A Framework for Developing Model for Measuring Readiness, Economic Benefits, and Economic Feasibility of Standard Implementation: A Case Study

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Abstract

Currently, the Indonesian government is considering electric vehicles as a replacement for fossil fuel vehicles. To support the program, swap battery technology is being considered as an innovation for alternative refueling option. It needs to be supported by standardization to facilitate commercialization and reduce various types of risks. Based on previous research, the development of a national standard design model for swap battery testing has been carried out and a standard draft has been generated. To expedite the implementation of the swap battery standard, several assessments are required of the stakeholders involved. This study aims to propose a framework to develop a measurement model for the effectiveness of the implementation of the swap battery standard by considering the readiness of battery stakeholders in implementing the standard, the economic benefits of implementing the standard, and techno-economic analysis to measure the investment feasibility of the swap battery testing system. Stakeholder readiness is measured by considering the readiness of technology components of technoware, humanware, infoware, and orgaware. Meanwhile, the assessment of the economic benefits of standard implementation is measured using ISO methodology. Finally, a techno-economic analysis is carried out by considering the ratio of costs and benefits.

Keywords
swap battery, standardization, technology readiness, economic benefits, economic feasibility

1. Introduction

Petroleum is the most consumed fossil fuel every year (Smil, 2017; BP, 2019). This not only leads to depletion of the supply of energy sources (BP, 2016), but also environmental pollution characterized by increasing carbon emissions (GCP, 2019; CDIAC, 2017). Therefore, it is necessary to make efforts to reduce the use of petroleum products so that the environment is maintained and that global energy sustainability can be developed. Currently, the government is considering electric vehicles as a replacement technology for fossil fuel vehicles, marked by the Presidential Regulation of the Republic of Indonesia Number 55 of 2019 concerning the acceleration of the battery-based electric motor vehicle program for road transportation. Based on this regulation, the government will gradually reduce fossil fuel-fueled vehicles.

Electric vehicles have an electric motor and a battery to store the energy needed to drive the vehicle. Swap battery technology is being considered as an innovation for alternative refueling options as swap batteries provide a faster method of refueling electric vehicles (Sun et al., 2019) and hassle-free (Ahmad et al., 2018). Swap batteries are a method of charging electricity by swapping an empty battery pack with a battery pack that is fully charged (Ahmad et al, 2018). The battery exchange process only takes 3-5 minutes (Wang et al., 2014; Shao et al., 2017; Liang et al., 2018). The swap battery technology allows charging the battery at a lower voltage and allows electric vehicles to travel non-stop on long journeys (Sun et al., 2019). Besides, this battery exchange technology is also supported by the Regulation of the Minister of Energy and Mineral Resources Number 13 of 2020 concerning Provision of Electricity Charging Infrastructure for Battery-Based Electric Motor Vehicles. One of the things that are regulated is the provision of a public electric vehicle battery exchange station as the electric charging infrastructure for battery-based electric motorized vehicles.

Swap battery technology as innovation needs to be supported by standardization. The development of standards can help emerging technology ecosystems to overcome problems and thus help the successful commercialization of new products (The British Standards Institution, 2020). Standards for product measurement and testing help companies to show customers that the innovative products being sold have the features that the company claims (Swann, 2000). Also, standards can contribute to confidence in technology and innovative products by reducing various types of risks, both to users and society, including health, safety, and environmental risks. Standards not only reduce the time to market of an innovative invention and technology, but also enable marketing in the early stages of its existence, for example by gathering support from all relevant stakeholders. Standards also help accelerate the diffusion of innovation (Blind, 2016).

Swap batteries are a new product that is still under development in Indonesia. Researchers in Indonesia have published research results in developing lithium battery products for electric vehicle applications. Sutopo et al (2013) analyzed the battery technology value chain for electric vehicles. Purwanto et al (2013), Rahmawati et al (2013), and Rahmawati et al (2014) studied the battery anode material and its performance. Nizam et al (2019) and Nizam et al (2020) developed a battery management system. Sutopo et al (2018) conducted a review of the electric vehicle charging system in Indonesia. Meanwhile, Wardayanti et al (2018), Yuniaristanto et al (2017) and Mursid and Sutopo (2019) respectively developed models for supplier selection, production scheduling, and pre-test market schemes for lithium batteries. Sutopo et al (2013) and Sutopo et al (2016) conducted a cost estimation analysis for battery manufacturers. Cost estimation analysis and feasibility studies for battery development have also been reviewed (Sutopo et al, 2013; Sutopo et al, 2016; Aristyawati et al, 2016; Sutopo et al, 2014; Kurniyati et al, 2016). The commercialization model of lithium battery technology and its feasibility has been developed by Sutopo et al (2013), Kurniyati et al (2017), and Atikah et al (2014). Furthermore, standardization of battery testing has been developed through research by Sutopo and Kadir (2017), Sutopo et al (2018), Sutopo and Kadir (2018), Rahmawatie et al (2017), Prianjani et al (2016).

Prianjani (2020) has developed a model to design the swap battery testing standard. From this research, a draft of swap battery testing standard has been produced. This standard-design refers to the international standard IEC 62840-2: 2016 swap battery testing regarding the Electric Vehicle Battery Swap System - Part 2: Safety Requirements. The test variables in this standard draft test are protection against electric shock, equipment constructional requirements, electromagnetic compatibility, and marking and instruction. This standard is aligned with domestic capabilities, refers to global standards, and protects battery swap stakeholders in Indonesia (Prianjani, 2020). Thus, it is hoped that this standard design can be immediately implemented by swap battery stakeholders in Indonesia.

The goal of standard development is of course to be adopted and implemented. The adoption of standards to accelerate the commercialization of swap batteries in the market is an effort so that the swap battery technology does not fall into the valley of death. The valley of death is a phase between successful research and innovation (Hudson and Khazragui, 2013). Valley of death implies that there are projects of basic research origin that are capable of producing socially desirable commercial products, processes, or services but are unable to obtain financing in the mid-stage (Ford et al., 2009). Therefore, it is necessary to evaluate the readiness of stakeholders in adopting and implementing standards. Furthermore, Sharif (2012) provides a technical framework for measuring technology adoption readiness, which is called Technometrics. The technique for measuring technology adoption is based on four components, namely technoware, humanware, infoware and orgaware (THIO).

In standardization, measuring the benefits of standard application and its impact on the implementing stakeholders is an important study. This is done to find out what are the benefits of implementing the standard for the company and how it affects the producer companies and consumers of swap batteries. ISO (International Organization for Standardization) has created a methodology for calculating the benefits of implementing standards, which is called ISO Methodology. In this book, a systematic approach has been provided for assessing the economic benefits of standards, namely the contribution of standards to the creation of economic value for companies/organizations (ISO, 2013).

In order to expedite the implementation of the standard for swap battery testing, it is necessary to analyze the economic feasibility of the Conformity Assessment Agency investment for swap battery products. Conformity Assessment Agency is an institution that carries out conformity assessment activities including institutional and activity assessment processes to state the suitability of an activity or a product to certain standard. Conformity assessment bodies can be in the form of testing laboratories, calibration laboratories and certification bodies (National Standardization Body, 2017). Testing laboratories and calibration laboratories have business activity processes that refer to ISO/IEC 17025. Meanwhile, the development of certification bodies will refer to ISO/IEC 17065 which contains an assessment of conformity to requirements for certification bodies for products, processes, and services.

The feasibility of implementing standards can also be analyzed using techno-economic analysis taking into account the costs and benefits of implementing standards. In addition, techno-economic analysis is required to synchronize the investment calculations for the swap battery testing laboratory and calibration laboratory with costs for product certification through product certification bodies. Thus, the application of standards is expected to provide benefits to the Conformity Assessment Agency and without burdening the swap battery manufacturers.

This study aims to generate a framework to develop a model for measuring the effectiveness of the implementation of the swap battery testing standard by considering the readiness of battery stakeholders in implementing standards, the economic benefits of standard implementation, and techno-economic analysis to measure the investment feasibility of a swap battery testing system. Thus, the final output of this study is the standard implementation by battery swap stakeholders.

2. Literature Review

This study combines four research concepts, namely "standard implementation", "economic benefits", "technology adoption" and "techno-economic analysis". We conducted the review on researches that have the same characteristics as this research. Besides, conducting literature studies can help researchers in understanding the appropriate methodology for solving problems in this research and knowing the current research position.

The THIO technology component classification, including technoware, humanware, inforware and orgaware, was first introduced by Sharif et al. (1987). Then Sharif (2012) developed a technology adoption readiness measurement framework based on the THIO component, which became known as the Technometric method. The value of the technology component index is expressed by the Technology Contribution Coefficient (TCC), which is used to evaluate the contribution of technology components. Furthermore, this model has been used to measure the readiness for adoption of various technologies, including traceability, processing of oil palm fruit, smart cities, measurement innovation, internal quality assurance systems, and solar cell technology (Nugraheni et al., 2018; Adejuwon et al., 2016; Vassileva et al., 2017; Mirzapour Al-e-Hashema et al., 2018; Yulherniwati and Ikhsan, 2018; Guntoro et al., 2019). In addition, this model is also used to measure the readiness of an organization to meet standards, such as standards for concrete reinforcing steel, tofu products, toys, and the competence of testing and calibration laboratories (Tania et al., 2019; Trusaji et al., 2018; Setiawan et al., 2015; Fauzi et al., 2018; Aqidawati et al., 2019; Rosanti et al., 2020). However, the use of the technometric method alone is not sufficient to evaluate the effectiveness of the implementation of the swap battery testing standard, considering that implementation does not only involve swap battery manufacturers but also needs to consider other stakeholders, namely conformity assessment laboratories (LPK) and product certification bodies (LSPro). Therefore, it is necessary to analyze the economic feasibility of the investment in the establishment of testing laboratories and certification bodies as part of the swap battery testing system.

There are some researches on measuring the effectiveness of standard implementation and its benefits. Sumaedi and Yarmen (2015) proposed an instrument that can be used to measure the effectiveness of the application of ISO 9001. Foli et al. (2010) evaluated the effectiveness of the planning and implementation stages of ISO 14001 on environmental management systems. Johnstone and Hallberg (2020) explores the role of contextual factors in the adoption of ISO 14001 and the improvement of environmental performance in SMEs. Magd and Nabulsi (2012) describe an evaluation of the application of ISO 9000 in organizations in the UAE to determine the effectiveness of standards-based on their use as a business process management approach or tool. Also, Siltori et al. (2020) have analyzed the main benefits of implementing and certifying ISO 9001: 2015 in Brazilian companies. In addition, Phalitatyasetri et al (2020) assesed the economic benefits of the implementation of batik standard in Indonesia. Furthermore, Carrillo-Labella et al. (2020) identifies the main motivations, barriers, and benefits expected from implementing ISO 14001 in the food industry. However, from several existing studies, there are no studies that consider the techno-economic analysis in measuring the effectiveness of standard implementation.

Prianjani (2020) has produced a swap battery testing standard design developed through the FACT and SEM methods. However, this research has not conducted an assessment of the economic benefits of the application of standards, so that it cannot evaluate the effectiveness of the implementation of the standard. Therefore, this research will calculate the economic benefits of the application of the standard for swap battery testing that has been designed. As for later, these economic benefits are analyzed and calculated using the ISO Methodology. The draft standard that has been produced can be used as a reference for the investment needs of tools and materials for battery testing, which will later be used to predict cash flow in the techno-economic analysis of the feasibility of a standard application. Thus, the contribution that can be made is in the form of economic control in the development of swap battery standards. Besides, this study uses a Technometrics model to assess the readiness of stakeholders in applying the swap battery standard, to obtain the achievement of the TCC value to evaluate the investment justification needed to improve overall performance, which will be considered in the techno-economic analysis.

3. Methods

The formulation of the problem is made based on what outputs will be achieved in this study. The problem that will be discussed further is how to design measuring instruments that consider THIO, which is used to measure the readiness of stakeholders in applying standards. Then how to determine the economic benefits of applying standards to stakeholders using ISO Methodology, and how to compile a techno-economic analysis model for standard application. The objectives to be achieved in this research are: designing a measuring instrument that considers THIO, which is used to measure the readiness of stakeholders in applying standards, determining the economic benefits of applying standards to stakeholders using ISO Methodology, and compiling a techno-economic analysis model for standard application.

The relevant system in this study is illustrated in Figure 1. Overall, 5 stakeholders play a role in implementing the standard. The first stakeholder is the standardization body as the agency that provides training, development, and coordinator of activities in the field of standardization, as shown in arrows A and B. Then the factory is the next stakeholder as the center for battery production. Next are the testing and calibration laboratory as the agency in charge of assessing the conformity of products produced by the factory, indicated by arrow I. Besides, there is also a product certification body that is tasked with certifying battery products, as shown in arrow J. Accreditation Committee is also involved in this standardization activity, namely as the executor of standardization body's duties and functions in the field of accreditation, as shown in arrow N.

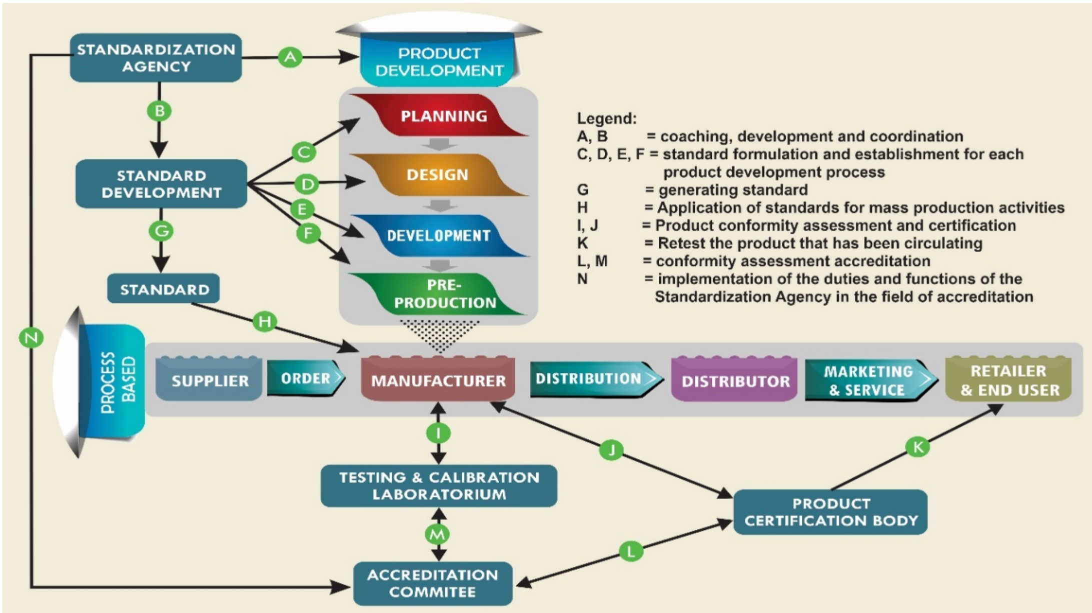

Figure 1. Relevant system of this study
(Sutopo, 2020)

Before the battery product is mass-produced and used as electric vehicle propulsion, it is necessary to develop a standard swap battery test. The standard development process becomes the standardization body's responsibility as a supervisor, developer, and coordinator of activities in the field of standardization. The development of standardization at the beginning of time needs to pay attention to the initial supply chain of the swap battery itself, namely at the product development stage which includes planning, design, development, and preproduction. This is shown in arrows C, D, E, and F. After the standard has been formulated and approved, it will be applied to the mass production process in the battery factory, as indicated by arrow H.

Swap battery products can be certified if there are testing and calibration laboratory and a product certification body that states that the product is suitable for consumer use. A good certification scheme is scheme five, which is a scheme that requires products that have been circulated to be re-tested (IECEx SYSTEM, 2013), as shown in arrow K. The requirements for the establishment of test and calibration laboratories and product certification bodies must follow the accreditation requirements set by accreditation committee, namely ISO/IEC 17025 and ISO/IEC 17065. This is shown in the arrows L and M.

Limitation of the problem is needed in this study to limit the scope of the problem so that research can be conducted in a more focused manner. Figure 2 shows the scope of the problems discussed in this study. Four processes are of concern, namely: (1) standard development and (2) standard establishment carried out by standardization body, (3) standard implementation by testing laboratories for testing products produced by battery manufacturers, and (4) standard labeling on products or certification activities carried out by a product certification agency. The standardization body in developing standards must consider the four processes to get benefits in the form of producer and consumer protection. The benefits of implementing the swap battery standard that is considered are the benefits felt by battery manufacturers and consumers. Investments are calculated in aggregate as costs to be compared with benefits. The investment considered is an investment in equipment for testing activities, while investment for certification activities is not taken into account. Implementation of standards by the testing lab aims to meet the standard criteria, not to meet the criteria for battery production. The fulfillment of the battery production criteria was carried out by the manufacturer and was not considered in this study.

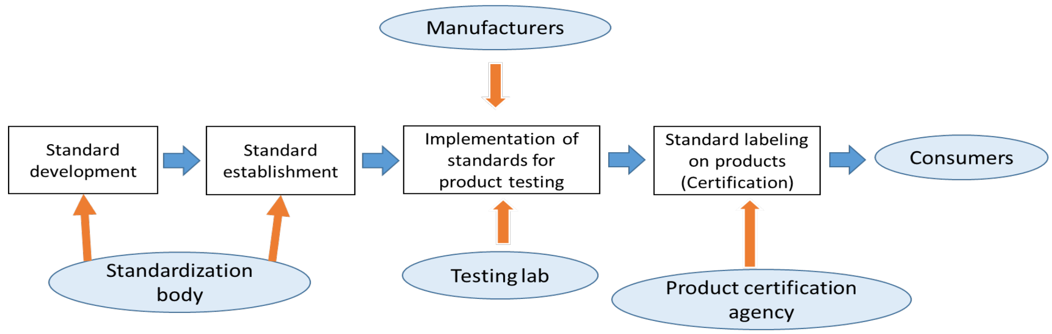

Figure 2. Scope of the problem

4. Results and discussion

4.1 Model Development Framework

The framework in this study consists of three parts, namely: measuring the technology readiness of implementing swap battery standards, assessing the economic benefits of implementing swap battery standards, and techno-economic analysis. Each part has its plot and stages. Figure 3 illustrates the framework used to develop the model.

4.1.1 Measurement of technological readiness for implementing swap battery standard

The first part of this research is to measure the technology readiness of applying the swap battery standard. The first step is to collect reference literature, namely the technology adoption readiness model from Nugraheni (2018), the draft of battery swap testing standard from Prianjani (2020), and the lithium-ion cell standard IEC 62660-1: 2017. Apart from that, it also identifies the business processes of the stakeholders involved, which consist of standardization bodies, testing laboratories, and product certification bodies. The identification of stakeholder business processes is carried out to determine which technology components need to be measured for each stakeholder.

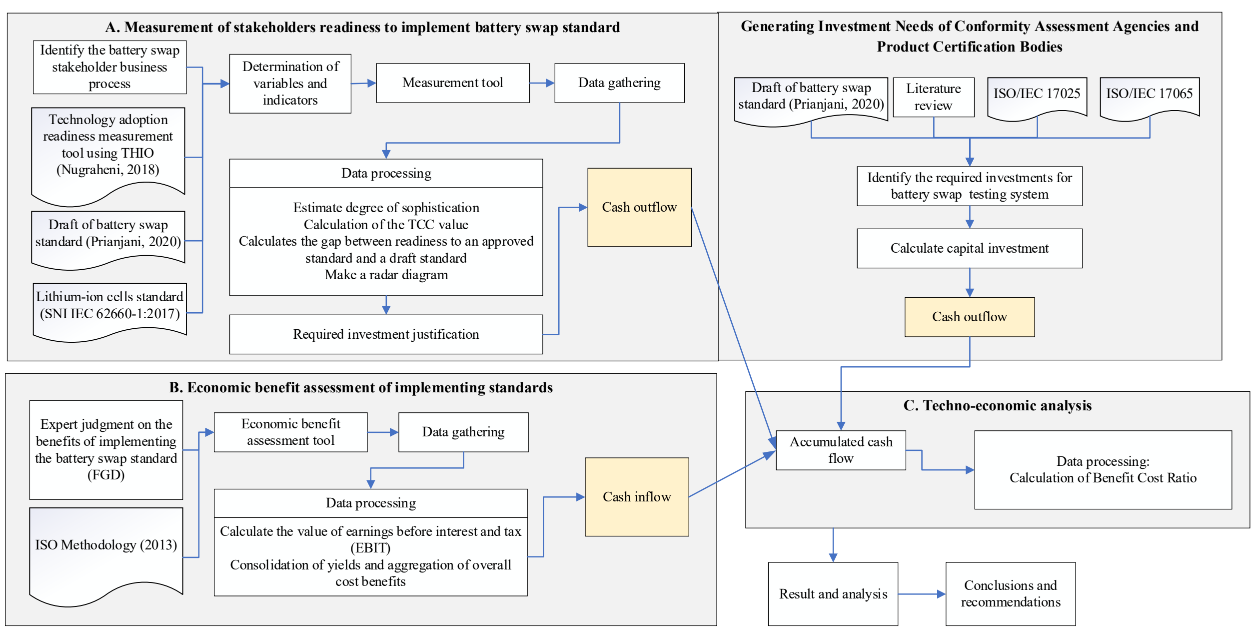

Figure 3. Model Development Framework

The next stage is to design the measurement instrument. The four works of literature previously mentioned are the basis for making the variables operational. The process and details of the variable operational stages are described in

4.2. The results of this stage are used as a basis for designing a questionnaire which then produces a technology readiness measurement tool.

After the measuring instrument was made, data collection was carried out through a survey to stakeholders. The survey results will be used as input in the data processing process. The steps taken in data processing are (1) recapitulation of survey results, (2) calculating the value of the Technology Contribution Coefficient (TCC), (3) making radar diagrams, and (4) calculating the gap in stakeholder readiness to the two standards.

The final step is to identify the need to improve the performance and level of technology readiness. This is determined based on the gap between the readiness of the stakeholder to meet the swap battery standard and the readiness of the stakeholder to meet the lithium-ion cell standard. The results of this process will later be used as input in the techno-economic analysis.

4.1.2 Assessment of the economic benefits of implementing the swap battery standard

The second part of this research is an assessment of the economic benefits of implementing the swap battery standard. The first step to take is to operationalize the variables to design a measurement tool for assessing the economic benefits of applying standards. This measuring tool is in the form of a questionnaire and is designed using the principles of ISO Methodology. The operationalization of variables for the assessment of economic benefits is described in detail in section 4.2. The aspects identified in this questionnaire are value chain, standard impact, value drivers, and operational indicators. After the measuring instrument has been made, data collection is carried out to stakeholders.

Also, a Focus Group Discussion (FGD) was conducted to collect information and data regarding the prediction of benefits that would be obtained from the application of the swap battery standard. The FGD participants were experts in the field of standardization. After that, a recapitulation of the survey and FGD results was conducted.

The data obtained from the survey and FGD are then processed to assess and consolidate results and aggregate the overall cost-benefit. The result of this stage is an estimate of the change in the quantitative value of the selected indicators obtained from comparisons before using the standard and after using the standard. The results of data processing will become input in the techno-economic analysis.

4.1.3 Techno-economic analysis

The third part is a techno-economic analysis. The first step is to determine the criteria and indicators that will be used to carry out the techno-economic analysis. Then the results obtained from the first and second stage are used as the basis for calculating the cost value for each predetermined indicator. After that, the value of the benefit-cost ratio (B/C ratio) is calculated and it is determined whether the application of the standard is feasible. Furthermore, a techno-economic model is built after obtaining the B/C ratio value. This model produces criteria that must be met when implementing the battery swap standard.

4.2 Measurement instrument

This section describes the variables to be studied and describes in detail the indicators and parameters included in these variables. These parameters were generated from the selected concepts that have been arranged. In addition, it also explains the operational definition and measurement mechanism as well as the scale of data used. We have generated variables for measuring the readiness of stakeholders in applying the swap battery standard and variables for assessing the economic benefits of applying the standard.

4.2.1 Readiness Measurement Parameters

The selected parameters are based on the Technometric concept in which the THIO technology components (technoware, humanware, infoware, orgaware) are integrated with existing standards, namely the draft of swap battery testing standard as a standard which is still in the formulation stage and the lithium-ion cell standard IEC 62660-1 as a comparison and benchmark. As for each stakeholder, the indicators and parameters used will be different depending on the stakeholder's business process itself.

To measure the readiness of a standardization body, only three components are measured, namely humanware, infoware, and orgaware. The criteria and indicators to measure readiness are taken from several studies, such as Sharif (2012), Arifianto (2011), and Nugraheni (2018). Meanwhile, all THIO technology components are considered to measure test lab readiness. Indicators from Technoware are equipment requirements according to the test requirements in the draft swap battery test standard and IEC 62660-1 lithium-ion cell standard. Meanwhile, indicators for measuring the readiness of humanware, infoware and orgaware components are determined based on the competency standards of the testing lab and the research results of Aqidawati et al (2019), who have developed a framework for measuring testing lab readiness. Furthermore, to measure the readiness of standardization bodies, we use indicators generated from the competency standards of product certification bodies (ISO / IEC 17065) and the research results of Fauziyah (2018). Only humanware, infoware and orgaware components are considered to measure the readiness of a product certification body. The measurement scale used in filling out the readiness questionnaire is an interval scale that refers to the research framework of Sharif (2012) and Nugraheni (2018). The framework for measuring stakeholder readiness is illustrated in Figure 4.

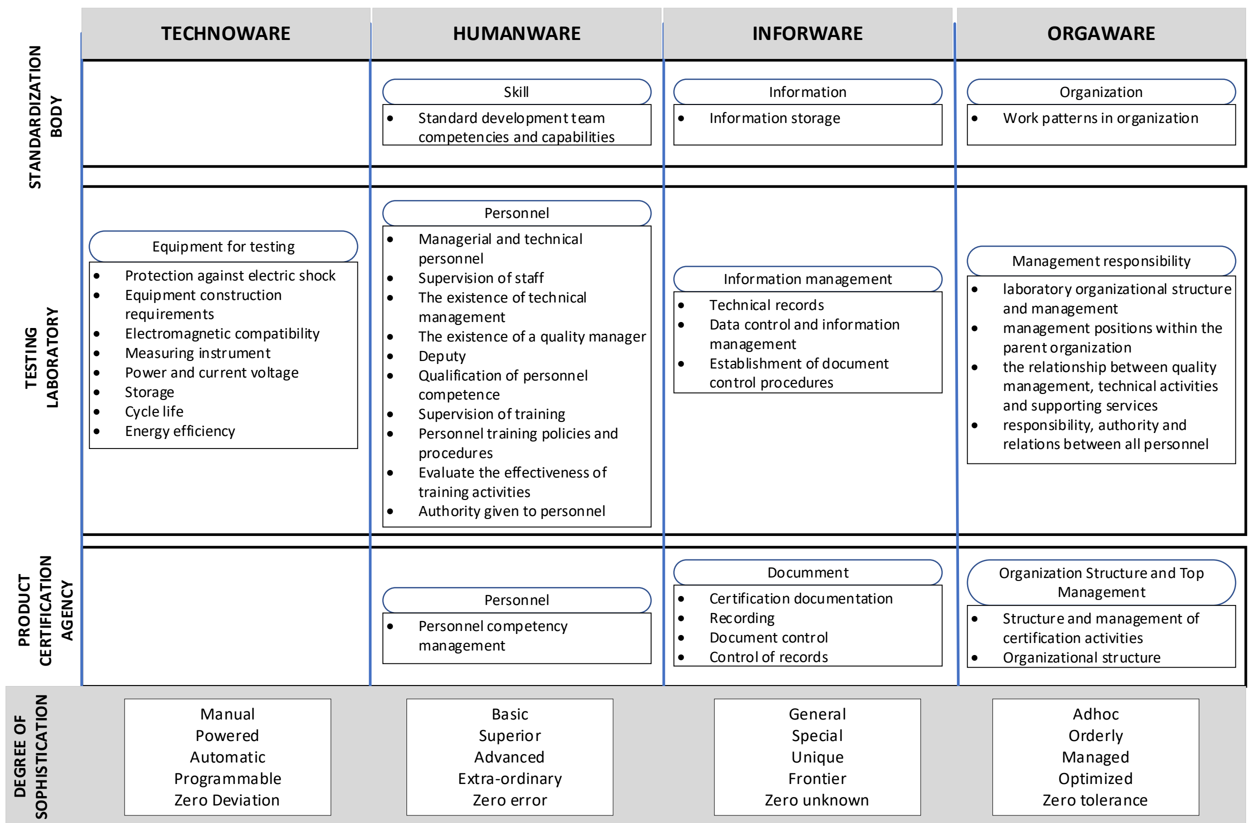

Figure 4. Stakeholder readiness measurement framework

4.2.2 Economic Benefits Assessment Parameters

The second instrument is a questionnaire used to determine the potential value chain and the impact of standard implementation by battery manufacturers. The formulation of the questionnaire used was based on Porter's value chain model. Meanwhile, the criteria and explanation of the criteria used to come from the ISO Methodology framework. The criteria for each business function are then translated into questions that will be asked in a questionnaire and a dichotomy scale is determined to fill in the criteria questions for each business function. The scale used is the dichotomy scale. If the respondent answers "yes", then asked for the estimated percentage and nominal value. The framework to assess the economic benefit of standard implementation is illustrated in Figure 5. The benefit assessment questionnaire was addressed to battery manufacturers and the consumer community consisting of standardization society and consumer associations. Benefits of standards can be identified along the entire company value chain and its external interfaces. They can be quantified in terms of impact on specific operational indicators and converted into financial terms.

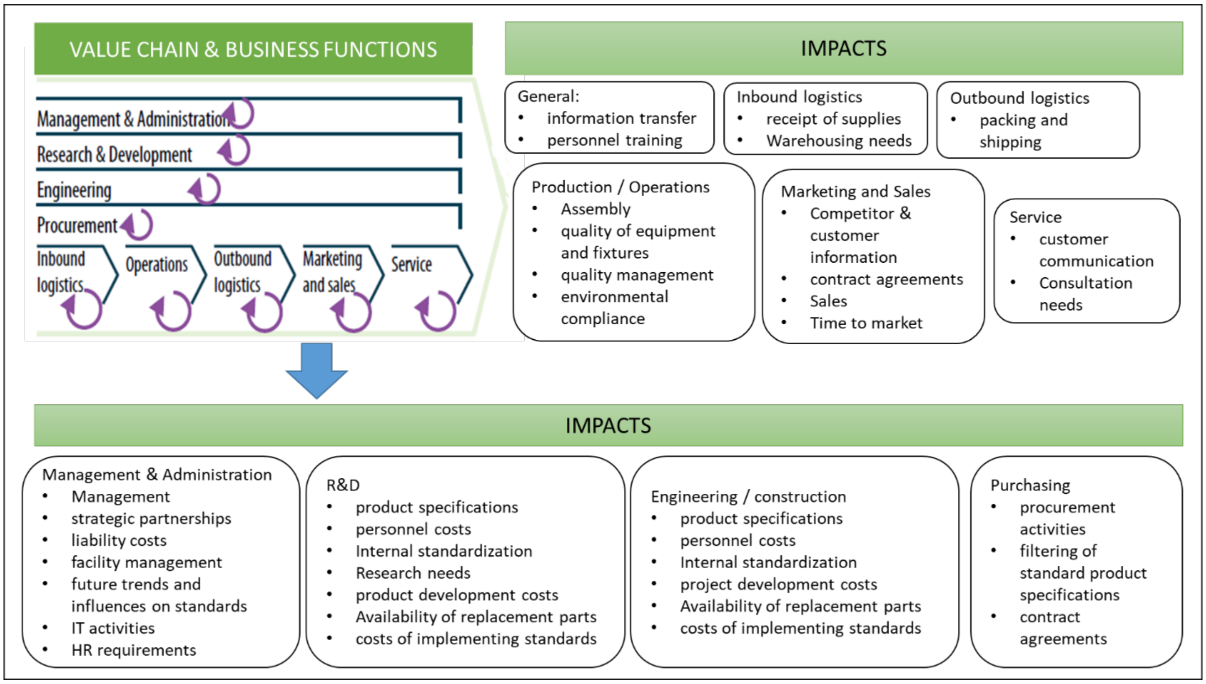

Figure 5. Economic benefit assessment framework

5. Conclusion

A framework has been designed to develop a model for measuring the readiness, benefits, and economic feasibility of standard implementation. The model developed aims to measure the effectiveness of the implementation of the swap battery testing standard by considering the readiness of battery stakeholders in applying standards, the economic benefits of a standard application, and techno-economic analysis to measure the investment feasibility of the swap battery testing system. This model integrates the conceptual approach of technology adoption with standardization. The model can be used as a reference for stakeholders who will apply the standard. From the THIO component readiness analysis, it can provide advice to the testing lab regarding what investments need to be made to improve company performance. In addition, this study can provide an overview of the prediction of economic benefits that will be obtained by battery manufacturers and consumers if they apply the swap battery standard. Based on the results of the techno-economic analysis, this study can provide recommendations to standardization bodies regarding the results of the feasibility of a standard application. Further research can be carried out to test the model by providing the results of its analysis data processing.

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