotal aspects to expedite the EV and battery swap ecosystem in Indonesia (PERPRES-RI, 2019). These aspects involve accelerating domestic Electric Vehicle and Battery Swapping Station (KBLBB) industry development, offering incentives, provisioning electric charging infrastructure, regulating electricity tariffs for electric vehicles, complying with technical provisions for electric vehicles, and ensuring environmental protection. However, in practice, **Interviewee 7** notes that the responsibility in the design of the circularity still does not exist. Battery waste is still considered and handled as Toxic waste, which the Ministry of Environment and Forestry regulates.

Shared Goals

In terms of shared goals, Indonesia has set ambitious targets aligned with its roadmap in "Grand Strategi Energy" (GSE). The nation aims to establish 10.000 Shared Public Electric Vehicle Battery Swapping Stations (SPBKLU) by 2025 and escalate this number to 15625 units by 2030, according to the official social media of MEMR (Ministry of Energy and Mineral Resource) (MEMR, 2023c).

In terms of the target for the e-motorcycle population, according to the Directorate General of Land Transportation, Ministry of Transportation, as of January 22, 2024, at 15:23 GMT +7, the total population of electric motorcycles equipped with the Type Test Registration Certificate (SRUT), one of the requirements for the vehicle registration certificate (STNK), is 99,594 units. This falls significantly short of the target mentioned on the social media account of the Ministry of Energy and Mineral Resources (MEMR, 2023c), which is 2,000,000 units by 2025.

Moreover, Indonesia has established Local Content Requirement (LCR) targets for Electric 2-Wheelers (E2W) and Electric 4-Wheelers (E4W). Several E2W and E4W brands have met the government's LCR target of 40% by 2022, with subsequent escalations planned, aiming for 60% compliance for both E2W and E4W in 2024, progressing to 80% for E2W in 2026 and E4W in 2030 (PERPRES-RI, 2023). While some EV industries might choose non-compliance with LCR assessments for B2C sales, government initiatives, including public procurement for official vehicles and customer incentives, seek to incentivize adherence to these requirements. The correlation between escalating LCR standards and the creation of a robust ecosystem for Electric 2-wheelers (E2W) and battery swapping becomes apparent. Upholding LCR stipulations necessitates fortifying the entire value chain, particularly in manufacturing crucial components like batteries, thereby emphasizing the interconnectedness between regulatory mandates and the evolution of a sustainable circular economy ecosystem.

Strong Network

Indonesia's electric vehicle (EV) landscape showcases a good network of actors in the value chain, one example is depicted by the Indonesia Battery Corporation (IBC) and its partnerships with leading Original Equipment Manufacturers (OEMs) and local e-motorcycle producers (GESITS). These alliances are not just about technological advancements but encompass critical facets like infrastructure and user experience via innovative solutions like the "Battery Energy Swap Technology by IBC" app (Mubarok, 2023). The active participation of industry giants like CATL, LG, and REG in the field of research and development, coupled with policy advocacy for standardized regulations and incentives, underlines a holistic push for the EV and battery sectors.

Simultaneously, the rise in EV adoption by major EV companies and emerging ventures like Swap, Oyika, and SGB-Volta emphasizes not only eco-friendly transport solutions but also a strong network for integrating battery swap devices into existing infrastructure such as gas stations, mini-marts, e-commerce hub, and ride-hailing operators. With the evolution from PERPRES No. 55 in 2019 to the more recent PERPRES No. 79 in 2023, the government has taken proactive steps to allocate designated areas for battery stations. These locations encompass a diverse range of spaces, including Stasiun Pengisian Bahan Bakar Umum (SPBU), Stasiun Pengisian Bahan Bakar Gas (SPBG), central and regional government offices, shopping centers, and public roadside parking areas. Moreover, the landscape witnesses a surge in EV adoption not only by established industry giants but also by emerging ride-hailing ventures like Electrum-Gogoro-Gojek. This surge not only promotes eco-friendly transport solutions but also strengthens networks for integrating battery swap devices into existing infrastructure nodes in their several operator hubs in the cities.

However, despite this progress, certain critical components remain incomplete within the network. Notably, the aspect of recycling in the EV and battery sectors has yet to be fully developed. As per insights from the Institute for Essential Services Reform (IESR), the infrastructure for recycling in these sectors may not materialize until at least 2025, underscoring a gap in the holistic sustainability of the EV landscape, as referenced in (IESR, 2023). Addressing this aspect will be pivotal to ensuring a comprehensive and sustainable EV ecosystem in Indonesia.

4.1.6. Innovation-Specific Institution

The National Battery Research Institute (NBRI) in Indonesia is a leading force in energy innovation. Established in December 2020, NBRI focuses on advancing battery technology for renewable energy applications. It serves as a platform for research, training, and collaboration among scientists, academics, industry partners, and government stakeholders. NBRI's primary goal is to develop a local battery manufacturing industry to support Indonesia's energy independence using its abundant resources.

Supported by the UK Government's Global Challenge Research Fund (GCRF) through Queen Mary University of London, NBRI aims to unite Indonesian stakeholders in battery research and increase awareness of its importance at the government level. Its activities include assessing Indonesia's battery research capabilities, promoting local manufacturing, and fostering global partnerships.

Despite its significant contributions, NBRI has not always been included in key standardization discussions, according to Interviewee 1, such as the formation of the Indonesia Battery Swap Standardization (SNI battery swap 8928:2023). NBRI was only involved in a few days of the working committee meeting session which is the final step of forming a standardization document. This oversight highlights a need for improved collaboration between NBRI and the government to ensure that standards align with industry advancements and national goals. Strengthening this partnership will be crucial for Indonesia to achieve its energy independence objectives and promote sustainable development. Another essential part of the discussion in terms of Innovation-Specific Institutions based on the proposed framework is stated below.

General Consensus

The general consensus, a challenging feat within Indonesia's diverse EV ecosystem, represents a widespread agreement or common accord within a group. A comparative table 4.3 highlights the variance in views across political entities such as PDIP, Gerindra, PKS, industry consortia like Periklindo and AEML, academic institutions including ITB and University of Indonesia, and advocacy groups such as WALHI and YLKI. This breadth of opinions from stakeholders reflects the complex landscape shaping the discourse and policy frameworks related to EV development in the country. Encouraging the political will across all political parties becomes crucial in fostering a collective effort to establish an ecosystem conducive to e-motorcycle battery swap advancements (Shahab, 2023).

For/Against	Organization Type	Name of Person /Org.	Opinion
For	Consortia	Association of Electric Vehicle Manufacturers of Indonesia (Periklindo)	"PERIKLINDO is committed to working with the government and other stakeholders to promote the adoption of EV motorcycles in Indonesia."
For	Consortia	Asosiasi Ekosistem Mobilitas Listrik (AEML)	"We should utilize EV to reduce carbon emissions and the downstream processing of natural resources for the advancement of Indonesia."
For	Political Party	Hasto Kristiyanto (PDIP)	"Electric vehicles have the potential to reduce air pollution and improve public health in Indonesia."
For	Political Party	Ahmad Muzani (Gerindra)	"Gerindra Party believes that electric vehicles have the potential to create new jobs and boost the Indonesian economy."
For	Researcher	Prof. Dr. Ir. Riri Fitri Sari, M.Sc. (ITB)	"The development of the electric vehicle industry is essential for Indonesia's economic and environmental future."
For	Government	Ministry of Finance	"The development of the electric vehicle industry is a strategic priority for Indonesia. It will help us to reduce our reliance on imported oil, improve our air quality, and create new jobs."
For	Government	Ministry of Transportation	"We believe that electric vehicles have the potential to revolutionize transportation in Indonesia. They are more affordable and environmentally friendly than conventional vehicles, and they can help to reduce our air pollution."
For	Government	Coordinating Minister for Maritime and Investment	"Electric vehicles are the future of transportation, and Indonesia is well-positioned to become a global leader in this industry. We have the resources, the talent, and the commitment to make it happen."
For	Government	Ministry of Environments	"The development of the electric vehicle industry is essential for improving Indonesia's air quality."
Against	Political Party	Fadli Zon (Gerindra)	"Electric motorcycles are too expensive and that the government should focus on improving public transportation instead."
Against	Political Party	Nurhasan Zayyin (PKS)	Zayyin has argued that electric motorcycles are not suitable for Indonesia's climate and industry. He has also expressed concerns about the availability of charging infrastructure.
Against	Researcher	Dr. Indrastuti Nasution (ITB)	"Electric vehicles are too expensive for most Indonesians. He has also expressed concerns about the availability of charging infrastructure, particularly outside of urban areas."
Against	Advocacy	WALHI	"WALHI criticized the government's focus on electric vehicles, arguing that it is a distraction from the need to address the root causes of climate change, such as deforestation and coal mining."
Against	Advocacy	YLKI	"Expressed concerns about the safety of electric motorcycles, particularly those that are imported from China."
Against	Researcher	Dr. Riza Noer (UI)	"Electric vehicles are not a sustainable solution for Indonesia's transportation needs. He has pointed out that Indonesia's electricity grid is still largely powered by coal."

Table 4.3: Opinions on Electric Vehicles in Indonesia (Shahab, 2023)

Moreover, the absence of a unified consensus extends beyond external stakeholders to fragmentation within the government, further complicating alignment efforts. A notable discord revolves around the early public policy approach, debating the merits of a 'pull' versus 'push' strategy and presenting trade-offs within policy decisions. This internal debate spotlights the challenge of aligning policies to promote circular innovation within the EV sector effectively. The 'pull' approach focuses on creating incentives and market mechanisms, while the 'push' strategy leans more on regulations and directives. This governmental disagreement likely stems from the delicate balancing act between economic factors, regulatory impact, and the dynamic nature of the market.

In addition, the ongoing presidential election in Indonesia, with three candidates, brings forth packages of vision and mission where one of their contents is related to the enhancement of the electric vehicle ecosystem in Indonesia. These election campaigns signify a potential shift in policy direction as candidates outline plans and commitments toward advancing the EV landscape. However, it's worth noting that among the three pairs of candidates, their vision and mission documents primarily focus on missions related to renewable energy utilization, downstream mining materials to foster domestic industries, and increasing local content requirements (TKDN). Explicit mentions regarding the enhancement of the EV ecosystem, especially in battery swap technology, are absent in their documents. Only candidate number 1 mentions a mission related to public electric vehicles and improving electric charging infrastructure (without specifying SPBKLU or battery swap stations) (Baswedan and Iskandar, 2023) (Pranowo and MD, 2023) (Subianto and Raka, 2023).

Figure 4.2: Presidential Candidates of Indonesia

Standardization

Despite differing viewpoints among these entities, regulations governing shared objectives have been outlined within Presidential Regulation (PERPRES) 55/2019 (in transition to the more recent update, PERPRES No.79, 2023), which is transitioning to the more recent update, PERPRES No.79, 2023, further elaborated in ministry regulations (Permen). However, these regulations lack detailed specifications and introduce uncertainties in the standardization process (SNI). As highlighted previously, the need for refined SNI standards is paramount, especially given the emergence of various consortia producing different types of charging ports, racks, and batteries. Consolidation among these entities becomes imperative within the limited timeframe before technologies are widely applied, preventing unnecessary future investments that could impede further development. Notably, this ongoing process demonstrates a continuous effort toward refinement and improvement, as indicated in the second interview with **Interviewee 1**. It is important to note that the National Battery Research Institute (NBRI) functions as an independent advisory body, ensuring that governmental decision-making processes (including standardization and other relevant aspects) are rooted in scientific knowledge and not arbitrary measures. The most updated SNI proposed by the National Standardization Institution is (SNI 8928:2023). Although the standard has been released, it remains voluntary until it is officially incorporated into relevant ministerial regulations according to the **Interviewee 1**.

Emerging Robust Policy

The transition from Presidential Regulation No. 55/2019 to the more recent update, PERPRES No. 79/2023, marks a significant shift in Indonesia's vehicle ecosystem policies. However, this transition has not occurred simultaneously across the board under the relevant ministries. Consequently, updates tend to be scattered, making it challenging to track and implement the changes effectively. This lack of synchronized implementation has resulted in ambiguous regulations, lacking comprehensive details, and often deficient follow-through.

Policies related to nurturing the vehicle ecosystem in Indonesia are distributed among six ministries as explained in Section 3.4. This complex division has led to regulations that are unclear, lacking in depth, and with minimal follow-through. One significant repercussion of weak monitoring and guidance in standardization is the proliferation of large motorcycle consortia with varied specifications, creating bottlenecks in the growth of battery swap stations within a region due to incompatible battery racks.

Additionally, within the Ministry of Environment and Forestry (KLHK), only two regulations were found. These regulations collectively consider lithium batteries as hazardous waste (B3 waste) rather than substances that can be processed into raw materials for new batteries:

- Permen LHK No. 6, 2021: PERATURAN MENTERI LINGKUNGAN HIDUP DAN KEHUTANAN REPUBLIK INDONESIA NOMOR 6 TAHUN 2021 TENTANG TATA CARA DAN PERSYARATAN PENGELOLAAN LIMBAH BAHAN BERBAHAYA DAN BERACUN (KLHK, 2021b).
- Permen LHK No. 12, 2021: PERATURAN MENTERI LINGKUNGAN HIDUP DAN KEHUTANAN REPUBLIK INDONESIA NOMOR 12 TAHUN 2021 TENTANG BAKU MUTU EMISI DAUR ULANG BATERAI LITHIUM (KLHK, 2021a).

4.1.7. Costumers

Customers play a pivotal role in the adoption of battery swap services. However, comprehensive data on users of battery swap services offered by major players such as SWAP, SGB, OYIKA, and Gogoro are not readily available. However, understanding the potential user base for battery swap services can be approached by examining the users of e-motorcycles. The Directorate General of Land Transportation, Ministry of Transportation, reported that as of January 22, 2024, there were 99,594 electric motorcycles equipped with the Type Test Registration Certificate (SRUT), a requirement for vehicle registration certificates (STNK). This figure falls significantly short of the Ministry of Energy and Mineral Resources' target of 2,000,000 electric motorcycles by 2025, as stated on their social media account (MEMR, 2023c). More insight related to the customers' knowledge, ownership preference, and the degree of resistance to change is given in the following section.

Knowledge and Awareness

The data acquired from a questionnaire involving 229 Indonesian respondents from 26 locations in Indonesia provides valuable insights. This survey was conducted by Interviewee 10. Most respondents are aware of the main benefits of owning an e-motorcycle instead of an ICE motorcycle, such as low operational costs and being eco-friendly. However, based on Figure 4.3, the highest percentage that can be achieved regarding knowledge of these benefits is 68% (related to the low operational cost and e-motorcycle as a non-emissive vehicle), indicating a significant potential to boost the knowledge and awareness of potential users of e-motorcycles, particularly those with a battery leasing scheme.

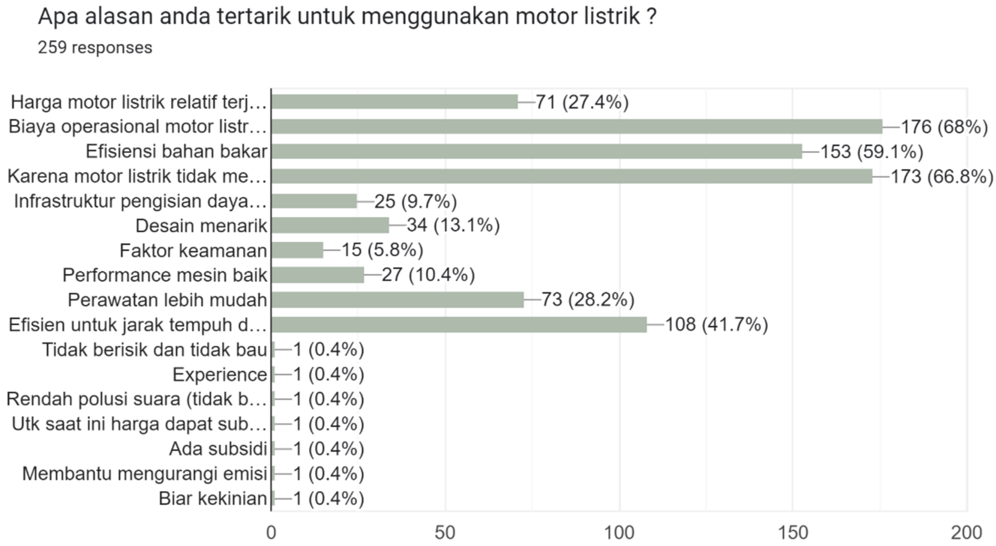

Figure 4.3: Questionnaire section: The Knowledge of buying E-motorcycle benefit

Resistance to Change

Notably, within the section comparing the Total Cost of Ownership (TCO) between electric and conventional vehicles, a compelling trend emerges. When presented with the options of ref-1 (”no battery replacement cost needed due to the ’battery swap’/lease mechanism,”), ref-2 (IDR 7.5 Million of battery price with an estimated price decrease of 5% per year), and ref-3 (IDR 8-9 Million of battery price with an estimated price decrease of 5% per year), a 90.7% of respondents, shown at figure 4.5 expressed their resistance to change to e-motorcycle. The remaining 9.3% of total respondents show a willingness to purchase an electric vehicle due to information from the given TCO table. A table of information given in this questionnaire section is shown in figure 4.4.

No	Jenis Perbandingan	MOTOR LISTRIK			MOTOR KONVENSIONAL (ICE)		
		Ref #1: Smoot Tempur	Ref 2: Viar Q1	Ref 3: Gesits G3	Ref 1: Honda Beat	Ref 2: Honda Scoopy	Ref 3: Honda Vario
1	Biaya Awal	Rp 18.5 juta	Rp 21.64 Juta	Rp 28.97 Juta	Rp 18 Juta	Rp 21.88 Juta	Rp 25.65 Juta
2	Biaya Pengoperasian	0.031786414 km/Wh, 20 K km / tahun = 629.2 KWh ~ Rp 1.04 Juta (Jika charge sendiri), Namun karena tidak bs dicharge dan harus tukar baterai, maka biaya penggunaan adalah Rp 10K / 50 km ~ Rp 4 Juta / tahun (untuk 20K km pemakaian per	0.025825133 km/Wh, 20 K km / tahun = 774.44 KWh ~ Rp 1.28 Juta per tahun	0.023358635 km/Wh, 20 K km / tahun = 774.44 KWh ~ Rp 1.41 Juta per tahun	62.8 km/liter, atau untuk pemakaian 20K km/tahun = 318.47 ltr/yr ~ Rp 3.18 juta per tahun	55.97 km/liter, atau untuk pemakaian 20K km/tahun = 357.33 ltr/yr ~ Rp 3.57 juta per tahun	47.04 km/liter, atau untuk pemakaian 20K km/tahun = 425.17 ltr/yr ~ Rp 4.25 juta per tahun
3	Pemeliharaan	Rp 600 - 800 ribu per tahun (Routine Maintenance and check) untuk pemakaian 20K km per tahun. Dominan penggantian belt dan berkala ban	Rp 700 - 900 ribu per tahun (Routine Maintenance and check) untuk pemakaian 20K km per tahun. Dominan penggantian belt dan berkala ban	Rp 800 ribu - 1 juta per tahun (Routine Maintenance and check) untuk pemakaian 20K km per tahun. Dominan penggantian belt dan berkala ban	Jika mengikuti siklus rekomendasi Routine Maintenance Pabrikan: +/- 1.6 - 2.2 jt / tahun untuk pemakaian 20K km per tahun	Jika mengikuti siklus rekomendasi Routine Maintenance Pabrikan: +/- 2 - 2.5 jt / tahun. untuk pemakaian 20K km per tahun.	Jika mengikuti siklus rekomendasi Routine Maintenance Pabrikan: +/- 2.2 - 2.75 jt / tahun. untuk pemakaian 20K km per tahun.
4	Masa Pakai Baterai vs. Mesin	Tidak ada biaya penggantian Baterei karena menggunakan mekanisme penukaran baterai	800 - 1000x charging, 40K km pemakaian, harus ganti baterai. Harga saat ini sekitar Rp 7.5 jt / baterai, turun 5% per tahun (est.)	800 - 1000x charging, 40K-50K km pemakaian, harus ganti baterai. Harga saat ini sekitar Rp 8-9 jt / baterai, turun 5% per tahun (est.)	Mesin dapat mengalami keausan dan perlu perbaikan, tetapi tidak ada biaya penggantian baterai besar. Dalam waktu 5 tahun awal relatif tidak banyak biaya perbaikan permesinan, kecuali dilakukan pemakaian jangka panjang		
5	Insentif Negara	Negara memberikan insentif atau potongan pajak untuk pembelian motor listrik, yang dapat membantu memulihkan biaya awal maks 7 Juta Rupiah per kendaraan dengan syarat TKDN			Tidak ada insentif khusus yang umumnya diberikan untuk motor konvensional.		
6	Keberlanjutan dan Lingkungan	Lebih ramah lingkungan karena tidak menghasilkan emisi langsung saat digunakan.			Menghasilkan gas buang yang dapat merugikan lingkungan. Perkiraan emisi gas buang = 91gr CO2 eqv per km. 20K km per tahun = 1820 kg eqv CO2 eqv (per kg = Rp 30)		

Figure 4.4: Table of Benefit in Questionaire: E-motorcycle vs ICE

Figure 4.5: Questionaire section: The preference of buying an E-motorcycle based on the given table of benefits

Ownership Preference

Emphasizing the scale of choice (1-5) among 228 respondents is crucial in understanding their inclination towards electric vehicle (EV) adoption and the factors influencing their decisions. As shown in Figure 4.6, among the 228 respondents, a significant 83.7%, as shown in Figure 4.6, indicated a high level of willingness (choosing 3-5 on the scale) to consider purchasing an EV if the price were more affordable compared to conventional vehicles (due to subsidy). This underscores the pivotal role of cost competitiveness in driving consumer adoption of EVs, indicating a strong inclination toward embracing electric mobility if it proves financially attractive.

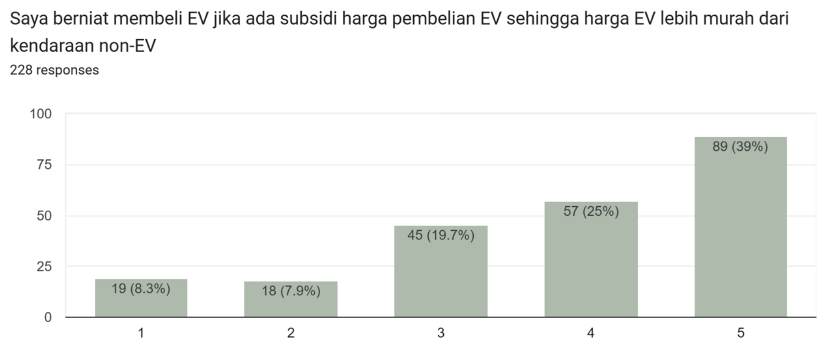

Figure 4.6: Questionnaire section: Preference of Customers willing to buy EV if the prices given are cheaper than conventional ones

Moreover, a substantial majority (85.1%), shown in Figure 4.7 expressed a similarly high level of interest (choosing 3-5 on the scale) in buying an EV provided ample charging stations were available in their living areas. This underlines the critical importance of charging infrastructure accessibility in influencing consumer decisions towards adopting EVs, showcasing a keen interest in practicality and convenience.

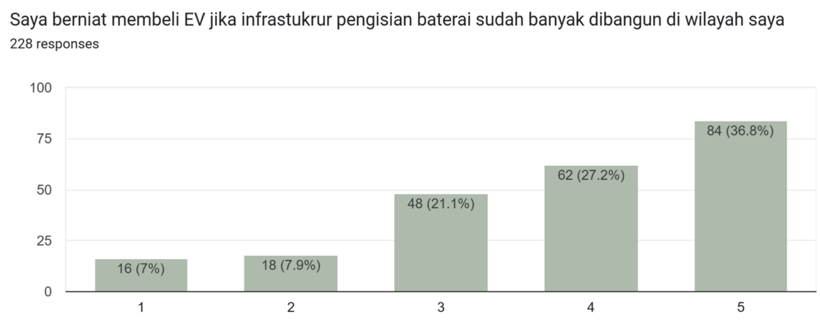

Figure 4.7: Questionnaire section: Preference of Customers willing to buy EV if the charging infrastructure is available in their living areas

Furthermore, an overwhelming 89.5% of respondents, as shown in Figure 4.8, highlighted the paramount significance (choosing 3-5 on the scale) of battery durability in their decision to incorporate an EV into their daily activities. This underscores the pivotal role of reliable battery technology in assuaging consumer concerns about EV performance and range anxiety, signifying a strong demand for dependable and long-lasting battery solutions.

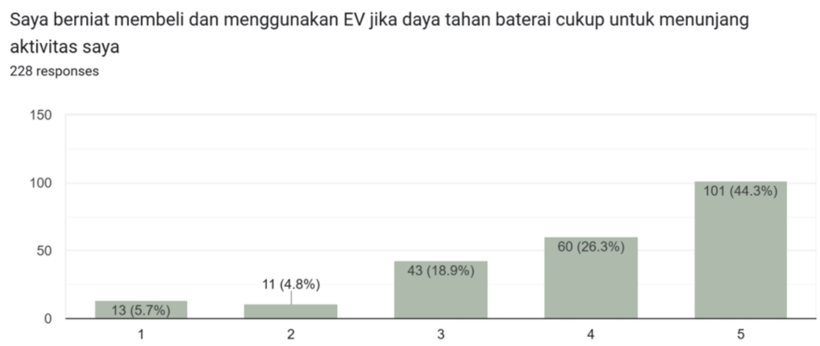

Figure 4.8: Questionnaire section: Preference of Customers willing to buy EV if the battery is durable enough to support their daily activities

These detailed preferences on the 1-5 scale paint a clear picture of consumers' priorities and concerns regarding EV adoption. Affordability, accessibility to charging infrastructure, and reliable battery technology emerge as primary determinants influencing consumers' willingness to embrace electric mobility.

4.2. Influencing Conditions For Circular Innovation

4.2.1. Knowledge and Awareness of Technology

Despite the burgeoning motorcycle-related business in Indonesia, challenges persist. Battery swap initiatives, as depicted in the Presidential Regulation 79 of 2023, illustrate that players in Indonesia are still in the phase of encouragement to not only import products but also to focus on technology transfer to increase Domestic Component Level (TKDN) compliance (PERPRES-RI, 2023). In addition, the incompleteness of the supply chain is evident, with limitations in establishing facilities, particularly in the cathode, cell, and recycling sectors, according to the IESR, which remain at small scales. Additionally, various aspects of the supply chain are dominated by overseas players (IESR, 2023).

Interviews with **Interviewee 1** and **Interviewee 9** underline the imperative need for continuous technological advancements and innovation in the battery cathode, battery cell, power electronics, Battery management system, interoperability, and circularity domain. Regarding circularity, battery waste is still considered and handled as toxic waste, emphasizing the importance of future explicit regulations, according to Interviewee 1.

Further compounding challenge related to the knowledge of interoperability, as emphasized by **Interviewee 2**, is the issue of flexibility concerning battery compatibility across different EV manufacturers. Protection mechanisms built into the batteries act as a double-edged sword. While they offer safety and security for battery operations, they also lead to exclusivity issues where a battery from one brand may not be compatible with a vehicle from another brand, owing to these protection devices. Further aspects related to the knowledge and awareness of technology are explained in the next section of the sub-blocks: Limited Scope of Circular Product and Large-Scale Demonstration.

Limited Scope of Circular Product

Some of the state players may have conducted MoUs with several overseas companies for recycling end-second-life batteries. However, despite substantial investments exceeding USD 20 billion (USD 20 Million for Recycling purposes alone) across the entire supply chain, the full integration of domestic EV supply chains awaits further realization. Several battery producers and recycling facilities are slated for operational commencement post-2025 (IESR, 2023). This depicts the limited scope of circular products existing in the market. According to Interviewee 8, the average lifespan of batteries for electric vehicles in Indonesia is around four years. Since this technology is relatively new, the supply of batteries to be recycled is considered small. Therefore, it makes sense to postpone the commencement of the recycling facility until 2025.

Based on the cause ”Delayed operational commencement of recycling and other part of end-to-end supply chain facilities,” the building blocks that are to be negatively affected include:

Building Blocks Affected by Limited Scope of Circular products

Main Building Blocks	Sub-blocks	Explanation
Resource Optimization	Integrated Product-Service Systems (PSS)	Battery renting scheme an enablers to minimize waste, but the recycling facility is still not available.
Complementary Products and Services	Industry-specific infrastructure	The delay of commencement of local battery cell producers, BMS developers, and recycling infrastructure will affect the complementary products and services building blocks.
Network Formation and Coordination	Strong Networks	The absence of a network of local battery cell producers, BMS developers, and recycling players in the market hinders the complete network formation.

Large-Scale Demonstration

In terms of large-scale demonstration, based on the data from interviews conducted by Deloitte in May 2023, the distribution of swapping stations among the top four private players, as of an interview conducted in May 2023 and illustrated in Figure 3.6, delineates the market share. "SWAP" holds 1,100 swapping stations (70.92%), "Volta" maintains 295 swapping stations (19.02%), "OYIKA" operates 150 swapping stations (9.67%), and "Gogoro" possesses six swapping stations (0.39%). These key players cater to various e-motorcycle brands and are often associated with either ride-hailing giants or third-party logistics (3PL) companies, shaping their adoption (Deloitte, 2023). Some of these players employ a leasing-based business model that moves the ownership of the battery from customers to service providers, which becomes the enabler of the circular business itself. However, all these players have different hardware specifications such as rack dimension, voltage level, port etc, making it become a bottleneck towards further larger demonstration.

Adding further context from the interview with **Interviewee 9**, concerns about the lack of coordination between the government-established public charging stations (SPKLU) and the battery swap stations (SPBKLU) were highlighted. The absence of alignment between these initiatives means that the SPKLU if synchronized with SPBKLU, could potentially act as distance buffers between the relatively scarce SPBKLU stations. This alignment would alleviate range anxiety among e-motorcycle users and stimulate the growth of electric motorcycles. Ultimately, it could enhance the economic feasibility of battery swap provision and e-motorcycle proliferation, fostering better economies of scale in their provision and adoption.

For the causes "Lack of standardization and interoperability (hardware, software, and protection mechanism)" and "The absence of alignment between SPKLU and SPBKLU placement," the building blocks that are to be negatively affected include:

Building Blocks Affected by Lack of Standardization and Alignment Causes

Main Building Blocks	**Sub-blocks**	**Explanation**
Product Performance and Quality	Resource Optimization	lack of standardization, interoperability in the design and the absence of alignment between SPKLU and SPBKLU lead to the inefficiency in the implementation of racks placements.
Product Price	Long Term Feasibility	Lack of standardization and interoperability create a bottleneck in the market expansion, affecting the long-term feasibility of business.
Complementary Products and Services	Ecosystem of Products and Services	As the buffer of the low population of battery swap stations (SPBKLU), the alignment between SPKLU and SPBKLU (Charging station) should improve the Ecosystem of Products and Services in the early phase of diffusion
Customers	Resistance to change and Ownership preferences	Standardization and the alignment between SPKLU and SPBKLU (Charging station) should solve the range anxiety of users in the early phase of battery swap system diffusion

On the other hand, the factor "Rental Basis for Battery Part on the Purchase of E-motorcycles" could positively impact the following building blocks:

Table 4.6: Building Blocks Affected by Rental Basis for Battery Part

Main Building Blocks	**Sub-blocks**	**Explanation**
Product Performance and Quality	Integrated Product-Service Systems (PSS)	The incorporation of a rental basis for the battery part can directly impact the Integrated Product-Service Systems, specifically through the introduction of a battery renting scheme aimed at minimizing waste. However, the recycling facility is identified as a partial block, indicating that the absence of recycling infrastructure hinders the full integration.

Continued on next page

Table 4.6 – continued from previous page

Main Building Blocks	Sub-blocks	Explanation
Complementary Products and Services	Industry-specific infrastructure	The absence of local battery cell producers, BMS developers, and recycling infrastructure are identified as barriers. The rental basis for the battery part may drive demand for industry-specific infrastructure. Still, the incomplete status suggests that challenges persist, possibly related to the lack of available recycling facilities.
Product Price	Total Cost of Ownership	The introduction of a rental basis for the battery part could lower the total cost of ownership, as the battery has the highest proportion of the total price of e-motorcycle
Customers	Awareness and Knowledge	The introduction of a rental basis for the battery part could impact customer awareness and knowledge. This approach may influence the perception of potential customers regarding the benefits and functionalities of electric motorcycles compared to conventional ones.

4.2.2. Knowledge and Awareness of Application and Market

Recognizing the financial constraints of many Indonesian motorcycle users, EV companies have strategically introduced leasing models, aligning with the value proposition of affordability and accessibility. In addition, to ensure seamless integration of e-motorcycle and battery swap stations into Indonesian lifestyles, e-motorcycle and battery swap providers strategically collaborate with existing infrastructure partners, such as minimarts and gas stations, to strategically place battery swap stations and ride-hailing companies. Battery swap has additional advantages for ride-hailing operators in terms of opportunity cost and idle time (Deloitte, 2023).

According to **interviewee 8**, ride-hailing companies partnered with one of the EV and battery swap providers find the collaboration extremely beneficial for operators and ride-hailing customers. Essentially, even with the daily rental fee, operators still profit daily. Furthermore, by using rented motorcycles, operators avoid using their motorcycles, many of which are old and worn out, some being 10 to 12 years old. It's not ideal to serve customers with such worn-out motorcycles. Instead, they can rent new, well-maintained motorcycles, saving on fuel costs as well. Additionally, there are stories from partners where they have motorcycles at home but need them for other purposes, such as when their spouse wants to start a business or when their child needs a motorcycle for school. They can't afford to buy another motorcycle, so they opt to rent, benefiting from using Electrum motorcycles without the hassle of purchasing fuel. These stories highlight the demand for electric motorcycles and the cost-saving benefits they offer.

However, it is essential to recognize that while the leasing model for individual users and ride-hailing operators serves as an enabler towards sustainability in the EV market (Gojek, 2020), challenges such as linear lock-in, uncertain returns, and asymmetric information among consumers persist as explained in the following sections.

Uncertain Return

Based on the interview with **Interviewee 6** financing in the battery swap sector favours startups pairing services with motorcycle sales. Standalone battery swap businesses struggle to attract investors due to uncertainties about standardization, viability, and Indonesia's complex supply chain. Diverse battery specifications across consortia complicate standardization efforts, hindering market scalability. New entrants must create their market by selling motorcycles alongside swaps, necessitating significant capital. Pure swap stations remain unfeasible without standardization, prompting a 'wait and see' approach from investors due to uncertain returns according to the **Interviewee 6**. Despite efforts to scale and create market demand, separate consortia systems lack interoperability, restricting growth potential. In addition, based on the interview with **Interviewee 6**, some players opt to sell their motorcycles or swap business below profitable prices in the near term to penetrate the market until achieving the economics of scale.

For the causes of investor hesitance and capital-intensive requirements, the building blocks that are to be negatively affected include:

Building Blocks Affected by Investor Hesitance and Capital Intensive Causes

Main Building Blocks	Sub-blocks	Explanation
Product Price	Long Term Feasibility	Investor hesitance due to the lack of standardization can impact the continuity of the e-motorcycle and battery swap firm in terms of market expansion
Production System	9 R(s) Capabilities	Capital-intensive requirements for new entrants can affect the enhancement of Product and Services Ecosystem in the long term

Linear Lock-in

Under the Ministry of Environment and Forestry, only two relevant regulations were identified:

1. Ministerial Regulation No. 12/2021 setting Emission Standards for Lithium Battery Recycling (KLHK, 2021a)
2. Ministerial Regulation No. 6/2021 outlining Procedures and Requirements for Managing Hazardous and Toxic Waste (KLHK, 2021a).

However, specific regulations that incentivize battery recycling mechanisms or enable government monitoring of battery circulation and lifespan in the market are absent. Presently, lithium batteries lack unique IDs or serial codes, rendering their traceability by the government impossible.

According to the **Interviewee 7**, the absence of explicit regulations regarding battery waste recycling leads to its default classification as hazardous waste (B3 waste). Despite the presence of lab-scale recycling devices such as BRIN and UGM, Indonesia lacks a dedicated body overseeing centralized battery recycling. This gap is exacerbated by the absence of comprehensive follow-up regulations associated with the accelerated implementation of Electric Vehicles (EVs) in Indonesia, as per Presidential Regulation No. 55/2019 (in transition to the more recent update, PERPRES No.79, 2023).

The introduction of electric vehicles in Indonesia, particularly electric motorcycles, is relatively recent, starting from 2019, with the absence of the battery serial numbers that the government records until now. Given the average 10-year lifespan of batteries and the current limited usage, potential issues may arise in the next decade. Consequently, addressing this matter isn't an immediate priority. The methods for returning batteries are under evaluation; options include a trade-in system between service providers and battery manufacturers (exchanging damaged batteries for new ones) or individual battery returns to manufacturers at a specified cost. If a trade-in system is adopted, the government would oversee the involvement of battery-producing entrepreneurs.

While the ultimate disposal of used batteries necessitates recycling, the Ministry of Industry plays a role in supporting the emergence and growth of battery recycling ventures. Although operational permits fall under KLHK, the Ministry of Industry contributes to planning, environmental documentation, environmental permits, and the issuance of operational clearances (SLO).

For the cause "Regulatory and Systemic Gaps in Battery Recycling and Traceability," the building blocks that are to be affected include:

Building Blocks Affected by Regulatory and Systemic Gaps in Battery Recycling and Traceability

Main Building Blocks	Sub-blocks	Explanation
Product Performance and Quality	Resource Optimization	Regulatory and systemic gaps in battery recycling and traceability increase the impact of battery waste in terms of resource utilization inefficiency
Production System	Strong Reverse Logistics	Regulatory and systemic gaps in battery recycling and traceability discourage the implementation of reverse logistics,

Asymmetric Information

In terms of symmetricity of Information among customers, the survey conducted by Populix until January 2022 revealed notable trends among respondents regarding their plans to purchase electric vehicles. Approximately 29% of respondents expressed intentions to buy electric motorcycles, while 31% were considering purchasing electric cars within the next five years (Dihni, 2022). The survey encompassed 1,002 Indonesian citizens, comprising 523 males and 479 females, aged between 18 to 55 years. The primary driving force behind respondents' interest in acquiring and using electric vehicles was environmental concerns.

A significant 77% of respondents were inclined towards electric vehicles due to their eco-friendliness, with 40% aiming for zero carbon emissions. Additionally, 36% considered electric vehicles due to rising fuel prices, while 31% saw them as cost-saving in terms of maintenance. This data hints at the persistence of information asymmetry regarding the benefits of electric vehicles. It's noteworthy that respondents came from diverse educational and financial backgrounds, suggesting varying levels of awareness and understanding about the advantages of adopting electric vehicles.

For the cause "Varying Levels of Awareness and Understanding (Impact of Diverse Backgrounds)," the building blocks that are to be negatively affected include:

Building Blocks Affected by Varying Levels of Awareness and Understanding (Impact of Diverse Backgrounds)

Main Building Blocks	Sub-blocks	Explanation
Customers	Awareness and Knowledge	Varying levels of awareness and understanding due to diverse backgrounds can impact the overall awareness and knowledge of potential customers regarding the benefits of owning EVs.

4.2.3. Natural, Human, and Financial Resources

According to the **Interviewee 3** and **Interviewee 12**, Indonesia has an abundance of nickel and a lack of lithium. Both become an important resource for building the cathode of the batteries, nickel for NMC (NMC stands for Nickel-Manganese-Cobalt, while LFP stands for Lithium-Iron-Phosphate). On the one hand, Indonesia has a reliance on imports, which incurs substantial costs, with imports of lithium oxide and hydroxide reaching $6.05M in 2022 (WITS, 2022).

On the other hand, although Indonesia has a decent supply of nickel for the world, not all nickels can be utilized in battery production. According to the **Interviewee 12**, there are distinct grades of nickel: class 1 for batteries and class 2 for ferronickel/MPI. **Interviewee 12** revealed that the emphasis of downstream processing is primarily on class 2 nickel, driven by demand in construction and stainless steel applications, particularly from China, the largest consumer. Despite this, China's slowing economic growth has led to a decline in the consumption of class 2 nickel. ANTAM, through its subsidiary Indonesia Battery Corporation (IBC), has entered into a joint venture with CBL (a joint venture company consisting of CATL and Ligen Resource Technology) to handle nickel from mining to battery cell production. This collaboration is currently ongoing, with a Memorandum of Understanding (MoU) already established. The joint venture involves a complex structure, potentially consisting of seven separate joint ventures.

The concentration of nickel mining concessions in Indonesia is particularly notable in Sulawesi, where the island holds significant nickel reserves. Central Sulawesi Province hosts the Indonesia Morowali Industrial Park (IMIP), while Halmahera Island in North Maluku Province is home to the Indonesia Weda Bay Industrial Park (IWIP). Additionally, PT VDNI operates the Konawe Industrial Park in South East Sulawesi Province (Huber, 2021). These locations signify key hubs for nickel processing and industrial activities. Recognizing the future demand for battery-grade nickel, Chinese companies have been proactive in investing in new High-Pressure Acid Leach (HPAL) facilities under construction in Indonesia (Ribeiro et al., 2021). The ban on nickel ore exports has resulted in the rapid growth of upstream battery-grade nickel refining facilities. However, the MHP produced, with an estimated production rate of 657 kilotons/year, has not yet been absorbed by the midstream industry to continue in the local battery precursor industry.

The pressing need for lithium and nickel as an important substance to build battery cathodes emphasizes the urgency for optimizing resource utilization in the near future, considering the relatively new technology adopted since 2019 and the ten-year lifespan of batteries. The further explanation related to the Natural, Human, and Financial Resources, which is reflected in the subblocks of influencing conditions (Resource Flow Optimization, Leadership and Team skill, and Availability of Finance), are explained in the following section.

Resource Flow Optimization

Circular innovation necessitates strong Leadership and Team Skills to drive its successful implementation. Visionary leadership capable of articulating a clear circularity strategy and assembling skilled and motivated teams is crucial. However, challenges persist in Indonesia, notably in standardization and interoperability concerning battery rack installations. The lack of clarity in regulations contributes to inefficiencies in terms of utilization of batteries and battery racks, evident in the multitude of providers' racks clustered in single locations with 60 types of battery in the Indonesia market (based on the interview with **Interviewee 9**), as depicted in Figure 4.9.

Figure 4.9: Multiple Battery Racks from Different Providers in One Place

Numerous battery swap stations from various brands contribute to inefficiencies in resource management for each service provider. The absence of standardized battery racks results in inefficiencies and challenges for each company. If all battery racks were standardized and interoperable, future capital expenditure (CAPEX) would decrease, primarily in terms of expanding battery swap station racks. Standardized battery racks would facilitate more optimal distribution among various brands, significantly reducing inefficiencies in resource allocation. This interoperability could streamline operations and enhance resource flow, benefiting all service providers in the electric vehicle sector.

Building Blocks Affected by Multiple, Non-Standard Battery Racks due to Weak Monitoring

Main Building Blocks	Sub-blocks	Explanation
Product Performance and Quality	Resource Optimization	non-standard battery racks due to lack of standardization in a single place can hinder resource optimization efforts.

Leadership and Team skill

In the realm of governance, particularly concerning leadership skills in adapting to new technologies like battery swap systems, the government faces a significant learning curve due to the technology's novelty. With only a handful of countries having successfully implemented this technology, the government is continually recalibrating regulations to align with on-ground realities. The lack of widespread experience in managing this technology necessitates an iterative approach, where regulations evolve in response to field observations and emergent challenges.

Within the HR context, the challenges echo the broader industry landscape. According to insights gathered from a legal ecosystem employee at a battery swap company, sourcing experienced talent for specialized roles like battery rack maintenance remains a hurdle. Consequently, companies often resort to hiring mechanics and electricians, subsequently conducting training and knowledge-sharing sessions facilitated by experts from countries like Korea and Japan, where similar businesses have been successfully implemented. This strategy underscores the scarcity of local expertise and the reliance on external guidance to bridge the knowledge gap and develop indigenous skill sets essential for the technology's efficient deployment. In addition, from **interviewee 2**, an extra effort is needed to fulfill the demand for competency within the company, as a talent with specific skill sets is barely available in the job market.

The effort of HR mentioned above is relevant to the result of the questionnaire from literature (Aqidawati et al., 2022). The HR competence, adequate HR numbers, effective coaching and training programs, as well as high awareness of implementing battery-swap system standards and stakeholder conformity to standards indicate a robust upskilling strategy. However, despite these positive indicators, **Interviewee 3** stated that there are additional challenges. The deployment of multiple ports with varying voltage levels and physical dimensions presents complexities that demand adaptable solutions. Although technology such as power electronics can address differences in battery-cabinet specifications, non-local production raises costs for battery swap providers, creating a bottleneck in their expansion due to increased capital expenditure (CAPEX). To address these challenges, there is a need for more extensive efforts to enhance competency in producing power electronics within battery racks. This improvement can serve as a bridge solution capable of resolving multiple standards and easing the standardization issue itself. By focusing on enhancing this specific skill set, the industry can potentially overcome hurdles related to standardization and advance the development of a more streamlined and efficient battery-swap system.

Another crucial competency in leveraging the population of e-motorcycles is converting ICE motorcycles to e-motorcycles. Although expected to reduce upfront costs and increase adoption, the cost of the conversion program is around IDR 15-23 million per unit, which is only about 20% lower than buying a new e-motorcycle (IESR, 2023). With such a high cost, the program struggled to enter the market as the consumer willingness to pay for the conversion program is around IDR 5 to 8 million. Batteries and conversion kits are usually imported and account for around 60% of the total cost. For comparison, the conversion cost in Indonesia is more expensive than the price of a new E2W in India. Furthermore, the conversion cost in India is only ⅓ of the price of a new E2W. Apart from the high upfront cost, there are other factors contributing to the slow adoption of converted E2W. The converted E2W has a shorter warranty period, ranging from 6 months to 1 year, and some even have no warranty period. As a comparison, spare parts for new E2Ws usually come with a 2-year warranty. In addition to the short warranty period, lack of knowledge about the conversion program and lack of experience in trying a converted motorcycle lead to low consumer confidence in the conversion program.

For the causes ”Lack of experience in the body of government due to technology novelty,” ”Lack of talents with specific skill-set available in the job market,” and ”Lack of talents within the research and development of power electronics, battery cell, and battery management system (BMS),” the building blocks that are to be negatively affected include:

Building Blocks Affected by Lack of Experience and Talents in Innovation

Main Building Blocks	**Sub-blocks**	**Explanation**
Innovation-Specific Institution	General Consensus	Lack of experience in the body of government due to technology novelty may impact the general consensus related to the development of the EVs ecosystem.
Innovation-Specific Institution	Standardization	Lack of talents with specific skill-sets available in the job market slow down the standardization processes and affect its quality within.
Production System, Product Performance and Quality	9 R(s) Capabilities, Design for Circularity, Resource Optimization, Integrated PSS	Lack of talents with specific skill-sets available in the job market slow down the building process of 9-R(s) Capabilities Blocks, affecting the circular production system, as well as the Product Performance and Quality
Innovation-Specific Institutions	Emerging Robust Policies	Lack of experience in the body of government due to technology novelty result in challenges in formulating and implementing effective policies.
ComplementaryProductst and Services	Collaboration	Lack of experience in the body of government due to technology novelty result in challenges in formulating and implementing effective policies, causing the emergence of multiple consortia with different specifications of products, which become the major issue for long-term

On the other hand, amid talent scarcity in the job market, the positive impact of implementing a robust upskilling strategy is explored. This strategy not only addresses the challenges posed by talent scarcity but also significantly influences various building blocks within the electric vehicle (EV) industry.

Table 4.12: Building Blocks Positively Affected by Robust Upskilling Strategy

Main Building Blocks	**Sub-blocks**	**Explanation**
Complementary Products and Services	Industry-specific Infrastructure	Additionally, the implementation of a robust upskilling strategy contributes to the development of industry-specific infrastructure. This strategy helps overcome talent shortages by enhancing the skills of the existing workforce, especially in areas like battery packing and supply chain management.

Availability of Finance

Recent statements from Indonesia’s Coordinating Minister for Maritime Affairs and Investment, Luhut Binsar Pandjaitan, shed light on the country’s aspirations to bolster both the upstream and midstream sectors. He articulated Indonesia’s vision to independently produce lithium batteries by 2025, aiming for global recognition as the third-largest lithium battery producer by 2027 or 2028. Emphasizing the seriousness of this endeavor, Luhut highlighted the substantial investments secured, totaling USD 31.9 billion, for the development of Indonesia’s battery industry’s supply chain until 2026 (Putri and Hidayat, 2023).

Moreover, Luhut underscored Indonesia's achievement in attracting significant foreign direct investment (FDI), amounting to USD 45.6 billion in the previous year. This milestone in FDI represents the highest recorded influx since 2000, signifying considerable confidence and interest from international stakeholders in Indonesia's growing e-motorcycle and battery industry.

However, the financial ecosystem still faces unique challenges at the operational level of battery swap providers according to **Interviewee 3**, and **interviewee 1**, the impending establishment of standardization norms is likely to entail considerable additional capital expenditures (CAPEX) for these entities. This financial burden arises from the need to adapt to standardized battery sizes, types, and swapping mechanisms, which would require significant modifications to existing infrastructure and technology.

For the cause ”Potential Financial challenges at the operational Level (Due to the absence of fixed standardization),” the building blocks that are to be negatively affected include:

Building Blocks Affected by Financial Challenges at Operational Level (Due to the Absence of Fixed Standardization)

Main Building Blocks	Sub-blocks	Explanation
Product Performance and Quality	Resource Optimization	Potential financial challenges at the operational level due to the absence of fixed standardization may lead to the placement of multiple racks (from several brands) in a single location which affects the resource optimization efforts.
Production System	Strong Reverse Logistics	Financial challenges in operations, caused by the absence of fixed standardization, may affect the availability of funding for reverse logistics within the production system of the e-motorcycle and battery swap providers.

On the other hand, positive factors such as substantially secured investment, strong governmental support, an abundance of nickel resources, and high levels of Foreign Direct Investment (FDI) significantly contribute to the robust growth of the Electric Vehicle (EV) industry. The table below outlines how these positive factors positively influence various building blocks within the industry.

Table 4.14: Building Blocks Positively Affected by Substantially Secured Investment in the EV Industr

Main Building Blocks	Sub-blocks	Explanation
Network Formation and Coordination	Strong Network	High levels of Foreign Direct Investment (FDI) positively impact network formation and coordination building blocks, ensuring financial stability and fostering growth in innovation, infrastructure, and network formation.
Production System	Strong Reverse Logistics	The abundance of nickel resources contributes positively to production system capabilities, supporting a stable and sustainable supply chain for battery production in the EV industry.
Product Price	Total Cost of Ownership	The abundance of nickel resources and The substantial investment of 31.9 billion USD contribute positively to the reduction of the total cost of ownership in the long term.
Production System	Strong Reverse Logistics,	High levels of Foreign Direct Investment (FDI) positively impact the growth of logistics system capabilities overall
Complementary Products and Services	Industry-specific infrastructure,	High levels of Foreign Direct Investment (FDI) also positively impact the growth of industry-specific infrastructure, fostering global partnerships and technological advancements.

4.2.4. Macro-economics and Strategic Aspect

The subsequent elaboration on the main influencing conditions, Macroeconomics and Strategic Aspects can be done by examining its sub-blocks, namely systemic perspective, conducive regulation, and economic condition. These sub-blocks are comprehensive enough to cover the elaboration of the Macroeconomics and Strategic Aspect, which picture the complex dynamics involved in terms of economics, regulation, and systemic conditions.

Systemic Perspective

In the realm of systemic collaboration and interaction, symbiotic relationships between governmental institutions and the nexus between government and private entities, both within national borders and on an international scale, have thrived. Yet, in a proactive stance against impending challenges—specifically the obstacles to market growth stemming from interoperability issues and supply chain bottlenecks—the designated coordinators from Indonesian ministries advocate for heightened efforts. These efforts necessitate meticulous regulations encompassing all dimensions derived from Presidential Regulation 55/2019 (in transition to the more recent update, PERPRES No.79, 2023).

However, of particular importance is the government's advisory and monitoring role over entrepreneurs, specifically regarding the aspect of open protocol asset wellness for batteries. This function catalyzes government-led initiatives aimed at monitoring circularity, spanning both recycling and second-life battery utilization, under the purview of the Ministry of Environment and Forestry. Moreover, the emphasis on standardization and collaboration among electric motorcycle consortia, overseen by the Ministry of Industry, stands as another crucial component according to the **Interviewee 4**.

These comprehensive regulations are poised to address a multitude of areas, fostering an environment conducive to sustainable growth and innovation within the electric vehicle ecosystem. The intent is to preemptively tackle forthcoming challenges, ensuring market expansion while navigating interoperability concerns and supply chain intricacies. The essence of the government's advisories, particularly regarding standardization and collaboration among consortia, emphasizes unity rather than competition. This approach aims to avoid market fragmentation caused by diverse specifications in motorcycles and non-interoperable battery racks. As highlighted in an interview with **Interviewee 4**, the Assistant Deputy of Maritime Industry and Transportation, the gradual limitation of ICE production will be done.

The causes of ”Supply Chain Bottlenecks due to the absence of some infrastructures,” ”Market fragmentation due to the existence of multiple consortia with diverse specifications,” ”The absence of open protocol and traceability of assets (batteries),” and ”Lack of government interference in the consolidation among consortia,” the building blocks that are to be negatively affected include:

Building Blocks Affected by Systemic Causes

Main Building Blocks	Sub-blocks	Explanation
Product Prices, Production System	Long Term Feasibility, Total Cost of Ownership, Strong Reverse Logistics	Supply chain bottlenecks due to the absence of local infrastructures in certain aspects can lead to the increase of price and long-term feasibility of the business
Innovation Specific Institution	Standardization	Market fragmentation due to the existence of multiple consortia with diverse specifications affects the standardization process become more complex
Complementary Product and Services	Collaboration	The lack of government interference in the consolidation among consortia may result in challenges related to a collaboration between consortia to alleviate the bottleneck of the market expansion
Product Performance and Quality	Resource Optimization	The lack of government interference in the consolidation among consortia may result in challenges related to a collaboration between consortia to enhance resource optimization by promoting the interoperability and integrated waste handling
Product Price	Term Feasibility, Total cost of ownership,	The lack of government interference in the consolidation among consortia may result in challenges related to a consolidation consortium in terms of the effect on the late implementation of strict standardization
Product Performance and Quality	Resource Optimization	The absence of open protocol and traceability of assets (batteries) negatively impact resource optimization by hindering efficient tracking and management of batteries throughout their lifecycle.
Network Formation and Coordination	Strong Network	The absence of open protocol and traceability adversely affects network formation and coordination, as it creates challenges in establishing transparent communication and data sharing among stakeholders in the EV industry.

Continued on next page

Table 4.15 – continued from previous page

Main Building Blocks	Sub-blocks	Explanation
Innovation-Specific Institution	Standardization	The innovation-specific institution is negatively influenced by the absence of open protocol and traceability, as it hampers the development and implementation of innovative solutions and standards in the EV sector.

Conducive Regulation

According to the **Interviewee 3**, the landscape of Electric Vehicle (EV) regulations in Indonesia is complex and unclear, involving 18 institutions and governmental ministries. However, this intricate web of rules can, at times, become fragmented and ambiguous, which also creates barriers for new entrants in this field. The current regulatory approach seems to be a push strategy without a corresponding pull mechanism. While the current regulations aim to stimulate market growth rapidly, they complicate standardization due to the proliferation of large consortia with diverse specifications for motorcycles, batteries, and battery racks. Conversely, pull mechanisms, such as local component rules, remain fluctuating. Nonetheless, the declaration by one battery manufacturer, BiruBatt, exceeding the local component requirement by 40% signifies a positive signal amid this regulatory turbulence.

The inconsistency within incentives adds another layer of complexity. The regulatory landscape surrounding electric vehicles in Indonesia showcases contradictory directives. While recent regulations exempt all EVs from vehicle tax (PKB) and vehicle ownership transfer fee (BBNKB), creating an incentive for adoption, this move introduces regional discrepancies. Varied tax rates across different regions might dissuade potential EV buyers due to differing financial burdens, like the contrast between Jakarta's 2% PKB for EVs and East Java's 5% (Shahab, 2023).

Although Indonesia's potential in the battery sector is promising, yet the country's value chain for battery cells remains underdeveloped. Intellectual property (IP) rights concentrated within a limited circle create high entry barriers for emerging startups. One proposed approach involves kickstarting the process by facilitating the importation of components. Jumpstarting the sector through component imports could serve as a foundational step toward bolstering Indonesia's prowess in battery technology. However, it's crucial to couple this with robust regulations governing technology transfer. Establishing clear and stringent regulations around technology transfer will be pivotal in ensuring that as the sector develops, Indonesia secures its competitive advantage in battery manufacturing. This approach seeks to foster an environment conducive to local innovation while leveraging global expertise through strategic imports.

For the causes "Complex and Unclear Regulatory Landscape, involving 18 ministries and Institutions," "Lack of Coordinated Regulatory Approach (push strategy without pull mechanism)," "Unnecessary Strict standards in SRUT for converted motorcycle," and "The time-consuming process to change vehicle registration from conventional to electric, deterring potential converters," the building blocks that are to be negatively affected include:

Table 4.16: Building Blocks Affected by Regulatory Challenges

Main Building Blocks	Sub-blocks	Explanation
Network Formation and Coordination	Division of Responsibility	The complex and unclear regulatory landscape, involving 18 ministries and institutions, can contribute to the division of responsibilities among various stakeholders, affecting the quality of the overall business process
Complementary Product and Services	Collaboration	The lack of a coordinated regulatory approach, with a push strategy without a pull mechanism in the early phase of the diffusion, leads to the emergence of multiple consortia, attempting to enhance the collaboration become more complex
Customers	Resistance to Changes	Unnecessary strict standards in SRUT for converted motorcycles can lead to resistance among ICE customers to convert their conventional motorcycle

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Table 4.16 – continued from previous page

Main Building Blocks	Sub-blocks	Explanation
Customers	Resistance to Change	The time-consuming process to change vehicle registration from conventional to electric, deterring potential converters, may contribute to customer resistance to change in adopting electric vehicles.

On the other hand, based on the information in this sub-chapter, the positive impact of Presidential Regulation and Initiatives (PERPRES 79 2023) is explored, highlighting its significant influence on various building blocks within the e-motorcycle and battery swap industry. As these regulations naturally become the main regulation, which later will be broken down again into newly updated versions of ministerial regulations, The presidential regulation provides a framework that enables businesses to exist despite challenges in building all innovation system blocks completely, offering room for improvement.

Economics Condition

Based on the analysis by LPEM FEB UI, the Indonesia Economic Outlook 2024 projects a stable GDP growth rate ranging from 5.0% to 5.1% in 2024. Although it has not experienced rapid growth, at least the GDP for the past three years has consistently been within the projected range of the IMF and WEF. Despite a slow acceleration in growth since late 2022, the manufacturing sector's growth remains below the overall economic growth rate. All expenditure components, except for exports and imports, have shown positive growth, including a surge in government spending, reaching 10.62% (y.o.y) in the second quarter of 2023. However, the Simultaneous General Election and global monetary conditions are crucial factors influencing the domestic economy in 2024. International economic policies will affect worldwide demand and Indonesia's economy through foreign trade, credit costs, and investments. While the positive impact of the election period involves increased liquidity for campaign purposes and private consumption, investment-related risks arise as investors tend to adopt a 'wait-and-see' approach pending election results (Rezki et al., 2024).

For the cause "The uncertainties surrounding the presidential election," the building block that is to be negatively affected includes:

Building Blocks Affected by Uncertainties in Political Conditions

Main Building Blocks	Sub-blocks	Explanation
Innovation-Specific Institution	Emerging Robust Policies	The uncertainties surrounding the presidential election and global monetary conditions may lead to challenges in formulating and implementing emerging robust policies within the innovation-specific institution, as the policies tend to be established by the political decision.

On the other hand, the positive impact of the stable growth of GDP (5.0-5.1%) is explored for various building blocks within the electric vehicle (EV) industry. The extensive table below outlines the specific building blocks that benefit from this positive economic factor.

Table 4.18: Building Blocks Positively Affected by Stable GDP Growth (5.0-5.1%)

Main Building Blocks	Sub-blocks	Explanation
Network Formation and Coordination	Strong Network	The stable growth of GDP (5.0-5.1%) positively influences network formation and coordination within the EV industry, as a growing economy fosters collaboration and coordination among stakeholders.
Complementary Products and Services	Collaboration	Businesses are more likely to engage in collaborative efforts in a stable economic environment, leading to improved collaboration building blocks in the EV industry.
Customers	Resistance to Changes	Growing economies often result in increased consumer confidence and purchasing power, positively influencing customer-related building blocks in the EV sector.

4.2.5. Competition

The subsequent exploration of the main factor, Competition, can be achieved by looking at its sub-blocks: Market positioning, Conventional Competition, and Value Proposition. These aspects cover essential elements for understanding competition within the electric vehicle (EV) industry. By examining each of these areas, we can gain valuable insights into market strategies, traditional competition, and the unique value that different companies offer. This analysis will provide a thorough understanding of the competitive environment and its impact on industry participants aiming for success in the battery swap market.

Market Positioning

Based on the historical growth of E2W, with 6 to 7 million motorcycles sold annually and 82% of Indonesian households owning a motorcycle, E2W adoption is expected to increase, especially considering the proposed IDR 7 million incentive. The incentive could result in approximately 40% price reductions on the market in 2023 for the average 1.5 kW models, 25% for the average 2 kW models, and 22% for the average 3 kW models (IESR, 2023).

DKI Jakarta and Bali have emerged as dominant locations that provide most of the existing battery swap stations in Indonesia, indicating the readiness of users in these areas to adopt new e-motorcycle and battery swap technologies. This trend also correlates with the income levels and willingness to pay among customers in these respective areas. By integrating technology into ride-hailing companies, e-commerce delivery, engaging ”ojek” drivers (selling e-motorcycles to them), and targeting individual e-motorcycle customers, these providers strategically position battery swap stations in frequently visited places like gas stations, mini-marts, etc., catering to users' daily routines. This strategic placement enhances accessibility and convenience for users, thereby facilitating greater acceptance and adoption of this emerging technology.

The positive impact of significant market potential for e-motorcycles, focus on high-readiness regions and integrated placement of battery swap stations at gas stations and mini-marts is explored for various building blocks within the electric vehicle (EV) industry. The extensive table below outlines the specific building blocks that benefit from these positive factors.

Table 4.19: Building Blocks Positively Affected by Market Potential for E2Ws and Integrated Battery Swap Stations

Main Building Blocks	Sub-blocks	Explanation
Network Formation and Coordination	Strong Network	The significant market potential for E2Ws positively influences network formation and coordination within the EV industry, attracting stakeholders and fostering collaboration in regions with high readiness.
Complementary Products and Services	Collaboration	The focus on high-readiness regions enhances collaboration building blocks, as targeted efforts attract stakeholders and create a conducive environment for EV development.
Complementary Products and Services	Ecosystems of Product/Service	The integrated placement of battery swap stations at gas stations and mini-marts positively impacts complementary products and services building blocks, providing convenient infrastructure for EV users.
Customers	Awareness, Knowledge, and Resistance to Change	Integrated placement of battery swap stations in Minimart, gas stations, and other public areas enhance customer-related building blocks by providing accessible and convenient charging solutions near residential areas, contributing to increased awareness of society.

Conventional Competition

The increasing adoption of e-motorcycles, spurred by incentives amounting to 7 million rupiahs and with plans to further add around 10 million rupiahs, as revealed in interviews with the **Interviewee 5**, signifies a significant push toward electric vehicle usage. However, despite these incentives, the e-motorcycle sector faces a persistent challenge in competing with internal combustion engine (ICE) motorcycles in terms of production and market dominance. When compared to data from the Ministry of Transportation, the number of electric motorcycles circulating in the market (both conversions and non-conversions) amounted to only 85,838 units during the period from 2017 to 2023.

This imbalance continues largely due to the absence of specific regulations limiting the purchase, production, or imposing time restrictions on the ownership of ICE motorcycles. Implementing limitations on ICE motorcycle usage on particular road segments or potentially restricting conventional motorcycle licenses could potentially serve as solutions. However, as per the insights from **Interviewee 4**, these measures are not feasible in the immediate future. These regulations will be gradually phased in once the production and operation of electric motorcycles are more established, with a larger population of operating units. This gradual approach aims to ensure smoother integration and increased prevalence of electric motorcycles before introducing limitations on conventional ICE motorcycles.

Moreover, in the context of after-sales concerns, insights from **Interviewee 9** emphasize the expensive nature of e-motorcycle maintenance due to the limited availability of spare parts in the market. Despite e-motorcycles having fewer moving parts than ICE motorcycles, their scarcity in the market contributes to higher maintenance costs. **Interviewee 9** suggests a collaborative approach between after-sales services of ICE motorcycles and existing e-motorcycle players to leverage their experience and create economies of scale. This collaboration is expected to drive down the costs of e-motorcycle maintenance and after-sales support, making them more economically viable for consumers.

An interesting note is the existing competition among EV companies and battery swap providers, which poses an intriguing observation. The nature of each battery swap system developed by EV companies or specific consortia is to create their own market by selling motorcycles. If left unchecked, this segmented market approach among providers could lead to a narrowing of market opportunities for each, becoming a bottleneck in the widespread diffusion of battery swap systems for motorcycles in Indonesia. **Interviewee 4** argues that associations and consortia should unite to compete with the internal combustion engine (ICE) industry instead of choking each other's market due to differences in standards of on-ground equipment, creating operational limitations for customers among different providers.

In terms of the causes of ”Market Dominance of ICE Motorcycles,” ”Lack of collaboration among e-motorcycle and battery swap consortia,” ”High Maintenance Costs for E-motorcycles compared to the conventional one,” ”Limited availability of spare parts after-sales,” and ”The absence of regulation limiting the purchase of ICE motorcycles,” the building blocks that are to be negatively affected include:

Building Blocks Affected by Competition-Related Causes

Main Building Blocks	Sub-blocks	Explanation
Customers	Ownership Preference and Resistance to Change	The market dominance of ICE motorcycles negatively affects the product performance and quality of electric vehicles (EVs) as the existing dominance creates a perception of inferior performance in comparison to internal combustion engine (ICE) motorcycles, impacting consumer preferences.
Product Price	Market Dominance of ICE Motorcycles	The dominance of ICE motorcycles in the market influences the pricing dynamics of EVs. The competition with traditional ICE motorcycles can lead to challenges in offering competitive and attractive pricing for electric vehicles, affecting their market adoption.

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Table 4.20 – continued from previous page

Main Building Blocks	Sub-blocks	Explanation
Complementary Products and Services	Market Dominance of ICE Motorcycles	The market dominance of ICE motorcycles creates challenges in establishing complementary products and services for electric vehicles. The established ecosystem around ICE motorcycles may hinder the development and adoption of supportive services specific to EVs.
Customers, Product Price	Resistance to Change, Total Cost of Ownership,	High maintenance costs for E-motorcycles compared to conventional ones may contribute to customer resistance to change in adopting electric motorcycles.
Customers, Product Price	Ownership Preference, Total Cost of Ownership,	Limited availability of spare parts after-sales can impact customers' ownership preference, particularly if conventional motorcycles offer more convenient access to spare parts.
Complementary Products and Services	Collaboration	The absence of collaboration among e-motorcycle and battery swap consortia hinders the development of complementary products and services for electric vehicles (EVs). In a competitive context, the reluctance to collaborate may impede the creation of a unified ecosystem supporting EV adoption.
Network Formation and Coordination	Strong Networks	The lack of collaboration negatively impacts the formation and coordination of strong networks within the EV industry. Without collaborative efforts, the development of a cohesive network among consortia becomes challenging, affecting the overall industry coordination.
Innovation-Specific Institution	General Consensus	The absence of collaboration among e-motorcycle and battery swap consortia hampers the establishment of a consensus within the innovation-specific institutions. The lack of collaboration among consortia may lead to disparate views and strategies, impacting the cohesive development of innovations in the e-motorcycle and battery swap technology.
Customers	Ownership Preference	The absence of collaboration affect customer ownership preferences. Without coordinated efforts, potential customers in certain locations may not receive a good ecosystem of battery swap stations due to the bottleneck of the expansion

Value Proposition

The following table presents a comparative overview of innovative companies pioneering advancements in urban mobility through transformative approaches to energy distribution, storage, and application. Each entity has a distinct focus on enhancing electric mobility experiences while addressing the evolving challenges within urban landscapes.

Table 4.21: Value Proposition of The-Big-4 Private Players of Battery Swap Providers in Indonesia

Company	Target	Value Proposition	Reference link
Gogoro + electrum	Ride-hailing company	Transform power to create positive change. We're taking on the mounting challenges we face in cities today through radically different solutions to distributing, storing, and applying energy. By eliminating barriers to electric fuel and elevating every riding experience, we're accelerating the shift to smart mobility and sustainable urban lifestyles.	`https://www.gogoro.com/about/`
Swap	Individual Driver	Swap Energy was created to reshape the future of urban mobility, eliminating long charging times for electric two-wheelers and contributing to a sustainable world. We are committed to supporting the nation's zero-emission goal by providing a revolutionized charging infrastructure.	`https://www.swap.id/aboutalt1`
Oyika	Individual driver	Oyika is a Motorbike Agnostic. We enable almost any electric motorbike with the solution to range anxiety and long charging times, thereby bridging the gap between manufacturers, consumers, and the growing delivery market.	`https://www.oyika.com/`
SGB Volta	Individual driver	Sistem Ganti Baterai. Berkendara makin nyaman, tanpa takut baterai habis, Cepat, hemat, tersebar lebih dekat.	`https://www.voltaindonesia.com/sgb`

The value propositions put forth by Gogoro + Electrum, Swap, Oyika, and SGB Volta resonate closely with the identified needs and preferences of potential customers in the urban mobility landscape. The data gleaned from the questionnaire in Section 4.1.7 underscores a growing awareness among consumers regarding the environmental impact of Internal Combustion Engine (ICE) motorcycles, with a significant percentage eager to embrace Electric Vehicles (EVs) given certain conditions.

The companies' focus on addressing issues such as range anxiety, charging infrastructure, and battery durability aligns seamlessly with the customer sentiments highlighted in the survey. Particularly, the battery swap business model, embraced by all four companies and evident through their growing unit of battery swap racks, directly tackles the concern for reliable battery technology, shifting ownership risks away from customers. This model corresponds with 89.5% of respondents emphasizing battery durability as a crucial factor in their consideration of EVs.

However, despite the synchronization between customer needs and the value propositions offered by these companies, challenges persist, notably the competitive pricing of ICE vehicles. The discrepancy in pricing remains a significant hurdle for widespread EV adoption. Government intervention through larger incentives and potentially limiting ICE vehicle production could serve as catalysts in bridging this gap, reinforcing the value propositions outlined by these companies.

Additionally, while Gogoro's value proposition appears directed toward broader urban mobility solutions, its initial market penetration focuses on increasing its presence within the GOJEK fleet. Interviews with GOJEK partners (conducted by **Interviewee 8**) reveal a high level of interest among motorcycle taxi drivers in renting electric motorcycles from Gogoro + Electrum. This interest stems from the solution these motorcycles provide to the partners' daily challenges. For instance, by renting electric motorcycles from Gogoro + Electrum, these partners can significantly increase their earnings by eliminating daily fuel expenses. The rental option allows them to operate profitably without using their motorcycles, which might be in poor condition and uncomfortable for passengers. The rented motorcycles are far more appealing and reliable. Moreover, this allows these partners' motorcycles to be used by their spouses for other purposes, such as grocery shopping or transporting their children to school.

The positive impact of the rental basis for the battery part on the purchase of e-motorcycles and the alignment of the value proposition with consumer environmental awareness is explored for various building blocks within the electric vehicle (EV) industry. The extensive table below outlines the specific building blocks that benefit from these positive factors.

Table 4.22: Building Blocks Positively Affected by Rental Basis for Battery Part and Value Proposition Alignment

Main Building Blocks	**Sub-blocks**	**Explanation**
Product Performance and Quality	all sub-blocks	The rental basis for the battery part positively impacts the product performance and quality by removing the battery waste from the customer side to the provider side, acting as an enabler for the design of circularity and resource optimization.
Product Price	Total Cost of Ownership	The rental basis for the battery part positively reduce the total cost of customers' ownership by removing the battery ownership from the customer side to the provider side
Customers	Awareness, Knowledge, and Ownership preferences	The alignment of the value proposition with consumer environmental awareness enhances customer-related building blocks, as it resonates with environmentally conscious consumers, fostering positive perceptions of EVs.

4.2.6. Accidents and Events

The subsequent exploration of the main factor, Accidents and Events, can be achieved by examining its sub-blocks: Internal Disruption, Cascading Effects, and Resilience. These aspects encompass essential elements for understanding how accidents and events impact the battery swap industry for e-motorcycles. By delving into each of these areas, valuable insights into disruptions within the stakeholders, their potential ripple effects, and the ability of the system to recover can be gained.

Internal Disruption

An evaluation by **Interviewee 6** highlights a proficient division of tasks under the Acceleration Program for Electric Vehicle Ecosystem in Indonesia governed by Presidential Regulation No. 55 of 2019 (in transition to the more recent update, PERPRES No.79, 2023). However, disparities in performance among ministries impact policy coherence, leading to contradictions in several policies. The time taken to resolve complex issues like standardization further exacerbates challenges.

For example, within the Ministry of Energy and Mineral Resources (ESDM), discussions concerning electric vehicle issues occur at monthly intervals due to constraints in human resources and a considerably heavy workload. This periodicity in discussions, approximately once a month, reflects the limitations in workforce availability and the overwhelming workload within the ministry. These constraints lead to delays in addressing critical matters related to electric vehicles, such as standardization issues.

In addition, conflicting regulatory stances between the Ministry of Energy and Mineral Resources (MEMR) and the Ministry of Maritime Industry and Transportation have emerged in the context of ICE conversion to accelerate the EV ecosystem establishment. MEMR encourages the growth of the e-motorcycle population by providing IDR 10 Million to new customers to purchase new e-motorcycles or convert their ICE motorcycles into e-motorcycles.

However, this agenda appears to contradict the agenda being carried out by the Ministry of Maritime Industry and Transportation in terms of applying ”Sertifikasi Registrasi Uji Tipe”, a certification of manufactured unit type registration (SRUT) for converted electric motorcycles. This contradiction is shown in the wide range of stringent standards of converted motorcycles similar to fuel-powered motorcycles, encompassing construction tests, dimensions, lights, wheels, turning radius, vehicle weight, brakes, speedometer function, horn sound level, seat belts, and emission tests. The stringent standards occasionally create bottlenecks in scaling up the population of electric motorcycles through conversion methods. Furthermore, in the case of motorcycle conversions, owners are required to change their vehicle registration (STNK) from conventional to electric, a process that consumes time. This has bred reluctance and apprehension among prospective customers who previously planned to convert their motorcycles, as revealed in an interview with **Interviewee 4**.

For the causes of ”Conflicting Regulatory Stances between ministries,” ”Heavy workload in several ministries,” and ”Disparities in performance among ministries which impact policy coherence,” the building blocks that are to be negatively affected include:

Building Blocks Affected by Regulatory Challenges and Policy Coherence

Main Building Blocks	**Sub-blocks**	**Explanation**
Innovation-Specific Institution	Heavy workload in several ministries	Heavy workload in several ministries may affect the functioning of innovation-specific institutions, impacting their ability to formulate and implement policies effectively in time.
Network Formation and Coordination	Division of Responsibility	Disparities in performance among ministries can have a cascading effect on network formation and coordination, which leads to the overall policy coherence within the industry and the ineffective division of responsibility in terms of regulation obedience control and monitoring

Cascading Effects - Consortia Divergence and Standardization Challenges

: The collaboration among consortia brings both cooperation and challenges. Divergent needs and business preferences among these groups might limit the market due to interoperability issues. The absence of standardized charging solutions for diverse motorcycles complicates battery swap system implementation, increasing technology investments and raising long-term feasibility concerns. The lack of uniformity in charging devices presents a complex scenario, necessitating standardized protocols for seamless adoption and scalability.

Cascading Effects - International Disruption and Supply Chain Vulnerability

: Indonesia's loss in the World Trade Organization (WTO) dispute with the EU regarding nickel export bans since 2019 poses significant concerns. The judgment stemmed from the perceived immaturity of downstream industries, potentially leading to foreign absorption of nickel, a vital component in lithium batteries.

The export bans initially aim to incentivize foreign firms to invest in nickel smelters and other processing plants in Indonesia. This move is intended to generate employment opportunities and boost the country's earnings from exporting essential raw materials. Jokowi has also hinted at potential bans on exporting unprocessed bauxite, tin, and copper. "Our goal is to halt the export of raw materials as they lack added value and fail to create jobs," he stated in October last year. The sue of the European Union through WTO may impede the supply chain development and investment in Indonesia's battery swap ecosystem which will ensure the resilience and growth of this sector (Strangio, 2022).

For the causes "Indonesia's loss in the WTO dispute with the EU over nickel export bans" and "Lack of standardization and interoperability (hardware, software, and protection mechanism)," the building blocks that are to be negatively affected include:

Building Blocks Affected by Cascading Effects

Main Building Blocks	Sub-blocks	Explanation
Production System, Product Price, Customers	Strong Reverse Logistics, Total Cost of Ownership, Ownership Preference	Indonesia's loss in the WTO dispute with the EU over nickel export bans may impact the security of national supply chains of battery raw material, and in the long term, it will surely affect the price of the product and the ownership preference of the customers
Network Formation and Coordination, Complementary Products and Services	Strong Networks, Ecosystem of Products and Services,	Lack of standardization and interoperability can hinder the formation of strong networks, especially in the absence of a coordinated regulatory approach. In the long term, it will lead to the bottleneck of market expansion

Resilience

Presently, the battery swap standards undergo continual evolution due to the intricate dynamics among market players. The existence of five prominent electric motorcycle consortia, each operating with distinct specifications, emphasizes an impending standard disruption. This change is seen as crucial in easing obstacles that hinder market growth, necessitating proactive navigation of evolving standards by all consortia for sustained growth and advancement.

Based on the literature, the evaluation of readiness for standard application employs an interval scale encompassing response categories such as "low," "medium," "high," "top," and "ideal." This scale draws inspiration from Sharif's research on evaluating the sophistication level of technological components. Particularly noteworthy is the aspect concerning stakeholders' capacity to adhere to standards, marked as "top." This designation underscores stakeholders' resilience in adapting to evolving standards (Aqidawati et al., 2022).

The positive impact of stakeholders' capacity to adapt to evolving standards is explored for various building blocks within the electric vehicle (EV) industry. The extensive table below outlines the specific building blocks that benefit from this positive factor.

Table 4.25: Building Blocks Positively Affected by Stakeholders' Capacity to Adapt to Evolving Standards

Main Building Blocks	Sub-blocks	Explanation
Innovation-Specific Institution	Emerging Robust Policy	Stakeholders' capacity to adapt to evolving standards positively influences innovation-specific institutions by fostering an environment that encourages continuous improvement and adherence to robust policy.
Innovation-Specific Institution	Standardization	The capacity of stakeholders to adapt to evolving standards gradually contributes to the process of standardization within the EV industry.
Network Formation and Coordination,	Strong network	Stakeholders' adaptability may enhance network formation and coordination by promoting future collaboration in response to evolving standards and requirements.

4.2.7. Socio-cultural Aspects

The subsequent exploration of the main factor, Socio-cultural Aspects, can be effectively discussed by focusing on its encompassing sub-blocks: Literacy and Motivation, Limited Information and Knowledge, and Informed Preference. These sub-blocks offer a solid framework for understanding the complex societal and cultural influences on the battery swap industry. By examining each sub-block closely, valuable insights into factors like literacy levels, what motivates people to adopt battery swap technology, access to information, and how consumer preferences are formed can be gained.

Literacy and Motivation

The data of preference of buying motorcycle in Figure 4.12, with survey questions: "Which vehicle (motorcycle or car) do you plan to buy within the next one, three, and five years? Which vehicle (motorcycle or car) do you wish to buy in the long term future?", indicates a gradual decline in the preference for fossil fuel-based motorcycles, with a growing inclination towards adopting electric or hybrid alternatives within the coming year. More respondents are inclined towards adopting electric motorcycles, with approximately 30% expressing a desire to buy one within the next year compared to the 19% still considering purchasing fossil fuel-powered motorcycles. This trend appears consistent even in the long run (PWC, 2023).

However, while there is a growing inclination towards electric motorcycles, the transition in consumer mindset is gradual within a five-year projection, indicating a need for increased efforts in consumer education and awareness to boost motivation towards adopting electric motorcycles in the short term.

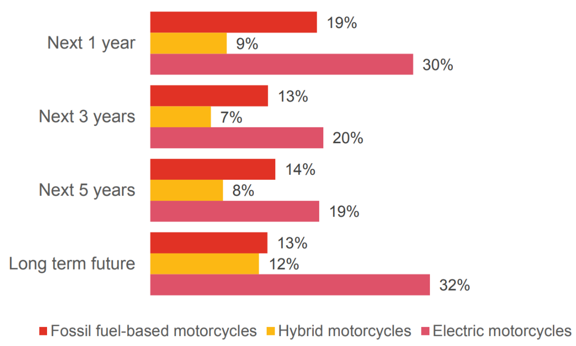

Figure 4.10: Expected Year of Purchasing E-Motorcycle

For the cause "Slow Shift in Consumer Motivation on Buying e-motorcycle within 5 years," the building block that is to be negatively affected includes:

Building Blocks Affected by Consumer Motivation Shift

Main Building Blocks	Sub-blocks	Explanation
Complementary Product and Services	Ecosystem of Products and Services	A slow shift in consumer motivation on buying e-motorcycles within five years may disrupt the market/ecosystem expansion planning

Limited Information and Knowledge

In terms of information sources, as seen in Figure 4.11, leveraging digital platforms and collaborative campaigns between influencers, companies, and government entities have contributed significantly to consumer education about electric mobility. With a substantial proportion of learning about EVs through online platforms and interpersonal interactions, there's a significant opportunity to expand this knowledge base, bridging the gap and fostering a community-oriented approach to promote eco-friendly transportation options in Indonesia. Within the respondent group, 54% acquire information about electric vehicles (EVs) through automotive websites, 52% from social media, 44% from online videos, and 35% from TV ads. These findings unveil a significant chance to bridge the information void and enlighten Indonesians about the genuine advantages of transitioning from traditional fuel-powered vehicles to eco-friendly alternatives. In Indonesian culture, interpersonal communication holds significance, as 25% of respondents gather EV information through conversations with friends and family. This presents an opening to establish a supportive community (PWC, 2023).

The data shows a heavy reliance on digital platforms and interpersonal communications for information about EVs. This could be limiting if these sources fail to provide comprehensive, accurate, and balanced information about electric motorcycles. In addition, some segments of the population may not be reached effectively by current information dissemination methods (like automotive websites or social media), leading to a knowledge gap in these groups.

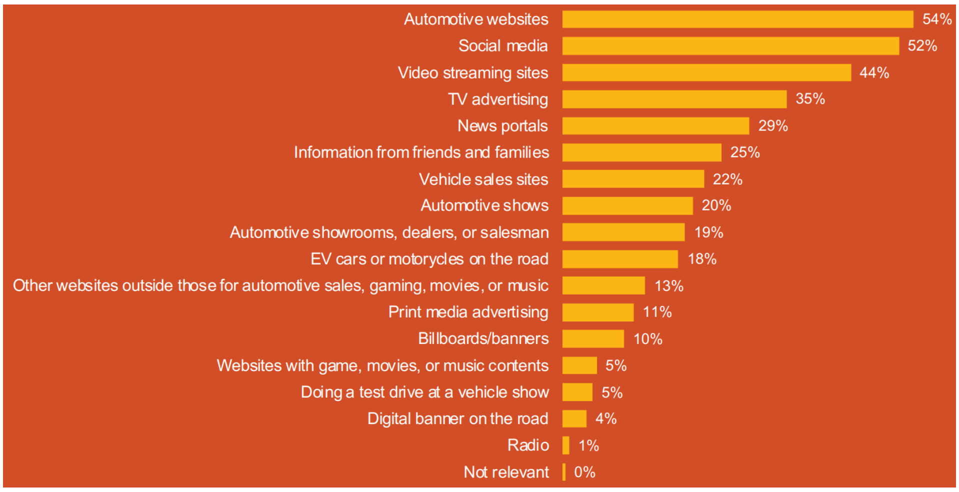

Figure 4.11: Costumer's Source of Information

For the cause of "Heavy reliance on a particular information source," the building block that is to be negatively affected includes:

Building Blocks Affected by Information Source Reliance

Main Building Blocks	Sub-blocks	Explanation
Customers	Awareness and Knowledge	Heavy reliance on specific information sources regarding the benefits of electric vehicles may result in an information gap in certain demographics within the customer base. This could affect the overall awareness and knowledge levels about electric vehicles in those specific groups.

Informed Preference

In terms of informed preferences, the majority of respondents highlighted the importance of environmental friendliness as the key factor influencing their intention to purchase electric vehicles, with 75% emphasizing this aspect for electric motorcycles as shown in Figure 4.12. Additionally, there was a positive perception among consumers who viewed electric vehicles as the future (57% for electric motorcycles). However, when it comes to preferences, while cost-effectiveness drove the preference for electric cars, the quieter engine stood out as the primary reason for choosing electric motorcycles among consumers (PWC, 2023).

The result of the survey reflects that consumers might not have a full understanding of the benefits and functionalities of electric motorcycles compared to fossil fuel-powered ones. This can influence their preference, as decisions might be made based on limited or superficial factors like noise levels rather than a comprehensive evaluation of all benefits.

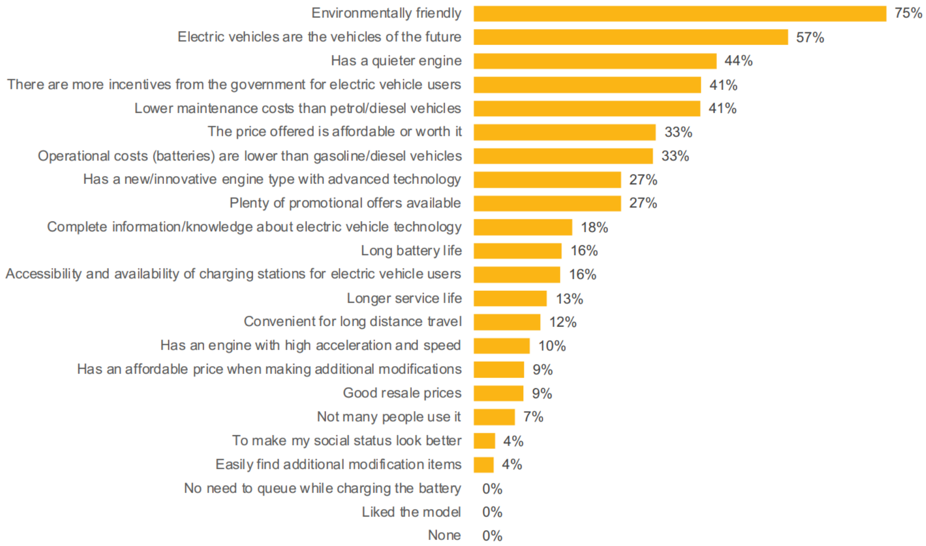

Figure 4.12: E-motorcycle Costumer's Motivation

For the cause "Lack of Comprehensive Understanding of the benefits and functionalities of electric motorcycles compared to fossil fuel-powered ones," the building block that is to be negatively affected includes:

Building Blocks Affected by Lack of Comprehensive Understanding

Main Building Blocks	Sub-blocks	Explanation
Customers	Awareness and Knowledge	The lack of comprehensive understanding of the benefits and functionalities of electric motorcycles compared to fossil fuel-powered ones may contribute to a knowledge gap among potential customers within the awareness and knowledge building block.

4.3. Chapter's Conclusion (Answers for SQ3, and SQ5)

4.3.1. Current State of Building Blocks (SQ3)

In addition to interpreting the state of the building blocks and their interplay with influencing conditions, this section serves as a comprehensive response to SQ3,**'What is the current state of each building blocks and influencing condition blocks in the Technical Innovation System (TIS) in terms of e-motorcycle battery swap system development in Indonesia? Which one is considered as complete, partially complete, or incomplete building blocks?'**, which delves into the examination of the status of these building blocks within a circular TIS framework. Drawing insights from the discoveries outlined in Section 4.1 and 4.2, it becomes evident that a majority of the building blocks and influencing conditions exist in a state of partial completeness. At the same time, some remain entirely incomplete, as depicted in Figure 4.13.

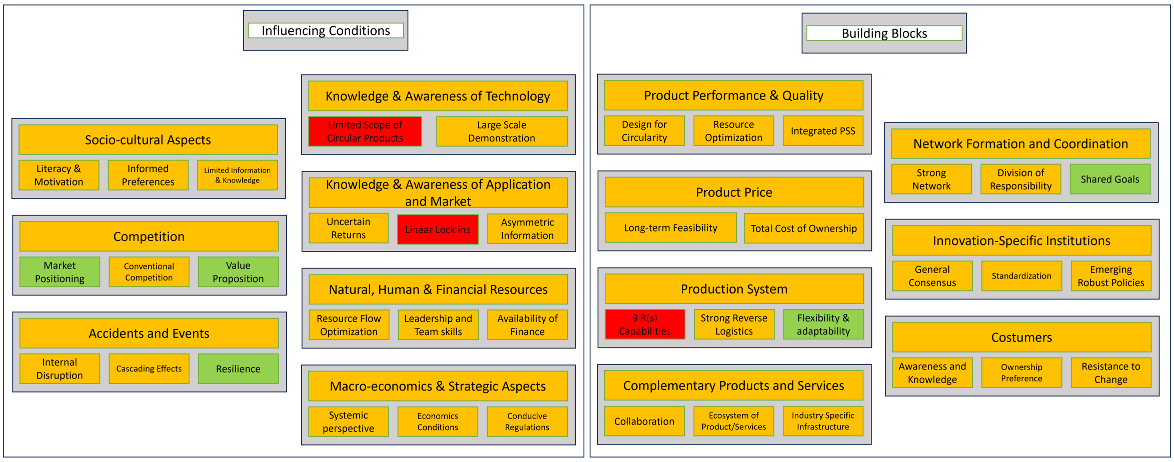

Figure 4.13: Current Status of Building Blocks and Influencing Conditions

Identified Barriers

Most of the building blocks, in the sub-level, remain partially complete and one of those is totally incomplete. The recapitulation of the barriers, which are derived from the statuses of each incomplete or partially complete building block, in the sub-level, is shown in the table below:

Main Building Blocks	Sub-blocks	Explanation of the incomplete/partially complete blocks
Product Performance and Quality	Design for Circularity	Unclear protocol at the business level. In the bigger scoop, only small parts of the Battery supply chain (including the recycling sector) exist commercially, most of them exist on a small scale(SME/LAB).
	Resource Optimization	Non-Interoperable Racks as a Resource Optimization Challenge
	Integrated Product-Service Systems (PSS)	Battery renting scheme as an enabler to minimize waste, but the recycling facility is still not available
Product Price	Long Term Feasibility	Lack of Feasibility of Market Expansion due to weak standardization control
	Total Cost of Ownership	High expenses related to maintenance and after-sales support
Production System	9 R(s) Capabilities	Lack of emphasis on the '9 (R)' capabilities within the battery industry
	Strong Reverse Logistics	Weak Reverse Logistics
Complementary Products and Services	Collaboration	Uncontrolled Growth of 2WEV Consortiums with Different Specifications of the Battery Swap System
	Industry-specific infrastructure	Only small parts of the Battery supply chain (including the recycling sector) exist commercially; most of them exist on a small scale(SME/LAB).
	Ecosystem of Product/Service	The disparity in charging port ranges, Rack sizes, and voltage levels
Network Formation and Coordination	Division of Responsibility	Overlapping Responsibilities among Ministries and Challenges in Regulatory Coordination
	Strong Networks	The network between state-owned companies, overseas battery manufacturers, recycling operators, and e-motorcycle manufacturers has been established in the form of an MoU. However, certain critical components remain incomplete within the network, and some of them do currently not exist commercially.
Innovation-Specific Institution	General Consensus	Disparities among Political Views related to the Development of EVs ecosystem
	Standardization	Delayed process of standardization
	Emerging Robust Policies	Updates of Policies tend to be scattered, making it challenging to track and implement the changes effectively
	Emerging Robust Policies	Lack in comprehensive details of Policies
Customers	Awareness and Knowledge	High number of potential customers that are still unaware of the complete benefits of owning EVs
	Resistance to Change	High resistance to change due to Price sensitivity and range anxiety
	Ownership Preference	"Preference of Customers willing to buy EV if the prices given are cheaper than conventional one"

Table 4.29: List of barriers (Incomplete / partially complete building blocks)

4.3.2. Relationship Between Barriers and Its Causes (SQ4)

The table 7.2 effectively illustrates the dynamics within circular TIS framework to answer the SQ4: '**How are identified barriers and its causes interconnected?**'. In this framework, each influencing condition that negatively affects the completeness or effectiveness of these building blocks is considered a cause of barrier. These cause of barriers are essentially negative aspects that can slow down, impede, or even prevent the successful development and implementation of a technological system. Conversely, conditions that have a positive impact on the development and completion of these building blocks are identified as drivers. This driver definition is also in line with the definition of the driver given in Raghav's report: 'Drivers can be defined as the factors or motivations that propel and stimulate the adoption and implementation of circular economy principles and practices' (Shankar, 2023). These drivers are beneficial aspects that facilitate and accelerate the progress and efficiency of the system. By categorizing these conditions into drivers and causes of barriers, the table provides a clear and structured way to understand the multifaceted factors that play a crucial role in the advancement of the e-motorcycle battery swap system in Indonesia. This distinction is vital for stakeholders to identify specific areas of improvement and to strategize effectively for overcoming challenges within the TIS framework. All identified drivers and causes of barriers are broken down in the explanation provided in the sub-chapter 4.2.

Influencing Condition (IC)	Sub-blocks of IC	Aspects	Driver / Cause of Barrier	Affected Building Blocks
Knowledge and Awareness of Technology	Limited Scope of Circular Product	Delayed operational commencement of recycling and/or other part of end-to-end supply chain facilities	Cause of Barrier	Resource Optimization, Complementary Products, Network Formation and Coordination
	Large Scale Demonstration	Lack of standardization and interoperability (hardware, software, and protection mechanism)	Cause of Barrier	Product Performance and Quality, Complementary Products and Services, Product Price
		The absence of alignment between SPKLU and SPBKLU placement	Cause of Barrier	Product Performance and Quality, Complementary Products and Services, Customers
		The rental basis for battery part on the purchase of e-motorcycle	Driver	Product Performance and Quality, Complementary Products and Services, Product Price, Customers
Knowledge and Awareness of Application and Market	Uncertain Return	Investor hesitance (in EV+Battery swap market) due to lack of standardization	Cause of Barrier	Product Price
		Capital intensive for new entrants	Cause of Barrier	Production System
	Linear Lock-in	Regulatory and Systemic Gaps in Battery Recycling and Traceability	Cause of Barrier	Product Performance and Quality, Production System
	Asymmetric Information	Varying Levels of Awareness and Understanding (Impact of Diverse Backgrounds)	Cause of Barrier	Customers
Natural, Human, and Financial Resources	Resource Flow Optimization	Multiple, Non-Standard Battery Racks in a single place due to weak monitoring from government	Cause of Barrier	Product Performance and Quality
	Leadership and Team Skill	Lack of experience in the body of government due to the technology novelty	Cause of Barrier	Innovation-Specific Institution, Complementary Product and Services
		Lack of talents with specific skill-set available in the job market	Cause of Barrier	Product Performance and Quality, Production system, Innovation-Specific Institution
		Robust upskilling strategy during the talent scarcity in the job-market	Driver	Complementary Products and Services
	Availability of Finance	Potential Financial challenges at the operational Level (Due to the absence of fixed standardization	Cause of Barrier	Product Performance and Quality, Production System, Network Formation and Co- ordination
		High levels of Foreign Direct Investment (FDI)	Driver	Network Formation and Coordination, Product Price, Production System, Complementary Products and Services
	Natural Resources	Abundance of Nickel resources	Driver	Product Price, Production System
Macro-economics and Strategic Aspect	Systemic Perspective	Supply chain bottlenecks due to the absence of local infrastructures in certain aspects	Cause of Barrier	Product Price, Production System
		Market fragmentation due to existence of multiple consortia with diverse specification	Cause of Barrier	Product Performance and Quality, Product Price, Complementary Products and Services, Network Formation and Coordination, Innovation specific Institution
		The absence of open protocol and traceability of asset (batteries)	Cause of Barrier	Product Performance and Quality, Product Price, Complementary Products and Services, Network Formation and Coordination, Innovation specific Institution

Influencing Condition (IC)	Sub-blocks of IC	Aspects	Driver / Cause of Barrier	Affected Building Blocks
		Lack of government interference in the consolidation among consortia	Cause of Barrier	Product Performance and Quality, Product Price, Complementary Products and Services, Network Formation and Coordination, Innovation specific Institution
	Conducive regulation	Presidential Regulation and Initiatives (PERPRES 79 2023)	Driver	All building blocks
		Complex and Unclear Regulatory Landscape, involving 18 ministries and Institutions	Cause of Barrier	Network Formation and Coordination
		Lack of Coordinated Regulatory Approach (push strategy without pull mechanism in the early phase of the technology diffusion)	Cause of Barrier	Complementary Product and Services
		Unnecessary Strict standards in SRUT for converted motorcycle	Cause of Barrier	Customers
		The time-consuming process to change vehicle registration from conventional to electric deters potential converters	Cause of Barrier	Customers
	Economics condition	Stable growth of GDP (5.0-5.1 %)	Driver	Production Systems, Complementary Products and Services, Customers
		The uncertainties surrounding the Indonesia presidential election	Cause of Barrier	Innovation Specific Institution
Competition	Market Positioning	Significant Market Potential for e-motorcycles	Driver	Network Formation and Co- ordination
		Focus on High-Readiness Regions	Driver	Complementary Products and Services
		Integrated Placement of Battery Swap Stations at gas stations and mini-marts	Driver	Customers, Complementary Products and Services
	Conventional Competition	Market Dominance of ICE Motorcycles	Cause of Barrier	Product Price, Complementary Products and Services, Customers
		Lack of collaboration among e-motorcycle and battery swap consortia	Cause of Barrier	Complementary Products and Services, Customers, Innovation-specific Institution
		High Maintenance Costs for E-motorcycles compared to the conventional one	Cause of Barrier	Product Price, Customers
		Limited availability of spare parts after-sales	Cause of Barrier	Product Price, Customers
		The absence of regulation limiting the purchase of ICE motorcycle	Cause of Barrier	Product Price, Customers
	Value Proposition	The rental basis for battery part on the purchase of e-motorcycle	Driver	Product Price, Customers
		Alignment of value proposition with Consumer Environmental Awareness	Driver	Customers
Accidents and Events	Internal Disruption	Conflicting Regulatory Stances between ministries	Cause of Barrier	Network Formation and Coordination, Innovation-Specific Institution
		Heavy workload in several ministries	Cause of Barrier	Innovation-Specific Institution
		Disparities in performance among ministries which impact policy coherence	Cause of Barrier	Network Formation and Co- ordination
	Cascading Effects	Indonesia's loss in the WTO dispute with the EU over nickel export bans	Cause of Barrier	Production System, Product Price, Customers
		Lack of standardization and interoperability (hardware, software, and protection mechanism)	Cause of Barrier	Network Formation and Coordination, Complementary Product and Services
	Resilience	Stakeholders' Capacity to Adapt to Evolving Standards	Driver	Product Performance and Quality, Product Price, Production System, Complementary Products and Services, Network Formation and Coordination, Innovation-Specific Institution
Socio-cultural Aspects	Literacy and Motivation	Slow Shift in Consumer Motivation on buying e-motorcycle within 5 years period	Cause of Barrier	Complementary Product and Services
	Informed preference	Lack of Comprehensive Understanding of the benefits and functionalities of electric motorcycles compared to fossil fuel-powered ones	Cause of Barrier	Customers
	Limited Information and knowledge	Heavy Reliance on Specific Information Sources of the benefit of EV, leading to information gap in certain demographics	Cause of Barrier	Customers

Table 4.30: Building blocks and its causes

5

ISM Analysis as The Complement for Circular-TIS Framework in Case Study

This chapter addresses Sub-question 5 (SQ5): **"What is the level of importance or priority to each of the identified causes of barriers to focus efforts and resources on those that are deemed most critical or time-sensitive?"** This question arises from the insights gained in Chapter 4, where an examination of barriers to E-Motorcycle Battery Swap systems in Indonesia was conducted.

Chapter 4 identified diverse challenges hindering the adoption of E-Motorcycle Battery Swap systems in Indonesia. In response, this chapter employs Interpretative Structural Modelling (ISM). The ISM analysis provides a practical framework for understanding the hierarchy and interdependencies of barriers, guiding the prioritization of interventions. This chapter contributes essential insights for stakeholders aiming to overcome obstacles and promote the widespread adoption of E-Motorcycle Battery Swap systems in Indonesia.

A MATLAB script has been developed for conducting the analysis, utilizing the initial barrier relationship matrix as input. The script outputs the hierarchy directly, and the interim stages are saved as individual Excel files for future reference. For a thorough understanding of the code's logic, refer to Appendix A, where the MATLAB script is detailed, and explanatory comments are provided within the script. This systematic approach facilitates informed decision-making, enabling stakeholders to strategically address causes of barriers that hinder the development of innovation building blocks for effective E-Motorcycle Battery Swap system adoption.

5.1. Application of ISM on The Identified Causes of Barriers

Following the steps outlined in the previous chapter, we aim to analyze the 33 identified barriers for India and derive a resulting level partition for each barrier. Utilizing the barrier levels and their inter-relations, a hierarchy flowchart that illustrates the relationships among the barriers and facilitates the identification of the most influential ones can be constructed.

However, it is crucial to note that within the influencing condition blocks, two details of causes in the ”Cascading Effect” and ”Large Scale Demonstration” blocks (shown in Table 4.30) are identical, specifically related to the Lack of standardization and interoperability (hardware, software, and protection mechanism). As a result, these will be treated as a single cause in the iteration of ISM. Consequently, the total count of causes of barriers associated with the ISM iteration, as shown in Table 5.1, is reduced to 32, as shown in the table below. In addition to the linkage between Table 4.30, and Table 5.1, Table 5.1 only shows the list of identified causes of barriers, excluding the identified drivers in Table 4.30, due to the scope of research that only focus on the causes of barriers analysis using ISM.

Table 5.1: Causes of Barrier No. # and Descriptions

Causes of Barrier No. #	Description
B1	Delayed operational commencement of recycling and/or other part of end-to-end supply chain facilities
B2	Lack of standardization and interoperability (hardware, software, and protection mechanism)
B3	The absence of alignment between SPKLU and SPBKLU placement
B4	Investor hesitance (in EV+Battery swap market) due to lack of standardization
B5	Capital intensive for new entrants
B6	Regulatory and Systemic Gaps in Battery Recycling and Traceability
B7	Varying Levels of Awareness and Understanding (Impact of Diverse Backgrounds)
B8	Multiple, Non-Standard Battery Racks in a single place due to weak monitoring from government
B9	Lack of experience in the body of government due to the technology novelty
B10	Lack of talents with a specific skill-set available in the job market
B11	The potential of financial challenges at the operational level (Due to the absence of fixed standardization)
B12	Supply Chain Bottlenecks due to the absence of several infrastructures
B13	Market fragmentation due to the existence of multiple consortiums with diverse specifications
B14	The absence of open protocol and traceability of assets (batteries)
B15	Lack of government interference in the unity of consortiums
B16	Complex and Unclear Regulatory Landscape, involving 18 ministries and institutions
B17	Lack of coordinated regulatory approach (push strategy without pull mechanism)
B18	Unnecessary strict standards in SRUT for converted motorcycles
B19	The time-consuming process to change vehicle registration from conventional to electric, deterring potential users
B20	The uncertainties surrounding the Indonesia presidential election
B21	Market dominance of ICE Motorcycles
B22	Lack of collaboration among e-motorcycle and battery swap consortiums
B23	High maintenance costs for E-motorcycles compared to the conventional one
B24	Limited availability of spare parts after-sales
B25	The absence of regulation limiting the purchase of ICE motorcycles
B26	Conflicting Regulatory Stances between ministries
B27	Heavy workload in several ministries
B28	Disparities in performance among ministries which impact policy coherence
B29	Indonesia’s loss in the WTO dispute with the EU over nickel export bans
B30	Slow Shift in Consumer Motivation on Buying e-motorcycle within 5 years period
B31	Lack of comprehensive understanding of the benefits and functionalities of electric motorcycles compared to fossil fuel-powered ones
B32	Reliance on Specific Information Sources of the Benefit of EV, leading to an information gap in certain demographics

5.1.1. Structural Self-Intersection Matrix (SSIM)

In accordance with Figure 2.1, the initial step of the Interpretive Structural Modeling (ISM) process involves the acquisition of SSIM, which is the matrix of inter-relation between identified causes of barriers, through expert opinions. This critical step is executed through a dedicated brainstorming session. The participants comprise three experts, as shown in Table 1.3, whose valuable insights and expertise contribute significantly to a solid foundation for the next steps of the ISM analysis.

The analysis of SSIM progresses to examine the contextual connections between each pair of identified variables. The relationships are represented by symbols ’V’, ’A’, ’X’, and ’O’, indicating ”i influences j,” ”j influences i,” ”i and j influence each other,” and ”i and j have no correlation,” respectively. These connections stem from a collaborative brainstorming session, integrating insights from three chosen respondents out of the list of 10 individuals mentioned in Chapter 4: Interviewees 1, 6, and 8. The table of brainstorming results is shown in Appendix G

As an example in the context of the relationships identified in the SSIM, a notable challenge arises in the delayed initiation of recycling processes and various components within the end-to-end supply chain facilities (B1). Represented by the letter 'O' in the corresponding table, this delay holds a consequential relationship with the fourth barrier (B4), specifically "Investor hesitance due to lack of standardization." The connection is explained by understanding that the postponement in commencing recycling processes and supply chain facilities exacerbates investor hesitance in the EV and battery swap market.

This delay signifies a lack of well-defined and standardized procedures, introducing uncertainties and reservations among potential investors. The intricate relationship suggests that the industry's growth is hindered when streamlined processes are not in place, thereby impacting investor confidence. In addition, the 'V' connection suggests that the same delay in B1 is a driving force behind the capital-intensive nature faced by new entrants (B5) in addressing battery disposal and environmental concerns.

5.1.2. Initial Reachability Matrix

After obtaining a matrix of interrelations between identified causes of barriers from experts' opinions during a brainstorming session, it is necessary to convert these qualitative relationships into a quantitative format for further analysis. The relationships identified in the previous SSIM must be converted into binary values (1s and 0s) for further analysis. The substitution rules for the notations 'V,' 'A,' 'X,' and 'O' are as follows:

- If the SSIM entry at position (i, j) is 'V,' then the corresponding entry in the initial reachability matrix becomes 1, and the entry at (j, i) becomes 0.
- If the SSIM entry at position (i, j) is 'A,' then the corresponding entry in the initial reachability matrix becomes 0, and the entry at (j, i) becomes 1.
- If the SSIM entry at position (i, j) is 'X,' then the corresponding entry in the initial reachability matrix becomes 1, and the entry at (j, i) also becomes 1.
- If the SSIM entry at position (i, j) is 'O,' then the corresponding entry in the initial reachability matrix becomes 0, and the entry at (j, i) also becomes 0.

It is important to note that in these rules, 'i' represents the row and 'j' represents the column in the matrices. For example, since a "V" at position (B1,B5) in the SSIM, the entries in position (B1,B5) become "1", and the entry at (B5,B1) becomes "0".

5.1.3. Final Reachability Matrix

While the initial reachability matrix facilitates the direct conversion of the SSIM into binary values (1s and 0s) for subsequent stages of barrier analysis, it still does not consider the transitivity between barriers. To illustrate, if barrier 'i' affects barrier 'j' and barrier 'j' impacts barrier 'k,' the rule of transitive relationships dictates that barrier 'i' also influences barrier 'k,' as depicted in Figure 2.2. These interconnected relationships might not be fully preserved during the translation from the SSIM. Consequently, it is imperative to revisit and revise these correlations in the final reachability matrix to ensure a comprehensive representation of the transitive influences among barriers.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28	B29	B30	B31	B32
B1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
B2	0	1	0	1	1	1	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
B3	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
B4	0	0	0	1	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B5	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B6	1	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B7	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1
B8	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
B9	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	0	0	0	0	0	1	1	0	1	1	0	0	0
B10	1	1	0	1	0	0	0	1	1	1	0	1	0	1	0	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0
B11	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
B12	1	0	0	1	1	0	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1	0	1	1	0	0	0	0	1	1	0	0
B13	1	0	0	1	1	0	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
B14	1	0	0	1	1	0	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
B15	0	1	0	1	1	0	0	1	0	0	1	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
B16	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	1	0	0	1	0	0	0	1	0	1	0
B17	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	0	1	1	1	0	1	1	0	0	1	1	0	0	0	0	0	0
B18	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0
B19	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1
B20	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
B21	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
B22	1	1	1	1	1	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
B23	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0
B24	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
B25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
B26	1	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0
B27	1	1	1	0	0	1	0	1	1	1	1	1	0	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	0	1	0	0
B28	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	1	1	0	1	0	0	1	1	0	0	1	0	1	0	0	0	0
B29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
B30	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	0
B31	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
B32	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1

Figure 5.1: Reachability Matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28	B29	B30	B31	B32
B1	1	1*	1*	1*	1	1*	1*	1*	0	0	1*	1*	1*	1*	0	0	0	1*	0	0	1*	1*	1*	1	0	0	0	0	1*	1*	1*	0
B2	1*	1	1*	1	1	1	1*	1	1*	1*	1	1*	1	1	1*	1*	1*	1*	1*	0	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*
B3	1*	1*	1	1*	1	1*	1*	1*	0	0	1*	1*	1*	1*	0	0	0	1*	0	0	1*	1	1*	1*	0	0	0	0	1*	1*	1*	0
B4	1*	1*	1*	1	1	1*	1*	1*	1*	1	1	1	1*	1*	0	0	0	1*	1*	0	1*	1*	1*	1*	0	0	0	0	1*	1*	1*	1*
B5	1*	1*	1*	1*	1	1*	1*	1*	0	0	1	1*	1*	1*	0	0	0	1*	0	0	1*	1*	1*	1*	0	0	0	0	1*	1*	1*	0
B6	1	1*	1*	1	1	1	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	0	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*
B7	1*	1*	1*	1	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	0	1	1*	1*	1*	1*	1*	1*	1*	1*	1	1	1
B8	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1	1*	1	1*	1	1	1	1*	1*	0	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*
B9	1	1	1	1	1	1	1	1	1	1	1*	1	1	1*	1	1	1	1	1	0	1*	1*	1*	1*	1	1	1*	1	1	1*	1*	1*
B10	1	1	1*	1	1*	1*	1*	1	1	1	1*	1	1*	1	1*	1*	1*	1	1	0	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*
B11	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1	1*	1	1*	1*	1*	1*	1	1*	0	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*
B12	1	1*	1*	1	1	1*	1*	1*	1*	1*	1	1	1	1	1*	1*	1*	1	1	0	1	1*	1	1	1*	1*	1*	1*	1	1	1*	1*
B13	1	1*	1*	1	1	1*	1*	1	1*	1*	1	1*	1	1	1*	1*	1*	1*	1*	0	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*
B14	1	1*	1*	1	1	1*	1*	1	1*	1*	1	1	1	1	1*	1*	1*	1*	1*	0	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*
B15	1*	1	1*	1	1	1*	1*	1	1*	1*	1	1	1	1	1	1*	1*	1*	1*	0	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*
B16	1	1	1	1	1	1	1	1	1*	1*	1	1	1	1	1	1	1	1	1	0	1*	1	1*	1*	1	1*	1*	1*	1	1*	1	1*
B17	1	1	1	1	1	1	1*	1	1*	1*	1	1	1	1	1	1*	1	1	1	0	1	1	1*	1*	1	1	1*	1*	1*	1*	1*	1*
B18	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1	1*	0	1	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*
B19	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1	0	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1
B20	1	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*
B21	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	0	1	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1*
B22	1	1	1	1	1	1*	1*	1*	1*	1*	1	1	1	1	1*	1*	1*	1*	1*	0	1*	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1*
B23	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	0	1*	1*	1	1	1*	1*	1*	1*	1*	1	1*	1*
B24	1	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	0	1*	1*	1*	1	1*	1*	1*	1*	1*	1	1*	1*
B25	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	0	1	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*
B26	1	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1	1	1*	1*	1*	1	1*	1*	0	1*	1*	1*	1*	1	1	1	1*	1*	1	1*	1*
B27	1	1	1	1*	1*	1	1*	1	1	1	1	1	1*	1	1	1	1	1	1	0	1*	1	1*	1*	1	1	1	1	1*	1	1*	1*
B28	1	1	1	1	1	1	1	1	1*	1*	1	1	1	1	1*	1	1	1*	1	0	1*	1	1	1*	1*	1	1*	1	1*	1*	1*	1*
B29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
B30	1*	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	0	1*	1	1	1	1*	1*	1*	1*	1*	1	1	1*
B31	1*	1*	1*	1*	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	0	1*	1*	1*	1*	1*	1*	1*	1*	1	1*	1	1*
B32	1*	1*	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	0	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1	1

Figure 5.2: Final Reachability Matrix

For example, in the figure 5.1, B1 affects B5 and B5 impacts B11 the rule of transitive relationships dictates that B1 also influences barrier B11. The relationship in position (B1, B11) that is initially denoted as ”0” in the reachability matrix, now has been replaced by ”1*” in Figure 5.2.

5.1.4. Level Partition

In this step, the updated reachability matrix is utilized to derive the reachability set, antecedent set, and intersection set, thereby categorizing the causes of barriers into distinct levels. The following is the result of the first iteration of the level partition for the causes of barriers in battery swap technology diffusion in Indonesia.

The reachability set for cause of barrier ’i’ indicates which causes of barriers are impacted by causes of barrier ’i’, while the antecedent set for cause of barrier ’i’ identifies causes of barriers that influence it. The intersection set represents the common elements between these two sets. A cause of barrier is assigned a level when its reachability and intersection sets align. In Figure 5.3, as the Cause of Barrier number 29 (B29) is the only element that has a common value in its reachability set and intersection set, B29 is assigned in Level 1 of partition. After

Cause of Barrier No. #	Reachability Set	Antacedent Set	Intersection Set	Level
B1	1,2,3,4,5,6,7,8,11,12,13,14,18,21,22,23,24,29,30,31	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,11,12,13,14,18,21,22,23,24,30,31	
B2	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B3	1,2,3,4,5,6,7,8,11,12,13,14,18,21,22,23,24,29,30,31	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,11,12,13,14,18,21,22,23,24,30,31	
B4	1,2,3,4,5,6,7,8,9,10,11,12,13,14,18,19,21,22,23,24,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,18,19,21,22,23,24,30,31,32	
B5	1,2,3,4,5,6,7,8,11,12,13,14,18,21,22,23,24,29,30,31	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,11,12,13,14,18,21,22,23,24,30,31	
B6	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B7	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B8	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B9	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B10	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B11	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B12	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B13	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B14	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B15	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B18	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B19	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B20	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,29,30,31,32	20	20	
B21	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B22	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B23	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B24	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B25	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B26	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B27	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B28	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B29	29	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,29,30,31,32	29	1st
B30	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B31	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,221,22,23,24,25,26,27,28,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	

Figure 5.3: First Iteration for Level Partitioning of Causes of Barriers in Indonesia

the first assignment of the level, B29 is removed from the reachability set for all causes of barriers (B1-B32).

Figure 5.4 below shows the second iteration of level partitioning.

Cause of Barrier No. #	Reachability Set	Antacedent Set	Intersection Set	Level
B1	1,2,3,4,5,6,7,8,11,12,13,14,18,21,22,23,24,30,31	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,11,12,13,14,18,21,22,23,24,30,31	2nd
B2	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B3	1,2,3,4,5,6,7,8,11,12,13,14,18,21,22,23,24,30,31	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,11,12,13,14,18,21,22,23,24,30,31	2nd
B4	1,2,3,4,5,6,7,8,9,10,11,12,13,14,18,19,21,22,23,24,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,18,19,21,22,23,24,30,31,32	2nd
B5	1,2,3,4,5,6,7,8,11,12,13,14,18,21,22,23,24,30,31	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,11,12,13,14,18,21,22,23,24,30,31	2nd
B6	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B7	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B8	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B9	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B10	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B11	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B12	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B13	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B14	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B15	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B18	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B19	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B20	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	20	20	
B21	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B22	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B23	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B24	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B25	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B26	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B27	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B28	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	2,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	
B29				
B30	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B31	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2nd
B32	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32	2,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,32	

Figure 5.4: Second Iteration for Level Partitioning of Causes of Barriers in Indonesia

In the second iteration, after removing all the barriers that have been assigned in the previous iteration from the reachability set, the same procedure is repeated. Each cause of barriers is checked to determine whether its reachability set is similar to its intersection set. Thus, there are 19 barriers assigned in level two of the partition: B1, B2, B3, B4, B5, B6, B7, B8, B11, B12, B13, B14, B18, B21, B22, B23, B24, B30, B31.

Figure 5.5 below shows the third iteration of level partitioning.

In the third iteration, after removing all the barriers that have been assigned in the previous iteration from the reachability set (B1, B2, B3, B4, B5, B6, B7, B8, B11, B12, B13, B14, B18, B21, B22, B23, B24, B30, B31), the same procedure is repeated. Each cause of barriers is checked to determine whether its reachability set is similar to its intersection set. Thus, there are 11 causes of barriers assigned in the level three of the partition: B9, B10, B15, B16, B17, B19, B25, B26, B27, B28, B32.

Finally, by removing all the causes of barriers that have been assigned in the third iteration, the only remaining

Cause of Barrier No. #	Reachability Set	Antacedent Set	Intersection Set	Level
B1				
B2				
B3				
B4				
B5				
B6				
B7				
B8				
B9	9,10,15,16,17,19,25,26,27,28,32	9,10,15,16,17,19,20,25,26,27,28,32	9,10,15,16,17,19,25,26,27,28,32	3^{rd}
B10	9,10,15,16,17,19,25,26,27,28,32	9,10,15,16,17,19,20,25,26,27,28,32	9,10,15,16,17,19,25,26,27,28,32	3^{rd}
B11				
B12				
B13				
B14				
B15	9,10,15,16,17,19,25,26,27,28,32	9,10,15,16,17,19,20,25,26,27,28,32	9,10,15,16,17,19,25,26,27,28,32	3^{rd}
B16	9,10,15,16,17,19,25,26,27,28,32	9,10,15,16,17,19,20,25,26,27,28,32	9,10,15,16,17,19,25,26,27,28,32	3^{rd}
B17	9,10,15,16,17,19,25,26,27,28,32	9,10,15,16,17,19,20,25,26,27,28,32	9,10,15,16,17,19,25,26,27,28,32	3^{rd}
B18				
B19	9,10,15,16,17,19,25,26,27,28,32	9,10,15,16,17,19,20,25,26,27,28,32	9,10,15,16,17,19,25,26,27,28,32	3^{rd}
B20	9,10,15,16,17,19,20,25,26,27,28,32	20	20	
B21				
B22				
B23				
B24				
B25	9,10,15,16,17,19,25,26,27,28,32	9,10,15,16,17,19,20,25,26,27,28,32	9,10,15,16,17,19,25,26,27,28,32	3^{rd}
B26	9,10,15,16,17,19,25,26,27,28,32	9,10,15,16,17,19,20,25,26,27,28,32	9,10,15,16,17,19,25,26,27,28,32	3^{rd}
B27	9,10,15,16,17,19,25,26,27,28,32	9,10,15,16,17,19,20,25,26,27,28,32	9,10,15,16,17,19,25,26,27,28,32	3^{rd}
B28	9,10,15,16,17,19,25,26,27,28,32	9,10,15,16,17,19,20,25,26,27,28,32	9,10,15,16,17,19,25,26,27,28,32	3^{rd}
B29				
B30				
B31				
B32	9,10,15,16,17,19,25,26,27,28,32	9,10,15,16,17,19,20,25,26,27,28,32	9,10,15,16,17,19,25,26,27,28,32	3^{rd}

Figure 5.5: Third Iteration for Level Partitioning of Causes of Barriers in Indonesia

cause of a barrier is B20. B20 is assigned as the final level of the hierarchy, considered the most important cause of barriers compared to the levels below it

Table 5.2: Causes of Barriers to the Diffusion of the Battery Swap System in Indonesia

Level of Hierarchy (ISM)	B#	Causes of Barriers
1st	B29	Indonesia's loss in the WTO dispute with the EU over nickel export bans
2nd	B1	Delayed operational commencement of recycling and/or other parts of the end-to-end supply chain facilities
	B2	Lack of standardization and interoperability (hardware, software, and protection mechanism)
	B3	The absence of alignment between SPKLU and SPBKLU placement
	B4	Investor hesitance (in EV+Battery swap market) due to lack of standardization
	B5	Capital intensive for new entrants
	B6	Regulatory and Systemic Gaps in Battery Recycling and Traceability
	B7	"Varying Levels of Awareness and Understanding (Impact of Diverse Backgrounds)"
	B8	Multiple, Non-Standard Battery Racks in a single place due to weak monitoring from government
	B11	The potential of financial challenges at the operational Level (Due to the absence of fixed standardization)
	B12	Supply Chain Bottlenecks due to the absence of several infrastructures
	B13	Market fragmentation due to the existence of multiple consortiums with diverse specifications
	B14	The absence of open protocol and traceability of assets (batteries)
	B18	Unnecessary strict standards in SRUT for converted motorcycle
	B21	Market dominance of ICE Motorcycles
	B22	Lack of collaboration among e-motorcycle and battery swap consortiums
	B23	High maintenance costs for E-motorcycles compared to the conventional one
	B24	Limited availability of spare parts after-sales
	B30	Slow Shift in Consumer Motivation on buying e-motorcycle within 5 years
	B31	Lack of a comprehensive understanding of the benefits and functionalities of electric motorcycles compared to fossil fuel-powered ones
3rd	B9	Lack of experience in the body of government due to the technology novelty
	B10	Lack of talents with a specific skill-set available in the job market
	B15	Lack of government interference in the unity of consortiums
	B16	Complex and Unclear Regulatory Landscape, involving 18 ministries and Institutions
	B17	Lack of coordinated regulatory approach (push strategy without pull mechanism)
	B19	The time-consuming process to change vehicle registration from conventional to electric, deterring potential users
	B25	The absence of regulation limiting the purchase of ICE motorcycle
	B26	Conflicting Regulatory Stances between ministries
	B27	Heavy workload in several ministries
	B28	Disparities in performance among ministries which impact policy coherence
	B32	Reliance on Specific Information Sources of the benefit of EV, leading to information gap in certain demographics
4th (Most Important)	B20	The uncertainties surrounding the Indonesia presidential election

5.1.5. ISM Result

Utilizing the results from the level partitioning step, the digraph of hierarchy among the causes of barriers can now be constructed. The figure below illustrates the interpretative structural modelling of the causes of barriers within the battery swap system diffusion attempt in Indonesia. The final result of ISM provides a structured framework that visually represents the hierarchy of barriers, from the most foundational (which affect others but are less influenced by them) to the most influenced (which are affected by many others but have little influence in return). This hierarchical structure is derived through a matrix of interrelations, which is analyzed to determine the levels of barriers in terms of their driving power and dependence power together.

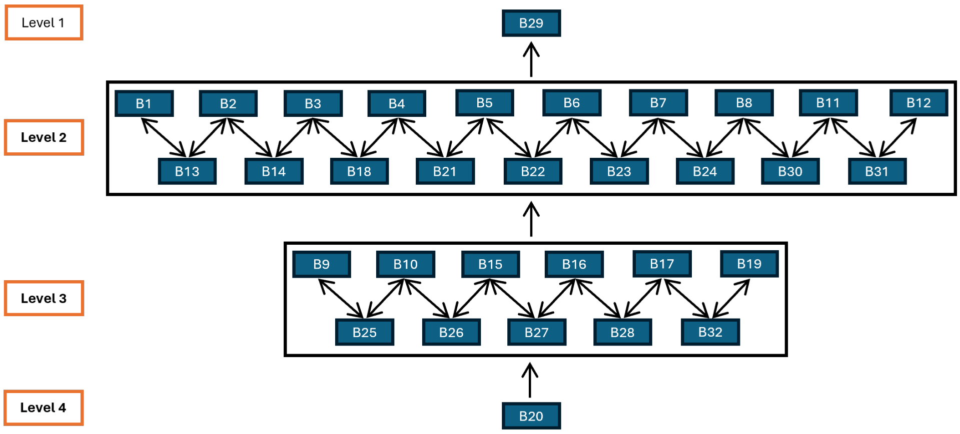

Figure 5.6: Hierarchical Digraph of Causes of Barriers

In this hierarchy, Level 4 (located at the lowest tier of the hierarchical graph) represents the most critical cause of barriers to be addressed. Solving this primary barrier is crucial to alleviate the challenges posed by the lower levels of causes (Level 3 and beyond). Considering that elements at the same level cannot have one-way arrows, as they mutually influence each other, it was essential to eliminate them at the same time. In addition, the indirect relation represented by the transitivity rule is removed from the final result.

Thus, ISM results reveal both the priority levels of various causes of barriers, based on their driving power and dependence and the directly complex web of relationships between these barriers. This dual insight is crucial for strategic planning and decision-making, as it enables stakeholders to identify not only the key barriers that need to be addressed but also how tackling one barrier might influence others within the system. Ultimately, the interpretative structural modelling reaches its final form by replacing the terms 'B1-B32' with the names of each cause of barriers. This is illustrated in Figure 5.7.

Based on Figure 5.7, at the core of the hierarchy lies Level 4, B20 is identified as the most critical causes of barriers which highlight the uncertainties surrounding the Indonesia presidential election. This barrier signifies significant political uncertainties that can potentially disrupt policy formation and regulatory initiatives crucial for battery swap technology for e-motorcycle adoption. Notably, this challenge is particularly pronounced during the time window of March to October 2024, which spans the period between the decision of the elected president by the Mahkamah Konstitusi (Constitutional Court) and the presidential inauguration.

In Level 3, the government's performance issues dominate, including lack of experience (B9), regulatory complexity (B16), and conflicting stances between ministries (B26). This stems from the fragmentation caused by the large coalition of parties during the 2019 presidential election which affected policy effectiveness according to

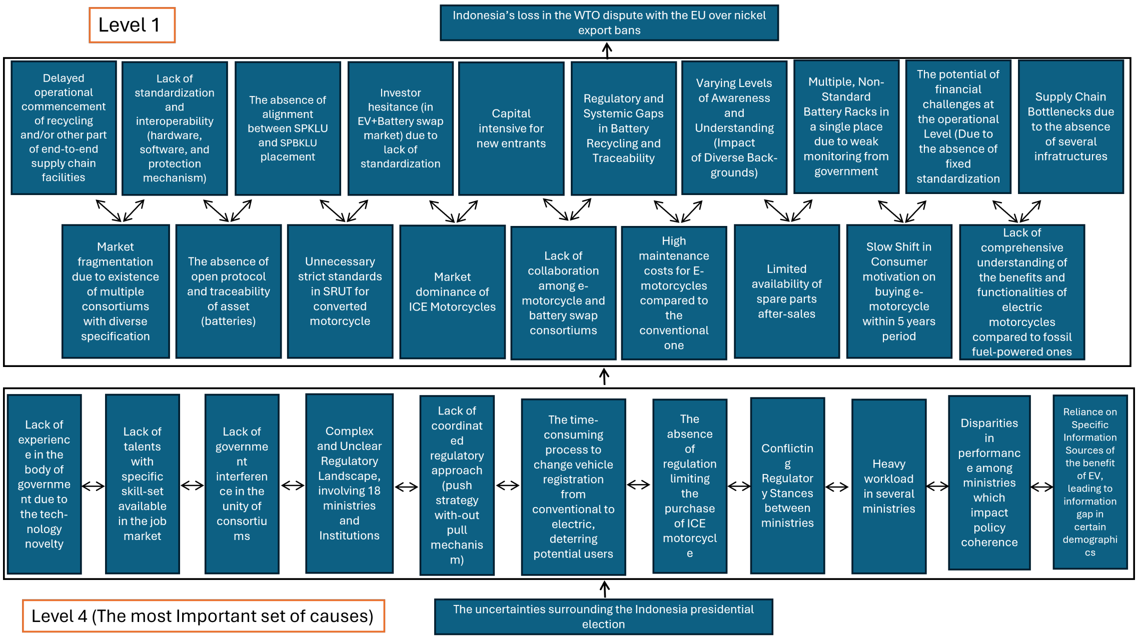

Figure 5.7: Hierarchical Relationship Between Causes of Barriers of Battery Swap Technology Diffusion in Indonesia

Interviewee 11. Preliminary vote counts for the 2024 elections suggest a recurrence of these challenges.

Also in Level 3, within the context of providing charging stations, the reflection of the primary tasks of ministries is reflected in the Directorates-General under the ministries. For example, the Ministry of Energy and Mineral Resources (ESDM), responsible for managing charging stations, lacks a specific directorate-general handling EVs (Dirjen-EBTKE, 2024). Instead, it falls under the Directorate-General of New and Renewable Energy and Energy Conservation (EBTKE), which focuses more on managing energy resources, energy conversion and conservation. This mismatch of tasks within directorates causes government performance issues. These issues lead to unclear standards and complex interoperability problems in Level 2 of the barrier hierarchy, eventually affecting Level 1.

Furthermore, regarding the two most prioritized levels (Levels 3 and 4) which comprise the highest priority causes of barriers, intervention from businesses or consortia is feasible. According to **interviewee 11**, the most vulnerable time for intervention regarding policy formation by the elected president is between March and October, following the announcement from the constitutional court until the inauguration period (March-October 2024). This window provides an opportunity for businesses or consortia to engage with the government and potentially influence policy decisions related to barriers in Levels 3 and 4 of the hierarchy.

This vulnerable period coincides with the timeline of the tradition of forming transition teams (initiated during the administration of President Susilo Bambang Yudhoyono) up to the current administration (Taufiqurrohman, 2014). The role of these teams includes preparing matters related to the readiness of institutions under the president and vice president (Siregar, 2014). They also prepare for the implementation of the vision and mission as presented during the previous campaign. During this period, issues related to the challenges faced by businesses involved in battery swaps can begin to be discussed according to the **Interviewee 11**. This discussion can occur through channels such as the Indonesian Chamber of Commerce (which has close ties with the highest levels of government in Indonesia) and at Level 3 through the designated Directorate-General. This engagement allows for the concerns of battery swap stakeholders to be brought to the attention of policymakers, potentially influencing decisions at Levels 3 and 4 of the hierarchy.

Addressing the causes of barriers identified in Level 3, particularly those related to government performance, can serve as a strategic precursor to alleviating the challenges outlined in Level 2, which can lead to more improved policy implementation in the e-motorcycle market and circularity in the process (B1, B3, B12, B18, B22). Additionally, resolving issues in level 3, such as the lack of government interference in consortium unity (B15) and the time-consuming process of changing vehicle registration (B19) can create a more conducive environment for collaboration in level 2(B13, B14, B22), streamline administrative procedures (B18) and reducing barriers to market entry (B5, and B11). Moreover, addressing regulatory complexities (B16, B17, B26) and disparities in performance among ministries (B27, B28) can lead to clearer and more coordinated regulatory frameworks(B6), fostering investor confidence (B4) and promoting industry growth(B12), resource efficiency(B8), and ICE motorcycle market dominances(B21), and E-motorcycle after-sales services(B24) and its affordability(B23). Furthermore, addressing information gaps (B32) can ensure that customers have access to accurate and comprehensive information (customer participation (Awareness (B7), thorough understanding(B31) and motivation(B30)).

The collective causes of barriers outlined across Levels 4, 3, and 2 obstacles ultimately affect Indonesia's capacity to utilize its nickel resources to its advantage. This led to Indonesia's loss in the WTO dispute with the EU over nickel export bans (B29). Consequently, the loss in the WTO dispute may result in limitations on Indonesia's authority to enforce export bans on nickel. This limitation could impede Indonesia's ability to regulate its national nickel market effectively as well as attract more overseas investors for related infrastructures (Strangio, 2022), crucial for supporting the development of battery swap and e-motorcycle ecosystem in the further step. Moreover, it could potentially diminish revenue generated from nickel exports, impacting the nation's overall income and economic stability.

5.2. Chapter's Conclusion (Answer for SQ5)

The successful adoption of battery swap technology and e-motorcycles in Indonesia faces various challenges across different levels of governance and industry. Understanding these barriers' hierarchy is crucial for stakeholders aiming to develop targeted strategies to overcome them. This analysis explores the causes of barriers at each level of the hierarchy, shedding light on the complexities hindering the progress of e-mobility initiatives in the Indonesian context.

Level 4: At Level 4, the most critical barrier arises from significant political uncertainties surrounding the Indonesia presidential election. Particularly pronounced between March and October 2024, these uncertainties have the potential to disrupt policy formation and regulatory initiatives crucial for the adoption of battery swap technology for e-motorcycles.

Level 3: Moving down the hierarchy, the government's performance issues take center stage at Level 3. These issues, including lack of experience, regulatory complexity, and conflicting stances between ministries, are worsened by the political interests fragmentation caused by the large coalition of parties during the 2019 presidential election. Such challenges impede policy effectiveness and hinder progress in e-motorcycle adoption.

Level 2: At Level 2, barriers emerge from operational challenges, standardization issues, regulatory complexities, and customer awareness gaps. The mismatch of tasks within directorates under ministries leads to unclear standards and complex interoperability problems, ultimately affecting policy implementation in the e-motorcycle market and hindering its growth potential.

The combined factors contributing to barriers across Levels 4, 3, and 2 have significant implications for Indonesia's utilization of its nickel resources. These challenges have contributed to Indonesia's defeat in the WTO dispute with the EU over nickel export bans (B29) in level 1 of the hierarchy. As a result of this loss, Indonesia may face constraints on its ability to enforce export bans on nickel, potentially hampering its capacity to regulate the national nickel market effectively. Furthermore, this limitation could deter overseas investors from investing in related infrastructures, which are crucial for supporting the development of the battery swap and e-motorcycle ecosystem. Additionally, it may lead to a reduction in revenue generated from nickel exports, impacting the nation's overall income and economic stability.

6

Derivation of Strategies

This chapter is dedicated to answering the Main Research Question (MQ): **What prioritized strategies can be implemented to overcome the identified causes of barriers and facilitate the successful large-scale diffusion of E-Motorcycle Battery Swap systems in Indonesia?** The strategy is derived from the step-by-step exploration of the research questions, from SQ1 to SQ5, gradually acquiring a comprehensive understanding of the factors hindering the development of the current ecosystem of e-motorcycle battery swaps in Indonesia. By systematically examining the causes of barriers at different hierarchical levels and understanding their interrelation, this chapter aims to provide targeted strategies to address each layer of challenges effectively.

As shown in Figure 5.7 in the previous chapter, Level 4 (located at the lowest tier of the hierarchical graph) represents the most critical cause of barriers to be addressed. Solving this primary barrier is crucial to alleviate the challenges posed by the lower levels of causes (Level 3 and beyond). Considering that elements at the same level cannot have one-way arrows, as they mutually influence each other, it was essential to eliminate them at the same time. This context highlights the interrelation of identified factors from the circular TIS-ISM framework within the hierarchy. It underscores the importance of addressing the root cause to overcome barriers within the battery swap ecosystem in Indonesia effectively.

6.1. Strategies On Each Level of Hierarchy

6.1.1. Strategy for Level 4 of Hierarchy

First of all, it is essential to recognize the absolute authority of the president in Indonesia to appoint ministry officials and directorate general heads of certain ministries (echelon one official). This authority extends even to organizations that were previously categorized as "agencies," which can be elevated to ministry status, as exemplified by the transformation of the Investment Coordinating Board (BKPM) from an agency under the president to a standalone Ministry of Investment and National Land Agency (BPN) evolving into the Ministry of Agrarian Affairs. Adding further context, agencies typically lack the autonomy to develop their own budget and work programs, unlike ministries.

Based on **Interviewee 11**, Strategic intervention from Companies into identified causes of barriers in level 4, the uncertainties surrounding the Indonesia Presidential Election (B20), is considered feasible through the engagement of businesses or consortia. Interviewee 11 highlighted the period between March and October, coinciding with the presidential transition phase. This period, vulnerable to external influence, presents a window for businesses or consortia to engage with the government, potentially impacting policy decisions related to barriers within Level 4 of the hierarchy.

Moreover, this vulnerable period aligns with the traditional timeline of forming transition teams, a practice initiated during the administration of President Susilo Bambang Yudhoyono and continued through subsequent administrations. These teams play a pivotal role in preparing matters related to the readiness of institutions under the president and vice president, as well as facilitating the implementation of the administration's vision and mission. During this phase, discussions about the challenges encountered by businesses (represented by the associations or consortium representatives) involved in battery swap operations can commence, facilitated through channels such as the Indonesian Chamber of Commerce and Industry (KADIN), known for its close ties with high-level government officials in Indonesia. This intervention can take the form of appointing consulting firms to address potential issues faced by existing consortia of companies. However, if the intervention does not yield the desired outcomes, stakeholders may opt for a "wait and see" approach, preferring to withhold the incoming program or strategy deployment until there is more clarity or support from the government. This cautious stance reflects a prudent strategy in uncertain political and regulatory environments.

Relevancy of The Strategy In Literature with The Ortt's Ten Niches Strategy

It appears that none of the ten niche strategies proposed are directly suitable for addressing the unique challenges posed by political uncertainty at this level. However, a new strategy emerges from the original content: the "Strategic Intervention through Presidential Transition Engagement Strategy." This strategy revolves around leveraging the transitional phase during the Indonesia Presidential Election (B20) to engage with the government and influence policy decisions related to barriers within Level 4 of the hierarchy. It involves strategic intervention by businesses or consortia to navigate the uncertainties surrounding the political transition period.

Driver Influence for Strategy Effectiveness

The burgeoning market potential for e-motorcycles in Indonesia, with 82% of households owning a motorcycle (IESR, 2023), presents a compelling opportunity to drive the effectiveness of the proposed strategy. Providers specializing in battery swap e-motorcycles hold a significant position in the diffusion of battery swap technology in Indonesia which contributes to the growth of the units that exist on the road, reaching around 100.000 units by January of 2023 (MEMR, 2023c). Consequently, they possess a rightful position to provide feedback and input to the government regarding the impact of current regulations on the conduciveness of expanding their business, especially for the standardization uncertainty. This underscores the relevance and timeliness of the proposed strategy, positioning it as a strategic enabler for industry growth and innovation within the battery swap e-motorcycle sector.

6.1.2. Strategy for Level 3 of Hierarchy

Level 3 of the hierarchy consists of 11 identified causes of barriers, with 9 of them related to the performance of the government (B9, B15, B16, B17, B19, B25, B26, B27, and B28). Additionally, one barrier is related to the availability of talents with specific skill sets in the job market (B10). In contrast, another is related to customer behaviour that heavily relies on particular information sources regarding the benefits of electric vehicles (B32). This reliance leads to an information gap within certain demographics.

In terms of deriving strategies to alleviate the causes of barriers in level 3, particularly the nine related to the performance of the government, intervention can only occur after ministry officials and directorate general heads of certain ministries (echelon 1 official) are appointed and active. Address such issues requires the formation of a unified consortium—a representative entity capable of covering the entire interests of battery manufacturers and e-motorcycle and battery swap providers. This mirrors the approach outlined in the strategy for alleviating causes in Level 4, which addresses potential future problems arising from the lack of interoperability for market expansion and other issues related to fostering end-to-end circularity in Indonesia. However, the focal point for intervention is now selected at the governmental level, strategically translating feedback from stakeholders into the strategic programs of ministries. The intervention of consortiums typically can be done at the directorate general level within ministries, according to Interviewee 11. For example, one might observe various activities organized by ministries, such as the annual renewable energy exhibition, EBTKE ConEx. During such events, the directorate general gathers stakeholders from the entire renewable energy industry, forming the consortium. It encompasses both internal and external stakeholders. The success or failure of addressing issues depends on the prevailing actions and objectives pursued within this framework.

In addressing the information gap caused by heavy reliance on specific sources, involving social media influencers to boost political will as well as potential customers' willingness to purchase due to a product's benefits is essential, as noted in the Paloma Circle discussion note shared by Interviewee 9. Social media influencers can be selected based on the demographic age of their viewers to ensure targeted and impactful communication. This inclusive approach broadens the reach of initiatives and enhances their effectiveness in addressing information gaps among diverse demographic groups. The goal of involving social media in this context is to boost awareness related to the benefits of shifting to the e-motorcycle and battery swap ecosystem

This strategy aligns with insights from Interviewee 13, who noted that the followers and viewers of social media content on BRIN official pages, such as Instagram, are relatively few. Involving social media influencers does not mean solely relying on them; rather, it entails collaborating with them alongside experts within their respective agendas. For instance, engaging social media content creators who review vehicles, such as Fitra Eri with 2.9 million subscribers (Eri, 2024), Ridwan Hanif with 3.1 million subscribers (Hanif, 2024), and Moto-Mobi with 1.5 Million subscribers (Motomobi, 2024), who have extensive experience in reviewing internal combustion engine vehicles but limited exposure to electric vehicles, can provide a fresh perspective on benefits of battery swap specifically and EVs ecosystem generally, rather than focusing solely on the technology and lifestyle. Additionally, tapping into trending YouTube podcasts such as "Close-the-Door" by Deddy Corbuzier with 22 million subscribers (Corbuzier, 2024), which have a large following, can further amplify the reach and impact of the messages regarding sustainable transportation solutions. Expanding on this, it is worth noting that social media influencers within the family vlog sphere such as Rafi Ahmad with 26 million subscribers (R. Ahmad, 2024) and those catering to youngsters such as Ricis official which has 44 million subscribers (Official, 2024), may wield significant influence over other segments of the population. Their ability to present content in a relatable and engaging manner can make them valuable partners in disseminating information about sustainable transportation solutions to a wider audience, including families and younger demographics. Collaborating with influencers from these diverse segments can help ensure that the message reaches various age groups and household structures, maximizing the impact of the communication strategy.

In terms of the lack of availability of workforce in the job market, the application of green skills in enterprises requires the support of all stakeholders—the industries, the government, and the community at large—as only in this way can the ‘silo effects’ separating government agencies, the business sector, civil society, and academia be overcome (Talavera, 2022). The lack of availability of workforce in the job market can be addressed by collaborating with the Indonesia Chamber of Commerce and Industry (KADIN) and its sub-national level (KADINDA) to play an active role in the Technical and Vocational Educational Training (TVET) ecosystem, especially in promoting collaborative dual TVET ”In-Company Trainer” and investing in formal educational training.

Additionally, talent acquisition can also be achieved through collaboration with the Indonesia Endowment Fund for Education (LPDP) for supply needs from master’s degree graduates with the experience of apprenticeship/internship abroad. Upon completion of the program, graduates are contracted to work with the collaborating company. Furthermore, collaboration with Markija for workers at the vocational level and sociopreneurship in the education sector can also address talent shortages. The advantage of this program is that selected students undergo a 2-year internship with standard European allowances and facilities at no cost. These programs align with the Merdeka Belajar Kampus Merdeka (MBKM) program initiated by the Ministry of Education and Culture, whereby students earn academic credits during their internship in Europe (Suteja, 2023).

Relevancy of The Strategy In Literature with The Ortt's Ten Niches Strategy

Among the ten niche strategies, the only one relevant to the proposed strategies is the Educate niche strategy. Two proposed strategies align with this niche strategy: the dual TVET program organized by KADIN, which focuses on transferring knowledge to suppliers, and the collaboration with social media influencers alongside experts within their respective agendas. These efforts can significantly influence various segments of the population and also impact political will which leads to general consensus enhancement.

Besides the strategy that aligns with Ortt’s ten niches strategy, a new proposed strategy is introduced: the Collaborative Regulatory Advocacy Strategy. This strategy focuses on one of the most crucial issues within the market dynamics: uncertain standardization. It involves forming a coalition of industry stakeholders, including battery manufacturers, e-motorcycle companies, and battery swap providers, to present a unified voice in regulatory discussions. In the Indonesian context, this coordination can be done between the directorate general of ministries and a unified consortium with the help of the Indonesia Chamber of Commerce (KADIN). This coalition will work closely with government agencies to advocate for favourable policies and regulations that support the growth and standardization of the battery swap ecosystem. Regular workshops and consultations between the coalition and government officials will be organized to discuss policy needs, share industry insights, and co-develop regulatory frameworks that address the specific barriers faced by the industry.

Driver Influence for Strategy Effectiveness

Some key players exhibit robust upskilling strategies during talent scarcity in the job market according to the **Interviewee 8**. This driver aligns with the proposed strategy of implementing dual TVET programs. More mature companies can share their experiences and lessons learned to accelerate the growth of others. Additionally, one of the identified drivers in terms of resilience is stakeholders' capacity to adapt to evolving standards (Aqidawati et al., 2022). This foundation can support the proposed Collaborative Regulatory Advocacy Strategy by providing a flexible and knowledgeable base of stakeholders who are prepared to engage in regulatory discussions.

6.1.3. Strategy for Level 2 of Hierarchy

In Level 2 of the hierarchy, there are 19 identified causes of barriers that can be categorized into several clusters, each representing distinct challenges slowing down the progress of e-motorcycle adoption and battery swap infrastructure development. These clusters include circular supply chain issues, operational issues, Standardization, Collaboration and Regulatory Issues, customer awareness issues, as well as market and industry dynamics. Some causes may present obstacles that companies cannot directly tackle on their own. These issues, such as delays in starting recycling operations (B1), Regulatory and Systemic Gaps in Battery Recycling and Traceability (B6), Market dominance of ICE Motorcycles (B21), and bottlenecks in the supply chain due to infrastructure gaps (B12), require government intervention.

Concerning Operational Challenges, the high maintenance expenses for E-motorcycles (B23) compared to conventional models and the scarcity of spare parts after-sales (B24) cause significant problems. To overcome these challenges, collaborating with Internal Combustion Engine (ICE)-based motorcycle companies, as recommended by **Interviewee 9**, should be a promising strategy. Partnering with established ICE manufacturers can tap into their maintenance expertise and spare parts distribution networks, potentially lowering costs and improving access to components for electric motorcycles. This cooperative effort has the potential to streamline maintenance processes and enhance the overall user experience, which further boosts the acceptance of the battery swap ecosystem.

In terms of Standardization, Collaboration, and Regulatory Issues, several challenges have been identified within the e-motorcycle and battery swap market. These include the lack of standardization and interoperability across hardware, software, and protection mechanisms (B2), Market fragmentation due to the existence of multiple consortia with diverse specifications (B13), The potential for financial challenges at the operational Level due to the absence of fixed standardization (B11), as well as issues such as investor hesitance due to regulatory gaps (B4) and the absence of open protocols for traceability (B14). Additionally, the lack of collaboration among e-motorcycle and battery swap consortia (B22) emphasizes these challenges.

To address these issues, companies can initiate collaborations among providers with software interoperability firms already operating in Indonesia, such as TRANSISI. These collaborations could focus on software interoperability, which serves as an initial step toward broader hardware interoperability. Additionally, PLN could collaborate with software and application developers for EV users, such as ICON+, a subsidiary of PLN and a leading player in this field. Leveraging PLN's extensive customer base and the ongoing development of its super app, aligning with ICON+'s expertise could streamline the integration of EV-related services into PLN's existing platform, thus enhancing the accessibility and convenience of EV adoption for millions of PLN customers.

Adding further context, **Interviewee 13** highlighted the early phase of the transition solution due to the application of standardization, which involves standardizing plug-and-socket systems and EVCC (Electric Vehicle Charging Controllers) without standardizing batteries, thus enabling motorcycle manufacturers to avoid the need for battery modifications and reducing the cost implications of standardization. This solution also acts as an enabler for serving battery charging stations (SPKLU) as a complementary part of the overall charging system alongside with the unevenly distributed battery swap stations (SPBKLU). **Interviewee 13** also emphasizes the establishment of a unified consortium that adheres to the specifications of published standards in the development of new e-motorcycle products. New entrants or smaller-sized companies could also adopt a ”wait and see” strategy regarding the formation of a unified consortium and the involvement of the government during the new period after the election. Alternatively, they could seek guidance from larger firms with significant market influence to develop market specifications based on their standards. Moreover, merger solutions or collaborations with established EV providers for new entrants of battery swap players can also be considered to reduce capital costs. Of course, any such collaboration should adhere to the specifications that are widely accepted in the market currently. If there is no probability of unifying the consortium and letting the natural selection process occur, this approach ensures alignment with prevailing industry standards while also potentially reducing barriers to entry for new players in the battery swap market.

Furthermore, in terms of regulatory issues, conversion workshops should advocate for the removal of unnecessary strict standards in the SRUT (Standard Reference Unit Test) for converted motorcycles. Besides simplifying the content of the SRUT standard, the administrative process conducted by motorcycle owners with the police should also be expedited (less than 1 day). This is because it can hinder customers' intentions due to motorcycles being unusable for too long for other purposes (work, picking up children, and so on).

Especially for new entrants, it may be prudent to await government-led standardization efforts to ensure alignment with industry-wide regulations. Despite interoperability challenges, e-motorcycle providers should prioritize cooperation over competition, particularly concerning post-purchase user experiences. This could involve collaborating on spare part provision and maintenance services, as suggested by **Interviewee 5**.

In the context of customer awareness Challenges, issues like varying levels of awareness across diverse backgrounds (B7), the lack of understanding about the benefits of electric motorcycles compared to traditional ones (B31), and the slow shift in consumer motivation to buy e-motorcycles within five years (B30) are significant barriers. It is important to note that tackling B7, B30, and B31 can be made easier by first addressing B32, which is about the information gap caused by relying too much on specific sources (lack of source variance), as found in Level 3. By dealing with the root problem of information gaps in Level 3, helping consumers understand the benefits of e-motorcycles can be done effectively. This means strategies like using social media influencers, as suggested in Level 3, are still crucial. These influencers can help spread the word about the advantages of electric motorcycles to different groups of people. This approach aligns to overcome customer awareness Challenges by ensuring everyone has the information they need to make informed decisions.

Additionally, recent research suggests that in Eastern regions, people tend to trust and value social media influencers more than in other areas (Pradhan et al., 2023). This is because these regions have a culture that favours influencers who are endorsed by groups. Moreover, the influence of similar interests or behaviours among users in these areas plays a bigger role in how people engage with social media content. When consumers are well-informed about the benefits and functionalities of electric motorcycles through initiatives like those involving social media influencers, their motivation to transition to electric vehicles can be accelerated. Thus, by bridging the information gap and fostering greater awareness, consumer motivation to embrace e-motorcycles can be encouraged sooner.

Relevancy of The Strategy In Literature with The Ortt's Ten Niches Strategy

In the context of ORTT's ten niche strategies, the only one relevant to the proposed strategies is the Educate niche strategy. One proposed strategy aligns with this niche strategy: the collaboration with social media influencers alongside experts within their respective agendas in developing social awareness and willingness to shift into new technology to accelerate their transition to e-motorcycles.

The other four proposed strategies do not overlap with Ortt's ten niche strategies: the Collaborative Maintenance Access Strategy, the Market Observation Approach for new entrants, the Market Leader Specification Alignment strategy, and the Software, Plug, socket, and EVCC-focused standardization strategy.

Driver Influence for Strategy Effectiveness

Existing drivers supporting Educate niche strategy include the prevalent business model among major players, offering battery part rentals with e-motorcycle purchases. This strategy is also aligned with government efforts to develop ecosystems in high-readiness regions like Jakarta and Bali, and bolstered by integrated infrastructure in public areas, which will encourage future consumers if they are informed correctly.

The existing driver supporting the focused standardization strategy is that all battery swap players have almost identical business models, offering battery part rentals with their product purchases. This uniformity will likely simplify the complexity of focused standardization in software, plug, socket, and EVCC, serving as an enabler in bridging battery swap stations with battery charging stations and acting as a system buffer.

6.1.4. Strategy for Level 1 of Hierarchy

At Level 1 of the hierarchy, the sole cause of the barrier identified is Indonesia's loss in the WTO dispute with the EU over nickel export bans (B29). This outcome may lead to restrictions on Indonesia's ability to enforce nickel export bans, potentially hindering its capacity to regulate the national nickel market effectively and attract overseas investors for related infrastructures. Since this issue involves complex international legal and trade matters, it cannot be directly addressed by individual companies. Instead, it requires coordinated efforts led by the government to navigate diplomatic and legal channels to mitigate the consequences of the dispute. However, progress in addressing Level 1 barriers can be facilitated by successfully tackling barriers at lower levels of the hierarchy. By resolving issues related to standardisation, collaboration, regulatory gaps, and customer awareness, companies can contribute to building a more favourable environment for addressing Indonesia's loss in the WTO dispute. As such, addressing Level 4, 3, and 2 barriers lays a foundation for effectively addressing Level 1 challenges, ensuring a comprehensive approach to promoting sustainable transportation solutions.

6.2. Chapter's Conclusion (Answer for Main Research Question)

Specific strategies proposed to effectively tackle the identified causes of barriers at each hierarchical level are stated as follows:

- **Level 4** - Engaging businesses during the presidential transition phase can influence policy through channels like KADIN via existing consortiums or associations. If interventions do not work, stakeholders may opt to wait and see before deploying programs or strategies, reflecting a cautious approach in uncertain political and regulatory environments. While existing niche strategies may not directly address political uncertainty, the "Strategic Intervention through Presidential Transition Engagement Strategy" emerges as a novel approach. Leveraging the transitional phase during the Indonesia Presidential Election (B20), it engages with the government to influence policy decisions. Additionally, the burgeoning market potential for e-motorcycles in Indonesia underscores the relevance of the strategy. Providers of battery swap e-motorcycles play a pivotal role, possessing the ability to provide feedback to the government and drive industry growth.
- **Level 3** - The proposed strategy aims to address key challenges within the market dynamics by leveraging collaborative efforts and strategic partnerships. It aligns with Ortt's ten niche strategies, particularly focusing on education and regulatory advocacy. The strategy involves forming partnerships with various stakeholders, including battery manufacturers, e-motorcycle providers, and government agencies, to influence ministry programs and advocate for favourable policies. Additionally, it includes initiatives such as dual TVET programs and collaboration with social media influencers to effectively communicate with potential customers. These efforts are crucial for enhancing workforce skills, addressing talent scarcity, and fostering regulatory frameworks conducive to the growth of the battery swap ecosystem. The strategy is well-aligned with identified drivers for effectiveness, such as robust upskilling strategies and stakeholders' capacity to adapt to evolving standards, thereby contributing to the overall resilience and sustainability of the industry.
- **Level 2** - The strategy involves partnering with ICE-based motorcycle companies to reduce maintenance costs and improve parts availability, collaborating with software interoperability firms and standardising components like plugs, sockets, and EVCC (enabling the battery charging stations (SPKLU) as a complementary part of the overall charging system alongside with the unevenly distributed battery swap stations (SPBKLU)). Advocating for removing strict "SRUT" standards in motorcycle conversions to increase the e-motorcycle population also can act as a support for the hybrid niche strategy. For new entrants, seeking guidance from larger firms to develop market specifications or doing a "wait and see" strategy on the government manoeuvre and the emergence of a unified consortium that applies the new standard in their latest products. The only proposed strategy that overlaps with Ortt's Educate niche strategy is utilizing social media influencers to raise customer awareness. Key drivers for the effectiveness of the strategy execution include the prevalent business models among major players and government efforts to develop ecosystems in high-readiness regions, supported by integrated infrastructure and simplified standardization processes.
- **Level 1** - The strategy involves coordinated efforts led by the government to mitigate the consequences, as companies cannot directly tackle this complex international legal and trade matter. Progress in addressing barriers at lower levels can contribute to creating a more favourable environment for addressing this challenge

7

Conclusion and Recommendation

7.1. Summary of Findings

This chapter serves as a comprehensive compilation of conclusions drawn from each sub-research question's (SQ1-SQ5) answer and the main research question's (MQ) answer, which have been individually elucidated in preceding chapters. By consolidating these findings, readers will gain a brief understanding of the key insights gleaned throughout the study, facilitating a deeper comprehension of the research outcomes and their implications.

7.1.1. Answers for SQ1

In response to SQ1, **'What are the key stakeholders in the various e-motorcycle battery swap-related sectors within Indonesia, and what are their interconnections?'**, There are 7 Involved Ministries with specific roles, on 5 out of 7 produced relevant regulations based on its umbrella regulation (Presidential Regulation 79/2023). 16 existing EV manufacturers, 6 OEM e-motorcycles, 29 conversion workshops, and five battery swap providers exist in Indonesia. The top private players, namely SWAP, Volta, OYIKA, and Gogoro, dominate the market share, shaping adoption through collaborations with ride-hailing giants and third-party logistics companies. The complete diagram of stakeholders, ranging from mining industries, recycling facilities, all-round players (IBC), and customers in the second-life cycle of the battery, is depicted in Figure 3.7.

7.1.2. Answers for SQ2

In response to SQ2, **'What is the current status of government policies, incentives, and the regulatory framework in Indonesia concerning E-Motorcycle Battery Swap systems?'**, the regulatory landscape in Indonesia is shaped by the concerted efforts of various ministries. There are five key ministries actively involved in the regulation of battery swap systems for e-motorcycles, each contributing to the comprehensive framework. The initial cornerstone of this regulatory landscape was laid in 2019 through Presidential Regulation (PERPRES) No. 55, which later manifested in five sets of regulations under different ministries.

Local content requirements for Electric Vehicles (EVs) in Indonesia aim to boost indigenous production and support the domestic EV industry. Initially set at 40% in 2019, these requirements progressively increased to 60% by 2024, further rising to a significant 80% between 2026 and 2030. However, a notable revision occurred with the issuance of PERPRES 79 in 2023, extending the initial 40% target until 2026, followed by a subsequent revision to 60% between 2027-2029. The ultimate goal is to achieve an 80% TKDN target beyond 2030, with exemptions applied to converted motorcycles done by specialized workshops.

The regulatory framework for Electric Vehicles (EVs) in Indonesia includes substantial government assistance and incentives:

- Ministry of Industry's Regulation (Permenperin 21/2023) guides assistance for E2W purchases with stringent criteria, including 40% local content maintenance and restrictions on price alterations.
- The Ministry of Energy and Mineral Resources Regulation (Permen ESDM 1/2023) focuses on charging infrastructure for Battery Electric Vehicles (BEVs), including device specifications, business permits, monitoring, and sanctions.
- Regulation from the Ministry of Internal Affairs (Permendagri No. 6 of 2023) exempts all EVs from PKB and BBNKB rates to enhance ownership preference.
- incentives (Ministry of Finances) include Tax Holiday (PMK 130/2020), Tax Allowance (PMK 96/2020), and Super Tax Deduction for research and development (PMK 153/2020), aiming to encourage EV development and utilization.

7.1.3. Answers for SQ3

In addition to interpreting the state of the building blocks and their interplay with influencing conditions, this section serves as a comprehensive response to SQ3,**'What is the current state of each building blocks and influencing condition blocks in the Technical Innovation System (TIS) in terms of e-motorcycle battery swap system development in Indonesia? Which one is considered as complete, partially complete, or incomplete building blocks?'**, which delves into the examination of the status of these building blocks within Raghav's TIS framework. Drawing insights from the discoveries outlined in Section 4.1 and 4.2, it becomes evident that a majority of the building blocks and influencing conditions exist in a state of partial completeness. At the same time, some remain entirely incomplete, as depicted in Figure 7.1.

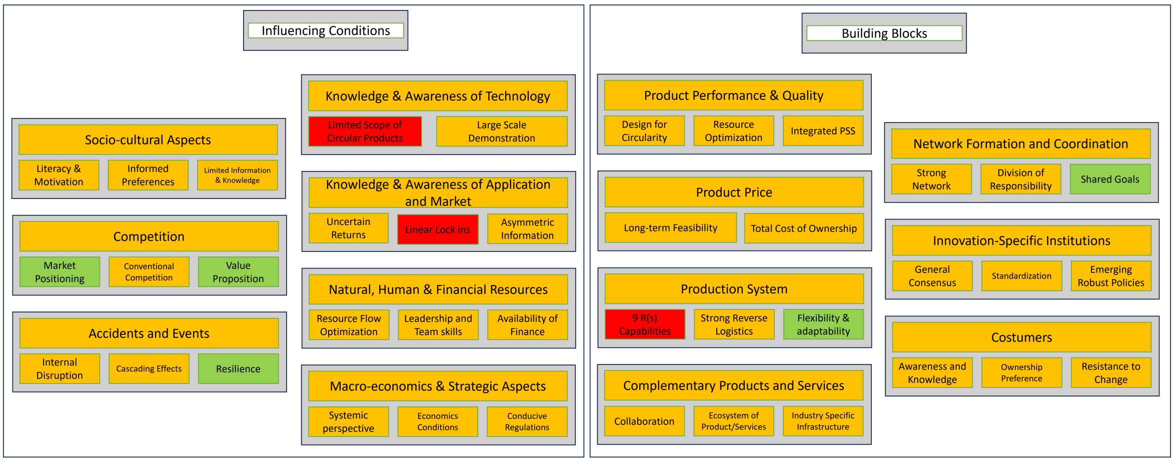

Figure 7.1: Current Status of Building Blocks and Influencing Conditions

Identified Barriers

Most of the building blocks in the sub-level remain partially complete, and one of those is totally incomplete. The recapitulation of the barriers, which are derived from the statuses of each incomplete or partially complete building block in the sub-level, is shown in the table below:

Main Building Blocks	Sub-blocks	Explanation of the incomplete/partially complete blocks
Product Performance and Quality	Design for Circularity	Unclear protocol at the business level. In the bigger scoop, only small parts of the Battery supply chain (including the recycling sector) exist commercially, and most of them exist on a small scale(SME/LAB).
	Resource Optimization	Non-Interoperable Racks as a Resource Optimization Challenge
	Integrated Product-Service Systems (PSS)	Battery renting scheme as an enabler to minimize waste, but the recycling facility is still not available
Product Price	Long Term Feasibility	Lack of Feasibility of Market Expansion due to weak standardization control
	Total Cost of Ownership	High expenses related to maintenance and after-sales support
Production System	9 R(s) Capabilities	Lack of emphasis on the '9 (R)' capabilities within the battery industry
	Strong Reverse Logistics	Weak Reverse Logistics
Complementary Products and Services	Collaboration	Uncontrolled Growth of 2WEV Consortiums with Different Specifications of the Battery Swap System
	Industry-specific infrastructure	Only small parts of the Battery supply chain (including the recycling sector) exist commercially; most of them exist on a small scale(SME/LAB).
	Ecosystem of Product/Service	The disparity in charging port ranges, Rack sizes, and voltage levels
Network Formation and Coordination	Division of Responsibility	Overlapping Responsibilities among Ministries and Challenges in Regulatory Coordination
	Strong Networks	The network between state-owned companies, overseas battery manufacturers, recycling operators, and e-motorcycle manufacturers has been established in the form of a MoU. However, certain critical components remain incomplete within the network, and some of them currently do not exist commercially.
Innovation-Specific Institution	General Consensus	Disparities among Political Views related to the Development of EVs ecosystem
	Standardization	Delayed process of standardization
	Emerging Robust Policies	Updates of Policies tend to be scattered, making it challenging to track and implement the changes effectively
	Emerging Robust Policies	Lack in comprehensive details of Policies
Customers	Awareness and Knowledge	High number of potential customers that are still unaware of the complete benefits of owning EVs
	Resistance to Change	High resistance to change due to Price sensitivity and range anxiety
	Ownership Preference	"Preference of Customers willing to buy EV if the prices given are cheaper than conventional one"

Table 7.1: List of barriers (Incomplete / partially complete building blocks)

7.1.4. Answer for SQ4

The table 7.2 effectively illustrates the dynamics within Raghav's TIS framework to answer the SQ4: '**How are identified barriers and its causes interconnected?**'. In this framework, each influencing condition that negatively affects the completeness or effectiveness of these building blocks is considered a cause of barrier. These cause of barriers are essentially negative aspects that can slow down, impede, or even prevent the successful development and implementation of a technological system. Conversely, conditions that have a positive impact on the development and completion of these building blocks are identified as drivers. This driver definition is also in line with the definition of the driver given in Raghav's report: 'Drivers can be defined as the factors or motivations that propel and stimulate the adoption and implementation of circular economy principles and practices' (Shankar, 2023). These drivers are beneficial aspects that facilitate and accelerate the progress and efficiency of the system. By categorizing these conditions into drivers and causes of barriers, the table provides a clear and structured way to understand the multifaceted factors that play a crucial role in the advancement of the e-motorcycle battery swap system in Indonesia. This distinction is vital for stakeholders to identify specific areas of improvement and to strategize effectively for overcoming challenges within the TIS framework. All identified drivers and causes of barriers are broken down in the explanation provided in the sub-chapter 4.2.

Influencing Condition (IC)	**Sub-blocks of IC**	**Aspects**	**Driver / Cause of Barrier**	**Affected Building Blocks**
Knowledge and Awareness of Technology	Limited Scope of Circular Products	Delayed operational commencement of recycling and other part of end-to-end supply chain facilities	Cause of Barrier	Resource Optimization, Complementary Products, Network Formation and Coordination
	Large Scale Demonstration	Lack of standardization and interoperability (hardware, software, and protection mechanism)	Cause of Barrier	Product Performance and Quality, Complementary Products and Services, Product Price
		The absence of alignment between SPKLU and SPBKLU placement	Cause of Barrier	Product Performance and Quality, Complementary Products and Services, Customers
		The rental basis for battery part on the purchase of e-motorcycle	Driver	Product Performance and Quality, Complementary Products and Services, Product Price, Customers
Knowledge and Awareness of Application and Market	Uncertain Return	Investor hesitance (in EV+Battery swap market) due to lack of standardization	Cause of Barrier	Product Price
		Capital intensive for new entrants	Cause of Barrier	Production System
	Linear Lock-in	Regulatory and Systemic Gaps in Battery Recycling and Traceability	Cause of Barrier	Product Performance and Quality, Production System
	Asymmetric Information	Varying Levels of Awareness and Understanding (Impact of Diverse Backgrounds)	Cause of Barrier	Customers
Natural, Human, and Financial Resources	Resource Flow Optimization	Multiple, Non-Standard Battery Racks in a single place due to weak monitoring from government	Cause of Barrier	Product Performance and Quality
	Leadership and Team Skill	Lack of experience in the body of government due to the technology novelty	Cause of Barrier	Innovation-Specific Institution, Complementary Product and Services
		Lack of talents with specific skill-set available in the job market	Cause of Barrier	Product Performance and Quality, Production system, Innovation-Specific Institution
		Robust upskilling strategy during the talent scarcity in the job-market	Driver	Complementary Products and Services
	Availability of Finance	Potential Financial challenges at the operational Level (Due to the absence of fixed standardization	Cause of Barrier	Product Performance and Quality, Production System, Network Formation and Co- ordination
		Abundance of Nickel resources	Driver	Product Price, Production System
		High levels of Foreign Direct Investment (FDI)	Driver	Network Formation and Coordination, Product Price, Production System, Complementary Products and Services
Macro-economics and Strategic Aspect	Systemic Perspective	Supply chain bottlenecks due to the absence of local infrastructures in certain aspects	Cause of Barrier	Product Price, Production System
		Market fragmentation due to existence of multiple consortia with diverse specification	Cause of Barrier	Product Performance and Quality, Product Price, Complementary Products and Services, Network Formation and Coordination, Innovation specific Institution
		The absence of open protocol and traceability of asset (batteries)	Cause of Barrier	Product Performance and Quality, Product Price, Complementary Products and Services, Network Formation and Coordination, Innovation specific Institution

Influencing Condition (IC)	Sub-blocks of IC	Aspects	Driver / Cause of Barrier	Affected Building Blocks
		Lack of government interference in the consolidation among consortia	Cause of Barrier	Product Performance and Quality, Product Price, Complementary Products and Services, Network Formation and Coordination, Innovation specific Institution
	Conducive regulation	Presidential Regulation and Initiatives (PERPRES 79 2023)	Driver	All building blocks
		Complex and Unclear Regulatory Landscape, involving 18 ministries and Institutions	Cause of Barrier	Network Formation and Coordination
		Lack of Coordinated Regulatory Approach (push strategy without pull mechanism in the early phase of the technology diffusion)	Cause of Barrier	Complementary Product and Services
		Unnecessary Strict standards in SRUT for converted motorcycle	Cause of Barrier	Customers
		The time-consuming process to change vehicle registration from conventional to electric deters potential converters	Cause of Barrier	Customers
	Economics condition	Stable growth of GDP (5.0-5.1 %)	Driver	Production Systems, Complementary Products and Services, Customers
		The uncertainties surrounding the Indonesia presidential election	Cause of Barrier	Innovation Specific Institution
Competition	Market Positioning	Significant Market Potential for e-motorcycles	Driver	Network Formation and Co- ordination
		Focus on High-Readiness Regions	Driver	Complementary Products and Services
		Integrated Placement of Battery Swap Stations at gas stations and mini-marts	Driver	Customers, Complementary Products and Services
	Conventional Competition	Market Dominance of ICE Motorcycles	Cause of Barrier	Product Price, Complementary Products and Services, Customers
		Lack of collaboration among e-motorcycle and battery swap consortia	Cause of Barrier	Complementary Products and Services, Customers, Innovation-specific Institution
		High Maintenance Costs for E-motorcycles compared to the conventional one	Cause of Barrier	Product Price, Customers
		Limited availability of spare parts after-sales	Cause of Barrier	Product Price, Customers
		The absence of regulation limiting the purchase of ICE motorcycle	Cause of Barrier	Product Price, Customers
	Value Proposition	The rental basis for battery part on the purchase of e-motorcycle	Driver	Product Price, Customers
		Alignment of value proposition with Consumer Environmental Awareness	Driver	Customers
Accidents and Events	Internal Disruption	Conflicting Regulatory Stances between ministries	Cause of Barrier	Network Formation and Coordination, Innovation-Specific Institution
		Heavy workload in several ministries	Cause of Barrier	Innovation-Specific Institution
		Disparities in performance among ministries which impact policy coherence	Cause of Barrier	Network Formation and Co- ordination
	Cascading Effects	Indonesia's loss in the WTO dispute with the EU over nickel export bans	Cause of Barrier	Production System, Product Price, Customers
		Lack of standardization and interoperability (hardware, software, and protection mechanism)	Cause of Barrier	Network Formation and Coordination, Complementary Product and Services
	Resilience	Stakeholders' Capacity to Adapt to Evolving Standards	Driver	Product Performance and Quality, Product Price, Production System, Complementary Products and Services, Network Formation and Coordination, Innovation-Specific Institution
Socio-cultural Aspects	Literacy and Motivation	Slow Shift in Consumer Motivation on buying e-motorcycle within Five years period	Cause of Barrier	Complementary Product and Services
	Informed preference	Lack of Comprehensive Understanding of the benefits and functionalities of electric motorcycles compared to fossil fuel-powered ones	Cause of Barrier	Customers
	Limited Information and knowledge	Heavy Reliance on Specific Information Sources of the benefit of EV, leading to information gap in certain demographics	Cause of Barrier	Customers

Table 7.2: Building blocks and its causes

7.1.5. Answer for SQ5

The successful adoption of battery swap technology and e-motorcycles in Indonesia faces various challenges across different levels of governance and industry. Understanding these barriers' hierarchy is crucial for stakeholders aiming to develop targeted strategies to overcome them. This analysis explores the causes of barriers at each level of the hierarchy, answering the sub-question 5 (SQ5): **What is the level of importance or priority to each of identified causes of barriers to focus efforts and resources on those that are deemed most critical or time-sensitive?**

Level 4: At Level 4, the most critical barrier arises from significant political uncertainties surrounding the Indonesia presidential election. Particularly pronounced between March and October 2024, these uncertainties have the potential to disrupt policy formation and regulatory initiatives crucial for the adoption of battery swap technology for e-motorcycles.

Level 3: Moving down the hierarchy, the government's performance issues take center stage at Level 3. These issues, including lack of experience, regulatory complexity, and conflicting stances between ministries, are worsened by the political interests fragmentation caused by the large coalition of parties during the 2019 presidential election. Such challenges impede policy effectiveness and hinder progress in e-motorcycle adoption.

Level 2: At Level 2, barriers emerge from operational challenges, standardization issues, regulatory complexities, and customer awareness gaps. The mismatch of tasks within directorates under ministries leads to unclear standards and complex interoperability problems, ultimately affecting policy implementation in the e-motorcycle market and hindering its growth potential.

The combined factors contributing to barriers across Levels 4, 3, and 2 have significant implications for Indonesia's utilization of its nickel resources. These challenges have contributed to Indonesia's defeat in the WTO dispute with the EU over nickel export bans (B29) in level 1 of the hierarchy. As a result of this loss, Indonesia may face constraints on its ability to enforce export bans on nickel, potentially hampering its capacity to regulate the national nickel market effectively. Furthermore, this limitation could deter overseas investors from investing in related infrastructures, which are crucial for supporting the development of the battery swap and e-motorcycle ecosystem. Additionally, it may lead to a reduction in revenue generated from nickel exports, impacting the nation's overall income and economic stability.

7.1.6. Answer for Main Research Question (MQ)

To answer Main Research Question (MQ): **What prioritized strategies can be implemented to overcome the identified causes of barriers and facilitate the successful large-scale diffusion of E-Motorcycle Battery Swap systems in Indonesia?**, specific strategies proposed to effectively tackle the identified causes of barriers at each hierarchical level are stated as follows:

- **Level 4** - Engaging businesses during the presidential transition phase can influence policy through channels like KADIN via existing consortiums or associations. If interventions do not work, stakeholders may opt to wait and see before deploying programs or strategies, reflecting a cautious approach in uncertain political and regulatory environments. While existing niche strategies may not directly address political uncertainty, the "Strategic Intervention through Presidential Transition Engagement Strategy" emerges as a novel approach. Leveraging the transitional phase during the Indonesia Presidential Election (B20), it engages with the government to influence policy decisions. Additionally, the burgeoning market potential for e-motorcycles in Indonesia underscores the relevance of the strategy. Providers of battery swap e-motorcycles play a pivotal role, possessing the ability to provide feedback to the government and drive industry growth.

- **Level 3** - The proposed strategy aims to address key challenges within the market dynamics by leveraging collaborative efforts and strategic partnerships. It aligns with Ortt's ten niche strategies, particularly focusing on education and regulatory advocacy. The strategy involves forming partnerships with various stakeholders, including battery manufacturers, e-motorcycle providers, and government agencies, to influence ministry programs and advocate for favourable policies. Additionally, it includes initiatives such as dual TVET programs and collaboration with social media influencers to effectively communicate with potential customers. These efforts are crucial for enhancing workforce skills, addressing talent scarcity, and fostering regulatory frameworks conducive to the growth of the battery swap ecosystem. The strategy is well-aligned with identified drivers for effectiveness, such as robust upskilling strategies and stakeholders' capacity to adapt to evolving standards, thereby contributing to the overall resilience and sustainability of the industry.
- **Level 2** - The strategy involves partnering with ICE-based motorcycle companies to reduce maintenance costs and improve parts availability, collaborating with software interoperability firms and standardising components like plugs, sockets, and EVCC (enabling the battery charging stations (SPKLU) as a complementary part of the overall charging system alongside with the unevenly distributed battery swap stations (SPBKLU)). Advocating for removing strict "SRUT" standards in motorcycle conversions to increase the e-motorcycle population also can act as a support for the hybrid niche strategy. For new entrants, seeking guidance from larger firms to develop market specifications or doing a "wait and see" strategy on the government maneuver and the emergence of a unified consortium that applies the new standard in their latest products. The only proposed strategy that overlaps with Ortt's Educate niche strategy is utilizing social media influencers to raise customer awareness. Key drivers for the effectiveness of the strategy execution include the prevalent business models among major players and government efforts to develop ecosystems in high-readiness regions, supported by integrated infrastructure and simplified standardization processes.
- **Level 1** - The strategy involves coordinated efforts led by the government to mitigate the consequences, as companies cannot directly tackle this complex international legal and trade matter. Progress in addressing barriers at lower levels can contribute to creating a more favourable environment for addressing this challenge

7.2. Validation

7.2.1. Validation for Level 4

At Level 4, Validator 2 highlighted a recurring pattern of events dating back to 2017, which preceded the 2019 presidential election. A brainstorming session initiated by the Ministry, involving PLN, revealed widespread stakeholder interest but identified a lack of effective regulation. The historical context suggests parallels with the current political landscape, particularly considering the significance of the winning coalition in the recent presidential election. Validator 4 confirmed that these findings apply not only to the battery swap ecosystem but also to broader industrial issues. Some players, including IBC, prefer to adopt a ”wait and see” approach regarding the election outcome, withholding program deployment to avoid a potential lack of support from the official government. This validated aspect significantly impacts stakeholders’ decisions and actions within the industry.

Validation For The Proposed Strategy in Level 4

In terms of strategy, Validator 4 validates the formal hearing via KADIN to the government during the vulnerable time of the presidential election. Validator 4 emphasizes the involvement of representatives from associations or consortia to approach the government via KADIN, leveraging their close ties with high-level government officials to address industry concerns effectively.

7.2.2. Validation for Level 3

Validator 2 scrutinized government performance, particularly the latest Indonesian National Standards (SNI) proposed by PLN and BSN. Despite swift processing, enforcement remains uncertain, with the Ministry of Industry’s delayed response post-2019 regulation only spurred by major electric vehicle manufacturers. PLN urges the Ministry to expedite crucial regulations and ensure compliance. Validator 2 also highlights a lack of expertise among ministries, leading to PLN and BRIN handling roadmap drafting and standards development. Minimal government intervention in standardization impedes a uniform regulatory framework.

Validator 2 points out the Ministry of Industry’s lack of proactive standardization, making the SNI non-mandatory and ambiguous. Also, while regulations on incentives are well-designed, their implementation is flawed, causing market disruption and delays due to information leaks and technical knowledge gaps among field officers.

Validator 1 also points out disparities among ministries affecting policy coherence. Interrelationships among institutions are not fully understood, leading to issues like road construction design mismatches for electric buses. Regional regulations on rental costs and ticket prices add complexity.

Validator 4 confirms the lack of experience within the government. The central government and BRIN need a better understanding of the industry to address its challenges. BRIN should play a more active role, coordinated through the Ministry of Maritime Affairs and Investment, but often operates independently, disregarding market needs. Standards should result from industry consensus, not government enforcement, to avoid unfair costs and hindered investment.

Validation For The Proposed Strategy in Level 3

Validator 3 supports using social media influencers and experts to boost public awareness about technology’s benefits at Levels 2 and 3. Drawing from personal experience, Validator 3 noted a significant shift in mindset towards exclusive breastfeeding, influenced by doctors and influencers on social media. This example underscores the power of credible voices in shaping public perception. Validator 3 stresses the need for experts to engage actively in these discussions to provide reliable information and guidance.

Additionally, all validators accepted the strategy of consortium/association intervention with echelon 1 officials via KADIN (and KADINDA at the regional level) for addressing regulatory issues, indicating general consensus or lack of dispute among the validators.

7.2.3. Validation for Level 2

Level 2 Validators emphasizes challenges like battery regulation gaps and interoperability issues. Additionally, Validator 3 and Validator 4 provide insights into the context-specific strategy regarding the alignment of SPKLU and SPBKLU placement in the evolving e-motorcycle technology ecosystem which is true if the spotlight is directed into the battery swap technology as the sole technology for e-motorcycle charging. If the context is zoomed out into the e-motorcycle technology ecosystem in Indonesia, not limited to the battery swap technology as the only technology available to charge the battery for e-motorcycles, SPBKLU should be the buffer for SPKLU instead, until the battery technology is ready to be charged with a higher current (without significant weight and dimension increases). In addition, the lack of interoperability does indeed serve as a cause of barrier. However, this also serves as a natural selection process until the preferred brands emerge in the market, which is proven eventually by some players leading the market share.

Validation For The Proposed Strategy in Level 2

Validator 2 emphasized the validity of the statement advocating for small companies to adopt a ”wait and see” approach as modifying specifications midstream cannot be done due to existing contracts with battery companies. Additionally, small association members highlight challenges in conforming to Indonesian standards, given prevalent technology transfers from China and rebranding practices which underscores the complexities involved in manufacturing frame and battery components.

It is noted that collaboration between e-motorcycle and ICE companies may not be feasible in practice, according to Validator 2, as demonstrated by previous unsuccessful attempts of GESITS in frame production.

Validator 4 validated the potential formation of a unified consortium across associations, suggesting that companies already producing new motorcycles with new standards may need a transition period before implementing unified standards. They must first utilise existing investments, considering the MoU between them and Investors, before cycling into new investments and embracing new standards. Validator 4 also validated the unnecessary SRUT standard, which slows down the increase in the population of electric motorcycle conversions and delays administrative procedures with law enforcement.

Validator 4 further recommended that administrative processes should ideally not exceed one day, considering that motorcycles are also used for livelihood purposes.

7.2.4. Validation for Level 1

At Level 1, Validator 2 questioned the relevance of Indonesia’s loss in the WTO dispute with the EU over nickel export bans, raising concerns about its impact on the battery swap and e-motorcycle ecosystem. Validator 2 noted that evolving battery technologies, like LFP, may not rely heavily on nickel, pointing out that IBC’s challenges stem from the dominance of lithium-ion batteries, which favour phosphate over nickel manganese. This specificity, Validator 2 argued, undermines the findings, as future battery developments could shift away from nickel.

Validator 1 acknowledged a connection between Level 1 and the discussed aspect but emphasized that Indonesia’s growing mid-supply chain industry needs government support. While nickel is crucial, other materials like lithium, cobalt, and manganese are also essential. Indonesia, rich in these resources, should aim to become a battery industry hub. Additionally, all batteries require copper and aluminium, which Indonesia has in abundance.

Validator 4 noted that the connection between Level 2 and Level 1 is weak. Despite IBC's projection of a 60 GWh demand by 2035, with motorcycles comprising a smaller portion, ongoing infrastructure development is sufficient. Even with increased demand, much of the refined materials will be exported. Thus, addressing Level 1 issues may not significantly impact the growth of Indonesia's battery swap ecosystem.

7.3. Scientific Relevance

This sub-chapter elucidates how this thesis work is interconnected with existing literature and articulates how it builds upon and advances the current knowledge base.

Knowledge Base

The foundation of this research lies primarily in the Technological Innovation System (TIS) frameworks developed by Ortt and Kamp (J. R. Ortt and Kamp, 2022), the Interpretative Structural Modeling (ISM) framework (Moelyanto et al., 2021), and the 10 niches strategies introduced by Ortt (J. Roland Ortt et al., 2013). The TIS building blocks and influencing conditions are adjusted based on Raghav's Circular TIS framework (Shankar, 2023), tailored to fit the proposed context of this thesis, which is further explained in Section 1.3.

The Circular TIS framework is instrumental in identifying and categorizing the elements and conditions that influence the success and development of technological innovations, providing a comprehensive view of the innovation process. **However**, it does not specifically identify which causes of barriers should be tackled first to ensure the completeness of building blocks. This is where ISM complements the Circular TIS framework by showing the hierarchy among causes of barriers, highlighting which ones should be prioritized.

Building Upon Existing Knowledge

This thesis addresses a significant limitation in existing TIS frameworks—the lack of a clear methodology for prioritizing causes of barriers to innovation. While TIS variants identify and categorize causes of barriers, they do not provide a structured approach for determining which causes of barriers should be addressed first. Also, TIS variants become less practical for policymakers and practitioners in deriving the strategy with the absence of the hierarchical relationship between causes of barriers.

By integrating ISM into the Circular TIS framework, deriving niche strategies will not be done solely based on the overall statuses of the building blocks and influencing conditions in the circular TIS framework only, but also at each level of the hierarchy of the causes of barriers generated by ISM, which produces a more detailed and practical insight for sequentially and effectively tackling the causes of barriers in identified Circular TIS. The contributions of this thesis are twofold:

- Enhanced Framework: Integrating the ISM framework into the Circular TIS framework enhances the Circular TIS framework by providing a clear method for prioritising niche strategies to address causes of barriers identified in the Circular TIS framework.
- Practical Application: The hierarchical approach associated with the circular TIS framework offers a more practical framework for policymakers and practitioners to derive the strategy. The TIS-ISM combined framework enables them to know the hierarchical relationship between the causes of barriers and introduce the strategy to address those causes step by step based on that hierarchical relationship.

How Does ISM Framework Enhance the Circular TIS Framework?

The identified cause of the barrier lying within the influencing condition with the "partially complete and incomplete" status in the circular TIS framework will raise barriers (partially complete/incomplete building blocks) that hinder the technology diffusion (J. R. Ortt and Kamp, 2022). By incorporating the ISM framework, deriving niche strategies can be done based on the hierarchical relationship within these causes of barriers. This leads to a more practical framework for practitioners and policymakers to alter the status of the influencing condition blocks from "partially/incomplete" to "complete," which ultimately aims to remove the barriers within the building blocks in the process of technology diffusion.

To what extent does the proposed strategy overlap with Ortt's Ten Niche Strategies(J. Roland Ortt et al., 2013)?

In analyzing the proposed strategies within the framework of Ortt's Ten Niche Strategies, it becomes evident that while some alignments exist, some notable deviations and innovations warrant further exploration.

At Level 4, the "Strategic Intervention through Presidential Transition Engagement Strategy" emerges as a new approach, outside Ortt's ten niche strategies, tailored to the unique challenges posed by political uncertainty during Indonesia's presidential transition. While Ortt's Ten Niche Strategies do not directly address this context, the essence of strategic intervention aligns to influence policy decisions to navigate uncertainties. This strategy presents an innovative adaptation to the political landscape, emphasizing the importance of timely engagement with governmental stakeholders to shape favourable outcomes for businesses operating within Level 4 dynamics.

Within Level 3, the proposed strategies exhibit both alignment with existing niche strategies and the introduction of new approaches. The alignment with the Educate niche strategy underscores the significance of knowledge transfer and awareness-building in driving behavioural shifts and fostering consensus. The Collaborative Regulatory Advocacy Strategy, on the other hand, introduces a novel approach to addressing uncertain standardization, emphasizing collaboration among industry stakeholders to advocate for supportive regulatory frameworks. While these strategies resonate with aspects of the Educate niche strategy, they also extend beyond it by directly engaging with regulatory processes to shape industry dynamics.

At Level 2, the alignment with the Educate niche strategy is reiterated, emphasizing the importance of leveraging social media influencers and experts to drive awareness and acceptance of new technologies. However, introducing innovative approaches such as the Collaborative Maintenance Access Strategy, Market Observation Approach, Market Leader Specification Alignment strategy, and Software, Plug, Socket, and EVCC-focused standardization strategy highlights the evolution of strategies tailored to the market's specific needs. While these strategies may not directly overlap with Ortt's predefined niches, they represent dynamic responses to emerging challenges and opportunities within Level 2 dynamics.

No niche strategy can be executed directly by companies in Level 1, as the causes of barriers in Level 1 shall be alleviated by the effect accumulation on solving the causes of barriers in Levels 2, 3, and 4.

7.4. Reflection and Evaluation on TIS-ISM Framework

7.4.1. Reflection on TIS-ISM Framework

The framework utilised for this case study adopts Raghav Shankar's approach, which examines the context of technology implementation in Europe. In practice, the building blocks and influencing condition blocks used remain relevant to the Indonesian context, including one highly pertinent building block: standardisation. However, it is worth noting that this framework could be further developed with building blocks that are more tailored to Indonesia, such as issues of corruption, collusion, and nepotism, which could be added as additional influencing condition blocks.

Furthermore, Raghav's framework can be integrated with Julius Engelen's framework, which suggests the addition of influencing conditions for data infrastructure. The inclusion of data infrastructure in the TIS framework is motivated by its role in accelerating the circular transition. Data is considered essential for enabling the formation of TIS building blocks for circular innovation. Data infrastructure is crucial for the development and circularity of battery swap technology. It enables real-time monitoring, predictive maintenance, and efficient energy management, optimizing operations and reducing costs. Enhanced user experience is achieved through seamless integration and usage pattern analysis. For circularity, data infrastructure ensures battery lifecycle management, improves recycling efficiency, and supports sustainability reporting. It also aids in regulatory compliance by informing policies and monitoring adherence to waste handling and environmental standards.

Additionally, there are several evaluations of Raghav's framework, particularly regarding the building block of "standardization." From the implementation findings, it is evident that standardization can serve as an influencing condition. According to the literature, standardization must be developed before the technology can be mass-produced and used as a driving force (Wahyudi Sutopo et al., 2022). As an example, in this research context, the weak monitoring from the government leading to multiple non-standard battery racks can hinder resource optimization efforts. At the same time, the lack of standardization and interoperability creates bottlenecks in market expansion, impacting the long-term feasibility of businesses. As the nature of the TIS-ISM framework is to find the interrelation between causes to alleviate the barriers, the writer suggests considering standardization as the cause of the barrier (rather than the barrier) that has interrelation with other causes and has influence to create barriers within the building blocks.

In addition, it is essential to emphasize the importance of validation immediately after completing Chapter 4. This validation process ensures the accuracy of the status of each building block and influencing condition, as assessed by the validators. Furthermore, based on this validation, it becomes evident that a bias exists in one aspect concerning maintenance cost. Specifically, if the focus of the "maintenance" cost here is on the customer side, the statement that maintenance cost is expensive should not universally represent e-motorcycles with swappable batteries, as the battery ownership model differs. In fact, with fewer moving parts than traditional ICE vehicles and the battery ownership residing with the provider, maintenance costs should theoretically be lower. However, if the focus is on the provider side, the statement holds true as they bear the responsibility of maintaining a fleet of batteries to ensure performance and service for customers. Addressing this bias requires a more nuanced discussion in Chapter 4 regarding the distinctions between swappable and permanent batteries and their respective effects on maintenance costs from both customer and provider perspectives. This discussion should also consider how these factors influence the increasing population of e-motorcycles and align with strategies for synchronizing swap stations (SPBKLU) and battery charging stations (SPKLU). Validation for Chapter 4 is crucial as it forms the foundation for applying the subsequent ISM framework. It ensures the accuracy and reliability of the information presented, identifies biases, and allows for informed decision-making and strategy implementation within the ISM framework.

Moreover, it is crucial to acknowledge that the TIS framework cannot capture status changes (conditions changes). Therefore, there is a need for the development of a framework to monitor changes in status over time, aiming to formulate new strategies in response to these changes.

Finally, it is important to understand the advantages and disadvantages of the Interpretive Structural Modeling (ISM) approach. ISM is an efficient way to translate expert knowledge into an understandable, structured model for the system, providing a better understanding of complex systems. It works well with qualitative factors and accurately divides hierarchies into levels of importance, which helps the researcher determine priority factors. However, an increase in the number of factors analyzed significantly increases implementation difficulty, as all relationships need to be defined. Manual work becomes challenging due to a larger number of factors, which necessitate the use of computers or tools like Matlab/python. Additionally, ISM lacks statistical validation, making all results hypothetical.

7.4.2. TIS-ISM Framework Evaluation

Based on the reflection above, several evaluations have been made to create a more ideal approach for studying the diffusion of battery swap technology in Indonesia. The changes to the framework are shown In Figure 7.2. The orange colour indicates which parts of the blocks should be removed, and the green colour indicates the additional parts that need to be added to the framework.

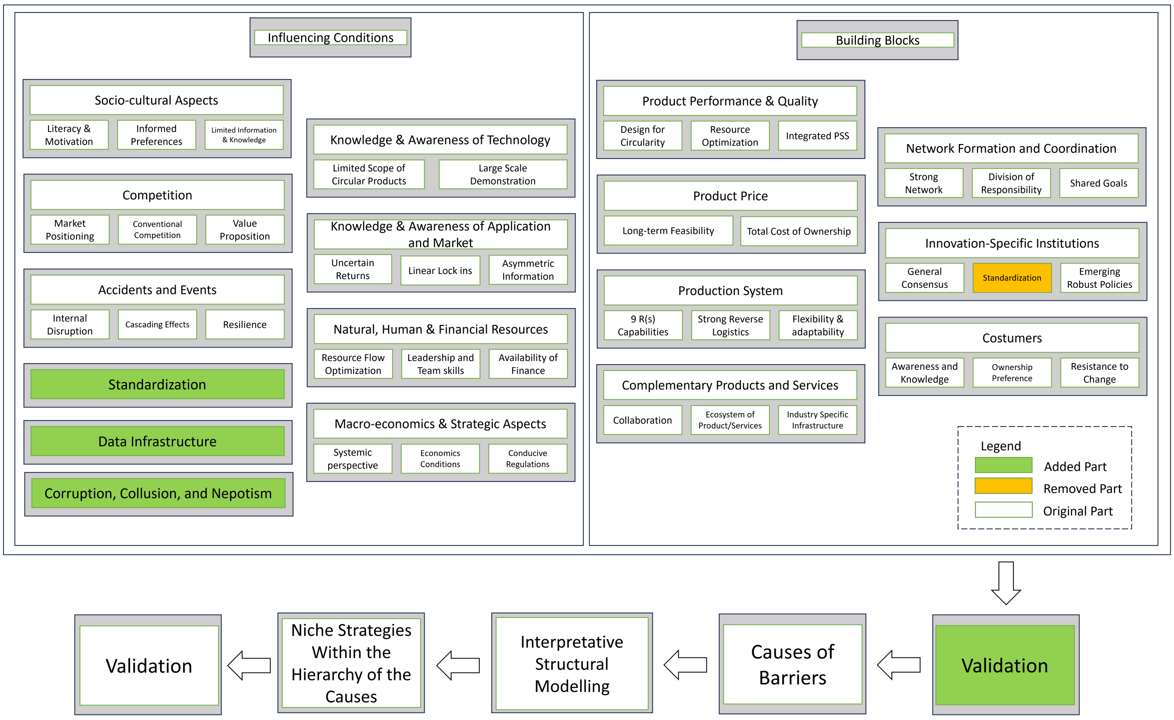

Figure 7.2: Evaluation in TIS-ISM Building Blocks and Influencing Conditions for Battery Swap Context in Indonesia

7.5. Recommendation for Future Research

Several recommendations to enhance the TIS-ISM framework in future research are proposed. These recommendations aim to address identified gaps and enhance the robustness and applicability of the TIS-ISM framework. The following three recommendations are suggested.

Development of a Framework to Monitor Changes in Status

One limitation of the current TIS framework is its inability to capture changes in status over time. Future research should focus on developing a dynamic monitoring framework to track these changes. This could involve creating a longitudinal study that periodically assesses the status of each building block and influencing condition, thereby allowing for the formulation of adaptive strategies in response to evolving conditions.

Follow-Up Questions:

- What are the key indicators that should be included in a dynamic monitoring framework for the TIS-ISM framework?
- How can longitudinal studies be designed to effectively track changes in the status of building blocks and influencing conditions over time?
- What adaptive strategies can be developed based on the data obtained from this monitoring framework to enhance the diffusion of battery swap technologies?

Internal Consistency Validation of Participants' Answers in SSIM Brainstorming Session

Future research should explore methods for internal consistency validation to enhance the reliability of participant responses in the SSIM brainstorming session within the TIS-ISM framework. It should be noted that SSIM later becomes the data basis for constructing the final product of ISM. This procedure could involve Cronbach's Alpha to validate the consistency of the relationships and hierarchies established through ISM in its Self-Structural Interaction Matrix (SSIM). For example, in the context of this thesis, the SSIM is a 33 x 33 matrix, requiring assessment of 1089 items. These items can be compiled into a questionnaire with a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) for several respondents. The goal is to check the alpha value, ensuring it is greater than or equal to 0.7, which is considered a reliable score. If the reliability is too low, we must repeat the process so that the participants in the next wave of brainstorming can adapt their answers accordingly.

If the reliability score is less than 0.7, the SSIM might not be consistent. In such cases, the brainstorming session of the SSIM step in the ISM framework should be repeated. This session should incorporate the findings from the reliability analysis and involve more participants to enhance the robustness of the data.

Follow-Up Questions:

- How can Cronbach's Alpha Validation method be applied to the TIS-ISM framework to enhance the reliability of the intercorrelation between causes of barriers discussed in the SSIM brainstorming session?

Analysis of Drivers and Their Hierarchy

The current TIS-ISM framework primarily focuses on identifying the causes of barriers to innovation. Future research should expand this focus to include an analysis of the drivers that facilitate innovation and their hierarchical relationships. Understanding the drivers will provide a more comprehensive insight for stakeholders, aiding in the development of strategies to accelerate technology adoption and diffusion.

Follow-Up Questions:

- What are the key drivers that facilitate the implementation and scaling of battery swap technologies in different contexts?
- How can these drivers be hierarchically structured to understand their relative importance and interactions?
- What methodologies can be employed to identify and analyze these drivers effectively within the TIS-ISM framework?
- How can insights from the analysis of drivers be used to complement the understanding of barriers, thereby providing a balanced perspective for stakeholders?

7.6. Recommendations for Actors

Based on the findings presented throughout this thesis, relevant stakeholders can take several strategic actions to address the challenges and capitalize on the opportunities identified. For businesses, using the insights from Chapters 3 to 6 can inform detailed strategic planning, including preparing for mediation to provide feedback to the government and improving collaboration among battery swap and electric motorcycle providers. This involves standardising specifications for batteries and control systems to prevent unnecessary expenditure due to future standardisation changes. Moreover, existing businesses can use this research as business intelligence to develop concrete strategies, such as preparing for circularity by tracing inventory methods and implementing maintenance strategies for interoperability. Recommendations include evaluating how current conditions affect the government's development plans to align strategies accordingly. Furthermore, stakeholders must consider the potential incentives proposed by the government as a result of enforcing standardization, as these could significantly impact business operations and investment decisions within the e-mobility sector.

Regarding concrete commendations, the government needs to strengthen relationships with scientists, particularly with institutions like BRIN, the main research body in Indonesia, and NBRI, a specialized research institution focusing on batteries. This collaboration is vital for shaping regulations that balance political and business interests, ensuring that the regulations issued can effectively address the complex challenges within the ecosystem. By involving research institutions in regulatory development, stakeholders can leverage scientific expertise to devise comprehensive solutions that promote sustainable growth and innovation within the e-mobility sector. Additionally, optimizing coordination between the Coordinating Ministry for Maritime Affairs and Investment as the coordinator of the electric vehicle implementation acceleration team in Indonesia is essential. It may require establishing a specialized team to ensure more optimal multi-stakeholder coordination. Taking a cue from the US, where they have ad hoc teams that drive discussions on specific issues, creating a similarly dedicated team could enhance coordination efforts and streamline decision-making processes. The government should prevent Leaks of information from the ministry holding regulations, causing customers to delay their purchases and disrupting the supply market. If revisions are needed, do not discuss them with the media. Even if it leaks to the media, the information should be cut off immediately to prevent people from delaying their purchases, thus achieving the incentive absorption target.

To achieve circularity success in the battery swap business and EVs in general, the Indonesian government must drive the battery ecosystem towards Nickel-based. This recommendation stems from the insight provided by **Validator 4**, which suggests that recycling products based on lithium iron phosphate (LFP), a lithium-based battery technology, is economically unviable compared to products from nickel manganese cobalt oxide (NMC), which is nickel-based technology, given the current technological capabilities.

Standardization can only occur when it is enforced or when entities unite (natural selection being the survival of the fittest, and it seems like the competition's winners are starting to emerge, with three dominant brands (SWAP ID, SGB, and Electrum) emerging from the nine players that appeared in 2019 according to **Validator 1**. A final recommendation for the government in extreme cases of standard enforcement is that collaboration with PLN as the sole electricity distributor for charging stations could ensure compliance, particularly in extreme instances where strict enforcement is necessary to maintain order and safety within the industry. If standardization is indeed mandated (enforced), there must be incentives post-implementation for affected players to prevent upheavals.

Regarding recommendations for the EV and battery swap industries, Small companies should consider adopting a ”wait and see” approach, as modifying specifications midstream cannot be done due to existing contracts with battery companies. Additionally, small association members highlight challenges in conforming to Indonesian standards, given prevalent technology transfers from China and rebranding practices, underscoring the complexities involved in manufacturing frame and battery components. A strategy of ”wait and see” is also recommended for new entrants, with an additional note: if they have limited capital or other options to enter the EV business (rather than battery swap), as the capital required is smaller compared to the battery swap business, which encompasses motorcycle production as well. Regarding the proposed strategy, merger solutions or collaborations with established EV providers for new entrants of battery swap players can also be considered to reduce capital costs.

It is recommended to consider forming a unified consortium across associations, with the prerequisite that companies already producing new motorcycles with new standards may require a transition period before implementing unified standards. They should initially utilize existing investments, taking into account Memorandums of Understanding (MoUs) between them and investors, before moving on to new investments and embracing new standards.

Furthermore, a recommendation for PLN, as a significant player with extensive management networks down to the minor regional levels, is to venture into the maintenance of electric vehicles (EVs). Collaboration with EV and battery swap manufacturers could be fruitful in this regard. PLN could leverage its existing infrastructure and expertise in maintenance to provide reliable services for EVs, thereby contributing to the sustainability and growth of the e-mobility sector.

Additionally, a recommendation for collaboration between IBC and PLN (PLN has a 25% shareholder and possesses knowledge excellence in the renewable energy business) is to partner with battery swap stations developed by IBC equipped with solar panels (PV). The number of standby batteries and the placement of battery swap station locations are optimised with the optimal battery charging time using PV. This aligns with the increasing national energy mix and avoids exacerbating issues during energy excess on Java Island by increasing PV utilisation in the battery swap ecosystem.

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A

Original TIS Building Blocks and Influencing Conditions

A.1. TIS Building Blocks

1. **Product Performance and Quality**: For widespread adoption, an innovative product requires a clear purpose, functionality, and capability alongside commendable performance and quality. It should present a viable alternative to prospective users, offering comparable or superior performance and quality compared to current or future competitors.
2. **Product Price**: Competitively pricing an innovative product is crucial for mass adoption. The price encompasses not just the financial cost but also non-financial aspects like the time and effort required for usage or maintenance. Competitive pricing balances cost against quality, making it an attractive option.
3. **Production System**: Achieving mass-market goals necessitates a robust production system characterized by large-scale facilities capable of maintaining high-quality production rates.
4. **Complementary Products and Services**: Introducing products to the market relies on various supporting products and services throughout the product lifecycle. The availability of these complementary elements is vital for widespread adoption.
5. **Network Formation and Coordination**: Effective networks involving suppliers, production workers, distributors, etc., are essential for shared vision realization. Multiple actors serving similar purposes can enhance competitiveness in terms of pricing and quality.
6. **Customers**: Targeted buyers aware of product benefits, possessing the knowledge, willingness, and means to acquire and use it, play a pivotal role in adoption. Building awareness, meeting values, and addressing interests and opinions are vital for customer acceptance.
7. **Innovation-Specific Institutions**: Support from formal and informal institutions—government policies, commonly accepted rules, beliefs, or behavior—is crucial for commercializing innovative products. Favorable

policies and subsidies significantly influence better adoption.

A.2. TIS Influencing Conditions

1. **Knowledge and awareness of technology**: Understanding both the basics and practicalities of technology significantly impacts TIS building blocks. Fundamental knowledge involves understanding the product, its production system, and its complementary products. Applied technology knowledge is necessary for developing, producing, repairing, and improving the product.
2. **Knowledge and awareness of application and market**: Knowing how to use innovation in specific applications, where to obtain it, and how to pay for it is crucial. Lack of this knowledge can hinder customer adoption. For companies, understanding the application helps define target customers better.
3. **Natural, human, and financial resources**: The availability of natural, human, and financial resources is vital for large-scale commercialization. Natural resources serve as raw materials and support infrastructure setup, while human resources drive operations, and financial resources facilitate procurement and labor payments.
4. **Competition**: Rivalry among companies offering similar products shapes pricing and value-added benefits, significantly influencing product positioning and perception in the market.
5. **Macro-economic and Strategic Aspects**: Economic conditions, market structures, and macroeconomic indicators like interest rates, inflation, GDP, employment, and trade dynamics affect the status of TIS building blocks, encouraging or impeding innovation uptake.
6. **Socio-cultural Aspects**: Societal values, behaviors, and cultural elements like education, language, social groups, and community dynamics influence TIS building blocks and innovation adoption by stakeholders.
7. **Accidents and External Events**: Unforeseen events within or outside the TIS can influence the formation of building blocks. For instance, accidents like Chernobyl significantly shaped public perceptions of nuclear energy technologies, impacting their adoption.

B

Ortt's Generic Ten Niches Strategy

1. **Demo, experiment, and develop niche strategy**
    - Lack of knowledge about the technology affects the product's availability due to insufficient quality performance.
    - A niche strategy can involve public demonstrations of the product in a controlled manner where limited performance quality is acceptable. Experimentation is also important to further develop the product, potentially in a research environment.
2. **Top niche strategy**
    - Lack of knowledge about the technology affects the product's availability at a reasonable price.
    - Lack of knowledge affects the production system's ability to produce products with consistent and adequate quality at a reasonable price.
    - Scarcity or high cost of resources affects the product's price.
    - A niche strategy can involve hand-made products made to order for a specific top-end market segment.
    - A skimming strategy can be adopted, supplying the top niche of customers first with a special product.
3. **Subsidized niche strategy**
    - Lack of knowledge about the technology affects the product's availability or the production system, impacting the product's reasonable pricing.
    - Scarcity or high cost of resources affects the product's price.
    - A niche strategy can involve subsidizing the product if its use by a specific segment is considered societally relevant or important.
4. **Redesign niche strategy**
    - Lack of knowledge about the technology affects the product's availability or the production system, impacting the product's reasonable pricing.

- Scarcity or high cost of resources affects the product's price.
- Lack of knowledge about the product's application or socio-cultural aspects affects the availability of appropriate institutional aspects (laws, rules, and standards), hampering diffusion.
- Socio-cultural aspects affect the availability of suppliers or customers.
- A niche strategy can involve introducing a simpler version of the product that can be produced with existing knowledge, using fewer resources, and at a lower price.
- A niche strategy can involve exploring an application where institutional aspects are more favorable, often leading to redesign.
- A niche strategy can involve exploring an application where suppliers or customers have no resistance to produce and use it, often leading to redesign.

5. **Dedicated system or stand-alone niche strategy**
    - Lack of knowledge about the technology affects the availability of complementary products and services.
    - A niche strategy can involve using the product in stand-alone mode or designing a dedicated system of complementary products and services (e.g., a local network when broader infrastructure is unavailable).
6. **Hybridization or adaptor niche strategy**
    - Lack of knowledge about the technology affects the availability of complementary products and services.
    - Scarcity of resources affects the availability of complementary products and services.
    - A niche strategy can involve using the new product in combination with the old product, allowing for the reuse of existing complementary products and services. Alternatively, an adaptor or converter can be provided to make the product compatible with existing complementary products and services.
7. **Educate niche strategy**
    - Lack of knowledge about the technology affects the availability of suppliers or customers.
    - A niche strategy can focus on transferring knowledge to suppliers.
    - An educate and experiment (pilot) niche strategy can be adopted to increase customer knowledge.
8. **Geographic niche strategy**
    - Lack of knowledge about the technology or its application affects the availability of appropriate institutional aspects (laws, rules, and standards).
    - Scarcity of resources affects the availability of the product or complementary products and services.
    - Socio-cultural or macro-economic aspects affect the availability of suppliers, customers, and appropriate institutional aspects.
    - Accidents and unexpected events affect the availability of appropriate institutional aspects.
    - A niche strategy can involve operating in areas where institutions (laws and rules) are more easily arranged or less strict.
    - A niche strategy can involve targeting geographic areas where resources, suppliers, or customers are available.

- A niche strategy can involve targeting geographic areas where suppliers are not hampered by unexpected events or accidents.

9. **Lead user niche strategy**
   - Lack of knowledge about the product's application affects suppliers' ability to understand customer applications, specific product requirements, and customer segments.
   - Socio-cultural aspects, macro-economic factors, or accidents and unexpected events affect the availability of suppliers or customers.
   - A niche strategy can involve finding innovators or lead users who can co-develop the product and are willing to experiment with it.

10. **Explore multiple markets niche strategy**
    - Lack of knowledge about the product's application affects customers' ability to understand applications, usage patterns, and product benefits.
    - A niche strategy can involve exploring multiple customer applications. Visibility of the initial applications might stimulate exploratory use in new applications.

C

Validation of The findings

C.0.1. Validation for level 4

At Level 4, **Validator 2** highlighted events dating back to 2017, preceding the 2019 presidential election, indicating a recurring pattern. A brainstorming session, initiated by the Ministry and involving PLN, revealed broad stakeholder interests but lacked effective regulation. It is then validated that the historical context suggests parallels with the current political landscape, especially given the significance of the winning coalition in the recent presidential election. **Validator 4** also validated that this aspect can also generally apply not only to the battery swap ecosystem but also to general industrial issues. Some players prefer to adopt a ”wait and see” approach regarding the outcome of the presidential election, including IBC, which withholds program deployment to avoid being unsupported by the official government. This aspect is validated to significantly affect stakeholders' decisions and actions within the industry.

Validation For The Proposed Strategy in Level 4

In terms of strategy, Validator 4 validates the formal hearing via KADIN to the government during the vulnerable time of the presidential election. Validator 4 emphasizes the involvement of representatives from associations or consortia to approach the government via KADIN, leveraging their close ties with high-level government officials to address industry concerns effectively.

C.0.2. Validation for level 3

Moving to Level 3, **Validator 2** scrutinized government performance, notably the introduction of the latest Indonesian National Standards (SNI) proposed by PLN and BSN. Despite swift processing, the enforcement of these standards remains uncertain, with the Ministry of Industry's delayed response post-2019 regulation only spurred by the entry of major electric vehicle manufacturers. PLN advocates for a more proactive role from the Ministry of Industry to expedite crucial regulations and ensure the compliance of the new standards. **Validator 2** also validates a lack of expertise among ministries, evident in the delegation of responsibilities to PLN and BRIN for roadmap drafting and standards development. While collaborative efforts with external institutions aim to enhance competencies, government intervention in standardization remains minimal, impeding uniform regulatory frameworks.

Adding context to this, government intervention for standardization can be said to be lacking according to the **Validator 2**, with key players failing to initiate standardization efforts (which should ideally be led by the Ministry of Industry). Consequently, the SNI has not yet become mandatory, as it was developed by BSN and PLN. It would be ideal if the Ministry of Industry took the lead to ensure all players comply with the rules. Within the SNI, there's a clause in the opening stating that the old SNI is not repealed, implying that the old standards are still applicable alongside the new ones, creating ambiguity in compliance requirements.

In terms of cause of barrier:Lack of experiences in the body of government, **Validator 1** suggests that Indonesia were in the early stages back then in 2019, hence there are many barriers due to lack of experience. However, there must be willingness and good intentions from each stakeholder to participate in discussions and revisions for regulatory improvements. The existing regulations are actually quite good, especially concerning incentives, but their implementation is lacking. As a validation of the aspect of minimal experience, complaints arise when incentives are associated with those who cannot afford them, creating a problem where those who cannot afford it also cannot buy the motorcycle (with household electricity below 900 watts). These people are struggling to make ends meet, not buy motorcycles. This occurred during the implementation of the first 7 million incentives. Another example is when there is a leak of information from the ministry holding regulations, causing customers to delay their purchases and disrupting the supply market. If revisions are needed, don not discuss it with the media. Even if it leaks to the media, the information should be cut off immediately to prevent people from delaying their purchases, thus achieving the incentive absorption target. In 2024, the incentives were already in place but were under review, causing the incentives to be withheld, leading people to delay their purchases again or revert to internal combustion engines (ICE). If the government wants to provide incentives, they should not leak it to the media. Even if it needs to be announced, it should be decided quickly without long delays. The realization of the budget from the Ministry of Maritime Affairs and Investment is poor, leading to a reduction in incentive recipient quotas in the following year. Another instance of lack of experience from **Validator 1**: field officers from the ministry cannot differentiate between identification voltage and working voltage, resulting in delays in registering battery swap stations.

Validator 1 also validates the disparities in performance among ministries, which impact policy coherence. Many regulations emerge concerning both new vehicles and conversions, supported by presidential regulations and standardization. However, as time progresses, it becomes apparent that there are interrelationships among institutions that are not fully understood. An extreme example is electric buses, where there are unresolved issues from the PUPR regulations perspective because road construction design is based on the chassis of 8-ton ICE vehicles from the Ministry of Transportation, while electric buses weigh 12 tons. It turns out that not only the electric vehicles need to be regulated, but also other aspects, including regulations from regional governments for the rental cost per kilometer per person. The ticket prices for electric buses are higher, while there are also significant fuel subsidies, among other issues.

Besides, **Validator 4**'s also validated the lack of experience in the body of the government, highlighting that the central government and BRIN, as the national research agency, must have a deeper understanding of the industry itself to accommodate aspirations and challenges. BRIN should be given a more active role by the central government, particularly coordinated through the Ministry of Maritime Affairs and Investment. However, BRIN sometimes holds its own perspective without considering the aspirations of existing swap players, leading to a disconnect, especially concerning technological aspects. For instance, BRIN's recent release of connectors reflects its own viewpoint, which may not align with or accommodate the needs of the evolving market or players. Additionally, caution is advised when discussing standards. Standards should ideally be a consensus among industries, not enforced by the government, to avoid unfair treatment of some players. Businesses may incur additional expenses to comply with standards, leading to reluctance to invest. Excessive government interference can backfire, potentially hindering industry progress.

Validation For The Proposed Strategy in Level 3

In terms of proposed strategy, **Validator 3** agrees with the utilization of social media influencers and experts to enhance public awareness regarding the benefits of technology in solving issues related to consumer awareness at Level 3 and Level 2. An example from **Validator 3**'s personal experience as a mother of one child: during the trend of exclusively breastfeeding for two years, which emerged when she had her first child, there was a significant shift in mindset from formula milk to breastfeeding. There was a period where **Validator 3** and other mothers argued about transitioning from formula milk to exclusive breastfeeding. Interestingly, on social media, many doctors advocated for the benefits of breastfeeding. This shift in perception was largely driven by influencers on social media. **Validator 3** emphasizes that experts need to engage actively in these discussions to provide credible information and guidance to the public.

In addition, all validators did not provide further comments related to the strategy of consortium/association intervention/audience to echelon 1 officials via KADIN (and KADINDA at the regional level) in terms of facing regulatory issues. This suggests that the proposed strategy was generally accepted or not disputed among the validators.

C.0.3. Validation for level 2

At Level 2, **Validator 2** validated the absence of battery regulations concerning recycling and second-life use which become a recurring topic in workshops. Additionally, as one of the stakeholder which also important in terms of second life use of the battery, PLN's original regulations prohibit the purchase of used goods (used battery), posing challenges for businesses not involved in procurement of new materials. However, there are avenues to navigate this, such as adopting service-based models where services are sold based on energy consumption rather than providing equipment to consumers.

The barrier of "high maintenance expenses compared to the ICE motorcycle" is considered biased if the cost of batteries is exclude according to the **Validator 3** and **Validator 1**, as electric motorcycles have fewer moving parts and should theoretically be cheaper to maintain. This is because in the battery swap business model, the ownership of the battery lies with the provider, not the customer. **Validator 3** noted that some sources conflated issues related to EVs with integrated batteries and EVs with swappable batteries. However, if the spotlight is directed to the battery swap provider, the statement is true according to the **Validator 3**, as the provider needs more cost to maintain battery assets to provide good service for customers.

The identified cause of the barrier ”The absence of alignment between SPKLU and SPBKLU placement”, and the strategy of making SPKLU as a buffer for SPBKLU to reduce the range of anxiety during this early phase of growing ecosystem is true if the context is focused on the large-scale diffusion of battery swap technology. However, according to **Validator 3**, if the context is zoomed out into the e-motorcycle technology ecosystem in Indonesia, not limited to the battery swap technology as the only technology available to charge the battery for e-motorcycles, SPBKLU should be the buffer for SPKLU until the battery technology is ready to be charged with a higher current (without significant weight and dimension increases). In the future, the market will return to its natural state of rapidly charging batteries without removing them from the motorcycle casing. In addition for this context, the statement from **Validator 1** emphasizes that The battery swap solution indeed solves the problem of battery charging speed in the short and mid-term and has an impact on increasing the population of e-motorcycle users, which also can drive the growth of the battery supply chain ecosystem.

Validator 4’s perspective underscores the validity of the strategy to align SPKLU and SPBKLU placement in this context. While the duration until SPKLU technology is fully utilized remains uncertain, not all businesses are sustainable. Consequently, SPBKLU players can leverage this technology transition period. Even if this phase lasts 10 to 15 years, it offers ample time for swap players to complete a business cycle and achieve profitability. Furthermore, it’s crucial to recognize that future transformations of SPBKLU may lean towards renting the battery, accommodating both charging stations and home charging, aligning with customer preferences. Ultimately, business models will converge based on individual choices and practical considerations, validating the strategy of SPKLU and SPBKLU placement alignment in this evolving landscape.

In terms of causes of barriers related to interoperability, according to **Validator 1**, the lack of interoperability does indeed serve as a barrier. However, this also serves as a natural selection process until the preferred brands emerge in the market. This is tied to the swap pattern and why brands like SWAP and Electrum are leading in the market, as their business models attract ride-hailing companies (SWAP with GRAB, Electrum with GOJEK, SGB with SICEPAT). Furthermore, their business models, such as payment per kilometer and the majority of their customers being from ride-hailing operators like GRAB and GOJEK, align with their preferences. As a legit example from **Validator 1**, in terms of research and Development, SWAP itself has upgraded its battery generation three times in the last three years (from around 1kWh to 2kWh), which emphasizes the need for significant capital to meet market demands. It is worth noting that one specific phenomenon among customers in Indonesia is the ”MUDIK” phenomenon during long holidays such as Idul Fitri, where people travel back to their hometowns over long distances, which is just one example. Significant capital is a necessity for battery swap companies to survive in the competition.

In terms of linear lock-in, **Validator 4** validated causes of barriers related to the delayed commencement of the recycling facility and other midstream infrastructure. For midstream issues, the supply chain bottleneck presents a chicken and egg situation. Production needs to be proportional to demand, sometimes requiring imports until the economic scale is suitable for local construction. Concerning the recycling facility, most swap players prioritize LFP batteries for their affordability and durability. However, IBC leverages our existing resource, nickel, impacting its circular economy. The recyclability of LFP batteries is low, almost negligible in terms of value, unlike NMC batteries, which can be profitable when recycled. This consideration extends to recycling and traceability for LFP batteries. Essentially, the cost recovery for LFP batteries is expensive, whereas NMC batteries turn a profit due to the presence of valuable materials like nickel, manganese, and cobalt mined from the recycling process.

Validation For The Proposed Strategy in Level 2

In terms of the proposed strategy, **Validator 2** emphasized the validity of the statement advocating for small companies to adopt a "wait and see" approach as modifying specifications midstream cannot be done due to existing contracts with battery companies. Additionally, small association members highlight challenges in conforming to Indonesian standards, given prevalent technology transfers from China and rebranding practices which underscores the complexities involved in manufacturing frame and battery components.

Validator 2 also addressed disagreement within the strategic considerations at Level 2, particularly regarding collaborations with internal combustion engine (ICE) players in terms of maintenance access. Caution is warranted due to potential resistance from ICE spare part outlets, which perceive electric vehicle penetration as a threat to their market share. This reluctance is exemplified by Gesits' experience, where attempts to utilize ICE networks for frame production were abruptly halted. Nonetheless, collaboration within the same e-motorcycle association remains viable.

Validator 1 also agrees with the strategy of "wait and see" for new entrants, with an additional note: if they have limited capital or other options to enter the EV business (rather than battery swap), as the capital required is smaller compared to the battery swap business, which encompasses motorcycle production as well. Regarding the proposed strategy, merger solutions or collaborations with established EV providers for new entrants of battery swap players can also be considered to reduce capital cost. **Validator 1** provided a comment: mergers can be done, but only among e-motorcycle companies. If it is among battery swap providers and their products are not interoperable yet, it would not be feasible because the principle pursued by the merger would not be achieved, which is to reduce operational costs while simultaneously adding assets.

Validator 4 validated the potential formation of a unified consortium across associations, suggesting that companies already producing new motorcycles with new standards may need a transition period before implementing unified standards. They must first utilize existing investments, consering MoU between them and Investors, before cycling into new investments and embracing new standards.

Validator 4 also validated the unnecessary SRUT standard, which slows down the increase in the population of electric motorcycle conversions and delays administrative procedures with law enforcement. Validator 4 further recommended that administrative processes should ideally not exceed one day, considering that motorcycles are also used for livelihood purposes.

C.0.4. Validation for level 1

At Level 1, **Validator 2** questioned the significance of the aspect discussed regarding Indonesia's loss in the WTO dispute with the EU over nickel export bans (B29). **Validator 2** raised concerns about whether this aspect genuinely impacts the growth of the battery swap and e-motorcycle ecosystem. There is apprehension that evolving battery technologies may shift towards LFP, which do not require large amounts of nickel or other bases. **Validator 2** shared insights into the challenges faced by IBC, attributing their suboptimal performance to the prevalence of lithium-ion (LI) battery technology, which leans towards phosphate rather than nickel manganese. **Validator 2** emphasized that this aspect is overly specific, considering the wide range of possibilities in battery development. This specificity diminishes the validity of the findings, as battery development extends beyond nickel utilization, and the trajectory of nickel usage remains uncertain over the next decade. This part of validation also in line with the insight from **Validator 3**.

According to **Validator 1**, there is indeed a connection between Level 1 and the discussed aspect, but with the caveat that there is a growing industry in the middle of supply chain (in between mining industries and battery swap providers), creating demand that requires time and government intervention. It should be noted that nickel is not the only base material in demand in Indonesia, so the barrier identified may not fully represent the situation. The weakness of the government's lack of decisiveness, as noted by the final validator, poses challenges for investors to build on time, and the government must assist in resolving this issue. However, the connection between Level 2 and Level 1 is too distant. Not only nickel is needed; other materials like lithium cobalt, manganese, etc., are also crucial. Indonesia should aim to become a battery industry hub because it possesses all the necessary raw materials. All batteries, regardless of their base, require copper and aluminum, both of which Indonesia has in abundance. In Sumatra, there is bauxite, which is essential for aluminum production.

Additionally, demand for batteries is a combination of both vehicles and motorcycles. IBC's projection of demand is approximately 60 GWh by 2035, with motorcycles comprising a smaller portion of this combined figure. Even if this demand projection is accurate, the ongoing infrastructure development for mining and smelting is sufficient, with one smelter capable of meeting Indonesia's needs. Moreover, even if Indonesia's demand strengthens, a significant portion of refined materials will still be exported. Therefore, according to **Validator 4**, addressing the issues at Level 1 may not significantly impact the growth of the battery swap ecosystem in Indonesia.

D

Human Research Ethic Committee (HREC) Checklist

Delft University of Technology
HUMAN RESEARCH ETHICS
CHECKLIST FOR HUMAN RESEARCH
(Version January 2022)

IMPORTANT NOTES ON PREPARING THIS CHECKLIST

1. An HREC application should be submitted for every research study that involves human participants (as Research Subjects) carried out by TU Delft researchers
2. Your HREC application should be submitted and approved **before** potential participants are approached to take part in your study
3. All submissions from Master's Students for their research thesis need approval from the relevant Responsible Researcher
4. The Responsible Researcher must indicate their approval of the completeness and quality of the submission by signing and dating this form OR by providing approval to the corresponding researcher via email (included as a PDF with the full HREC submission)
5. There are various aspects of human research compliance which fall outside of the remit of the HREC, but which must be in place to obtain HREC approval. These often require input from internal or external experts such as Faculty Data Stewards, Faculty HSE advisors, the TU Delft Privacy Team or external Medical research partners.
6. You can find detailed guidance on completing your HREC application here
7. Please note that incomplete submissions (whether in terms of documentation or the information provided therein) will be returned for completion **prior to any assessment**
8. If you have any feedback on any aspect of the HREC approval tools and/or process you can leave your comments here

I. Applicant Information

PROJECT TITLE:	**Revving up Sustainability: Addressing Barriers and Shaping Solutions for E-Motorcycle Battery Swap Adoption in Indonesia**
Research period: *Over what period of time will this specific part of the research take place*	**November 2023 – July 2024**
Faculty:	**Electrical Engineering, Mathematics and Computer Science**
Department:	**Sustainable Energy Technology**
Type of the research project: *(Bachelor's, Master's, DreamTeam, PhD, PostDoc, Senior Researcher, Organisational etc.)*	**Master's thesis**
Funder of research: *(EU, NWO, TUD, other – in which case please elaborate)*	**Research is not funded**
Name of Corresponding Researcher: *(If different from the Responsible Researcher)*	**Okto Fenno**
E-mail Corresponding Researcher: *(If different from the Responsible Researcher)*	**oktofenno@student.tudelft.nl**
Position of Corresponding Researcher: *(Masters, DreamTeam, PhD, PostDoc, Assistant/ Associate/ Full Professor)*	**Masters student**
Name of Responsible Researcher: ***Note:** all student work must have a named Responsible Researcher to approve, sign and submit this application*	**Dr. Linda M. Kamp**
E-mail of Responsible Researcher: *Please ensure that an institutional email address (**no Gmail, Yahoo, etc.**) is used for all project documentation/ communications including Informed Consent materials*	**L.M.Kamp@tudelft.nl**
Position of Responsible Researcher : *(PhD, PostDoc, Associate/ Assistant/ Full Professor)*	**Assistant Professor**

II. Research Overview

***NOTE:** You can find more guidance on completing this checklist here*

a) Please summarise your research very briefly (100-200 words)

What are you looking into, who is involved, how many participants there will be, how they will be recruited and what are they expected to do?

Add your text here – (please avoid jargon and abbrevations)
I am looking to understand the main drivers and barriers of battery swap technology for e-motorcycles in Indonesia, as well as identify possible strategies for companies and policy makers to facilitate large scale diffusion of this technology. 8-12 participants will be recruited via LinkedIn/ public emails or contact details provided on their own websites; no remuneration will be offered for participation. Participants are expected to participate in an interview via Microsoft Teams and answer a few questions to provide insight into the topic.

b) **If your application is an additional project** related to an existing approved HREC submission, please provide a brief explanation including the existing relevant HREC submission number/s.

Add your text here – (please avoid jargon and abbrevations)
No

c) **If your application is a simple extension of, or amendment to,** an existing approved HREC submission, you can simply submit an HREC Amendment Form as a submission through LabServant.

III. Risk Assessment and Mitigation Plan

NOTE: You can find more guidance on completing this checklist here

Please complete the following table in full for all points to which your answer is "yes". Bear in mind that the vast majority of projects involving human participants as Research Subjects also involve the collection of **Personally Identifiable Information (PII)** and/or **Personally Identifiable Research Data (PIRD)** which may pose potential risks to participants as detailed in Section G: Data Processing and Privacy below.

To ensure alighment between your risk assessment, data management and what you agree with your Research Subjects you can use the last two columns in the table below to refer to specific points in your Data Management Plan (DMP) and Informed Consent Form (ICF) – **but this is not compulsory**.

It's worth noting that **you're much more likely to need to resubmit your application if you neglect to identify potential risks**, than if you identify a potential risk and demonstrate how you will mitigate it. If necessary, the HREC will always work with you and colleagues in the Privacy Team and Data Management Services to see how, if at all possible, your research can be conducted.

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
A: Partners and collaboration						
1. Will the research be carried out in collaboration with additional organisational partners such as: • One or more collaborating research and/or commercial organisations • Either a research, or a work experience internship provider[1] *[1] If yes, please include the graduation agreement in this application*		**No**				
2. Is this research dependent on a Data Transfer or Processing Agreement with a collaborating partner or third party supplier? *If yes please provide a copy of the signed DTA/DPA*		**No**				
3. Has this research been approved by another (external) research ethics committee (e.g.: HREC and/or MREC/METC)? *If yes, please provide a copy of the approval (if possible) and summarise any key points in your Risk Management section below*		**No**				
B: Location						

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
4. Will the research take place in a country or countries, other than the Netherlands, within the EU?		**No**				
5. Will the research take place in a country or countries outside the EU?	**Yes**		**Indonesia:** - **Language barrier**	The PI speals Indonesian fluently		
6. Will the research take place in a place/region or of higher risk – including known dangerous locations (in any country) or locations with non-democratic regimes?		**No**				
C: Participants						
7. Will the study involve participants who **may** be vulnerable and possibly (legally) unable to give informed consent? (e.g., children below the legal age for giving consent, people with learning difficulties, people living in care or nursing homes,).		**No**				
8. Will the study involve participants who **may** be vulnerable under specific circumstances and in specific contexts, such as victims and witnesses of violence, including domestic violence; sex workers; members of minority groups, refugees, irregular migrants or dissidents?		**No**				
9. Are the participants, outside the context of the research, in a dependent or subordinate position to the investigator (such as own children, own students or employees of either TU Delft and/or a collaborating partner organisation)? *It is essential that you safeguard against possible adverse consequences of this situation (such as allowing a student's failure to participate to your satisfaction to affect your evaluation of their coursework).*		**No**				
10. Is there a high possibility of re-identification for your participants? (e.g., do they have a very specialist job of which there are only a small number in a given country, are they members of a small community, or employees from a partner company collaborating in the research? Or are they one of only a handful of (expert) participants in the study?		**No**				
D: Recruiting Participants						
11. Will your participants be recruited through your own, professional, channels such as conference attendance lists, or through specific network/s such as self-help groups		**No**				
12. Will the participants be recruited or accessed in the longer term by a (legal or customary) gatekeeper? (e.g., an adult professional working with children; a		**No**				

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
community leader or family member who has this customary role – within or outside the EU; the data producer of a long-term cohort study)						
13. Will you be recruiting your participants through a crowd-sourcing service and/or involve a third party data-gathering service, such as a survey platform?		**No**				
14. Will you be offering any financial, or other, remuneration to participants, and might this induce or bias participation?		**No**				
E: Subject Matter *Research related to medical questions/health may require special attention. See also the website of the CCMO before contacting the HREC.*						
15. Will your research involve any of the following: • Medical research and/or clinical trials • Invasive sampling and/or medical imaging • Medical and *In Vitro Diagnostic Medical* Devices Research		**No**				
16. Will drugs, placebos, or other substances (e.g., drinks, foods, food or drink constituents, dietary supplements) be administered to the study participants? *If yes see here to determine whether medical ethical approval is required*		**No**				
17. Will blood or tissue samples be obtained from participants? *If yes see here to determine whether medical ethical approval is required*		**No**				
18. Does the study risk causing psychological stress or anxiety beyond that normally encountered by the participants in their life outside research?		**No**				
19. Will the study involve discussion of personal sensitive data which could put participants at increased legal, financial, reputational, security or other risk? (e.g., financial data, location data, data relating to children or other vulnerable groups) *Definitions of sensitive personal data, and special cases are provided on the TUD Privacy Team website.*		**No**				
20. Will the study involve disclosing commercially or professionally sensitive, or confidential information? (e.g., relating to decision-making processes or business strategies which might, for example, be of interest to competitors)		**No**				
21. Has your study been identified by the TU Delft Privacy Team as requiring a Data Processing Impact Assessment (DPIA)? *If yes please attach the advice/ approval from the Privacy Team to this application*		**No**				
22. Does your research investigate causes or areas of conflict?		**No**				

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
If yes please confirm that your fieldwork has been discussed with the appropriate safety/security advisors and approved by your Department/Faculty.						
23. Does your research involve observing illegal activities or data processed or provided by authorities responsible for preventing, investigating, detecting or prosecuting criminal offences *If so please confirm that your work has been discussed with the appropriate legal advisors and approved by your Department/Faculty.*		**No**				
F: Research Methods						
24. Will it be necessary for participants to take part in the study without their knowledge and consent at the time? (e.g., covert observation of people in non-public places).		**No**				
25. Will the study involve actively deceiving the participants? (For example, will participants be deliberately falsely informed, will information be withheld from them or will they be misled in such a way that they are likely to object or show unease when debriefed about the study).		**No**				
26. Is pain or more than mild discomfort likely to result from the study? And/or could your research activity cause an accident involving (non-) participants?		**No**				
27. Will the experiment involve the use of devices that are not 'CE' certified? *Only, if 'yes': continue with the following questions:*		**No**				
• Was the device built in-house?						
• Was it inspected by a safety expert at TU Delft? *If yes, please provide a signed device report*						
• If it was not built in-house and not CE-certified, was it inspected by some other, qualified authority in safety and approved? *If yes, please provide records of the inspection*						
28. Will your research involve face-to-face encounters with your participants and if so how will you assess and address Covid considerations?		**No**				
29. Will your research involve **either:** a) "big data", combined datasets, new data-gathering or new data-merging techniques which might lead to re-identification of your participants **and/or** b) artificial intelligence or algorithm training where, for example biased datasets could lead to biased outcomes?		**No**				
G: Data Processing and Privacy						

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
30. Will the research involve collecting, processing and/or storing any directly identifiable PII (Personally Identifiable Information) including name or email address that will be used for administrative purposes only? (eg: obtaining Informed Consent or disbursing remuneration)	**Yes**		**Access to participant information (names, email addresses, occupation, video, and audio recordings) by a third party via a cyber-security attack.**	**1. Gather as little sensitive information as possible and only strictly necessary from participants. Identified necessary data: name, whatsapp number, gender (implicitly assumed from interviews, not explicitly asked), occupation and area of expertise, involvement in current/previous projects regarding the studied field, audio and video recording of interviews for transcription/analysis. 2. Participants will be given the option of not having video recorded (only audio) during interviews. 3. All interviews will be conducted online through a secure platform (Microsoft Teams) and using a private internet network to avoid cyber-security threats. 4. All data collected will be kept on a private, password protected drive only accessible by myself. 5. Participants will be anonymised in the published work, only their area of expertise will be mentioned, 6. All data collected will be promptly deleted as soon as the research is concluded (expected date is July 2024).**		
31. Will the research involve collecting, processing and/or storing any directly or indirectly identifiable PIRD (Personally Identifiable Research Data) including videos, pictures, IP address, gender, age etc and **what other Personal Research Data** (including personal or professional views) will you be collecting?	**Yes**		**Interviews with participants will be recorded after explicit consent has been given (both audio and video). Access to participant information (names, email addresses, occupation, video, and audio recordings) by a third party via a cyber-security attack.**	**1. Gather as little sensitive information as possible and only strictly necessary from participants. Identified necessary data: name, email address, gender (implicitly assumed from interviews, not explicitly asked), occupation and area of expertise, involvement in current/previous projects regarding the studied field, audio and video recording of interviews for transcription/analysis. 2. Participants will be given the option of not having video recorded (only audio) during interviews. 3. All interviews will be conducted online through a secure platform (Microsoft Teams) and using a private internet network to avoid cyber-security threats. 4. All data collected will be kept on a private, password protected drive only accessible by myself.**		

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
				5. Participants will be anonymised in the published work, only their area of expertise will be mentioned, 6. All data collected will be promptly deleted as soon as the research is concluded (expected date is July 2024).		
32. Will this research involve collecting data from the internet, social media and/or publicly available datasets which have been originally contributed by human participants		No				
33. Will your research findings be published in one or more forms in the public domain, as e.g., Masters thesis, journal publication, conference presentation or wider public dissemination?	**Yes**		**Access to participant information (names, email addresses, occupation, video, and audio recordings) by a third party via a cyber-security attack. Accidentally pubishing people's details in the thesis report and journal publication**	**Only anonymous quotes will be included in the MSc thesis. All other personal data will be kept separately and deleted at the end of the project.**		
34. Will your research data be archived for re-use and/or teaching in an open, private or semi-open archive?	**yes**		**Access to participant information (names, email addresses, occupation, video, and audio recordings) by a third party via a cyber-security attack. Accidentally pubishing people's details in the thesis report and 4TU portal**	**Only "process" level documents will be made available (template of consent forms, interview questions). All personal data will be deleted at the end of the project.**		

H: More on Informed Consent and Data Management

NOTE: You can find guidance and templates for preparing your Informed Consent materials) here

Your research involves human participants as Research Subjects if you are recruiting them or actively involving or influencing, manipulating or directing them in any way in your research activities. This means you must seek informed consent and agree/ implement appropriate safeguards regardless of whether you are collecting any PIRD.

Where you are also collecting PIRD, and using Informed Consent as the legal basis for your research, you need to also make sure that your IC materials are clear on any related risks and the mitigating measures you will take – including through responsible data management.

Got a comment on this checklist or the HREC process? You can leave your comments here

IV. Signature/s

Please note that by signing this checklist list as the sole, or Responsible, researcher you are providing approval of the completeness and quality of the submission, as well as confirming alignment between GDPR, Data Management and Informed Consent requirements.

Name of Corresponding Researcher (if different from the Responsible Researcher) (print)

OKTO FENNO

Signature of Corresponding Researcher:

Date: 10/01/2024

Name of Responsible Researcher (print)

DR. LINDA M. KAMP

Signature (or upload consent by mail) Responsible Researcher:

Date: 10/01/2024

V. Completing your HREC application

Please use the following list to check that you have provided all relevant documentation

Required:

- **Always:** This completed HREC checklist
- **Always:** A data management plan (reviewed, where necessary, by a data-steward)

- **Usually:** A complete Informed Consent form (including Participant Information) and/or Opening Statement (for online consent)

Please also attach any of the following, if relevant to your research:

Document or approval	Contact/s
Full Research Ethics Application	After the assessment of your initial application **HREC will let you know if and when you need to submit additional information**
Signed, valid Device Report	Your Faculty HSE advisor
Ethics approval from an external Medical Committee	TU Delft Policy Advisor, Medical (Devices) Research
Ethics approval from an external Research Ethics Committee	Please append, if possible, with your submission
Approved Data Transfer or Data Processing Agreement	Your Faculty Data Steward and/or TU Delft Privacy Team
Approved Graduation Agreement	Your Master's thesis supervisor
Data Processing Impact Assessment (DPIA)	TU Delft Privacy Team
Other specific requirement	Please reference/explain in your checklist and append with your submission

E

Data Management Plan

Plan Overview

A Data Management Plan created using DMPonline

Title: (Master thesis)-Revving up Sustainability: Addressing Barriers and Shaping Solutions for E-Motorcycle Battery Swap Adoption in Indonesia

Creator: Okto Fenno

Principal Investigator: Dr. Linda M. Kamp

Data Manager: Okto Fenno

Affiliation: Delft University of Technology

Template: TU Delft Data Management Plan template (2021)

ORCID iD: 0000-0001-9992-9220

Project abstract:

In the context of the challenges faced by the global transportation sector and Indonesia's endeavors to embrace sustainable solutions, the focus narrows down to the intricacies of the e-motorcycle battery swap industry within the Indonesian landscape.

Indonesia, a significant player in the motorcycle market, finds itself at a crossroads of potential and challenges. Despite enthusiastic government targets for electric motorcycles, the integration of these vehicles has encountered hurdles, especially in the realm of charging infrastructure. The country grapples with issues such as affordability, standardized batteries, and operational complexities associated with battery swapping stations. Moreover, a delicate balance is required, as potential users hesitate without a robust infrastructure, while service providers are cautious due to uncertain market demand—a classic chicken-and-egg dilemma.

This thesis proposal delves into these complexities, aiming to illuminate the path forward for the e-motorcycle battery swap business in Indonesia. Leveraging the Technological Innovation Systems (TIS) Framework, the study aims to comprehensively understand the dynamics within this industry. Additionally, Interpretive Structural Modeling (ISM) will be employed to dissect and prioritize existing barriers, establishing clear hierarchies among them. This meticulous analysis sets the stage for the proposal to introduce tailored and effective strategies, specifically designed to tackle the most critical obstacles. The research data will be acquired from literature studies and interviews from expert.

The proposal's structure mirrors this systematic approach. Chapter 2 embarks on a comprehensive literature review, meticulously exploring existing gaps in the field. Chapter 3 outlines the primary research questions, sub-questions, and the chosen methodology, offering a blueprint for the investigative process. In Chapter 4, the research methods and the research flow diagram will be meticulously dissected, providing insight into the analytical approach. Finally, Chapter 5 presents a proposed timeline, offering a detailed schedule that charts the course for the thesis.

ID: 140879

Start date: 09-11-2023

End date: 27-06-2024

Last modified: 08-01-2024

(Master thesis)-Revving up Sustainability: Addressing Barriers and Shaping Solutions for E-Motorcycle Battery Swap Adoption in Indonesia

0. Administrative questions

1. Name of data management support staff consulted during the preparation of this plan.

My faculty data steward, Nicolas Dintzner, has reviewed this DMP on 01/08/2024

2. Date of consultation with support staff.

2024-01-08

I. Data description and collection or re-use of existing data

3. Provide a general description of the type of data you will be working with, including any re-used data:

Type of data	File format(s)	How will data be collected (for re-used data: source and terms of use)?	Purpose of processing	Storage location	Who will have access to the data
Participant contact detail		from personal and professional network	To contact participants	OneDrive	Thesis Author (Okto Fenno) Thesis Supervisors (Linda Kamp and Hanieh Khodaei) if necessary
Excel Spreadsheet	.xls	Excel Spreadsheet	to fill the questionnaire of inter-relation between barriers	OneDrive	Thesis Author (Okto Fenno) Thesis Supervisors (Linda Kamp and Hanieh Khodaei) if necessary one dedicated spreadsheet per participant
Interview recording and transcript (Indonesian/English)	mp4	Microsoft Teams	To obtain insights and transcript regarding barriers of e-motorcycle battery swap large scale diffusion (manually written due to the absence of Indonesian transcript in MS Teams)	OneDrive	Thesis Author (Okto Fenno) Thesis Supervisors (Linda Kamp and Hanieh Khodaei) if necessary
All Iteration of Interpretative Structural modelling (from the first iteration until the end of iteration)	.xls	microsoft excel	to obtain the final form of hierarchical relationship between barriers from the data (from google spreadsheet.)	OneDrive	Thesis Author (Okto Fenno) Thesis Supervisors (Linda Kamp and Hanieh Khodaei) if necessary

4. How much data storage will you require during the project lifetime?

- < 250 GB

II. Documentation and data quality

5. What documentation will accompany data?

- Methodology of data collection
- README file or other documentation explaining how data is organised

III. Storage and backup during research process

6. Where will the data (and code, if applicable) be stored and backed-up during the project lifetime?

- OneDrive

IV. Legal and ethical requirements, codes of conduct

7. Does your research involve human subjects or 3rd party datasets collected from human participants?

- Yes

8A. Will you work with personal data? (information about an identified or identifiable natural person)

If you are not sure which option to select, first ask your Faculty Data Steward for advice. You can also check with the privacy website . If you would like to contact the privacy team: privacy-tud@tudelft.nl, please bring your DMP.

- Yes

8B. Will you work with any other types of confidential or classified data or code as listed below? (tick all that apply)

If you are not sure which option to select, ask your Faculty Data Steward for advice.

- No, I will not work with any confidential or classified data/code

9. How will ownership of the data and intellectual property rights to the data be managed?

For projects involving commercially-sensitive research or research involving third parties, seek advice of your Faculty Contract Manager when answering this question. If this is not the case, you can use the example below.

This is an internal TU Delft Master Thesis Project.

10. Which personal data will you process? Tick all that apply

- Other types of personal data - please explain below
- Data collected in Informed Consent form (names and email addresses)
- Telephone numbers
- Photographs, video materials, performance appraisals or student results
- Email addresses and/or other addresses for digital communication
- Signed consent forms
- Names and addresses

Job description, name of employers, and domain of activity

11. Please list the categories of data subjects

Employees, Founder/Cofounder of related start ups, policy-analyst, researcher in government and independent institution in Indonesia

12. Will you be sharing personal data with individuals/organisations outside of the EEA (European Economic Area)?

- No

15. What is the legal ground for personal data processing?

- Informed consent

16. Please describe the informed consent procedure you will follow:

An information sheet about the project and informed consent form will be sent out to participants to read and sign before interviews take place. Verbal consent will also be reiterated before recording interviews.

17. Where will you store the signed consent forms?

- Same storage solutions as explained in question 6

18. Does the processing of the personal data result in a high risk to the data subjects?

If the processing of the personal data results in a high risk to the data subjects, it is required to perform a Data Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data during your research (check all that apply).
If two or more of the options listed below apply, you will have to complete the DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to receive support with DPIA.
If only one of the options listed below applies, your project might need a DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to get advice as to whether DPIA is necessary.
If you have any additional comments, please add them in the box below.

- None of the above applies

22. What will happen with personal research data after the end of the research project?

- Personal research data will be destroyed after the end of the research project
- Anonymised or aggregated data will be shared with others

Anonymization will be performed for published Master Thesis.

23. How long will (pseudonymised) personal data be stored for?

- Other - please state the duration and explain the rationale below

no data will be stored after completion of project apart from anonymized data published in the study.

24. What is the purpose of sharing personal data?

- Other - please explain below
- For research purposes, which are in-line with the original research purpose for which data have been collected

we are not going to share personal data

25. Will your study participants be asked for their consent for data sharing?

- Yes, in consent form - please explain below what you will do with data from participants who did not consent to data sharing

If participants do not agree with the anonymized data sharing they will not participate in the study and their data will not be collected and/or any existing data will be immediately deleted.

V. Data sharing and long-term preservation

27. Apart from personal data mentioned in question 22, will any other data be publicly shared?

- All other non-personal data (and code) underlying published articles / reports / theses

consent material, survey question, interview question, programming script

29. How will you share research data (and code), including the one mentioned in question 22?

- All anonymised or aggregated data, and/or all other non-personal data will be uploaded to 4TU.ResearchData with public access

Data will be used for quotes in published thesis but participants will remain anonymous.

30. How much of your data will be shared in a research data repository?

- < 100 GB

31. When will the data (or code) be shared?

- As soon as corresponding results (papers, theses, reports) are published

32. Under what licence will be the data/code released?

- CC BY-SA

VI. Data management responsibilities and resources

33. Is TU Delft the lead institution for this project?

- Yes, the only institution involved

34. If you leave TU Delft (or are unavailable), who is going to be responsible for the data resulting from this project?

My thesis supervisor Linda M. Kamp (L.M.Kamp@tudelft.nl)

35. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

The conducting researcher (Okto Fenno) will be responsible for data management in the project, no financial resources or additional time are expected to be necessary.

Planned Research Outputs

Text - "Revving up Sustainability: Addressing Barriers and Shaping Solutions for E-Motorcycle Battery Swap Adoption in Indonesia"

Planned research output details

Title	Type	Anticipated release date	Initial access level	Intended repository(ies)	Anticipated file size	License	Metadata standard(s)	May contain sensitive data?	May contain PII?
Revving up Sustainability: Addressing Barriers and ...	Text	2024-09-01	Open	None specified	100 GB	Creative Commons Attribution 4.0 International	None specified	No	No

F

Letter of Consent for Conducting Interview

Interview, Questionnaire, and Validation Informed Consent Form

Research project title: Revving up Sustainability: Addressing Barriers and Shaping Solutions for E-Motorcycle Battery Swap Adoption in Indonesia
Research investigator: Okto Fenno
Research supervisor: Dr. Linda M. Kamp

You are being invited to participate in a research study titled "Revving up Sustainability: Addressing Barriers and Shaping Solutions for E-Motorcycle Battery Swap Adoption in Indonesia". This study is being done by Okto Fenno from the TU Delft Sustainable Energy Technology Master Programme.

The purpose of this research study is to understand the main drivers and barriers of battery swap technology for electric motorcycle in Indonesia, as well as identify possible strategies for companies and policy makers to facilitate adoption of this technology. The process will be divided into 3 steps: 1) Interview, 2) filling questionnaire, and 3) validation (if necessary). Those steps will take you approximately 60 minutes of barriers and strategy interview, 30 minutes of barriers inter-relation questionnaire, and 30 minutes of validation (if necessary). The interview will be used to obtain insights on the topic and form part of a published master's Thesis. We will be asking you to answer some questions on what drives and hinders the technological adoption of battery swap technology for e-motorcycle and what strategies may be useful for companies and policy makers to scaling up the diffusion of technology in Indonesia market. The questionnaire will be used to obtain inter-relationships between identified barriers, and validation will be used to obtain the validity of the findings.

This consent form is necessary for us to ensure that you understand the purpose of your involvement and that you agree to the conditions of your participation. Would you therefore sign this form to certify that you approve the following:

1. The interview will be recorded, and a transcript will be produced.
2. You will be sent the transcript and given the opportunity to correct any factual errors.
3. The transcript of the interview and the questionnaire responses will be analysed by Okto Fenno as research investigator.
4. Access to the interview transcript, and questionnaire responses, will be limited to Okto Fenno and academic colleagues and researchers with whom he will collaborate as part of the research process.
5. Any direct quotations from the interview (and validation session if any), and questionnaire that are made available through academic publication or other academic outlets will be anonymized so that you cannot be identified, and care will be taken to ensure that other information in the interview that could identify you is not revealed.

As with any online activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by taking the following measures:

1. Gathering as little personal information as possible and only strictly necessary from participants. Identified necessary data: name, email address, occupation and area of expertise, audio, and video recording of interviews for transcription/analysis.
2. You will be given the option of not having video recorded (only audio) during interviews.
3. All interviews will be conducted online through a secure platform (Microsoft Teams) and using a private internet network to avoid cyber-security threats.
4. All data collected will be kept on a private, password protected drive only accessible by researchers mentioned below.
5. You will be anonymised in the published work, only your area of expertise will be mentioned, and all participants will be referred to as they/them (e.g., "Participant 1 is a high-level executive at a sustainable energy company" and "Participant 1 stated that they identify the following barriers for technological uptake").
6. Actual recordings of interviews will be promptly deleted as soon as the research is concluded (expected date is June 2024).
7. Questionnaire will be made using Microsoft spreadsheet with single access on each participants (with email invitation) to ensure the privacy and objectivity of all participants.

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions and to opt out of including data gathered during your interview before June 2nd, 2024.

By signing this form, I agree that:
1. I am voluntarily taking part in this project. I understand that I don't have to take part, and I can stop the interview at any time;
2. The transcribed interview or extracts from it may be used as described above;
3. I have read the Information sheet;
4. I don't expect to receive any benefit or payment for my participation;
5. I can request a copy of the transcript of my interview, and questionnaire and may make edits I feel necessary to ensure the effectiveness of any agreement made about confidentiality;
6. I have been able to ask any questions I might have, and I understand that I am free to contact the researcher with any questions I may have in the future.

Participant's name :

31 January 2024

______________________________ ________________

Participant's signature Date

Should you have any questions or need to contact us, you can do so using the following details:

Okto Fenno
oktofenno@student.tudelft.nl
Corresponding Researcher

G

Result of SSIM Brainstorming Session

Cause of Barrier No. #	Description	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28	B29	B30	B31	B32
B1	Delayed operational commencement of recycling and/or other part of end-to-end supply chain facilities		O	O	O	V	A	O	O	A	A	O	A	A	A	O	A	A	O	O	A	A	A	O	X	O	A	A	A	O	O	O	O
B2	Lack of standardization and interoperability (hardware, software, and protection mechanism)			O	V	V	V	O	V	A	A	V	O	V	V	A	A	A	O	O	O	O	X	O	O	O	O	A	A	O	O	O	O
B3	The absence of alignment between SPKLU and SPBKLU placement				O	V	O	O	O	A	O	O	O	O	O	O	A	A	O	O	O	O	X	O	O	O	O	A	A	O	O	O	O
B4	Investor hesitance (in EV+Battery swap market) due to lack of standardization					V	A	A	O	A	X	X	X	A	A	A	A	A	O	O	A	O	A	O	O	O	O	O	A	O	O	O	O
B5	Capital intensive for new entrants						A	O	O	A	O	X	A	A	A	A	A	A	O	O	O	O	A	A	A	O	O	O	A	O	A	A	O
B6	Regulatory and Systemic Gaps in Battery Recycling and Traceability							A	O	A	O	V	O	O	O	O	A	A	O	O	O	O	O	O	O	O	A	A	A	O	A	O	O
B7	Varying Levels of Awareness and Understanding (Impact of Diverse Back-grounds)								O	A	O	O	O	O	O	O	X	O	O	O	O	V	O	O	O	O	O	O	A	O	V	X	X
B8	Multiple, Non-Standard Battery Racks in a single place due to weak monitoring from government									A	A	V	O	X	A	X	X	X	O	O	O	O	V	O	O	O	O	A	A	O	O	O	O
B9	Lack of experience in the body of government due to the tech-nology novelty										X	O	V	V	O	V	V	V	V	V	O	O	O	O	O	V	V	A	V	V	O	O	O
B10	Lack of talents with specific skill-set available in the job market											O	V	O	V	O	O	O	V	V	O	V	O	V	O	O	O	A	O	O	O	O	O
B11	The potential of financial challenges at the operational Level (Due to the absence of fixed standardization												A	X	A	A	A	A	X	O	O	O	A	A	O	O	O	A	A	O	V	O	O
B12	Supply Chain Bottlenecks due to the absence of several infratructures													V	X	A	A	A	X	X	O	V	A	V	V	O	A	A	A	V	V	O	O
B13	Market fragmentation due to existence of multiple consortiums with diverse specification														X	A	A	A	O	O	O	O	X	V	O	O	A	O	A	O	O	O	O
B14	The absence of open protocol and traceability of asset (batteries)															A	A	A	O	O	O	O	A	V	O	O	O	A	A	O	O	O	O
B15	Lack of government interference in the unity of consortiums																A	A	O	O	O	O	V	V	O	O	O	A	O	O	O	O	O
B16	Complex and Unclear Regulatory Landscape, involving 18 ministries and Institutions																	V	V	V	O	O	V	O	O	V	O	A	A	V	O	V	O
B17	Lack of coordinated regulatory approach (push strategy with-out pull mechanism)																		V	V	O	V	V	O	O	V	X	A	A	O	O	O	O
B18	Unnecessary strict standards in SRUT for converted motorcycle																			O	O	V	O	O	O	O	O	A	O	O	V	O	O
B19	The time-consuming process to change vehicle registration from conventional to electric, deterring potential users																				O	O	O	O	O	O	O	A	A	O	V	O	X
B20	The uncertainties surrounding the presidential election and global monetary conditions																					O	O	O	O	O	O	O	O	O	O	O	O
B21	Market dominance of ICE Motorcycles																						O	O	O	A	O	O	O	O	V	O	O
B22	Lack of collaboration among e-motorcycle and battery swap consortiums																							O	V	O	O	A	A	O	A	O	O
B23	High maintenance costs for E-motorcycles compared to the conventional one																								V	O	O	O	A	O	X	O	O
B24	Limited availability of spare parts after-sales																									O	O	O	O	O	X	O	O
B25	The absence of regulation limiting the purchase of ICE motorcycle																										A	A	O	O	O	O	O
B26	Conflicting Regulatory Stances between ministries																											X	A	O	V	O	O
B27	Heavy workload in several ministries																												V	O	V	O	O
B28	Disparities in performance among ministries which impact policy coherence																													O	O	O	O
B29	Indonesia's loss in the WTO dispute with the EU over nickel export bans																														O	A	O
B30	Slow Shift in Consumer motivation on buying e-motorcycle within 5 years period																															V	A
B31	Lack of comprehensive understanding of the benefits and functionalities of electric motorcycles compared to fossil fuel-powered ones																																A
B32	Reliance on Specific Information Sources of the benefit of EV, leading to information gap in certain demographics																																

Figure G.1: Structural Self-Intersection Matrix From Experts Brainstorming Session

H

Raghav's Main Building Blocks and Influencing Conditions Blocks

Table H.1: Building Blocks

Block Name	Description
Product performance and quality	A product (with all subsystems including hardware and software components) is required with a sufficiently good performance and quality (absolutely or relatively compared to other competitive products). Lacking performance or quality can hamper large-scale diffusion.
Product price	A product (with all subsystems) is required with a reasonable price (absolutely or relatively compared to other competitive products). The price of a product involves financial and non-financial (e.g., time and effort) investments to acquire and use the product. A prohibitively high price can hamper large-scale diffusion.
Production system	A production system that can produce large quantities of products with sufficiently good performance and quality (absolutely or relatively compared to competitive products), is required for large-scale diffusion. A lack of production system can hamper large-scale diffusion.
Complementary products and services	Complementary products and services for the development, production, distribution, adoption, use, repair, maintenance, and disposal of an innovation are required. Unavailable, incompatible, or too expensive complementary products and services can hamper large-scale diffusion.

Continued on next page

Table H.1 – *Continued from previous page*

Block Name	**Description**
Network formation and coordination	Required actors and sufficient coordination of their activities to develop, produce, distribute, repair, maintain, and dispose of products are required for large-scale diffusion. Coordination can be emergent and implicit (e.g., the market mechanism) or can be formal and explicit (e.g., an industry association). Coordination can involve actual collaboration and a shared vision regarding the innovation and the TIS around it. If types of actors and coordination amongst these actors are needed yet missing, large-scale diffusion can be hampered.
Customers	Customer segments are required for large-scale diffusion. Potential customers with a need for the innovation should be identified. To become actual customers, they should be aware of the product, see its benefits relative to other innovations, and have the knowledge, means, and willingness to acquire and use it. If actual customers are lacking, large-scale diffusion can be hampered.
Innovation-specific institutions	These institutions refer to formal policies, laws, and regulations either describing norms and requirements regarding the product, production facilities, and complementary products and services or describing how actors (on the supply and demand side of the market) should deal with the product and system around it. Specific institutions can stimulate or hamper large-scale diffusion.

Table H.2: Influencing Conditions

Influencing Condition	**Description**
Knowledge and awareness of technology	This involves both fundamental and applied technological knowledge. Fundamental knowledge refers to the technological principles involved in components of the TIS, like the product, production, and complementary products and services. Applied technological knowledge refers to the knowledge required to develop, produce, repair, maintain, and improve these components. When relevant actors lack knowledge and awareness of technology for their role, this can affect the formation of several TIS building blocks.
Knowledge and awareness of application and market	This refers to knowledge of (1) potential applications, (2) knowledge of the market (structure) and the actors involved in these applications. This knowledge is required for all actors including customers to formulate strategies, articulate product requirements and find or target other actors. When actors lack such knowledge required for their role, this can affect the formation of several TIS building blocks.

Continued on next page

Table H.2 – *Continued from previous page*

Influencing Condition	**Description**
Natural, human and financial resources	Resources can refer to natural, human, and financial resources. Natural resources refer to raw materials that can be acquired by each organization separately or by associations of organizations. Human resources refer to individuals with the right knowledge and competences. Increasing human resources may involve education programs, courses, and training on the job. Financial resources can come from various sources. Lack of natural, human, or financial resources can affect the formation of TIS building blocks.
Competition	Competition can refer to competition between products based on old and new technologies but may also refer to competition between different product versions with a new technology. Since different product versions often require different production systems and complementary products and services, competition arises between networks of companies. The combined complex patterns of competition may hamper the formation of TIS building blocks.
Macro-economic and strategic aspects	Macro-economic aspects refer to the overriding economic situation, such as a recession or economic growth. Strategic aspects refer to interests of countries which are often reflected in generic institutions and government policies. Macro-economic and strategic aspects can influence the formation of TIS building blocks.
Socio-cultural aspects	Socio-cultural aspects refer to the norms and values in a particular culture or socio-technical system. These conditions might be less formalized than the laws and rules in the innovation-specific institutions. They include methods and habits, norms and values (“the way to do things”) and may become visible in interest groups or relevant stakeholder groups. Socio-cultural aspects can influence the formation of different TIS building blocks.
Accidents and events	Accidents and events may emerge both outside a TIS (e.g., wars, political turmoil or natural disasters) or from within a TIS (e.g., accidents with products or in production, emergence of new technologies). Accidents and events can influence the formation of several TIS building blocks.

I

Driving and Dependence Power in the Final Reachability Matrix

Causes of Barriers #	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28	B29	B30	B31	B32	Driving Power
B1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	0	0	0	0	1	1	1	0	20
B2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B3	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	0	0	0	0	1	1	1	0	20
B4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	1	1	1	1	0	0	0	0	1	1	1	1	24
B5	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	1	0	0	1	1	1	1	0	0	0	0	1	1	1	0	20
B6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	32
B21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
B30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B31	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
B32	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	31
Dependance Power	31	31	31	31	31	31	31	31	28	28	31	31	31	31	27	27	27	31	28	1	31	31	31	31	27	27	27	27	32	31	31	28	

Figure I.1: Driving and Dependence Power in the Final Reachability Matrix

J

ISM MATLAB Source Code

```
"""
clc
clear all

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Input data and initialization
[num,data] = xlsread('SSIMinitial1.xlsx', 'A1:AG33')
barrier = 32 %num of barriers exist

% Initialize the reachability matrix with zeros
reachability_matrix = zeros(barrier+1,barrier+1);


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% % Loop through the raw data to fill the reachability matrix
for i = 2:size(data, 1) % Loop over rows
    if i<barrier

        for j = 1+i:size(data, 2) % Loop over columns

        % Get the value from the data cell array
        value = data{i, j};

        % Check if the value is a char (string) and not empty or NaN
                    if value =='V'
                        reachability_matrix(i, j) = 1;
                        reachability_matrix(j, i) = 0;
```

```
                    elseif value == 'A'
                        reachability_matrix(i, j) = 0;
                        reachability_matrix(j, i) = 1;
                    elseif value == 'X'
                        reachability_matrix(i, j) = 1;
                        reachability_matrix(j, i) = 1;
                    elseif value == 'O'
                          reachability_matrix(i, j) = 0;
                          reachability_matrix(j, i) = 0;
                    end




        end

    elseif i == barrier
        j ==barrier+1
        value = data{i, j};

        % Check if the value is a char (string) and not empty or NaN
                    if value =='V'
                        reachability_matrix(i, j) = 1;
                        reachability_matrix(j, i) = 0;
                    elseif value == 'A'
                        reachability_matrix(i, j) = 0;
                        reachability_matrix(j, i) = 1;
                    elseif value == 'X'
                        reachability_matrix(i, j) = 1;
                        reachability_matrix(j, i) = 1;
                    elseif value == 'O'
                          reachability_matrix(i, j) = 0;
                          reachability_matrix(j, i) = 0;
                    end

    end
end

%if i = j , value = 1
for k = 2:barrier+1
reachability_matrix(k, k) = 1;
end

reachability_matrix_print = num2cell(reachability_matrix);
reachability_matrix_print(1,:) = {'','B1', 'B2', 'B3', 'B4', 'B5', 'B6', 'B7', 'B8', 'B9', 'B10', 'B11', 'B12', 'B13', 'B14', 'B15', 'B16', 'B17', 'B18', 'B19', 'B20', 'B21', 'B22', 'B23', 'B24', 'B25', 'B26', 'B27', 'B28', 'B29', 'B30', 'B31', 'B32'};
```

```matlab
reachability_matrix_print(:,1) = {'';'B1'; 'B2'; 'B3'; 'B4'; 'B5'; 'B6'; 'B7'; 'B8'; 'B9'; 'B10'; 'B11'; 'B12'; 'B13'; 'B14'; 'B15'; 'B16'; 'B17'; 'B18'; 'B19'; 'B20'; 'B21'; 'B22'; 'B23'; 'B24'; 'B25'; 'B26'; 'B27'; 'B28'; 'B29'; 'B30'; 'B31'; 'B32'};
% Write the reachability matrix to a new Excel file
writecell(reachability_matrix_print, 'reachability_matrix.xlsx');
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%applying transitivibility in the reachability matrix
% final reachability_matrix
% Initializing the final transitivity matrix
final_reach_matrix = reachability_matrix;

% To track the changes
check_mat = reachability_matrix;
c = 2; % Counter to see transitivity

while true
    prev = final_reach_matrix;
    for i = 2:barrier+1
        for j = 2:barrier+1
            for k = 2:barrier+1
                % Skip cases where i, j, or k are equal
                if i ~= j && j ~= k && i ~= k
                    % Add the condition c <= 2 and check other conditions
                    if final_reach_matrix(i, j) == 1 && final_reach_matrix(j, k) == 1 && final_reach_matrix(i, k) == 0 && c <= 2
                        final_reach_matrix(i, k) = 1; % Update final reachability matrix
                        check_mat(i, k) = c; % Update matrix to show where transitivity affects
                    end
                end
            end
        end
    end

    c = c + 1;

    if isequal(final_reach_matrix, prev)
        break;
    end
end



%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
%to check the change in the initial reachability matrix
check_mat;

check_mat_print = num2cell(check_mat);
check_mat_print(1,:) = {'','B1', 'B2', 'B3', 'B4', 'B5', 'B6', 'B7', 'B8', 'B9', 'B10', 'B11', 'B12', 'B13', 'B14', 'B15', 'B16', 'B17', 'B18', 'B19', 'B20', 'B21', 'B22', 'B23', 'B24', 'B25', 'B26', 'B27', 'B28', 'B29', 'B30', 'B31', 'B32'};
check_mat_print(:,1) = {'';'B1'; 'B2'; 'B3'; 'B4'; 'B5'; 'B6'; 'B7'; 'B8'; 'B9'; 'B10'; 'B11'; 'B12'; 'B13'; 'B14'; 'B15'; 'B16'; 'B17'; 'B18'; 'B19'; 'B20'; 'B21'; 'B22'; 'B23'; 'B24'; 'B25'; 'B26'; 'B27'; 'B28'; 'B29'; 'B30'; 'B31'; 'B32'};
writecell(check_mat_print, 'Final␣reachability␣matrix␣check.xlsx');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Write the final reachability matrix to a new Excel file (with driving and
% dependance power


final_reach_matrix_for_print =final_reach_matrix;
driving_power = sum(final_reach_matrix_for_print,2);
dependance_power = [sum(final_reach_matrix_for_print,1) 0];
final_reach_matrix_for_print = [final_reach_matrix_for_print driving_power];
final_reach_matrix_for_print = [final_reach_matrix_for_print;dependance_power];


final_reach_matrix_print = num2cell(final_reach_matrix_for_print);
final_reach_matrix_print(1,:) = {'','B1', 'B2', 'B3', 'B4', 'B5', 'B6', 'B7', 'B8', 'B9', 'B10', 'B11', 'B12', 'B13', 'B14', 'B15', 'B16', 'B17', 'B18', 'B19', 'B20', 'B21', 'B22', 'B23', 'B24', 'B25', 'B26', 'B27', 'B28', 'B29', 'B30', 'B31', 'B32', 'Driving␣Power'};
final_reach_matrix_print(:,1) = {'';'B1'; 'B2'; 'B3'; 'B4'; 'B5'; 'B6'; 'B7'; 'B8'; 'B9'; 'B10'; 'B11'; 'B12'; 'B13'; 'B14'; 'B15'; 'B16'; 'B17'; 'B18'; 'B19'; 'B20'; 'B21'; 'B22'; 'B23'; 'B24'; 'B25'; 'B26'; 'B27'; 'B28'; 'B29'; 'B30'; 'B31'; 'B32'; 'Dependance␣Power'};

writecell(final_reach_matrix_print, 'Final␣reachability␣matrix.xlsx');



%level partitioning of the final reachability matrix
reachability_set = zeros (barrier);
antacedent_set =zeros (barrier);   %initialization of reachability, antacedent, and intersection matrix
intersection_set = zeros (barrier);


for i = 2:barrier+1
    for j = 2:barrier+1
        if final_reach_matrix(i,j) ==1; %for forming reachability set
            reachability_set(i,j) = j-1;
```

```
        end
        if final_reach_matrix(j,i) ==1; %for forming antacedent set
            antacedent_set(i,j) = j-1;
        end

        if final_reach_matrix(i,j) ==1 && final_reach_matrix(j,i) ==1 ; %for forming intersection set, finding common element
            intersection_set(i,j) = j-1;
        end
    end
    end

 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
 %Print initial level partitioning value
    reachability_set_init = reachability_set;
    antacedent_set_init = antacedent_set;
    intersection_set_init = intersection_set;

  % Initialize cell arrays to store the stringified versions of the matrices
reachabilityStrings = cell(size(reachability_set_init, 1), 1);
antacedentStrings = cell(size(antacedent_set_init, 1), 1);
intersectionStrings = cell(size(intersection_set_init, 1), 1);

% Convert each row into a comma-separated string
for i = 1:size(reachability_set_init, 1)
    reachabilityStrings{i} = join(string(reachability_set_init(i,:)), ',');
    antacedentStrings{i} = join(string(antacedent_set_init(i,:)), ',');
    intersectionStrings{i} = join(string(intersection_set_init(i,:)), ',');
end

% Combine into a single cell array for writing to Excel
combinedData = [reachabilityStrings, antacedentStrings, intersectionStrings];

% Write to Excel
filename = 'level_partitioning_before_iteration.xlsx';
writecell(combinedData, filename, 'WriteMode', 'overwritesheet');

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% %labelling hierarchy level among barriers
hierarchy = zeros(barrier,barrier);

% %
x=1;
while true
    y = 1 ;% counter for column-wise
    for i = 2:barrier+1
        if (sum(reachability_set(i,:) == intersection_set(i,:)) ==  barrier+1 && nnz(
```

```
            reachability_set(i,:))~=0)
            hierarchy(x,y) = i-1;

            y = y+1

        end
    end



 for j = 1:barrier
    if hierarchy(x,j)~=0
        a= hierarchy(x,j);
        reachability_set(a+1,:) = zeros(1,barrier+1);
        intersection_set(a+1,:) = zeros(1,barrier+1);
        antacedent_set(a+1,:) = zeros(1,barrier+1);

        reachability_set(:,a+1) = zeros(barrier+1,1);
        intersection_set(:,a+1) = zeros(barrier+1,1);
        antacedent_set(:,a+1) = zeros(barrier+1,1);



%hapus semua elemen di row lain of reach matrix and antacedent matrix !,
% print perubahannya
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%delete element in other rows and columns for next iteration

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    else
        break;
    end
 end
x = x+1

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Print level partitioning on each iteration

% Assuming reachability_set, antacedent_set, and intersection_set are defined somewhere above
     this snippet
numIterations = 10; % Replace with the actual number of iterations you have


    filename = sprintf('level_partitioning_iteration_%d.xlsx', x);


    % Initialize cell arrays to store the stringified versions of the matrices
```

```
    reachabilityStrings = cell(size(reachability_set, 1), 1);
    antacedentStrings = cell(size(antacedent_set, 1), 1);
    intersectionStrings = cell(size(intersection_set, 1), 1);

    % Convert each row into a comma-separated string
    for i = 1:size(reachability_set_init, 1)
        reachabilityStrings{i} = join(string(reachability_set(i,:)), ',');
        antacedentStrings{i} = join(string(antacedent_set(i,:)), ',');
        intersectionStrings{i} = join(string(intersection_set(i,:)), ',');
    end

    % Combine into a single cell array for writing to Excel
    combinedData = [reachabilityStrings, antacedentStrings, intersectionStrings];

    % Write to Excel
    writecell(combinedData, filename, 'WriteMode', 'overwritesheet');




%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

if (nnz(reachability_set)==0)
    break;
end
end


% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```