MODELLING BATTERY SWAPPING INDUSTRY DEVELOPMENT STRATEGY TO SUPPORT NET ZERO EMISSIONS TRANSITION

Riskiyadi[1,2] & A.D. Setiawan[1*]

ARTICLE INFO

Article details
Submitted by authors 23 Mar 2024
Accepted for publication 7 Oct 2024
Available online 13 Dec 2024

Contact details
* Corresponding author
a.d.setiawan@ui.ac.id

Author affiliations
1 Industrial Engineering Department, Faculty of Engineering, Universitas Indonesia, Jakarta, Indonesia

2 State Electricity Company (PLN), Jakarta, Indonesia

ORCID® identifiers
Riskiyadi
https://orcid.org/0009-0007-0903-2673

A.D. Setiawan
https://orcid.org/0000-0002-7453-190X

DOI
http://dx.doi.org//10.7166/35-4-3026

ABSTRACT

The Government of Indonesia has set a roadmap towards net zero emissions by 2060, which includes accelerating the adoption of electric motorcycles. The government assigned the State Electricity Company (PLN) to accelerate the adoption by optimizing the potential of conventional motorcycle users and ride hailing. The battery swapping scheme is an attractive choice for companies to increase their profits. However, users still experience uncertainty about battery swapping. It is thus imperative to implement a battery reservation strategy to make it easy for battery swapping users to exchange them. The battery swapping industry is a complex system that involves many interrelated elements. Such a development of strategy would require a holistic view of the process and a definition of the relationships between the elements. This research aimed to develop a conceptual model for a battery swapping industry development strategy with a system dynamic modelling approach and a business model canvas framework. The conceptual model is presented in a system diagram, and a causal loop diagram provides the first information that has an impact on the company's intervention in the battery swapping industry development strategy. Furthermore, the business model canvas should help to communicate the key aspects easily.

OPSOMMING

Die regering van Indonesië het 'n padkaart opgestel vir netto nul-emissies teen 2060, insluitend die versnelling van die aanvaarding van elektriese motorfietse. Die regering het die Staatselektrisiteits-maatskappy (PLN) aangewys om die aanvaarding te versnel deur die potensiaal van konvensionele motorfietsgebruikers en ritte te optimeer. Die batteryruilskema is 'n aantreklike keuse vir maatskappye om wins te verhoog. Gebruikers ervaar egter steeds onsekerheid oor batterywisseling. Dit is dus noodsaaklik om 'n batterybespreking-strategie te implementeer om dit maklik te maak vir batteryruilgebruikers om batterye te ruil. Die batteryruilbedryf is 'n komplekse stelsel wat baie onderling verwante elemente behels. So 'n strategie vereis 'n holistiese siening om die proses te begryp en die verhoudings tussen elemente te definieer. Hierdie navorsing het ten doel om 'n konseptuele model vir battery-uitruiling industrie-ontwikkelingstrategie te ontwikkel met 'n stelseldinamika-modelleringbenadering en besigheidsmodel-raamwerk. Die konseptuele model is teenwoordig in 'n stelseldiagram; die oorsaaklike lusdiagram verskaf die eerste inligting wat 'n impak het op die maatskappy se ingryping in die battery-uitruilingsbedryf-ontwikkelingstrategie. Verder sou die sakemodel raamwerk help om die sleutelaspekte maklik te kommunikeer.

1. INTRODUCTION

The increasing temperature of the Earth led more than 100 world leaders to support the proposal and agree to keep the temperature increase below 2°C at the 21st Conference of the Parties (COP), which took place from November 30 to December 31, 2015 at the Paris Agreement on Climate Change [1, 2]. The targets of each country ratifying the agreement are set out in its nationally determined contribution (NDC). This has made the decarbonisation agenda, environmental factors, and socioeconomic growth factors some of the main focuses in each country's long-term national strategy [3]. To reduce its carbon footprint and achieve net zero emission (NZE), the Indonesian government implemented primary principles, percentages, and a roadmap towards achieving the zero-emission target [4].

Through the Indonesian Ministry of Energy and Mineral Resources, the roadmap aims gradually to issue regulations in the form of presidential regulations related to new and renewable energy (NRE) and retirement coal, to issue the NRE law, and to build smart grids, smart meters, two million electric cars, and 13 million motorcycles until 2060, when the NRE mix is targeted to reach 100%. It would be dominated by solar and hydro and the use of electric vehicles (EVs), and electricity consumption would reach 5,308 kilowatt-hours per capita (kWh/capita) [4]. The transportation sector accounts for a quarter of Indonesia's energy needs; by 2020, transportation sector emissions constituted 27% of Indonesia's total greenhouse gas (GHG) emissions. As a contributor to reducing energy sector emissions, decarbonising the transport sector would critical for Indonesia to achieve its net zero goal. GHG emissions from transportation would need to be reduced by three million tons of carbon dioxide equivalent (CO_2-eq) annually until 2030 and by seven million tons of CO_2-eq from 2030 to 2050 [5]. Indonesia is committed to reducing its CO_2 emissions; one way to do this would be by increasing the adoption of EVs despite significant difficulties with infrastructure, technology, cost, and user acceptance [6].

The government has also issued fiscal and non-fiscal policies to boost the adoption of EVs. A fiscal policy has been issued in Government Regulation Number 74 of 2021, by which the government exempts sales tax on luxury goods based on the emission level of the battery electric vehicle (BEV). The Ministry of Home Affairs Regulation No. 1 of 2021 establishes that the maximum annual tax and transfer fee for BEVs is only 10% of the cost calculation. Non-fiscal policies are found in the Presidential Instruction No. 7 of 2022 on EV adoption for government service vehicles and in the Ministry of Transportation Regulation No. 15 of 2022 on the conversion of vehicles other than those with two wheels. The Ministry of Industry (MOI) also issued Ministerial Regulation No. 6/2022 on technical requirements, the national EV roadmap, and the local content requirement (LCR) guidelines. The Ministry of Energy and Mineral Resources Regulation No. 13/2020 deals with the standardisation of charging plugs and electricity tariff policies for public EV charging stations and battery replacement. The Ministry of Transportation Regulation No. 44 of 2020 covers EV testing and certification, while the Ministry of Commerce Regulation No. 45 of 2020 contains electric motorised special vehicle regulations, including safety requirements, driving behaviour, and vehicle lanes. The Ministry of Trade Regulation No. 65 of 2020 legitimises 2W to electric 2W (E2W) conversions, and regulates conversion vehicle components and the requirements for converting small and medium enterprise (SME) conversion workshops, along with safety requirements and administrative processes [5].

The availability of charging infrastructure is essential, and would remove an obstacle to EV adoption. The lack of charging infrastructure is a psychological barrier to consumers adopting EVs, known as 'range anxiety', which means that consumers do not feel safe with the range offered by EVs because they would still have difficulty finding charging infrastructure. Investment in such infrastructure needs to be intensified in order to meet the IEA recommendation of one charger for every 10 EVs [5]. In July 2023 the extent of EV infrastructure was 616 charging stations and 1,401 battery swap stations, while there were 12,395 EVs and 40,312 electric motorcycles [7]. Based on this data, the ratio between charging stations and electric cars was 1:20, and between battery swap stations and the number of electric motorcycles it was 1:29.

Battery swapping allows electric motorcycle users to travel far without experiencing long charging times at battery swapping stations [8]. This improves efficiency by reducing household costs, providing a constant supply of energy, meeting the energy needs of EVs, allowing battery charging in less than two minutes, and being convenient to use [9]. There have been many studies related to battery swapping on operations [10-18]. Factors for the adoption of battery swapping technology for EVs at exchange stations have also been investigated [1, 9, 19]. Other research discusses models or frameworks to develop business processes and to improve operational cost efficiency [8, 20-22]. In contrast, the current research discusses the development strategy of the battery swapping industry [1, 23]. However, none of the other studies quantitatively addressed the business development of the battery swapping industry using the business model canvas framework.

The development of the battery swapping industry is essential to eliminate range anxiety, which is a primary obstacle to the market penetration of EVs, and to optimise the potential of electric motorcycle ride hailing service providers in order to increase the profitability of battery swapping station providers. Battery swapping and battery reservation technology would be a solution to these problems. It would ensure the availability of the desired battery at the battery swapping station and also allow EVs to travel far without experiencing long battery charging times [8]. The business model canvas serves as a framework for the value-creation process [23]. The battery swapping industry is a complex system that involves many interrelated elements; so the development of a strategy would require a holistic understanding of the process and a definition of the relationships between its elements. Therefore, it would be necessary to identify, map, and communicate a workable business model concept to describe the dynamics of the battery swapping industry's development more comprehensively.

This study offers a conceptual model for devising a systematic strategy for the development of the battery swapping industry's business. The development of the conceptual model uses a system dynamics approach to gain insights into developing a battery swapping industry strategy, and is a first step to identifying effective policies to improve sustainability in the battery swapping industry, thus supporting the NZE transition. In addition, a framework will be built using the business model canvas to understand and develop a dynamic and effective business model.

2. LITERARURE REVIEW

Charging EVs still takes longer than refuelling traditional vehicles, making many consumers hesitant to switch. As a solution, battery swapping allows EVs to be charged within minutes [24]. Battery swapping technology is the superior solution for future road mobility, and has significant implications for the transport industry and for electrical systems [25]. Battery swapping technology is innovative in providing range satisfaction in using EVs, advancing zero-carbon vehicle transportation, and improving environmental sustainability [19]. Battery swapping is an alternative that addresses the technical problems of price, range, and charging time, thus allowing users of two-wheeled EVs to replace a depleted battery with a fully charged one easily at the desired charging station [1].

Sales tax incentives and technological advances could increase public interest in switching to electric motorcycles [26]. The right incentive policies to improve the acceptance of electric motorcycles would relate to cost and time, such as tax discounts and free parking, rather than product quality, such as quality assurance and warranties [27]. The government and vehicle manufacturers could improve users' perceptions of and attitudes to electric motorcycles by highlighting innovative designs and user-friendly operational functions. In addition, vehicle manufacturers could increase consumer confidence by providing good after-sales service and improving product quality. The government could also offer incentives and subsidies to encourage the use of electric motorcycles, and expand the availability of the charging infrastructure [28]. Four main factors influence EV adoption behaviour: psychological factors, social factors, environmental factors, and policy factors [29]. Ride hailing service drivers in Indonesia would be willing to adopt electric motorcycles by purchasing or renting them if the purchase or rental costs were affordable and if the mileage that could be achieved by electric motorcycles were adequate for their needs. In addition, the availability of proper charging infrastructure would be an essential factor in ride hailing drivers' decision to adopt electric motorcycles [30].

Battery reservation would be helpful to ensure the availability of the required batteries, to optimise the travel time of EVs, and to reduce waiting times at battery replacement stations [8]. The battery reservation scheme would be used to manage battery replacement requests that would enable EVs to obtain status messages that are released by battery replacement stations through mobile edge nodes so that electric cars could select the right battery replacement station to replace an exhausted battery [13]. The battery swapping station (BSS) business model has emerged, influenced by the increasing attention to EV batteries and the deregulation of the electricity market. BSS could also support a sustainable EV ecosystem and generate profits in the power grid with battery reservation strategies, resulting in increased overall profits and longer battery life [11].

3. METHODOLOGY

The researcher developed a causal loop diagram (CLD) model of the battery swapping service industry [1], assuming a willingness to adopt electric motorcycles for ride hailing services [30] and a battery swapping process model with a reservation method [8], using the business model canvas framework [31] to support its economic, social, and environmental sustainability. The literature review above aimed to determine the variables that correlate with industry and the relationship between the variables selected from expert judgements and related theories. The relationships between variables can be seen in Figure 1, with arrows with positive or negative polarity symbols indicating a causal impact or vice versa. The feedback relationships between the variables in the CLD are further analysed through a system-thinking pattern to understand the problem better [32]. Once the system process is established, a system diagram defines the entire process and the strategy for sustainable battery swapping. The system diagram shows the problem owner and the goals desired by the problem owner, all the stakeholder participants in the industry development, how the system works, and the policy interventions needed to influence the system output. The business model canvas framework helps to identify and understand the key elements of a business model, such as critical resources, processes, and stakeholders, and how the interaction between these elements could create value for the company [23].

4. RESULT AND DISCUSSIONS

4.1. Actor Analysis

Actors are classified into three categories: those affected by the problem and the solution, those formally involved in the policy intervention, and those interested in the implementation of the solution [1].

The Government of Indonesia (GoI) is the first actor. By building adequate battery swapping facilities, the government wants to develop an adequate battery swapping industry to boost the growth of electric motorcycle users [33]. The government has drawn up a road map to achieve NZE by 2060 by targeting the number of EV users [4].

The second actor is a state electricity company known as PLN. The government assigns PLN as the vehicle for the development of battery-based EVs, and continues to support all programmes to accelerate the EV ecosystem. PLN invites investors to work together to accelerate the construction of profitable battery swapping stations [34]. Therefore, PLN is expected to intervene in the battery swapping process to reduce the anxiety of electric motorcycle users [33].

The third actor is conventional motorcycle users. They are concerned about the limited mileage and the lack of charging infrastructure for EV motorcycles, which hinder the growth of the EV market [5].

The fourth actor is existing electric motorcycle users. Those users have the right to decide whether to use battery swapping services [1]. They need the assurance that batteries will be obtainable at the battery swapping station using the battery reservation service [8].

The fifth actor is ride hailing services. Those service providers are oriented to low operating costs, reliable battery swapping networks, and profitability [30]. The increased adoption of ride hailing services is expected to boost profit growth for battery swapping station infrastructure providers.

The actors are analysed below (Table 1) according to six characteristics: problem perception, cause of problem, objective, interest, resources, and position.

Table 1: Characteristics of development battery swapping industry actors in Indonesia

Actor	Problem perception	Cause of problem	Objective	Interest	Resource	Position
Government of Indonesia	Limited battery swap facilities hamper EV market growth [5]	Battery swapping industry is low or not profitable [1]	Develop battery infrastructure swapping infrastructure to increase the number of electric motorcycle users [1]	Adequate battery swapping facilities [5]	Authority to enact regulations to develop the battery swapping sector [1]	Establish a road map towards NZE 2060 for implementation [4]
State electricity company (PLN)	Government assignment to be the vehicle for the development of battery electric motor vehicle implementation [35]	Efforts to reduce carbon emissions [36]	Strengthen EV infrastructure [7]	Profitable battery swapping business [37]	Policies to influence electricity tariffs [1] and intervention in the battery swapping process	Encourage and promote the use of EVs [38]
Conventional motorcycle users	Running out of battery at the station because another vehicle has taken it away [8]	Not implementing online battery reservations [8]	To eliminate range anxiety and difficulty finding charging infrastructure [33]	Obtain certainty of battery availability at battery swapping stations [8]	The decision not to switch to EVs [1]	Waiting to adopt an electric motorcycle [1]
Electric Motorcycle Users	Uncertainty about obtaining batteries at battery swapping stations [8]	Not considering battery reservation [8]	Unlimited driving range [19] and minimise the battery swapping lead time [8]	Easy to use technology and affordable access [19]	The decision not to use battery swapping [1]	Waiting to use battery swapping [1]
Electric motorcycle ride hailing services	Limited range leads to anxiety about running out of power on the go and lack of charging infrastructure [30]	Access to a reliable and convenient network of battery swapping stations [30]	Lower operating costs and environmental benefits [30]	Benefits ride hailing service providers [30]	The power of not adopting EVs [30]	Waiting to adopt the use of an electric motorcycle

4.2. Conceptual Model

4.2.1. System Diagram

Figure 1 shows the system diagram of the development of the battery swapping service industry. The diagram has several elements: system inputs, outputs, objectives, company interventions, problem owners, stakeholders, and the CLD as a system model. Inputs into the system include external factors that the problem owner cannot influence, or that are difficult to influence. Policy variables correspond to the intervention of the problem owner; the CLD defines the pattern structure, visualising the cause-and-effect relationships between variables or components in the battery swapping industry service. Outputs are measured as objective criteria that are used as indicators to assess the effectiveness of company interventions, the precise number of users of battery swapping services, the profit for companies providing battery swapping services, and the total reduction of CO_2 emissions. Company interventions will be applied to evaluate the model's behavior and each policy's effectiveness in achieving the objectives.

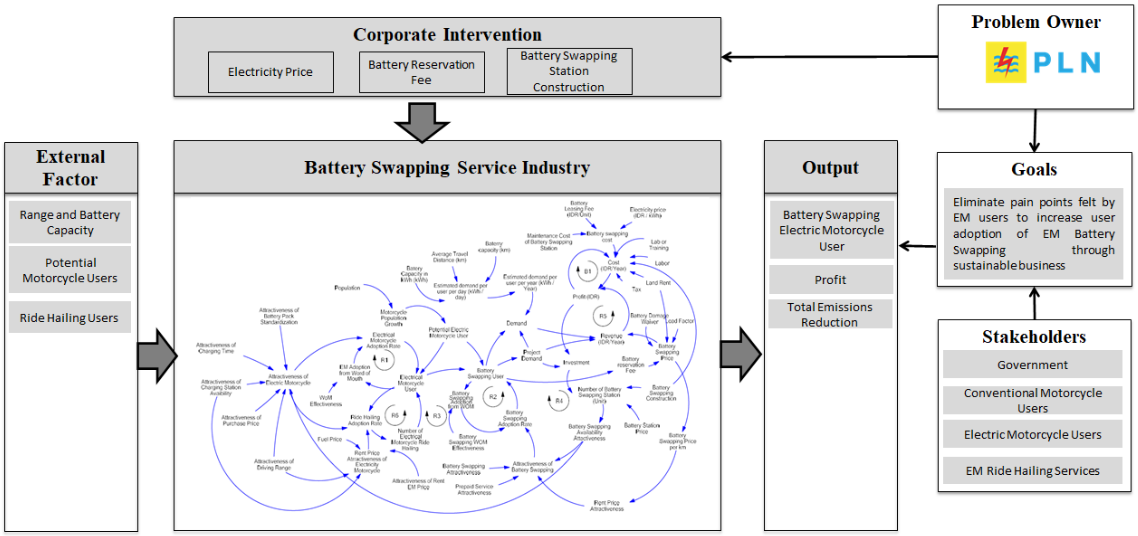


Figure 1: System diagram for the development of the battery swapping industry in Indonesia (Note: An enlarged version of the CLD is provided in Figure 2)

4.2.2. Causal Loop Diagram

Figure 2 shows the CLD for the strategic development process of the battery swapping industry. The CLD has seven loops: six causality reinforcing loops, and one causality balancing loop. Loops R1 to R5 are the base model of the CLD of the battery swapping service industry in Indonesia [1].

The following is an explanation of each loop:

- Loop R1 explains the impact of word-of-mouth on electric motorcycle adoption. A greater number of users of electric motorcycles would imply a stronger word-of-mouth (WOM) effect, thus influencing a growing number of users to switch to electric motorcycles.
- Loop R2 describes the effect of word-of-mouth on battery swapping user adoption. Similarly, an increase in battery swapping users could increase battery swapping adoption among potential word-of-mouth users.
- Owing to infrastructure development, Loops R3 and R4 represent the adoption of electric motorcycles and battery swapping. A greater number of users could result in higher profits for battery swapping station providers. It would also increase the added value of the business, and encourage the provider to build additional infrastructure to attract potential users.
- Loop R5 explains that investment in the battery swapping industry would increase as profits increase. Revenue would also be influenced by battery reservation strategies to improve the service and user convenience.
- Loop R6 represents the increased adoption of ride hailing services obtained by purchasing or renting an electric motorcycle [30]. Strengthening the number of electric motorcycle users would increase the number of battery swapping users.
- Loop B1 balances revenue and cost to generate profit; the cost component would be influenced by the battery swapping cost and laboratory or training costs [1], taking into account taxes, labour, and land rent [16].

4.2.3. Mapping Causal Loop Diagram to Business Model Canvas

The business model canvas is a model that describes the rationale for how an organisation or company creates, delivers, and captures value [39]. A canvas-shaped business model framework consists of nine boxes of interlocking elements that show the logic of how a company intends to make money. These nine blocks cover the four main areas of the business: customers, offerings, infrastructure, and financial viability. The nine elements in the business model canvas are customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partners, and cost structure.

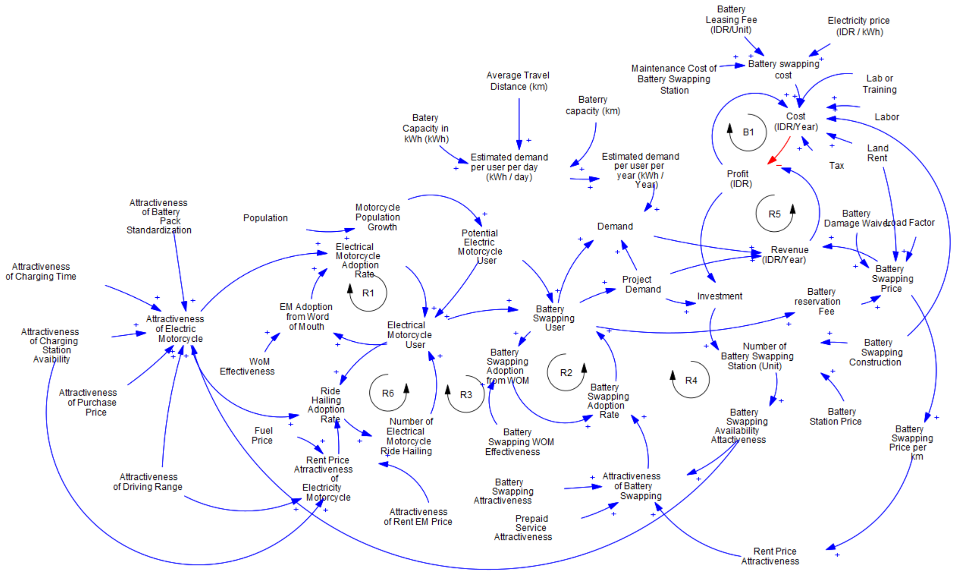


Figure 2: Causal loop diagram of the development of the battery swapping industry in Indonesia, adapted from [1]

Table 2 explains the mapping of the business model canvas, with its nine key elements, in developing a battery swapping industry strategy to develop battery swapping stations in Indonesia. The following explains the nine elements in the business model canvas.

- **Key partners**

  Key partners include key stakeholders who are involved in the value creation process and who enable the business to run. In the business model, partners are intermediaries who do not belong to the company but who play a role in turning products/value into money. In general, companies must have four types of cooperative relationship in business to meet certain needs: strategic alliances, joint new business development efforts, coopetition, and key supplier relationships. Strategic partnerships are generally used between companies that do not have a competitive relationship. Cooperation is intended to complement one another's products/services so that they have more market power. Joint new business development efforts can be applied to companies that have just launched their business start-ups. This strategy would be more effective if the products/services offered already had a clear identity and trademark. The coopetition strategy occurs after the company has passed its business start-up period. It is intended to maintain market control, usually through agreements between competitors. Key supplier relationships could be interpreted as a form of cooperation that must exist for all companies: those still in the start-up stage, and those that are already sustainable [40]. In this business, the type of partner is a critical supplier relationship. Some of the partners that cooperate in the development of the battery swapping industry business are the Government of Indonesia, ride hailing providers, and battery swapping stations material suppliers.

- **Key activities**

  'Key activities' are the core activities that must be mastered and the processes to run the company's business. The key activities in the battery swapping industry business development strategy are the electrical energy transaction process, the construction of battery swapping stations, the installation and maintenance of battery swapping stations, product development, and cooperation with ride hailing transportation providers. All these key activities work synergistically to run the business.

- **Key resource**

  'Key resources' are the tangible and intangible assets that determine the company's business success. Generally, the required resources are human, technological, financial, and physical (raw materials) [41]. Resources enable companies to create and offer value propositions, reach markets, maintain relationships with customer segments, and generate revenue. The key resources of the battery swapping industry development strategy are the number of battery swapping stations, their locations, the availability of electric power, and multi-payment methods in conducting transactions.

- **Value proposition**

  Value propositions are bundles of a product or service that benefit specific customer groups [39]. The value proposition must have relevance to both the customer's needs and the value created by the business to satisfy them. Battery swapping stations that attract battery swapping users previously had the value proposition of eliminating range anxiety and cutting waiting time when charging batteries. However, the development of the battery swapping industry's business is needed, given the uncertainty of getting batteries at battery swapping stations. The problem that occurs suggests that the availability of batteries at the battery swapping station is not known to battery swapping users, resulting in uncertainty. A battery swapping station in its business development should be based on improving the battery swapping process, which could be a new way of attracting consumers while addressing their problem. The value propositions in the business model canvas of the development of a battery swapping industry strategy are as follows. The development of the battery swapping station is designed to provide certainty about obtaining the required battery so that the problems that occur are solved. The battery swapping station does not have a reservation feature on the battery swapping application, meaning that users must transact directly at the location.

  Easy and convenient battery swapping. Determining the value proposition on ease and convenience is based on the uncertainty of having battery swapping users appreciate of the availability of batteries. Users cannot easily make reservations, but it can be done online from anywhere. The largest battery swapping station network is a product advantage that answers the needs of the Indonesian government in improving the national electric motorcycle ecosystem.

- **Customer relations**

  Customer relationships are about how a company establishes a good relationship with its customers. There are three important principles: get, keep, and grow. *Get* means winning customers – the effort to direct consumers to the company's product sales channel. The next stage is to *keep* the customers – the effort to persuade customers who have been won to continue to trust in and subscribe to the products/services that are offered. The third principle is to 'grow' the customers – the effort to increase the number of customers in order to increase sales [40]. In maintaining the relationship with customers with the company, the development of the battery swapping industry strategy needs to carry out the following activities:

  Getting customers. To get customers, the main thing is to promote the product. Promotions could be carried out by advertising on social networking media and websites, through the company's employees, and by direct promotion to consumers.

  Keep customers. The primary way to retain customers is by creating loyalty through giving attention to them. Loyalty in consumers could be built by maintaining and improving the quality, reliability, and innovation of the battery swapping station's operations. At the same time, attention could be offered by providing advice about and impressions of the battery swapping station's products through contact centre services.

  Increase the number of customers. Increasing the number of customers could be achieved by innovating and developing products that meet the needs of customers in the field. The relationship between spreading promotions, creating customer loyalty, and innovating products that fit customers' needs could increase the number of battery swapping users.

- **Channels**

  Channels are a means for companies to deliver value propositions to their customer segments and to connect with their customers. Communication, distribution, and sales networks are some of the company's ways of relating to their customers. Channels play an essential role in the customer experience. The battery swapping transaction system in the business model canvas is carried out using PLN's mobile application in its network of offices. Information and its use is conveyed through PLN's social media and websites. The sales system has been chosen to give consumers and companies a sales channel that is easy to use.

- **Customer segment**

  The target market for a company's products is divided into four types: the existing market, a re-segmented market, a new market, and a clone market. Each market needs certain competitive specifications [40]. Battery swapping stations are used by electric motorcycle users who run out of battery power. However, not all electric motorcycles charge their batteries at battery swapping stations because only electric motorcycles that use battery swapping technology can use them. According to Blank and Dorf (2012), the development of the battery swapping industry belongs to a *segmented* market. This is because only certain electric motorcycles can use it; but greater advantages are needed to increase the attractiveness of battery swapping stations. Based on the provided value propositions, developing the battery swapping industry strategy could deliver convenience and comfort for users.

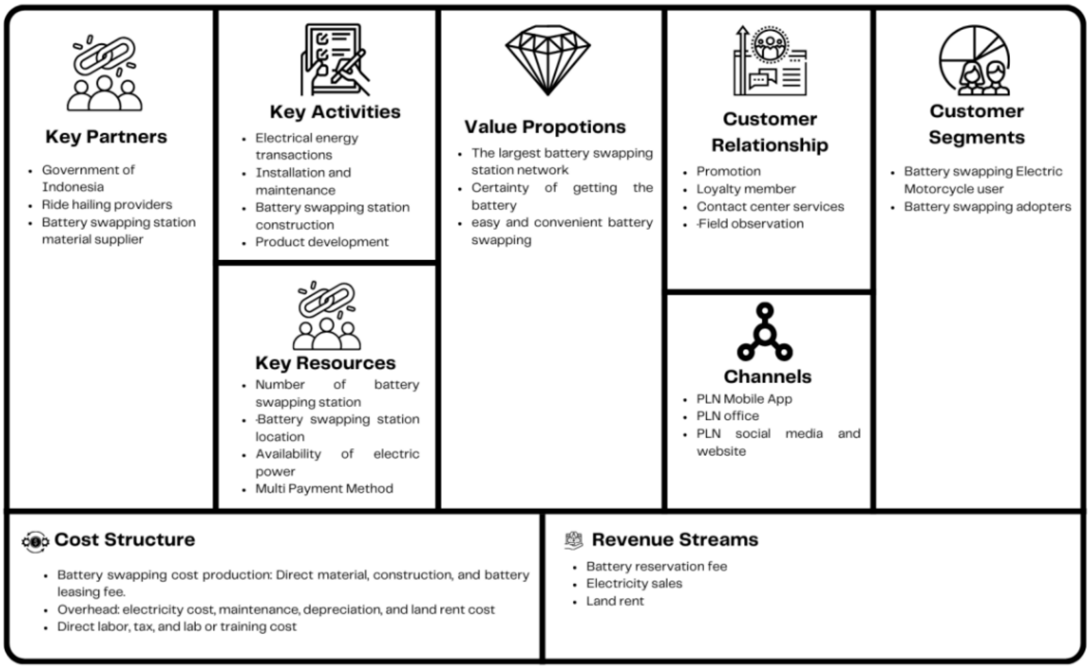
- **Cost structure**

  The cost structure is the part of the business model canvas element that describes all the costs that arise when operating a particular business model. Creating and delivering value, maintaining customer relationships, and generating revenue incur costs. This cost calculation is relatively more straightforward once the essential resources, key activities, and critical partnerships have been determined [39]. In the business model canvas, the costs associated with business functions that are particularly focused on developing the battery swapping industry strategy are those associated with battery swapping production: direct materials, construction costs, and battery rental costs; those associated with overheads: electricity costs, maintenance, depreciation and land rental costs; and direct labour, taxes, and laboratory or training costs.

- **Revenue stream**

  'Revenue streams' is a term that describes the cash that a company generates from each customer segment. If customer satisfaction is the heart of a business model, then revenue streams are its arteries [39]. Revenue streams are usually measured in respect of money obtained by the company from customers. The primary revenue streams of the battery swapping product development strategy are electricity sales, battery reservation fees, and land rent.

Table 2: Business model canvas scheme



5. CONCLUSION

The researcher has developed a conceptual model for a strategy to develop a battery swapping industry in order to support the net zero emissions transition, using a system dynamics approach and a business model canvas framework. The CLD shows the correlation between profitable business development and the company's implemented interventions. Battery reservation fees are important in increasing company profits while providing battery swapping users with certainty and convenience in obtaining batteries.

A multi-actor analysis, system diagrams, and the CLD assisted the development of the model, while the business model canvas served as the product development framework. The multi-actor analysis provided insight into the actors involved with the battery swapping business development, while the system diagram and the CLD offered further insight into how all the variables are connected and influence one another. The system diagram also provides a better understanding of a battery swapping process that comprehensively supports sustainability, and shows the objectives of the process, the output indicators that correspond to the targets, the external factors that may affect the uncertainty in the process, the stakeholder involvement, and the company's intervention in the system. The CLD also explains the interactions between the variables in the battery swapping industry, which constitute six causal reinforcing loops and one causal balancing loop. The interaction of variables affects how the problem owner and the stakeholders respond in order to develop the battery industry.

The business model canvas defines a strategy to help companies to map and communicate key aspects of the business model in an easy-to-understand way and to visualise the desired design or building blocks – including consumers, target markets, value propositions, and financials – when starting a business. Battery swapping stations are also necessary for users' adoption of battery swapping, as they affect the attractiveness of the battery swapping infrastructure and electric motorcycles. The problem owner must ensure the sustainability of the business by creating a profitable intervention for the company with the concept of battery reservation and by guaranteeing the availability of battery swapping stations to users at an appropriate electricity tariff.

The state electricity company PLN supports the government of Indonesia in accelerating the adoption of electric motorcycles as a way to realise its roadmap towards net zero emissions by 2060. The government has issued fiscal and non-fiscal policies to support the programme [42]. To attain this goal, companies need a robust strategy to remain sustainable and survive. They could implement policy interventions from electricity tariffs, battery reservation fees, or battery swapping construction. Each intervention would have a different impact and level of effectiveness. Thus a company's strategy to increase the number of battery swap motorcycles could ultimately help the government's programme.

This study has had no quantitative way to test the conceptual model and to verify the business model. Therefore, the impact of a company's intervention on the system would need to be analysed further. For future research, the conceptual model is expected to be developed into a stock-flow diagram in order to explore the influence of policy making in developing a battery swapping strategy to support social, economic, and environmental sustainability. Then the initial canvas business model would undergo solution testing to determine the level of customers' acceptance of the business model and to verify whether the model is correct and produces value for the company.

FUNDING

This research was funded by the Faculty of Engineering, Universitas Indonesia, Seed Funding Hibah Professor dan Lektor Kepala Fakultas Teknik 2023/2024, grant number NKB-2580/UN2.F4.D/PPM.00.00/2023.

REFERENCES

[1] A. D. Setiawan, T. N. Zahari, K. Anderson, A. O. Moeis, and A. Hidayatno, "Examining the effectiveness of policies for developing battery swapping service industry," *Energy Reports,* vol. 9, pp. 4682-4700, 2023. doi:10.1016/j.egyr.2023.03.121

[2] UNFCCC, "Paris agreement: Decision 1/cp. 17–unfccc document fccc/cp/2015/l. 9/rev. 1," 2015.

[3] N. Reyseliani, A. Hidayatno, and W. W. Purwanto, "Implication of the Paris agreement target on Indonesia electricity sector transition to 2050 using TIMES model," *Energy Policy,* vol. 169, 113184, 2022. doi:10.1016/j.enpol.2022.113184

[4] Ministry of Energy and Mineral Resources (ESDM), “Ini Prinsip dan Peta Jalan Pemerintah Capai Net Zero Emission,” A. Pribadi, ed. Jakarta, 2021.
[5] D. Kurniawan, et al., “Indonesia energy transition outlook (IETO) 2023,” *Institute for Essential Services Reform*, Jakarta, December 2022. [Online]. Available: https://iesr.or.id/en/pustaka/indonesia-energy-transition-outlook-ieto-2023. Accessed: 05/02/2024.
[6] A. D. Setiawan, T. N. Zahari, F. J. Purba, A. O. Moeis, and A. Hidayatno, “Investigating policies on increasing the adoption of electric vehicles in Indonesia,” *Journal of Cleaner Production,* vol. 380, 135097, 2022. doi:10.1016/j.jclepro.2022.135097
[7] State Electricity Company (PLN), “Peminat kendaraan listrik semakin banyak, PLN perkuat infrastruktur pengisian daya,” G. A. Trianto, ed. Jakarta: PLN, 2023.
[8] J. D. Adler and P. B. Mirchandani, “Online routing and battery reservations for electric vehicles with swappable batteries,” *Transportation Research Part B: Methodological,* vol. 70, pp. 285-302, 2014. doi:10.1016/j.trb.2014.09.005
[9] G. Adu-Gyamfi, H. Song, E. Nketiah, B. Obuobi, M. Adjei, and D. Cudjoe, “Determinants of adoption intention of battery swap technology for electric vehicles,” *Energy,* vol. 251, 123862, 2022. doi:10.1016/j.energy.2022.123862
[10] H. Farzin, “Reliability cost/worth assessment of emergency B2G services in two modes of battery swap technology,” *Sustainable Energy, Grids and Networks,* vol. 31, 100787, 2022. doi:10.1016/j.segan.2022.100787
[11] W. Infante, J. Ma, and A. Liebman, “Operational strategy analysis of electric vehicle battery swapping stations,” *IET Electrical Systems in Transportation,* vol. 8, no. 2, pp. 130-135, 2018. doi:10.1049/iet-est.2017.0075
[12] A. Uribe, M. Fernández-Montoya, J. Vargas, G. Osorio-Gómez, and A. Montoya, “Discrete event simulation for battery-swapping station sizing for hybrid and electric motorcycles,” *Journal of Cleaner Production,* vol. 390, 136155, 2023. doi:10.1016/j.jclepro.2023.136155
[13] D. Wang, Y. Cao, K.-K. R. Choo, Z. Yang, Z. Sun, and H. Cruickshank, “Secure battery swapping: A reservation scheme with conditional privacy-preserving bidirectional heterogeneous aggregate signcryption and incentive mechanism,“ *IEEE Transactions on Vehicular Technology,* vol. 72, no. 11, pp. 14087-14102, 2023. doi:10.1109/TVT.2023.3281592
[14] H. Wu, G. K. H. Pang, K. L. Choy, and H. Y. Lam, “An optimization model for electric vehicle battery charging at a battery swapping station,” *IEEE Transactions on Vehicular Technology,* vol. 67, no. 2, pp. 881-895, 2017. doi:10.1109/TVT.2017.2758404
[15] Y. Wu, S. Zhuge, G. Han, and W. Xie, “Economics of battery swapping for electric vehicles—simulation-based analysis,“ *Energies,* vol. 15, no. 5, 1714, 2022. doi:10.3390/en15051714
[16] W. Zhan, Z. Wang, L. Zhang, P. Liu, D. Cui, and D. G. Dorrell, “A review of siting, sizing, optimal scheduling, and cost-benefit analysis for battery swapping stations,” *Energy,* vol. 258, 124723, 2022. doi:10.1016/j.energy.2022.124723
[17] N. Zhang, Y. Zhang, L. Ran, P. Liu, and Y. Guo, “Robust location and sizing of electric vehicle battery swapping stations considering users’ choice behaviors,” *Journal of Energy Storage,* vol. 55, 105561, 2022. doi:10.1016/j.est.2022.105561
[18] T.-y. Zhang *et al.*, “Deployment optimization of battery swapping stations accounting for taxis’ dynamic energy demand,” *Transportation Research Part D: Transport and Environment,* vol. 116, 103617, 2023. doi:10.1016/j.trd.2023.103617
[19] G. Adu-Gyamfi *et al.*, “Towards sustainable vehicular transport: Empirical assessment of battery swap technology adoption in China,” *Technological Forecasting and Social Change,* vol. 184, 121995, 2022. doi:10.1016/j.techfore.2022.121995
[20] C. Li, N. Wang, W. Li, Q. Yi, and D. Qi, “A battery centralized scheduling strategy for battery swapping of electric vehicles,” *Journal of Energy Storage,* vol. 51, 104327, 2022. doi:10.1016/j.est.2022.104327
[21] S. Shao, S. Guo, and X. Qiu, “A mobile battery swapping service for electric vehicles based on a battery swapping van,” *Energies,* vol. 10, no. 10, 1667, 2017. doi:10.3390/en10101667
[22] J. Yang, W. Liu, K. Ma, Z. Yue, A. Zhu, and S. Guo, “An optimal battery allocation model for battery swapping station of electric vehicles,” *Energy,* vol. 272, 127109, 2023. doi:10.1016/j.energy.2023.127109
[23] L. Gozali *et al.*, “The important role of system dynamics investigation on business model, industry and performance management,” *International Journal of Productivity and Performance Management,* vol. 73, no. 4, pp. 945-980, 2023. doi:10.1108/IJPPM-07-2021-0399
[24] Z. Yang, Q. Lei, J. Sun, X. Hu, and Y. Zhang, “Strategizing battery swap service: Self-operation or authorization?” *Transportation Research Part D: Transport and Environment,* vol. 110, 103411, 2022. doi:10.1016/j.trd.2022.103411
[25] A. Vallera, P. Nunes, and M. Brito, “Why we need battery swapping technology,” *Energy Policy,* vol. 157, 112481, 2021. doi:10.1016/j.enpol.2021.112481

[26] L. R. Jones, C. R. Cherry, T. A. Vu, and Q. N. Nguyen, “The effect of incentives and technology on the adoption of electric motorcycles: A stated choice experiment in Vietnam,” *Transportation Research Part A: Policy and Practice,* vol. 57, pp. 1-11, 2013. doi:10.1016/j.tra.2013.09.003
[27] T. T. M. Truong, “Effectiveness of policy incentives on electric motorcycles acceptance in Hanoi, Vietnam,” *Case Studies on Transport Policy,* vol. 13, 101020, 2023. doi:10.1016/j.cstp.2023.101020
[28] D. N. Su, D. Q. Nguyen-Phuoc, P. T. K. Tran, T. Van Nguyen, T. T. Luu, and H.-G. Pham, “Identifying must-have factors and should-have factors affecting the adoption of electric motorcycles: A combined use of PLS-SEM and NCA approach,” *Travel Behaviour and Society,* vol. 33, 100633, 2023. doi:10.1016/j.tbs.2023.100633
[29] T. Eccarius and C.-C. Lu, “Powered two-wheelers for sustainable mobility: A review of consumer adoption of electric motorcycles,” *International Journal of Sustainable Transportation,* vol. 14, no. 3, pp. 215-231, 2020. doi:10.1080/15568318.2018.1540735
[30] T. A. Waluyo, M. Z. Irawan, and Dewanti, “Adopting electric motorcycles for ride-hailing services: Influential factors from driver’s perspective,” *Sustainability,* vol. 14, no. 19, 11891, 2022. doi:10.3390/su141911891
[31] F. Cosenz, “Supporting start-up business model design through system dynamics modelling,” *Management Decision,* vol. 55, no. 1, pp. 57-80, 2017. doi:10.1108/MD-06-2016-0395
[32] A. Hidayatno, *Berpikir sistem: Pola berpikir untuk pemahaman masalah yang lebih baik*. LeutikaPrio. 2013
[33] I.R.F. Surya, P. Aji, and F.A. Padhilah, “Indonesia electric vehicle outlook 2023,” IESR study report February 2023. [Online]. Available: https://iesr.or.id/pustaka/indonesia-electric-vehicle-outlook-ievo-2023
[34] State Electricity Company (PLN), “Sambut makin masifnya penggunaan kendaraan listrik, PLN kebut pembangunan SPKLU dan SPBKLU,” PLN, 2023.
[35] Ministry of Energy and Mineral Resources (ESDM), “Akselerasi Implementasi KBLBB Butuh Kolaborasi dan Inovasi,” Kementrian ESDM, 2021.
[36] State Electricity Company (PLN), “Kendaraan Listrik Jadi Upaya Penurunan Emisi Karbon, Begini Perhitungan Emisinya Menurut PLN,” PLN, 2023.
[37] State Electricity Company (PLN), “Yuk Merapat, PLN Cari Mitra Usaha untuk Bangun Lebih dari 100 SPKLU,” PLN, 2021.
[38] State Electricity Company (PLN), “PLN Dorong Penggunaan Kendaraan Listrik Guna Kurangi Polusi Udara,” PLN, 2023.
[39] A. Osterwalder and Y. Pigneur, *Business model generation: A handbook for visionaries, game changers, and challengers*. John Wiley & Sons, 2010.
[40] S. Blank and B. Dorf, *The startup owner’s manual: The step-by-step guide for building a great company*. John Wiley & Sons, 2012.
[41] A. D. Setiawan, A. Sutrisno, and R. Singh, "Responsible innovation in practice with system dynamics modelling: The case of energy technology adoption," *International Journal of Innovation and Sustainable Development,* vol. 12, no. 4, pp. 387-420, 2018. doi:10.1504/IJISD.2018.095048
[42] N. Syaifudin, A. Sutrisno, and A. D. Setiawan, "The Impact of Fiscal Transfer on Energy Efficiency in Indonesia," *Energy Procedia,* vol. 65, no. 0, pp. 239-247, 2015. doi:10.1016/j.egypro.2015.01.037