Innovation and Technology Readiness Level of Mobile Charging Station Swap Battery: A Conceptual Study

Alifah Dian Rahmania
Magister Program of Industrial Engineering
Faculty of Engineering
Universitas Sebelas Maret
Surakarta, Indonesia
alifahdianrahmania@student.uns.ac.id

Wahyudi Sutopo
University Centre of Excellence for Electrical Energy Storage Technology
Research Group Industrial Engineering and Techno-Economic
Industrial Engineering Department, Faculty of Engineering
Universitas Sebelas Maret
Surakarta, Indonesia
wahyudisutopo@staff.uns.ac.id

Renny Rochani
Research Group Industrial Engineering and Techno-Economic
Industrial Engineering Department, Faculty of Engineering
Universitas Sebelas Maret
Surakarta, Indonesia
rennyrochani@staff.uns.ac.id

Abstract

Electric vehicles can reduce pollution and lower the use of fossil fuel. However, currently, in Indonesia, the supporting infrastructure for electric motorcycles is still very limited. The lack of infrastructure charging station for electric motorcycles causes some problems for the community to access power. This research develops an idea of mobile charging station swap battery technology (MCSSB). Apart from preparing infrastructure battery swap for the community, MCSSB can be used as commercialization equipment for entrepreneurs. This study aims to determine the Technology Readiness Level (TRL) of MCSSB. The results of the development of technological innovations are at the feasibility study stage. It means that attention should be paid to the aspects for technological feasibility, such as operational aspects, market aspects, environmental aspects, and organizational aspects. The TRL calculation is at level 5, which means that the code validation and components are in a simulation environment.

Keywords
Mobile Charging Station, Swap Battery, Innovation, TRL and Technopreneur.

1. Introduction

Electric vehicles are one of the important things to overcome problems related to environmental pollution, the limited and decreasing supply of conventional fuels, and global warming due to the increasing use of fossil-based fuels in transportation equipment (Kumara & Sukerayasa, 2009). The use of electric-based vehicles (KBL) can be a solution to reduce the use of fossil fuel vehicles (Iskandar, 2021). Electric vehicles are considered a substitute for fossil fuel vehicles due to rising fossil fuel prices and accompanying environmental problems, and are predicted to increase dramatically shortly (Nazari Heris et al., 2022). Based on a survey conducted by Populix with 1002 respondents in Indonesia in February 2022, as many as 13% of respondents already have an electric motorbike, and 29% plan to buy an electric motorbike. For electric motorcycle brands that are already distributed in Indonesia, such as United, viar, gesits, sellis, ecobike, BFgoodrich, and niu (Populix, 2022). Speaking of electric vehicles, nothing is complete without a charging station. The development of electric vehicles must be supported by battery charging infrastructure so that users do not experience problems in charging batteries which cause more and more people turn to electric vehicles (Dharmawan et al., 2021). There are 10 future trends of electric vehicle charging infrastructure to show the will and determination to build a green and efficient industrial ecosystem. First, charging electric vehicles such as refueling from charging time, power, and voltage. Second, the availability of better-charging, improved development, quality, and the ability to adapt to a complex operating environment. Third, energy saving environment, charging design add new energy sources and save energy so that carbon emission will be reduced. Fourth, there is a standardization of core components, charging stations that are compatible with each other or cannot be replaced. Fifth, charging will be everywhere, such as in office construction, housing, government, and hospitals. Sixth, low-power DC charging, by implementing plug-and-play charging without any code. Seventh, various charging modes, not only for electric motorcycles and electric cars, but also for buses and trucks. Eighth, an all-digital charging facility, using smart networks, IoT, 5G, cloud computing, remote control, big data, and artificial intelligence. Ninth, Tighter controls for security and privacy protection. The tenth, integrated multi-network convergence node and the entrance of the Vehicle Internet (Huawei, 2020). In the future, power plants with renewable energy sources will develop electric vehicles that can be recharged with the electrical energy produced by these plants (Kumara & Sukerayasa, 2009).

In Indonesia, public electric vehicle charging infrastructure is divided into three, namely SPLU (General Electricity Supply Station), SPKLU (General Electric Vehicle Charging Station), and SPBKLU (General Electric Vehicle Battery Exchange Station) (Dharmawan et al., 2021). Furthermore, the mobile charging infrastructure is mobile charging technology (MBC) classified into three main types namely, truck charging stations, portable charging, and vehicle-to-vehicle power transfer (Afshar et al., 2021).

According to the General Plan of National Energy in 2025, Indonesia is targeting 2.13 million electric motors. However, currently, in Indonesia, the supporting infrastructure for electric motorbikes is still very limited, the public is not urgent to have electric vehicles, and there is a lack of socialization to intensify zero emissions. The increase in the number of electric motorbikes must be balanced with adequate infrastructure. If the supporting infrastructure for electric motorbikes is limited, people will feel anxious, worried, and have difficulty accessing charging electric vehicles. Therefore, the researcher proposes a technology in the form of a mobile charging station swap battery. Products or technologies that have been used commercially are developed through stages that proceed. The reliability of these products and technology is continuously improved so that they are always ahead of the competition. On the other hand, the success of an innovation is also determined by the success of the commercialization of the product or technology (Kresnowati & Bindar, 2021). However, from some of the explanations above, not all technological innovations can be present in the market. There are many stories of inventions that are never revealed, and many breakthrough ideas that have the potential to fall into the so-called "valley of death" of technology because of the gap between academic research and industrial commercialization. This is a missed opportunity for economic and social progress and competitiveness of companies (Amalia et al., 2020). It needs to be supported in terms of technology, innovation, and manufacturing to be successful in the market (Nugrahadi et al., 2020).

This research was conducted to improve infrastructure in Indonesia based on electric vehicles, and to develop innovation and technological readiness from mobile charging station swap batteries, which in addition to making it easier for people to exchange batteries, can also be commercialization opportunities for entrepreneurs. With the existence of a mutually supportive ecosystem, it is hoped that it can help the government in reducing the use of oil-fueled motorcycles. Battery swap-based charging stations have provided added value to consumers because they are practical, fast, do not wait for long, and cheap energy. As for the charging swap batteries mobile can make it easier for the community if they run out of power and are far from the battery exchange station, because the mobile can move around. Mobile battery swap charging stations also don't need to queue or wait at fixed battery exchange stations, saving time. MCSSB is a new technological innovation and can be commercialized into a technopreneur or a technology-based business or business so that the benefits from a technopreneur can also be seen to attract investors and entrepreneurs who take part in developing MCSSB technological innovations.

There are previous studies on mobile charging stations, such as Mobile charging stations for electric vehicles-A review (Afshar et al., 2021) but none have discussed mobile swap batteries. This research uses the terms of technology innovation development method, Technology Readiness Level, and technopreneur. The concept of the Technology

Readiness Level (TRL) formulates the stages of technology and product development in nine stages, starting from the idea development stage (Stage 1) to the technology and product development stage to be commercialized (Stage 9) (Kresnowati & Bindar, 2021).

1.1 Objectives

This study aims to determine the development of technological innovation, readiness level technology, and technopreneurs in mobile charging station swap batteries, which in turn can improve the battery exchange infrastructure in Indonesia.

2. Literature Review

2.1 System Innovation

Being innovative is not enough just to have a new idea. Every new idea must be managed properly for the innovation to succeed. Innovation management is an approach to generating, evaluating, validating, and putting new ideas into practice. Choosing the right innovation management process is a challenge because innovation is unpredictable so the way to know the process is going well is to try it in real life (Nugrahadi et al., 2020). Most of the time, innovation seems to work in the short term but doesn't seem very successful in the long run. The main reasons for this are often unrealistic expectations in the future evolution of technology and a lack of insight into unforeseen impacts. The second observation is that only in some are cases the basic barriers are scientific or technological problems. Usually, organizational, administrative, and institutional problems get in the way (Carayannis et al., 2015). The purpose of the innovation system can be said to be the creation, diffusion, and exploitation of innovations (Carayannis et al., 2015). An innovation system can be analyzed at the national, regional, sectoral and international levels. The analysis of actors and institutions at each level complements the analysis of innovation actors at other levels (Carayannis et al., 2015). (Figure 1)

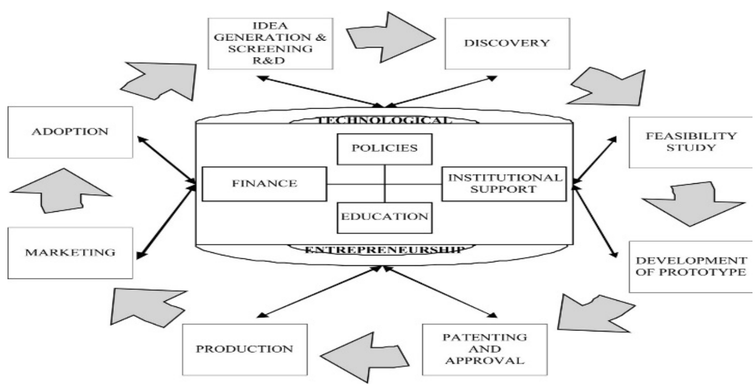

Figure 1. Innovation Technology Development (Siyanbola et al., 2011)

2.2 Technology Readiness Level

One of the characteristics of successful innovation is the level of readiness. Measurement of the level of technology readiness or often referred to as Technology Readiness Level (TRL) is an "indicator" that shows how ready/mature technology is to be applied, marketed, and used by consumers. Shown by a scale of 1 – 9 where each scale is a measure that indicates the level of maturity or technology readiness. Scale 1 indicates basic principles, scale 2 indicates concept formulation, scale 3 indicates proof of concept, scale 4 indicates component code validation in the laboratory, scale 5 indicates code validation, components in a simulation environment, scale 6 indicates model demonstration or prototype in the relevant environment. , a scale of 7 indicates a demonstration of a model or prototype in an actual application environment, a scale of 8 indicates that it has been tested and demonstrated in an actual application, and a level of 9 indicates that the technology has been tested tested/proven. (Figure 2)

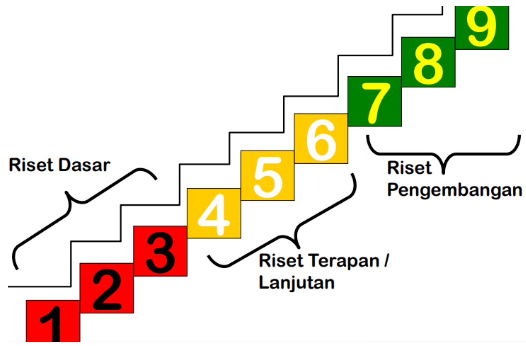

Figure 2. Technology Readiness Level

2.2 Technopreneur

Technology-based entrepreneurship has a better role in promoting sustainability. Technological entrepreneurship is an entrepreneur who uses technology as a factor in converting resources into goods and services. The utilization of technology is intended to produce new and innovative products through the commercialization process(Nugrahadi et al., 2020). Technopreneurship is part of entrepreneurship (Suryati et al., 2020). Techno-preneurship aims to market inventions created by academic scientists through patents, licensing, startups, and collaboration between universities and industry (Grimaldi et al., 2011).

2.4 Mobile Charging Station

A mobile charging station is a charging device for electric vehicles, with one or more charging outlets, which can offer electric vehicle charging services at any time and any location so that users are comfortable and don't have to worry about running out of electric vehicles power. Mobile charging stations are divided into three, namely truck car charging stations, portable charging stations, and vehicle-to-vehicle power transfer (Afshar et al., 2021). Mobile Charging Station can be placed at a designated Fixed Charging Station which has an extra parking area. The filling station owner must be connected to a filling station server (Charging Station Server) operated by an independent system operator or regional transmission organization. All information about the installed Charging Pole must be reported to the Charging Station Server (Atmaja & Mirdanies, 2015).

2.5 Swap Battery

A battery swap is the exchange of a depleted electric motor vehicle battery with a fully charged battery. Battery exchange is intended for 2-wheeled electric vehicles, namely motorcycles, and 3-wheeled vehicles such as tricycles. Several companies have invested in developing battery charging and swapping infrastructure in recent years. In Indonesia, there are already several domestic and foreign companies that have developed battery swaps, such as Indonesia's energy swap, oyika, ezyFast, gogoro, kymco, gesits, and sgb volta.

2.6 State of The Art

Table 1. State of The Art

No.	Researcher	Title	Topics
1.	(Moghaddam et al., 2021)	Dispatch management of portable charging stations in electric vehicle networks	Portable Charging Station
2.	(Abualola et al., 2022)	A V2V charging allocation protocol for electric vehicles in VANET	Vehicle to Vehicle power transfer
3.	(Afshar et al., 2021)	Mobile charging stations for electric vehicles—A review	Mobile Charging Station
4.	(Aqidawati et al., 2020)	Lesson Learned in Developing and Implementing Global Business Strategy to Commercialize Battery Swap	Swap Battery

		Technology: A Comparative Study	
5.	(Habibie et al., 2020)	Comparative Analysis of Developing Innovation Products on Electric Motorcycle Conversion: Lesson Learned to Commercialization	Innovation Development
6.	(Straub, 2015)	In search of technology readiness level (TRL) 10	Technology Readiness Level

From the state-of-the-art explanation above, it shows that the mobile charging station swap battery has never been studied, so this research will discuss the development of technological innovation and the level of technological readiness from MCSSB. (Table 1)

3. Methods

This study analyzes the development of mobile technology for Battery Exchange Stations in Indonesia. The research was conducted with qualitative data. Data sourced from secondary data. Secondary source data retrieval is carried out using search engines and manufacturing websites with several keywords from the beginning of the emergence of technology until now in 2022. Next, analyze data related to the development of technological innovations. Next, analyze data related to the level of technology readiness and the level of commercialization readiness. Furthermore, lessons learned for mobile charging station swap battery technology were carried out. Furthermore, conclusions and suggestions can be drawn that are useful for future research. Figure 3 shows the selection of the framework to be discussed in this study.

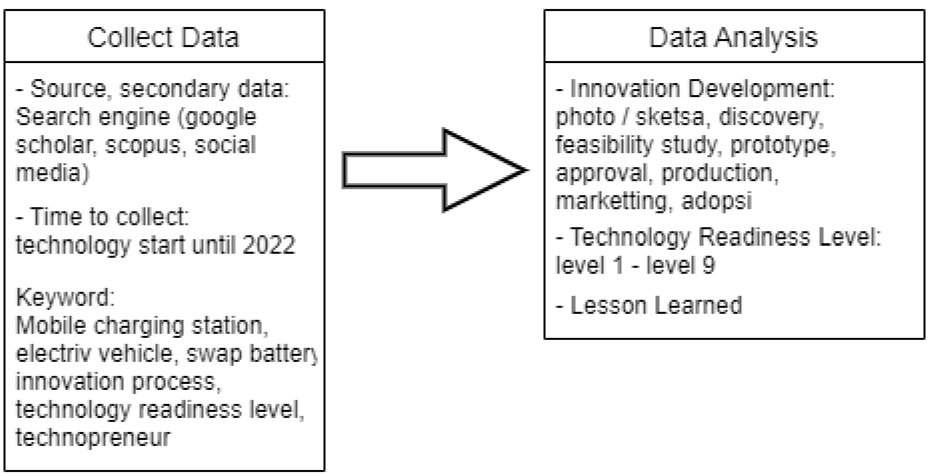

Figure 3. Framework selection

4. Results and Discussion

4.1 Technological Innovation Development

Charging station swap battery is a new thing, so it is necessary to know how far and at what stage in the development of this technological innovation until the technology can be adopted and used by the community. Because the valley of death usually causes various technological products to be unsuccessful in launching on the market (Sutopo, 2019).

1. Photo / sketsa Cycle

Figure 4. Concept of Mobile Charging Station Swap Battery

In a mobile charging station, a swap battery requires 3 main components, namely a tricycle truck, billboard, and a swap battery cabinet. The vehicle also uses an electric vehicle, the researcher uses the example of a three-wheeled vehicle belonging to volta. Using a three-wheeled electric vehicle truck to officially have an STNK from the regional police. The specifications of this three-wheeled electric vehicle belonging to Volta are having dimensions of 1920 x 1100 x 680 (Mm), having a mileage of 45 km and a maximum speed of 25km/hour, and can lift a maximum load of 250Kg. Next are the dimensions of the box, which can later be adjusted to the dimensions of the battery swap. The dimensions of the box have dimensions of 150 x 100 x 100 cm, while the dimensions of the swap for 1 battery are 177 x 177 x 130 mm and weigh 10 kg. So in a box truck, if you use a 4-door battery swap cabinet, it will leave a space of 78 x 28 x 48 cm. Swapping the 4-door battery requires 3000 watts of power. Furthermore, the dimensions of the billboard so that advertisements from electric vehicles can be conveyed to the public are 100 x 100 cm. (Figure 4)

2. Discovery Cycle

There are already several on the market regarding mobile charging stations for electric car vehicles, but the invention or idea of MCSSB for electric motor vehicles has not yet been found in the market. So this discovery will be an opportunity in the market, in addition to making it easier for the mobile charging station infrastructure itself to be able to move from one location to another easily and not bound by time. In addition, advertisements on vehicles can be used as marketing campaigns for using electric vehicles. In addition, from a technopreneur perspective, this technology can be commercialized by SMEs.

3. Feasibility study Cycle

In terms of operational feasibility, it can be determined from the expertise and skills of human resources, such as a driver who drives a truck has a driving license, knows how to replace a motorcycle battery, knows if there is damage or a short circuit in the truck or battery cabinet, knows regular maintenance, and know the entire system in MCSSB. In terms of market analysis can include products or services, supply, demand, strategy, and penetration. Opportunities for Small and Medium Enterprises can be incorporated, such as electric vehicle agents, and battery agents. The demand for electric vehicles will continue to increase, in addition to being environmentally friendly which can save on gasoline costs and maintenance costs compared to conventional motorbikes by 75%, as well as the availability of swap battery facilities with swap prices of Rp. 7500,- for 60km. Already available and available spare parts and after-sales team. Demand and supply are carried out such as socialization, agreement, administration, education, activities, and monitoring. From an environmental perspective, it is clear to minimize the use of gasoline and reduce carbon emissions. From an organizational perspective, many stakeholders can help the growth of electric vehicles, government support for educational institutions to research electric vehicles and support for improving charging infrastructure, government support for SMEs or industries engaged in electric vehicles, and a workforce that can make them operate. and perform maintenance on electric vehicles. Furthermore, in the cycle of technological innovation development stages, the development of a prototype, patenting and approval, production, marketing, and adoption cannot yet be implemented, because MCSSB technology is still about the concept.

4.2 Technology Readiness Level

The next step is to analyze the Technology Readiness level quickly. There are 9 levels in the technology readiness level, researchers categorize the MCSSB technology in level 5, which shows code validation, and components in a simulation environment. The three important components in the MCSSB that have been identified, the technology regarding swap batteries, electric three-wheeled vehicles, and billboards in the form of video Tron has been proven. So that the MCSSB concept remains to make one product like Figure 4.

A value of 0 means that it is not fulfilled, a value of 1 means that it is 20% fulfilled, a value of 2 means that it is 40% fulfilled, a value of 3 means that it is 60% fulfilled, and a value of 4 means that it is 80% fulfilled, and a value of 5 means that it is fully fulfilled. The quick TRL assessment is based on the subjective opinion of the researcher, as well as the opinions of stakeholders who will develop technological innovations. The following is the TRL calculation from MCSSB:

1. Technology Readiness Level 1

In level 1, some indicators have been met for MCSSB technology. 100% readiness to fulfill basic assumptions and laws such as physics and chemistry that will be used in mobile charging station swap battery technology has been determined, empirical studies and previous research on the basic principles of the technology to be developed have been determined, and the formulation of research hypotheses has been determined.

2. Technology Readiness Level 2

A few MCSSB technological indicators have been reached at level 2. It has been determined that all of the equipment and systems are ready for usage. It has been decided to research the technology literature that will be created to enable its application. It is established how the theoretical and empirical design will work. The fundamental components of the future technology are understood. It has been mastered and understood how to characterize the technology components that need to be developed. Every component of the technology that will be produced has had its performance predicted. The primary functions needed can function well, according to preliminary investigation. models and simulations to verify the applicability of the fundamental concepts. Analytical investigation to verify the validity of its fundamental assumptions; the technology's component parts can be developed independently. The tools are reliable and valid. understanding the steps involved in doing the experiment.

3. Technology Readiness Level 3

Some MCSSB technological indicators have been reached at level 3. The ability of analytical investigations to be fully completed supports the forecast of the performance of the technological parts. The basic systems' traits, attributes, and performance capabilities have been discovered and forecast. The ability of technological aspects to forecast the future is supported by models and simulations. It is quite likely and possible to mimic the development of this technology starting with the first step of employing a mathematical model. It is understood from theory, empirical research, and experimental data that the technological system's component parts can function effectively. The required level of 60 percent readiness has been reached, and studies in the lab have been run to see whether the technology can actually be used as well as to forecast how well each component will function.

4. Technology Readiness Level 4

In level 2, some indicators have been met for MCSSB technology. 100% readiness to fulfill the laboratory tests of the components separately has been carried out. The system requirements for the application according to the user are known (adopter wishes). The results of laboratory experiments on the components show that these components can operate. Component integration research has started. 80% readiness to fulfill key manufacturing processes has been identified and reviewed in the lab. 60% readiness to test the main function of the technology in the relevant environment. A laboratory-scale technology prototype has been created. The integration of technology systems and lab-scale design has been completed.

5. Technology Readiness Level 5

In MCSSB technology it is possible to only reach level 5, which means code validation, and components in a new simulation environment will be implemented. Due to the absence of prototype preparation and component integration. 80% readiness to fulfill indicators of hardware production preparation and market research & laboratory research to select the fabrication process. 20% readiness to fulfill prototype manufacture, testing of supporting machines and equipment, integration of the system to be tested or simulated, prototype accuracy, laboratory conditions similar to the real environment, and reviewing of the production process.

4.3 Lesson Learned

Broadly speaking about MCSSB, namely, new mobile charging station swap battery technology innovations can improve charging infrastructure, making it easier for people who use 2-wheeled electric vehicles (motorcycles) to charge because they are flexible, can move from place to place, and do not take time. long. In addition, video Tron on mobile trucks can be used for commercialization by SMEs. Inside the mobile truck, the transporter carries 4 exchange batteries. The technology is still in the feasibility test stage, and the technology readiness level is at level 5. This research is still conceptual, it can still be further developed to the feasibility testing stage in the actual environment so that it can be adopted by the community.

5. Conclusion

The increasing use of 2-wheeled electric vehicles is not matched by the existing infrastructure. The limited infrastructure for charging station swap batteries makes people anxious and worried. Therefore, the Mobile charging station swap battery for 2-wheeled electric vehicles is a new technology idea. MCSSB can be moved, flexible, and not bound by time. An analysis of the development of technological innovation and a rapid analysis of the level of technological readiness is carried out. The results obtained from the development of technological innovations at the feasibility study stage, in the cycle of development of a prototype, patenting and approval, production, marketing, and adoption stages cannot be implemented, because MCSSB technology is still about the concept. The level of technology readiness is at level 5, which indicates code validation, and components in a simulation environment. The three important components in the MCSSB have been identified, the technology regarding swap batteries, electric three-wheeled vehicles, and billboards in the form of video Tron has been proven. So that the concept of MCSSB Lives to make a single unit of a product. In the future, it is hoped that the feasibility study will discuss the analysis of techno-economic costs.

Acknowledgments

Penelitian ini didanai oleh RKAT PTNBH Universitas Sebelas Maret tahun anggaran 2022 melalui skema **PENELITIAN FUNDAMENTAL** (PF-UNS) dengan Nomor Surat Perjanjian Penugasan Penelitian: 254/UN27.22/PT.01.03/2002

References

Abualola, H., Otrok, H., Mizouni, R., & Singh, S. A V2V charging allocation protocol for electric vehicles in VANET. *Vehicular Communications*, *33*, 100427. (2022). https://doi.org/10.1016/j.vehcom.2021.100427

Afshar, S., Macedo, P., Mohamed, F., & Disfani, V.. Mobile charging stations for electric vehicles — A review. *Renewable and Sustainable Energy Reviews*, *152*(September), 111654. (2021) https://doi.org/10.1016/j.rser.2021.111654

Amalia, N. V., Sutopo, W., & Hisjam, M. A Comparative Analysis for Batik Wastewater Treatment Equipment Technology Development in Indonesia: Technopreneurship & Innovation System. *ACM International Conference Proceeding Series*. (2020). https://doi.org/10.1145/3429789.3429863

Aqidawati, E. F., Sutopo, W., & Pujiyanto, E. Lesson learned in developing and implementing global business strategy to commercialize battery swap technology: A comparative study. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, *August*, 1002–1013. (2020).

Atmaja, T. D., & Mirdanies, M. Electric vehicle mobile charging station dispatch algorithm. *Energy Procedia*, *68*, 326–335. (2015). https://doi.org/10.1016/j.egypro.2015.03.263

Carayannis, E. G., Samara, E. T., & Bakouros, Y. L. Innovation and Entrepreneurship: Theory, Policy and Practice.

In *Springer Int Publishing* (9th editio). Springer Int Publishing. (2015). https://doi.org/10.1007/978-3-319-11242-8

Dharmawan, I. P., S Kumara, I. N., & Budiastra, I. N. Perkembangan Infrastruktur Pengisian Baterai Kendaraan Listrik Di Indonesia. *SPEKTRUM*, *8*(3), 90–101. (2021).

Grimaldi, R., Kenney, M., Siegel, D. S., & Wright, M. 30 years after Bayh-Dole: Reassessing academic entrepreneurship. *Research Policy*, *40*(8), 1045–1057. (2011). https://doi.org/10.1016/j.respol.2011.04.005

Habibie, A., Sutopo, W., & Budijanto, M. Comparative analysis of developing innovation products on electric motorcycle conversion: Lesson learned to commercialization. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, *August*, 979–990. (2020).

Huawei. *Huawei shares 10 trends in EV charging infrastructure at The Solar & Storage Live in London*. https://solar.huawei.com/eu/news/eu/2020/12/Huawei-shares-10-trends-in-EV-charging-infrastructure-at-The-Solar-Storage-Live-in-London(2020).

Iskandar, H. Studi Analisis Perkembangan Teknologi Kendaraan Listrik Hibrida. *Journal of Automotive Technology Vocational …*, *02*(1), 31–44. (2021). https://journal.upy.ac.id/index.php/jatve/article/view/1488

Kresnowati, M. T. A. P., & Bindar, Y. MEMAHAMI PENGEMBANGAN TEKNOLOGI DAN PRODUK INDUSTRI PROSES DARI TAHAP RISET KE TAHAP KOMERSIAL: STUDI KASUS PENGEMBANGAN INDUSTRI FERCAF. *Jurnal Sosioteknologi*, *Volume 20,* 149–162. (2021).

Kumara, N. S., & Sukerayasa, I. W. Tinjauan perkembangan kendaraan listrik dunia hingga sekarang. *Teknologi Elektro*, *8*(1), 74–82. (2009).

Moghaddam, V., Ahmad, I., Habibi, D., & Masoum, M. A. S. Dispatch management of portable charging stations in electric vehicle networks. *ETransportation*, *8*, 100112. (2021). https://doi.org/10.1016/j.etran.2021.100112

Nazari Heris, M., Loni, A., Asadi, S., & Mohammadi ivatloo, B. Toward social equity access and mobile charging stations for electric vehicles: A case study in Los Angeles. *Applied Energy*, *311*. (2022). https://doi.org/https://doi.org/10.1016/j.apenergy.2022.118704

Nugrahadi, B., Sutopo, W., & Hisjam, M. Technopreneurship & Innovation System: A Comparative Study Analysis for E-Trike Development in Indonesia. *ACM International Conference Proceeding Series*, 1251–1262. (2020). https://doi.org/10.1145/3429789.3429805

Populix. *Indonesian Modern Painters libre*. (2022).

Siyanbola, W. O., Aderemi, H. O., Egbetokun, A. A., & Sanni, M. Framework for technological entrepreneurship development: key issues and policy directions. *American Journal of Industrial and Business Management*, 10–19.v

Straub, J.x In search of technology readiness level (TRL) 10. *Aerospace Science and Technology*, *46*(701), 312–320. (2011). https://doi.org/10.1016/j.ast.2015.07.007

Suryati, Sutopo, W., & Hisjam, M. Technopreneurship & Innovation System: Comparative Analysis of Technology Development of Salt Derivative Products in Indonesia. *ACM International Conference Proceeding Series*. (2020). https://doi.org/10.1145/3429789.3429806

Biography

Alifah Dian Rahmania is a student at Master Program of Industrial Engineering Department, Universitas Sebelas Maret, Surakarta, Indonesia. She obtained her Bachelor of Engineering degree in Industrial Engineering from Brawijaya University in 2019. She also owns a small business called Media Ilmu as a publishing and offsetting brand. Her research interests are technopreneur, e-business design, and business strategic management.

Wahyudi Sutopo is a professor in industrial engineering and Head of Industrial Engineering and Techno-Economics Research Group, Department of Industrial Engineering, Universitas Sabellas Maret (UNS), Surakarta, Indonesia. He is also a researcher for the center of excellence for electrical energy storage technology (CoE-EEST), the president of the industrial engineering and operations management (IEOM) society for Indonesia's professional chapter, and the Director of IEOM Asia Pacific Operation. His educational background is the profession of an engineer from UNS (2018); a doctor and bachelor's in industrial engineering from Institute Technology Bandung (2011 & 1999); and a master of management science from Universitas Indonesia (2004). His research interests include supply chain engineering, engineering economy & cost analysis, and technology innovation & commercialization. Dr. Sutopo has completed research projects with more than 45 grants and carried out research projects funded by the Institution of Research and Community Services - UNS, Ministry of Research and Technology / National Agency for Research and Technology, Indonesia Endowment Fund for Educational (LPDP), PT Pertamina (Persero), PT Toyota Motor Manufacturing Indonesia, and various other companies. He has written four textbooks, seven-chapter books and made five intellectual property rights (IPR) in the form of copyrights and three patents. He has initiated commercializing research outputs of UCE-EEST UNS related to energy storage technology and electric vehicle conversion through start-ups where he is one of the founders, namely PT Batex Energi Mandiri and PT. Ekolektrik Konversi Mandiri. Dr. Sutopo has published articles on over 185 documents indexed by Scopus with H-index 12. His email address is wahyudisutopo@staff.uns.ac.id.

Renny Rochani is a lecture in Industrial Engineering Faculty at Universitas Sebelas Maret-Surakarta, Indonesia. She is also in the Research Group Industrial Engineering and Techno-Economic Industrial Engineering Department, Faculty of Engineering Universitas Sebelas Maret Surakarta, Indonesia. Her recent research is to develop a mobile battery swap charging station for electric motorcycles in Indonesia.