Developing Model of Technological Base Interoperability for Collaborating Multivariate-attribute Quality Control in Digital Supply Chain: A Preliminary Study

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Abstract

Interoperability plays an important role in the digital supply chain, especially in strengthening the integration and agility of the supply chain and thus improving customer service and sustainable organizational performance. This article aims to conduct an initial literature review on developing a model for determining interoperability requirements to ensure product collaboration between companies which is a smart connected product (SCP). There are three research questions formulated in this study, i.e., : (1). how to develop interoperability requirements on SCP (case study on Electric Motorcycle Swappable Battery/EMSB); (2). how to control quality to ensure product collaboration according to requirements, and (3). how to develop an economic impact assessment model to implement companies' interoperability requirements. Using limited literature review and adopting Denyer and Tranfield's five steps in the literature review, this study explores academic literature to answer research questions that should be further studied. From the study results, it was found that the development of interoperability requirements had to be carried out in three domains, i.e., physical components, smart components, and connectivity components, using the Framework for Analysis Comparison and Testing Standard (FACTS). Quality Control (QC) tools have played a role in the standard testing phase so that interoperability requirements could be tested and proven applicability. In developing the economic impact assessment model, the ISO Methodology - Economic Benefit of Standards (EBS) framework could be used to solve problems.

Keywords
Interoperability, Smart Connected product, Control Chart, Economic Benefit Standard, and Digital Supply Chain.

1. Introduction

Academics, practitioners, and organizations have widely discussed the concept of Industry 4.0. This is a new manufacturing paradigm that combines smart factories, smart machines, smart systems, smart production, and smart processes in one integrated network that unites the real and virtual worlds through the use of Cyber-Physical Systems (CPS) technology. This paradigm becomes a new industrial approach that includes a series of future industrial developments with technological advances that will increase the productivity and efficiency of the company (Zhou et al., 2016).

Industry 4.0 is projected to impact supply chains, business models, and processes significantly. Researchers used different names for Industry 4.0 in the context of supply chain management, i.e., digital supply network (DSN), digital supply chain, Internet of Things, e-supply chain, supply chain 4.0, e-logistics, logistics 4.0, etc. The digital supply chain can be defined as developing information systems and adopting innovative technologies to strengthen supply chain integration and agility to improve customer service and sustainable organizational performance (Ageron et al., 2020).

Industry 4.0 is marked by increasing digitization and automation in manufacturing and creating digital processes to facilitate interaction between all elements of the company. Implementing Industry 4.0 in the supply chain system can increase company productivity (Kayikci, 2018). The main benefits of Industry 4.0 on the supply chain are to reduce product delivery lead times to customers, reduce the time to respond to unexpected events, and drive significant improvements in the quality of decision-making (Barreto et al., 2017). Industry 4.0 can help companies carry out complex and dynamic processes and to handle large-scale production and customer integration (Rennung et al., 2016). Industry 4.0 can positively benefit today's sales and operations planning and logistics processes (Santos et al., 2017).

For successful technological transformation to Industry 4.0, there are three things must be considered : (1) horizontal integration through the value chain, (2) vertical integration and networking of manufacturing or service systems, and (3) end-to-end engineering of the entire value chain (Wang et al., 2016). Vertical integration requires intelligent cross-linking and digitization of business units at different hierarchical levels in the organization. Therefore, vertical integration can be done by transforming into a smart factory. In contrast, horizontal integration creates value between organizations to enrich the product life cycle using information systems, financial management, and efficient material flow. Horizontal and vertical integration enables real-time data sharing, increased productivity in resource allocation, coherent work business units, and accurate planning. Finally, end-to-end engineering assists the technological product development process that supports taking into account customer requirements, product design, maintenance, and recycling.

There are seven design principles that must be considered in the transformation to Industry 4.0, i.e: interoperability, real-time data management, virtualization, decentralization, agility, service orientation, and business process integration (Lidong and Guanghui, 2016). Interoperability is crucial for technology implementation in the Industry 4.0 era. An important requirement for successful collaboration with industrial partners is standardization (mechanical, electrical, and communication between all subsystems) (Weyer et al., 2015). This standardization is essential to ensure the interoperability of the interaction of components from different manufacturers (Turovets and Vishnevskiy, 2019). The interoperability challenge is getting more significant because the development of increasingly advanced and fast information technology has also revolutionized the product. In the past, technology was only part of mechanical and electrical systems. However, today products have become complex systems that combine hardware, sensors, data storage, microprocessors, software, and connectivity in a variety of ways, known as the "Smart Connected Product" (SCP).

This research used a case study on Indonesia's Electric Motorcycle Swap Battery (EMSB). Battery swap technology is one of the alternative refueling options because battery swaps provide a faster method for refueling electric vehicles (Sun et al., 2019) and are hassle-free (Ahmad et al., 2018). The battery swap is a method of charging electricity by exchanging empty battery packs with battery packs that are full of electricity (Ahmad, et al., 2018). The battery exchange process only takes 3-5 minutes (W. N. Wang et al., 2014); (Shao et al., 2017); (Liang and Zhang, 2018). A swap battery is an example of a real SCP because its components consist of a battery pack, battery management system (BMS), communication system, and connectors with complex interactions between components. Currently, electric motorcycles in Indonesia have differently swappable (SB) / non-swappable (NSB) batteries so that consumers can

only exchange their SB at the battery swap charging station (BSCS) according to the EMSB brand respectively. This becomes a heavy burden for EMSB manufacturers because the provision of BSCS requires a very large investment. On the other hand, the market problem is that consumers do not get certainty about the range of mileage when using EMSB. These technological and market issues have hampered EMSB's business model and impacted Indonesia's slow diffusion of technology for electric motorcycles. For this reason, supply chain engineering is needed in the early stages of EMSB technology innovation to support SB and BSCS systems that can be 'exchanged and operated between brands' or known as 'interoperability .'The concept of interoperability is expected to be a driver in the early-stage supply chain engineering of entities involved in the EMSB industry to create competitiveness and encourage effective and efficient business models.

1.1 Objectives

This article aims to conduct an initial literature review related to the study of developing an interoperability requirements model to ensure collaboration between companies with the characteristics of their products which are SCPs. There are three research questions formulated in this study:

- RQ1: How to develop interoperability requirements on SCP (case study on EMSB)?
- RQ2: how to control quality to ensure product collaboration according to requirements?
- RQ3: How to develop an economic impact assessment model to implement companies' interoperability requirements?

2. Literature Review

The problems presented in the previous sub-chapter cannot be solved partially. However, they must be carried out with an interdisciplinary approach so that the study is carried out entirely and comprehensively. If it is associated with the Body of Knowledge (BoK) Industrial Engineering (IE), solving these problems involves four BoKs, i.e., supply chain management, product design and development, quality and reliability engineering, and economic engineering, as shown in Figure 1.
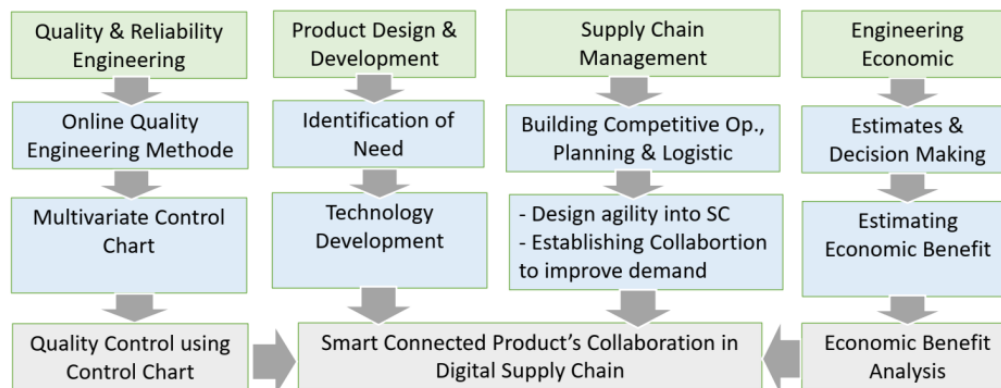

Figure 1. Interdisciplinary approach to solving problems based on the Body of Knowledge Industrial Engineering

The problems related to supply chain management issues in Building Competitive Operations, Planning, and Logistics. This is associated with Designing agility into a supply chain and Building collaboration to replace or increase demand forecasts. Collaboration occurred at the product level where the product characteristics are smart connected products. So this is closely related to BoK Product design and development, especially related to the identification of needs and development of technology. Furthermore, interoperability requirements are needed in product collaboration between companies, which are used as a reference in quality control. In this case, the use of control charts is also for validation and verification of the applicability of interoperability requirements. In the final stage, an economic analysis is carried out to evaluate the economic impact of the interoperability requirements, which refers to the BoK Engineering Economics. Based on this description, three main study objects will be studied in the literature review: smart connected products, interoperability, and quality control using control charts.

2.1. Smart Connected Products (SCP)

Smart Connected Products (SCP) have three core elements: physical components, "smart" components, and connectivity components (Porter and Heppelmann, 2014); (Mohelska and Sokolova, 2016). Smart components amplify the capabilities and value of physical components. At the same time, connectivity reinforces the capabilities and value of smart components and enables some of them to exist outside the physical product itself. The result is a good grade improvement cycle. Physical components consist of the product's mechanical and electrical components; for example, this car product includes engine blocks, tires, and batteries. Intelligent components consist of sensors, microprocessors, data storage, controls, software, and usually an embedded operating system and user interface, for example, car products: engine control unit, anti-lock braking system, touchscreen display. The connectivity component consists of ports, antennas, and protocols that enable wired or wireless connections with the product. According to Porter and Heppelmann (2014), Connectivity has three forms, which can be present together :

- One-to-one: The individual product is connected to the user, manufacturer, or other product via another port or interface, for example, when a car is connected to a diagnostic engine.
- One-to-many: A central system is continuously or intermittently connected to many products simultaneously. For example, many Tesla automobiles are connected to a single manufacturer system that monitors performance and provides service.
- Many-to-many: Some products connect to other product types and external data sources. Examples of agricultural equipment are connected to optimize the farming system, for example, automatic tillers that provide fertilizer at the proper depth and intervals, and seeders follow placing corn seeds directly in the fertilized soil.

There are many other terms for SCP, including Smart Objects (Sabou et al., 2009), Intelligent Product (Neal et al., 2019) and, Smart Product (Lenz et al., 2020), digitalized connected product (Mikusz, 2018). These terms have been considered to have the same meaning and are interchangeable. According to the "Smart Products Consortium," a smart product is "an autonomous object designed for self-regulated embedding into different environments during its life cycle, supporting natural product-to-human interactions. Smart products can proactively interact with users by using the sensing, input, and output capabilities of the environment so that they can self-control based on the situation and contextually. Knowledge and related functionality can be shared and distributed among multiple smart products that emerge over time." (Sabou et al., 2009). According to Kammler et al. (2020), the capability of smart products is strongly influenced by six characteristics of design specifications, i.e., context–awareness, personalization, connectivity, engagement, service bundling, and systemic design.

The capabilities of smart connected products can be grouped into four categories: (1). Monitors: sensors and external data sources enable monitoring of product condition, operation, and the external environment to produce improvements and actionable intelligence; (2). Control: in-product software allows for control and personalization; (3). Optimization: monitoring and control capabilities enable optimization algorithms to improve product/service performance and remote repair; (4). Automation: the combination of enhanced monitoring, control, and optimization capabilities with software algorithms and business logic enables the product to work independently (Mohelska and Sokolova, 2016); (Porter and Heppelmann, 2015).

2.2. Interoperability and Standardization

The term interoperability emerged in the early 90s in computer science and is defined as "the ability of two (or more) systems or components to exchange information and use the information that has been exchanged" (IEEE, 1990). Interoperability has developed in several domains, i.e., transportation, military, medicine, etc. Furthermore, interoperability has a specific definition and interpretation according to the perspective of each domain (Daclin et al., 2006).

Enterprise interoperability is the ability to exchange and share resources (e.g., information, devices, etc.) and uses them in meaningful ways (da Silva Serapião Leal et al., 2019); while according to Ameri et al. (2022), Interoperability is the ability of two or more heterogeneous but relevant systems to communicate, interpret correctly, act on meaningful and accurate information with minimal effort. Interoperability is not only a matter of software and information technology but also business processes (Khisro and Sundberg, 2020).

The transformation of digital technology in various industries is a necessity in entering industry 4.0, so the interoperability of products and elements in complex systems has an important role. Standardization is a leading tool in government policy interventions for modernization and acceleration of innovation. Standards in the field of digital technology have unique characteristics compared to other domains. First, digital technology is a complex system consisting of various parts and elements, both hardware and software, which can be developed by different suppliers in different ways, so interoperability must be ensured. (Foster and Heeks, 2013). Second, modern information systems are designed with high switching costs. For the customer, its implementation means significant expenditure on integration, learning, etc. From an evaluation perspective, standards can serve as indicators of project effectiveness. As the innovation cycle accelerates, standards and related activities become tools for solving global challenges, especially in manufacturing in high-tech industries (Wakke and Blind, 2015); (Blind and Mangelsdorf, 2016). Therefore, standards can stimulate the development of new technological solutions and improvements to existing ones (Zoo et al., 2017). Third, the intrinsic network effect can only be achieved if the number of users increases. Massively using information technology requires the compatibility of systems, products, and services in the global market, and the main tools are standards (Foster and Heeks, 2013).

The standard development process is consensus-based, open, and transparent, facilitating stakeholder agreement on technical specifications and implementation (Narayanan and Chen, 2012; Baron et al., 2014). Like an open innovation process, standards development brings together the knowledge and experience of various stakeholders, resulting in solutions that are relevant and accessible to the general public (Pilena et al., 2021). In addition, the existence of standards encourages the diffusion of innovation through harmonizing technological solutions in complex systems with verification based on conformity assessments (security, compatibility, etc.) (Zoo et al., 2017).

2.3. Quality Control using Control Chart

Interoperability requirements are used as a reference to ensure product collaboration between manufacturers can be operated together without problems. Therefore, its implementation in SCP requires quality control (QC). One of the essential tools in QC is the Control Chart which Walter A. Shewhart developed for the first time in 1931. Control charts were initially developed known as univariate charts, which can only be used to monitor single characteristics of a process. There are two types of control charts based on the monitored quality characteristics, namely variable and attribute control charts. Variable control charts were developed to monitor quality characteristics of metrics (variable scales or ratios) such as length or height. On the other hand, to monitor nonmetric quality characteristics (categorical scale: defects, color, softness, etc.), attribute control charts are used (Montgomery, 2013). Thus, if a company wants to monitor numerical and categorical data simultaneously, it is necessary to use two types of graphs (variables and attributes) individually, which is inefficient. As technology advances and customer expectations increase, monitoring several quality characteristics simultaneously is necessary.

In 1947 Hotelling introduced the multivariate control chart, so the chart is known as the T^2 Hotelling Chart. However, Hotelling's T^2 chart is not sensitive to minor shifts and is a work in progress (Xia et al., 2018). To overcome these weaknesses, the Multivariate Exponentially Weighted Moving Average (MEWMA) and Multivariate Cumulative Sum (MCUSUM) control chart methods have been developed to accommodate multivariable characteristics. The development of the theory of control charts is presented in Table 1. In the industrial era 4.0, with very complex product characteristics, it is necessary to simultaneously monitor several quality characteristics, variables, and attributes (Ahsan et al., 2020).

Table 1. Theory development of Control Chart

Year	Figure	Theory Contribution
1931	W.A. Shewart	Univariate Control Chart
1947	Harold Hotelling	Multivariate Control Chart
1954	E.S. Page	Multivariare Cumulative Sum (MCUSUM) Control Chart
1959	S.W. Robert	Multivariate Exponential Weighting Moving Average (MEWMA) Control Chart
1990 - …..		Latent Structure Methods: Principal Component Analysis (PCA)

Source: (Montgomery, 2013).

3. Methods

In this paper, the methodology uses a qualitative approach. It adapts the five steps of a systematic literature review by Denyer and Tranfield (2009) (Abdirad and Krishnan, 2020), which consists of (1) question formulation, (2) locating studies, (3) study selection and evaluation, (4) analysis and synthesis, and (5) reporting results, as presented in Figure 2.

Step 1: Formulation of the research question (RQ)

Step 2: Locating Study. Determine the object of study and identify keywords to answer the RQ. The main study objects consist of interoperability, SCP, and quality control. The keywords used in this paper are divided into three parts according to the main study object, as presented in Table 2. In this initial study, the search engines used to search the initial literature were Scopus and ScienceDirect because Scopus and ScienceDirect are the most popular publications that provide subscription-based access to large databases, as seen in several literature reviews (Tober, 2011).

Step 3: Study Selection and Evaluation. To ensure that the literature obtained is relevant to this topic, each paper is reviewed through a Focus Group Discussion (FGD) with the research group of Centre of Excellence for Electrical Energy Storage Technology, Universitas Sebelas Maret – Industrial Engineering and Techno-Economy, Faculty of Engineering, Universitas Sebelas Maret.

Step 4: Analysis and synthesis. At this stage, each paper is reviewed by classifying it according to the criteria presented in Table 2.

Step 5: Reporting Results. The results of the review paper are then presented in Table 3, Table 4, and Table 5 in subchapter 4 (data collection).
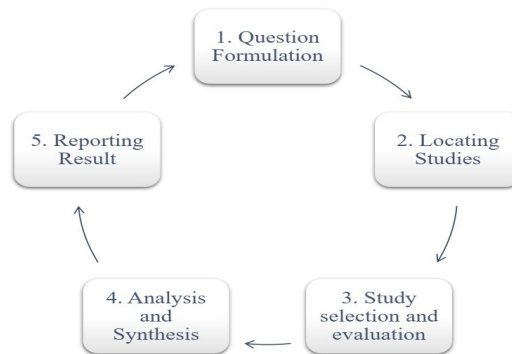

Figure 2. Methodology Literature review

Table 2. Keyword and Criteria Analysis in the literature review

Study object	Keyword	Criteria for analysis and synthesis
Smart Connected Product	"smart product or smart connected product or digitized product and industry 4.0 or Industrie 4.0 or fourth industrial revolution"	The characteristics of the design specification are context–awareness, personalization, connectivity, embeddedness, service bundling, and systemic design.
Interoperability and standardization	*"interoperability and supply chain* or digital supply chain"*	Approach Method (Quantitative vs. qualitative); Domain interoperability (physical components, smart or connectivity)
Control Chart	*"interoperability or standard and multivariate control chart"*	Data Types (variable and attribute); The method used (T2 Hotelling, MEWMA, or PCA); Application (real case vs. simulation)

4. Data Collection

The results of the review paper related to SCP in the initial study of this research are presented in Table 3, then the results of the initial study related to interoperability are presented in Table 4 and those related to the control chart are presented in Table 5.

Table 3. The results of the review paper on the characteristics of smart (connected) products

Term	Author (year)	Context-Awareness	Personalization	Connectivity	Embeddedness	Service Bundling	Systemic Design	Total
Smart Product	Santos et al. (2017)	√		√	√			3
Smart Product	Kahle et al. (2020)	√	√	√	√			4
Smart Product	Neal et al. (2019)	√		√	√			3
Smart Product	Lenz et al. (2020)	√	√	√	√			4
Smart Product	Maas et al. (2008)	√		√			√	3
Smart Product	Dawid et al. (2017)	√		√	√	√	√	4
Smart Product	Mayer et al. (2011)	√		√	√	√	√	4
Smart Product	Hultink and Rijsdijk (2009)	√	√		√			3
SCP	Zheng et al. (2020)	√	√	√	√	√	√	6
SCP	Mikusz (2018)	√	√	√	√	√	√	6
SCP	Mohelska and Sokolova (2016)	√	√	√	√	√	√	6
SCP	Michael and James (2015)	√	√	√	√	√	√	6
SCP	Porter and Heppelmann (2014)	√	√	√	√	√	√	6

Table 4. The results of a review paper with an Interoperability study

No	Author	Title	Publisher	Approach Method		Domain of Interoperability			Result
				Quantitative	Qualitative	Physic	Smart	connectivity	
1.	Gabriel Leal, Wided Guédria, Hervé Panetto (2019)	An ontology for interoperability assessment: a systemic approach	Journal of Industrial Information Integration, Elsevier, 2019, 16:100100, pp.1-13. ff10.1016/j.jii.2019.07.001ff. ffhal-02237124ff	√	√		√		INAS (Interoperability Assessment) To determine the interoperability of the system (quantitative and qualitative)
2.	Farhad Ameri, Dusan Sormaz, Foivos Psarommatis and Dimitris Kiritsis (2022)	Industrial ontologies for interoperability in agile and resilient manufacturing,	International Journal of Production Research, 60:2, 420-441, DOI: 10.1080/00207543.2021.1987553		√		√		Development of interoperable software applications to support data access throughout the product life cycle using the IOF (Industrial Ontology Foundry) method.
3.	Jwan Khisro and Håkan Sundberg (2020)	Enterprise interoperability development in multi relation to collaborations: Success factors from the Danish electricity market	Journal of Enterprise Information Systems, 14:8, 1172-1193, DOI: 10.1080/17517575.2018.1528633		√		√		• Identify and clarify success factors for solving business process problems and data fragmentation in developing enterprise interoperability in multi-relational collaboration.
4.	Electric Power Research Institute (2019)	Interoperability of Public Electric Vehicle Charging Infrastructure	www.epri.com		√	√	√	√	• Without interoperability, the charging infrastructure will be fragmented and inefficient and resulting in poor customer service. • Infrastructure development requires interoperability, transparency, and open standards to streamline system integration and improve customer experience.
5.	This Research	Developing Model of Technological-based		√	√	√	√	√	

		Interoperability For Collaborating Multivariate-attribute Quality Control in Digital Supply Chain								

Table 5. Review paper QC

No	Author	Title	Publisher	Type of Data		Multivariate Control Chart			Application	
				Variable	Attribute	T^2 Hotelling	MEWMA	PCA	Real case	simulation
1.	Aries Susanty, M. Mujiya Ulkhaq, and Devi Amalia (2018)	Using Multivariate Control Chart to Maintain the Quality of Drinking Water in Accordance with Standard	International Journal of Applied Science and Engineering. 2018. 15, 2: 83-94	√		√	√		√	
2.	M. Ahsan, M. Mashuri , Wibawati, H. Khusna and M.H Lee (2020)	Multivariate Control Chart Based on Kernel PCA for Monitoring Mixed Variable and Attribute Quality Characteristics	Symmetry 2020, 12, 1838; doi:10.3390/sym12111838. www.mdpi.com/journal/symmetry	√	√			√		√
3.	This Research	Developing Model of Technological-based Interoperability For Collaborating Multivariate-attribute Quality Control in Digital Supply Chain		√	√			√	√	

5. Results and Discussion

At this stage, the discussion description will try to answer the research question formulated in the early stages.

RQ1: How to develop interoperability requirements on SCP?

As stated earlier regarding the case study used in this study, the swapped battery is an example of a real SCP because its components consist of a battery pack, battery management system (BMS), communication system, and connectors with complex interactions between components. Based on Table 3, the characteristics of smart products and smart connected products can be distinguished based on design specifications. The SCP must meet the design specification's six characteristics: context–awareness, personalization, connectivity, embeddedness, service bundling, and systemic design. First is the Context-Awareness specification; this specification can be interpreted as the product's "Intelligence" associated with context awareness. The swap battery can meet these specifications because it is equipped with sensors in the BMS. Second, personalization specifications are related to product adjustment to user needs (product adaptation based on user perspective). The swap battery is equipped with a BMS with control capabilities so that the product allows technology adaptation to the needs of its users. The third is the connectivity specification, describing the product's ability to communicate with other products, systems, and users. Connectivity serves two purposes: The exchange of information between the product and its environment and the contribution to cross-product functionality. The swap battery is equipped with IoT, which is also connected to the BMS so that it can provide information regarding the condition of the SoH (State of Health) and SoC (State of Charge) battery and can also access the nearest BSCS location. Fourth, embeddedness specifications, namely "Classic" Products coupled with embedded Information Technology (IT) (sensors, microprocessors, hardware, software, etc.). In the swapped battery, sensors, BMS, and GPS are embedded in the battery pack. Fifth, service bundles consist of interconnected products in combination with value-enhancing services to optimize overall results. Related to these characteristics, the business orientation of swap battery products does not only stop at selling products but also relates to battery maintenance and rental services to increase customer satisfaction. Moreover, related to the Systemic design specification, it can be explained that the smart product ecosystem is considered an interacting network. Within these networks, individuals and organizations work together to create added value from product and service bundling. Swap battery products are part of a larger system, such as charging and energy storage systems.

Furthermore, based on the results of the initial study in Table 4, it is known that three of the four papers (75%) only focused on the smart component domain, and only one paper (25%) considered interoperability in the three domains (physical, smart and connectivity). This is understandable because the study of interoperability comes from the discipline of computer science, so the discussion is more focused on the ability of the system to exchange data and information. However, according to EPRI (2019), electric vehicle charging infrastructure interoperability must be carried out in three domains. Without interoperability, the charging infrastructure will be fragmented and inefficient and resulting in poor customer service. Infrastructure development requires interoperability, transparency, and open standards to streamline system integration and improve customer experience.

Inconsistent ways of developing standards can lead to misguided interpretations and ultimately result in standards that are unclear and difficult to implement. The FACTS (Framework for Analysis, Comparison, and Testing Standard) approach is a methodology developed by NIST (National Institute of Standards and Technology, US Department of Commerce) that provides a framework for analyzing, comparing, and testing standards. The FACTS approach helps provide a framework for analysis, comparison, and standard testing by structuring and formalizing information that refers to the Zachman framework. There are four main stages, namely (1). Analysis of stakeholder needs from this stage can identify all needs from various perspectives, and Technical Analysis, where each stakeholder needs must be described and formulated standard technical concepts, (2). Standard Comparison for harmonization of existing and applicable standards; and (3). Standard Testing to verify and validate standards. Such measures can improve how standards are developed, understood, and implemented. The advantage of this approach is that it can be applied to all three standard life cycles separately (Witherell et al., 2013). This approach has been used in standard development research, namely Prianjani et al. (2016); Aristyawati et al. (2016); Rahmawatie et al. (2017); Sutopo et al. (2018); and Prianjani et al. (2018). Therefore, the development of interoperability requirements can use FACT as a framework.

RQ2: How to control quality to ensure collaboration in accordance with interoperability requirements?
Interoperability requirements are used as a reference for product collaboration between manufacturers so that they can be operated together without problems. The biggest challenge is the complex product characteristics of SCP. Therefore, its implementation in SCP requires quality control (QC). Based on the initial study in Table 3, it can be seen that product quality monitoring can be carried out using standard references. In the industrial era 4.0, with very complex product characteristics, it is necessary to simultaneously monitor several quality characteristics, variables, and attributes (Ahsan et al., 2020). The case study is a battery swap product characteristic of SCP products, so that quality monitoring will be carried out on attribute and variable data. Based on Table 5, two papers can be used as references in this study, namely (Susanty et al., 2018) and (Ahsan et al., 2020). Susanty et al. (2018) used variable data so that the tool used is a multivariable control chart applied to control the quality of bottled drinking water. Then Ahsan et al. (2020) developed a quality control model on two types of variable and attribute data simultaneously using a mixed multivariate attribute based on Principle Component Analysis (PCA). The Ahsan et al. (2020) model trial used the data set of previous studies so that the number of samples was limited. Quality monitoring in this study can refer to the model of Ahsan et al. (2020) by adding a bootstrap resampling method to improve the accuracy of determining control limits.

The QC tool is used in the standard testing phase in connection with the FACT approach in developing interoperability requirements so that the development of interoperability standards/requirements can be tested and proven its applicability through the implementation of QC using a multivariate-attribute control chart.

RQ3: How to develop an economic impact assessment model to implement companies' interoperability requirements?
Implementing standards (interoperability requirements) at the EMSB company is projected to impact significantly. ISO Methodology – Economic Benefit Standard (EBS) provides a framework for measuring the impact of standards on organizational value creation with an emphasis on the organization's business, to provide clear and well-managed criteria for decision makers to assess matters relating to standards, and to provide guidance in assessing the merits of standards in specific industry sectors (ISO, 2013). The ISO methodology provides a consistent framework of criteria, guidelines, and tools for assessing standard economic benefits from the perspective of individual organizations, i.e., profit-oriented companies or public companies. The application of the ISO methodology can help companies know better the activities and organizational processes related to using standards with an overview of improving performance and maximizing the derived profits (Pratiwi et al., 2018). This approach has been used by several researchers, including Pratiwi et al. (2018); Phalitatyasetri et al. (2019); Kristiningrum et al. (2021) conducted an assessment of the standard economic impact in real terms, and Aqidawati et al. (2022) conducted an assessment based on predictive values based on a questionnaire. In this research, an economic impact assessment can refer to (Aqidawati et al., 2022) with a different case, namely the EMSB.

Based on the discussion of RQ1, RQ2, and RQ3, To develop the model in this study, two frameworks were used, namely FACT and ISO Methodology. The relationship between the two approaches is shown in the research framework presented in Figure 3. it can be identified the potential novelty and contribution of this research study, which are as follows :
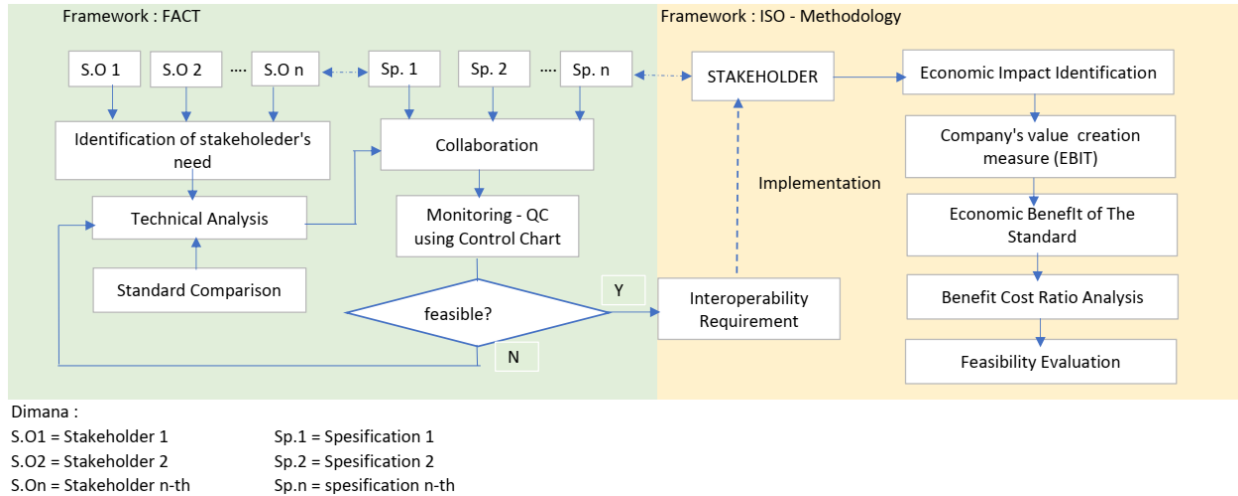
Figure 3. Research framework

Potential Novelty :

- Interoperability studies were conducted on three domains of Smart Connected Product (SCP) components: physical components, smart components, and their connectivity components, using quantitative and qualitative approaches.
- Development of interoperability standards/requirements tested and proven their applicability through QC implementation using a multivariate-attribute control chart.

Potential Contribution :

- Generate a model/systematic approach to determining interoperability requirements based on technology in the EMSB.
- Produce an economic benefits assessment model for implementing interoperability standards for the EMSB.
- Produce academic manuscripts as a reference for the preparation of government policies on interoperability standards that have been tested in theory and their applicability for all EMSB stakeholders (research products in the form of government policy briefs);

However, to clarify the research position, a more systematic and comprehensive systematic literature review (SLR) study is still needed by involving metadata from other search engines such as Web of Science, Google Scholar, etc.

6. Conclusion

- The interoperability requirements on SCP (EMSB case) need to be developed using the FACT framework in three domains, namely physical components, smart, and connectivity. QC tools play a role in the standard testing phase so that interoperability requirements can be tested and proven applicability. Then, the impact assessment model development for the interoperability requirements can use the ISO Methodology-EBS framework.
- In the initial study, the potential for novelty and research contributions have been identified, but to clarify the position of this research, a systematic and comprehensive study of SLR with more extensive metadata is still needed.

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