A Supply Chain Analytics for The Electric Motorcycle Business with Swappable Battery System – A Descriptive Analytic from the IoT Data

Yusuf Priyandari
A Doctoral student at the Industrial Engineering Department, Faculty of Engineering, Universitas Sebelas Maret, Surakarta, Indonesia.
priyandari@ft.uns.ac.id

Wahyudi Sutopo and Fahrina Fahma
Industrial Engineering Department, Faculty of Engineering, Universitas Sebelas Maret, Surakarta, Indonesia
wahyudisutopi@staff.uns.ac.id, fakhrinafahma@staff.uns.ac.id

Muhammad Nizam
Electrical Engineering Department, Faculty of Engineering, Universitas Sebelas Maret, Surakarta, Indonesia
Centre of Excellence for Electrical Energy Storage Technology, Universitas Sebelas Maret, Surakarta, Indonesia
muhammad.nizam@staff.uns.ac.id

Hendro Wicaksono
Jacobs University Bremen, Campus Ring 1, Bremen, 28759, Germany
h.wicaksono@jacobs-university.de

Abstract

Internet of Things (IoT) and big-data analytics imply the development of supply chain analytics (SCA). Despite industries recognizing SCA's potential benefits, its utilization is not massive yet. The study aims to develop reports based on the descriptive-analytic task of SCA for the electric motorcycle business with a swappable battery system. There are two goals: 1) exploration of the business process and the data generated by IoT from the electric motorcycle industry, and 2) generating descriptive analytics for minimum attribute data from the company to get insights about swap transactions at their battery swap station locations. We used general questions that usually will be answered by the descriptive-analytic task for generating some visualizations of the data. As a result, the company knows that about 60% of the battery swap stations have transactions below the average, peak time at 7-10 am and 1-6 pm, and most of the transactions are conducted on Thursday and Friday. The other result is that there are five questions or decisions that the company should deeply review.

Keywords
Battery swap station, electric motorcycle, internet of things, supply chain analytics.

1. Introduction
1.1 Background of the Study
The Ministry of Industry of the Republic of Indonesia targets the sales of electric motorcycles in 2025 to be 1.76 units and increase to 2.45 million in 2030 (Andryanto 2022). The target is to support the world trend toward using electric vehicles, which are energy-efficient and environmentally friendly. This target is expected to be achieved because electric motorcycle consumers are facilitated by battery swapping stations (BSS) to get a fully charged battery and

swap it with their discharged battery. The time taken for swapping is between 3 to 5 minutes. So, the consumers no longer have to charge the battery at home or the battery charging station (BCS), which takes 2 to 3 hours.

Electric motorcycles with a battery swap mechanism developed a business model relying on the Internet of Things (IoT) components. These components include an electric motorcycle (EM), swappable battery (SB), battery swapping station (BSS), electric motorcycle mobile application (EMAp), and IoT platform. The battery has a battery management system (BMS) device; while mounted in the vehicle, it periodically sends data to the motorcycle dashboard and the company's cloud data. Electric motorcycle user gets information on the remaining battery power and estimated mileage on the motorcycle's dashboard. Battery power information or remaining mileage can also be observed via EMAp. In addition, EMAp provides information about nearby BSS locations and the number of batteries available to the consumer. Battery swapping activities are carried out using the help of EMAp for payment transactions, opening empty compartments, and obtaining a fully charged battery from another container in the BSS. IoT platform used by the company for monitoring the battery charging process at each BSS location, the use of electrical resources, the conditions and disturbances that occur in BSS, and battery exchange activities carried out by consumers.

The data sent by IoT components to the company's cloud database forms big data. In addition to being used for consumer services for electric motorcycle users, this big data can generate insights that support the decision-making process and create knowledge and wisdom for the company. To generate knowledge, data needs to be processed using a mechanism, which is now known as business analytics (BA) (Jun et al. 2019; Phillips-Wren & Adya 2020). The form of BA is at least a software platform that visually presents information and knowledge to users and provides analytical results in the form of descriptive, predictive to prescriptive (Hassan 2019). BA platforms can be unified with IoT platforms or stand-alone (De Nardis et al. 2022). The use of BA requires not only the ability to use analytical data devices but also knowledge of the context of the system (object of study) (Hassan 2019). That is one of the reasons why in different system contexts, different IoT platforms are also needed (Lu & Cecil 2016; Ramachandran et al. 2022) or, in other words, require a specific BA process.

1.2 Aim of the Study

The industrial 4.0 era, with the support of the internet of things (IoT) and big data, has encouraged the establishment of a supply chain model known as a digital supply chain (DSC) (Ageron et al. 2020; Büyüközkan & Göçer 2018). Büyüközkan & Göçer (2018) mentioned that one of the challenges of DSC is the lack of analytical tools and inaccuracies in demand planning and lack of knowledge in dealing with the volatility of supply chain management. In contrast, DSC's success is supported by better information and sophisticated analytics and decision support systems driven by predictive analytics to help accelerate responses to competitors' movements, technological changes, and strengthen adaptability. BA is one of the solutions because it has a positive impact on decision-making ability (Cao & Duan 2015), and improves decision quality (financesonline 2022).

This research is in collaboration with an electric motorcycle manufacturer that implements a battery-swapping system in BSS. The manufacturer intends to optimize its IoT platform to generate valuable insights to support decision-making. Therefore, the company shares data with researchers to explore the data. Thus, this study aims to determine how the availability of minimal data attributes can provide insights for the company through the BA processes. The process of data analytics is limited to descriptive analytics tasks. These objectives can be achieved by conducting: (1) exploring business processes and interactions between IoT components in the process of replacing electric motorcycle batteries in BSS, and (2) conducting descriptive analytics using a BA tool against data obtained from the company. The study results are expected to encourage the company to utilize supply chain analytic for insight and recommendation.

2. Literature Review

2.1 Internet of Things Platform

The Internet of Things (IoT) platform is a system or sub-system of a business that collects data from a set of interacting sensors, processes it into information, and provides outputs or services for specific uses (Sorri et al. 2022). Sorri et al. (2022) state that data, information and services provided by IoT are the basis for transforming the creation of added value in a business ecosystem. According to him, there are ten categories of IoT frameworks, and they all need to be involved in designing an IoT system. One of the categories is related to processing information through a technology, for example, cloud computing, data mining or data analytics. Another category is related to services, while IoT must be able to provide process improvement of service for its users through the use of innovative applications, data visualization, decision making and so on. Technically, there are six layers of IoT technology (Farooq et al. 2015), the fifth layer is in the form of applications used by users usually in the form of mobile applications, and the sixth layer is the business layer in charge of managing all applications and services provided by IoT (Farooq et al. 2015),

The sixth layer of IoT is known as the IoT platform, which is a system that makes it easier for business people or IoT developers to build or manage IoT devices (Roihan 2022; Wopata 2021). Statista (2022) reported that the number of IoT platforms in 2015 was as many as 260 and grew to 620 in 2019. The IoT platform consists of four main components/layers: application management, data management, telecommunication management and device management (Wopata 2021). The data management layer has sub-components of data analysis and artificial intelligence or machine learning.

IoT platforms have been widely developed worldwide because each business model requires the customization of an IoT platform (McClelland 2020). In general, the industrial segment of IoT platform users in the fields of Agriculture, Cities, Healthcare, Supply Chain, Retail, Buildings, Transportation / Mobility, Energy, Manufacturing / Industrial, and others (IOT Analytics 2021). These articles are examples of IoT platforms developed for agriculture (Gómez-Chabla et al. 2019; Ramachandran et al. 2022), manufacturing (Bi et al. 2014; Lu & Cecil 2016), and supply chain (Rezaei & Faghihi-Nezhad 2022).

2.2 Supply Chain Analytic in Digital Supply Chain

Hassan, (2019) states that business analytics is a terminology that stands alone or is different from the terminology of data science and big-data analytics. Business analytics was born from three scientific discourses: business intelligence and data warehousing, computer science and artificial intelligence, and mathematics and statistics. Business analytics can be defined based on the characteristics of human activities in solving a problem by providing insights through data exploration and analysis that combines the concepts of artificial intelligence and information systems on an application device to achieve an output desired by users (Hassan 2019). Some other definitions and characteristics of business analytics can be seen in the reference (Davenport & Harris 2017; Lepenioti et al. 2020).

Business analytics differs from business intelligence (BI) when reviewed at the scope of tasks and the insights generated. Business analytic tasks include descriptive, predictive, and prescriptive analytics, while business intelligence does not include prescriptive (Lepenioti et al. 2020; Tableu 2022). Descriptive analytics is used to answer what has been and is happening, predictive analytics answers what will happen and why, while prescriptive analytics answers what should be done and why (Erl et al. 2016; Lepenioti et al. 2020). Value-added increases in these phases known as hindsight, insight, and foresight, as the complexity of the methods used to produce outputs increases (Erl et al. 2016). By its definition, business analytics requires an "application device" commonly referred to as a business analytics platform. The business analytic development methodology follows the data analytics methodology, as do the techniques or methods used for analysis (Erl et al. 2016; Hassan 2019).

A digital supply chain (DSC) is an intelligent technology system capable of managing big data and coordinating digital hardware, software and network devices to support and synchronize interactions between organizations by making services more valuable, accessible and affordable with consistent, agile and effective outputs (Büyüközkan & Göçer 2018). Another definition, according to Ageron et al., (2020), is the development of information systems and the adoption of innovative technologies that strengthen the integration and agility of the supply chain to improve customer service and the sustainability of organizational performance.

Büyüközkan & Göçer (2018) stated that the performance to be achieved in DSC is speed, flexibility, global connectivity, real-time inventory, intelligence, transparency, scalability, innovation, proactive, and eco-friendly. DSC has three pillars: digitalization, technology implementation, and effective supply chain management. To achieve effective supply chain management, it is necessary to carry out supply chain integration, automatization, reconfiguration, and supply chain analytics (SCA) in the supply chain process (plan, source, make, deliver, and return). SCA has three sub-objectives: real-time decision execution to provide a competitive advantage, process optimization to deliver effective results and efficiency, and advanced predictive capabilities that make processes more accurate, reliable, and efficient.

The term SCA which is in line with the concepts of business intelligence (BI) and business analytics (BA) began to appear in 2008 (Sahay & Ranjan 2008). The SCA will extract and generate meaningful information for decisionmakers in the company from the amounts of data generated and captured by supply chain systems. So, in this research, we used SCA instead of BA.

3. Methodology

The first goal of this article is to explore the business process of an electric motorcycle manufacturer in Indonesia that implements a battery swapping system in BSS. The interaction between IoT subsystems of electric motorcycles generates data, so exploration is aimed at seeing the data and/or information formed. The investigation is carried out on mobile applications, vehicle dashboards, manual documents on battery use, vehicles and battery swapping processes in BSS, and some additional information from electric motorcycle manufacturers as the BSS operators.

The second goal of this article is to provide insights from the data to the company using a descriptive-analytical approach. Descriptive analytics is one of the capabilities that SCA must have (Chae & Olson 2013) and its purpose is to answer what phenomena happened, and are often presented through ad-hoc reporting (Erl et al. 2016; Lepenioti et al. 2020). Questions that usually will be answered by descriptive analytics include:

- What was the … over the past x period?
- What is the number of … as categorized by …?
- What is the daily/monthly/yearly … earned/gained by each …. ?

The data processed is limited to the data provided by the manufacturer in the form of: (1) battery-swapping transactions in the initial phase of cooperation between electric motorcycle manufacturers and delivery service companies (business to business, B2B) for all BSS locations in Jakarta, and (2) battery swapping transaction at a BSS location, which is taken seven months later. The expected outcome of descriptive analytics through data visualization is to provide initial insights for the company and can raise several questions related to battery supply chain operations that need to be reviewed more deeply by the company. The user of the analytical results in this study is the head of BSS operations and the business development director. The data analytics device used is Tableau (Milligan 2022), which is used in the visualization process.

4. Discussion

4.1 Business Process EMSB and Data Stream

The electric motorcycle manufacturing entity is also a producer of the BSS, SB, and developer of EMAp. The manufacturer is also an entity that carries out the installation, operation and monitoring of BSS operations. In early 2022, the manufacturer started the cooperation phase of selling electric motors with one of the logistics companies for delivery services to increase the penetration of electric motor sales. The manufacturer sells vehicles to the logistics company for use by couriers. This scheme forms a business-to-business (B2B) model of electric motor sales. The manufacturer also sells electric motorcycles to general consumers (Business to Consumer, B2C). The B2B cooperation obliges the manufacturer to install BSS at locations where the logistics company operates. The BSS can be used for logistic currier and general consumers.

Three main events on the use of electric motorcycles are supported by a battery swapping system on BSS, all three of which are presented in Figure 1. The first event is battery use in electric motorcycle (event A). This event generates data and/or information that consumers can observe directly on the motorcycle dashboard (DH) and through the mobile application (EMAp). We do not only differentiate in observing raw data, but also the information displayed on the IOT components, and we simplify with the term "stream data". The data stream displayed on the mobile application can be obtained because each battery pack has a battery management system (BMS) component, which is the center of controlling the battery charging-discharging process, a communication device with a motorcycle component and a component that sends data periodically to the company's cloud database. The BMS has a smart card and a global positioning system (GPS) component so that EMAp can monitor the coordinates of the motorcycle's location. Information obtained by consumers through the motorcycle dashboard includes the number of batteries used in the vehicle, the total power available on the battery, and the estimated remaining distance. Information obtained by consumers on the EMAp includes the nearest BSS location with battery availability, balance to pay for the battery swapping process, information on the total power available on the motor battery used, and information about the electric motorcycle (engine number, police number, and the owner's name). The electric motorcycle owner can register more than one vehicle and battery on the mobile application device. Stream data based on event A presented in Table 1

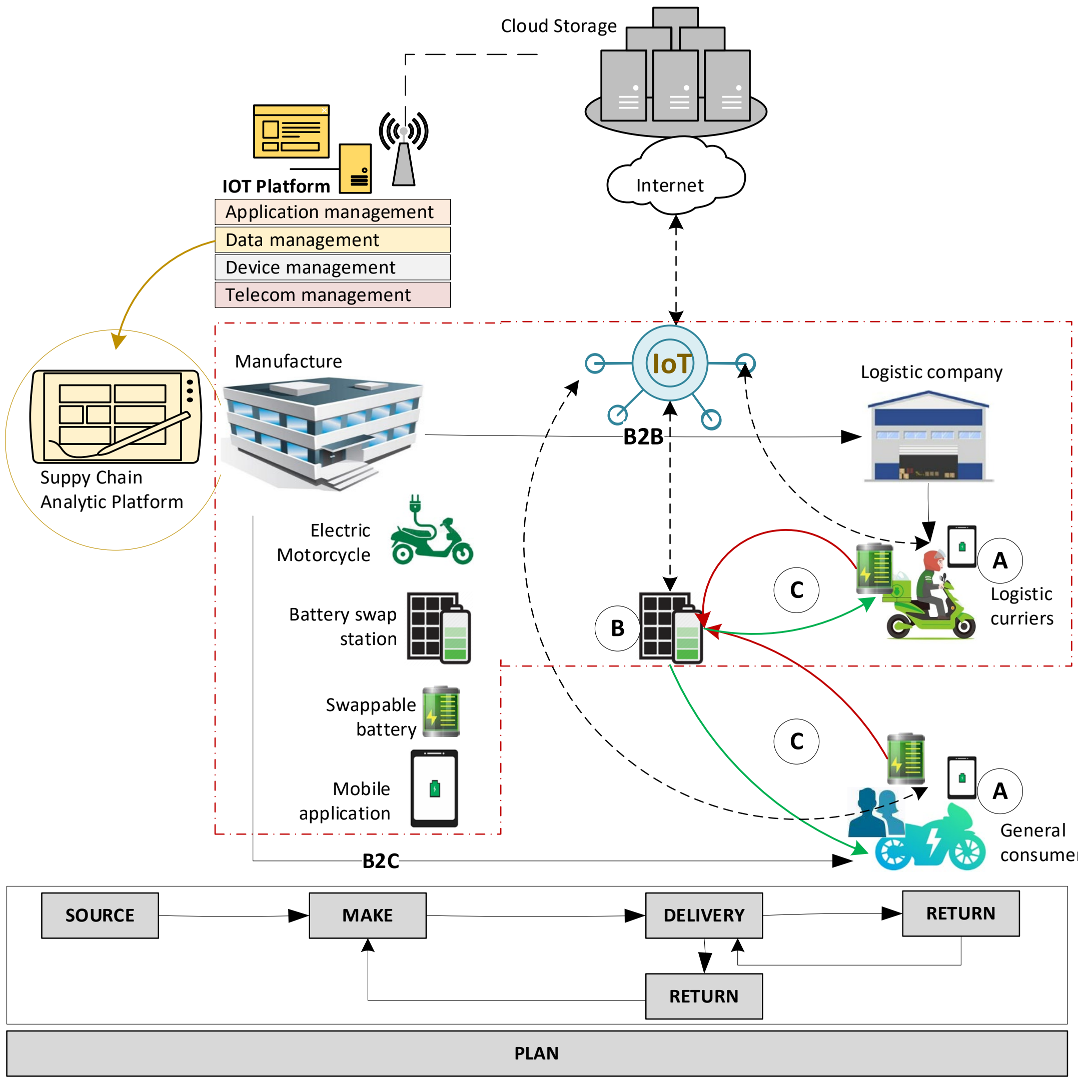


Figure 1. The business process of electric motorcycles with swap battery

The second event is the BSS operation (Figure 2). This event operates independently with the presence or absence of the battery replacement process by consumers. The BSS performs the battery charging process and monitors the battery's condition. The BSS installed at each location has eight boxes (compartments) or 12 boxes for the charging process. There is at least one empty box. This empty box is used later to insert the battery which consumers will exchange for the charging process. The BSS can send data via the internet because it has a smart card. Based on the BSS installation guide, it is necessary to set the selection of internet provider access points for interconnection with internet services. The data streams obtained from the activities performed by BSS are generally presented in Table 2, but these data streams do not yet describe all the raw data sent by BSS to the data cloud.

Table 1. Stream Data from BMS while a battery is active in a motorcycle

No	Data Stream	Description	Displayed on
1.	Battery identity	ID for each battery. Usually, a unique number which places in BMS.	-
2.	Smart card number	Electronic or smart card number placed in BMS	-
3.	Timestamps	Timestamps when the BMS sends raw data.	

4.	State of charge	State of charge (SOC) is the level of charge of an electric battery relative to its capacity. The units of SoC are percentage points (0% = empty; 100% = full)	DH, EMApp
5.	State of health	A figure of merit of the condition of a battery (or a cell, or a battery pack), compared to its ideal conditions. The units of State of health (SOH) are percent points (100% = the battery's conditions match the battery's specifications). The BMS may use different parameters of SOH [wiki source]. The Parameter of SOH: voltage, temperature, battery age, etc.	-
6.	Battery longitude, latitude	Coordinate the location of the battery/motorcycle.	EMApp
7.	Number of battery	A number of active batteries in the motorcycle.	DH, EMApp
8.	Remaining distance	The remaining distance that can be traveled (km)	DH, MApp
9.	Motorcycle machine code	Machine number of electric motorcycle registered by a user	MApp
10.	Police number of motorcycle	Police number of electric motorcycle registered by a user	MApp
11.	Balance	Balance for battery swapping	MApp

Table 2. Stream data from BSS operation

No	Data stream	Description
1.	BSS Identity	ID of BSS
2.	BSS location	Longitude, Latitude
3.	BSS name	The name of the BSS location
4.	Compartment code	ID for each compartment
5.	Smart card number	Electronic or smart card number placed in BMS
6.	Compartment status	e.g., active, error, etc.
7.	Battery identity	ID Battery in each compartment
8.	State of charge	SOC of a battery
9.	State of health	SOH of e battery
10.	Timestamps	Timestamps when the BMS sends raw data.

The third event is battery swapping (Figure 3). This event started with consumers scanning BSS's QR Code using a mobile application. If the consumer has enough balance, an empty compartment will open and the consumer can insert their empty battery, install plugins for charging and close the case. Next a box containing a fully-charged battery opens; the consumer disconnects the electrical plugin and takes the battery. A replacement battery can then be installed on the vehicle. The process of swapping this battery is claimed to only take no more than five minutes. However, the condition of the consumer's internet connection at the BSS location can affect the speed of the exchange process. The stream data from the event C, is in Table 3. The data stream does not represent all raw data sent by BSS smart cards; for example in Table 3, the manufacturer does not inform about attributes of power (electric) used in a BSS.

Table 3. Data from the battery swapping at a BSS

No	Data	Description
1.	Battery identity	Battery ID (in and out).
2.	Timestamps	Timestamps when the swapping process occurred.
3.	Customer name	Customer name
4.	Customer type	Category of the customer, e.g., logistic currier or general consumer
5.	Motorcycle machine number	Customer name
6.	Police number of motorcycle	
7.	BSS Identity	
8.	BSS location	longitude, latitude
9.	BSS name	BSS name
10.	Compartment code	Compartment code for battery in and out.
11.	Compartment status	e.g., active, error, etc.
12.	State of charge	SOC of battery (in and out)
13.	State of Health	SOH of battery (in and out)
14.	Payment info	Payment info

4.2 Descriptive analytic for BSS operation

Descriptive analytics for the 1st data.

The first data is battery swapping transactions at 82 of the BSS points installed in the office locations of freight forwarding service companies. Transaction data for 15 days from January 31, 2022 to February 14, 2022. This data is categorized as the initial phase of the electric motorcycle manufacturer partnering B2B with the delivery service companies. Data attributes are transaction-date, customer-name, customer-type, machine-number (electric motorcycle ID), police-number, BSS-name, sum-of-swap (sum of battery swapping for a courier at a date), and latitude-longitude (coordinate of BSS). This first data contains 2.431 rows. The data provided by the manufacturer is not entirely raw data, but data that has been processed (summation, aggregation); for example the attribute of the sum-of-swap is the sum of the swapping process carried out by a courier on a specific date.

For 15 days of battery swapping from 82 BSS locations, there were 3.808 swap transactions. The number of batteries swapping per day was 159 times on January 31, 2022, and continued to increase until 323 times on February 14, 2022, Figure 3. The number of electric motorcycles started at 99 and increased to 161. The decline in swapping transactions occurred only on February 12. Trends and data patterns show a correlation between the number of swaps and the number of vehicles making transactions. The number of vehicles that make transactions over time increases because this period is the time when the logistics company began the adoption of the use of electric motorcycles for their curriers. At the bottom of Figure 2, it is known that the average number of batteries swapping per day per motorcycle is between 1 and 2 times for all BSS locations. Based on this insight, a deeper study that needs to be carried out by the motorcycle manufacturer, as well as BSS operators is whether the number of swapping per-day of swapping has met the expected ideal target? (Q1).

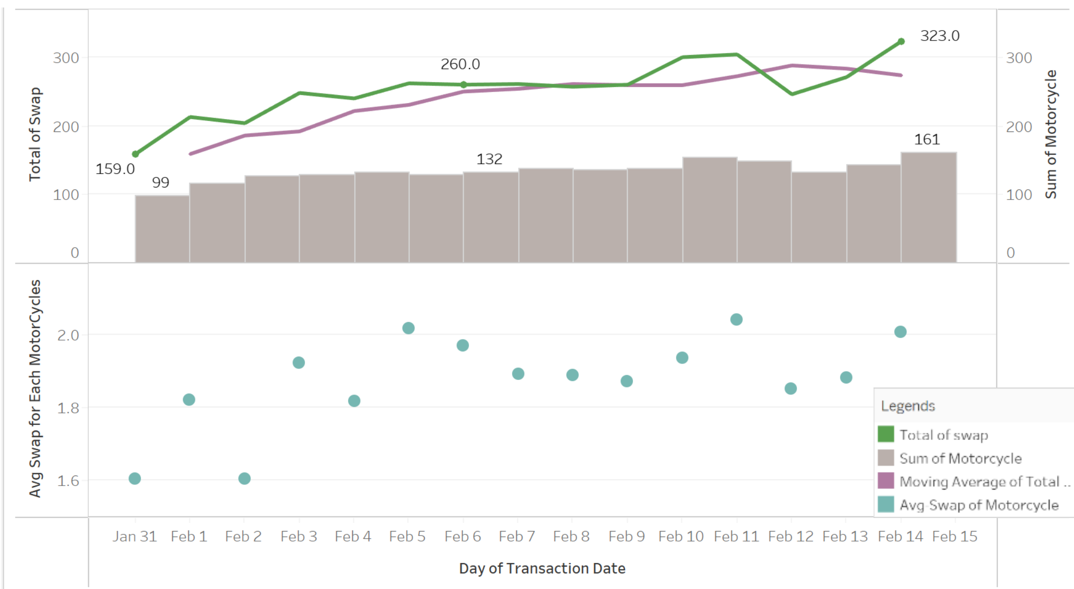


Figure 2. Total and average of swap battery per day

The number of battery swapping grouped by location, minimum one time and maximum 244 times, Figure 3. The place where many swapping occurs is SCTJT. Of the 82 BSS locations, 80% of battery swapping occurred in 32 sites (40% of the total locations). If you visually look at the location map, this location is in the Tangerang or West Jakarta areas, Figure 4. Both visualizations give attention to the company in the form of the following: What factors significantly affect the number of swaps at a BSS location? (Q2). There are adjacent locations but the number of exchanges between the two is very different, so is it necessary to relocate BSS? (Q3),

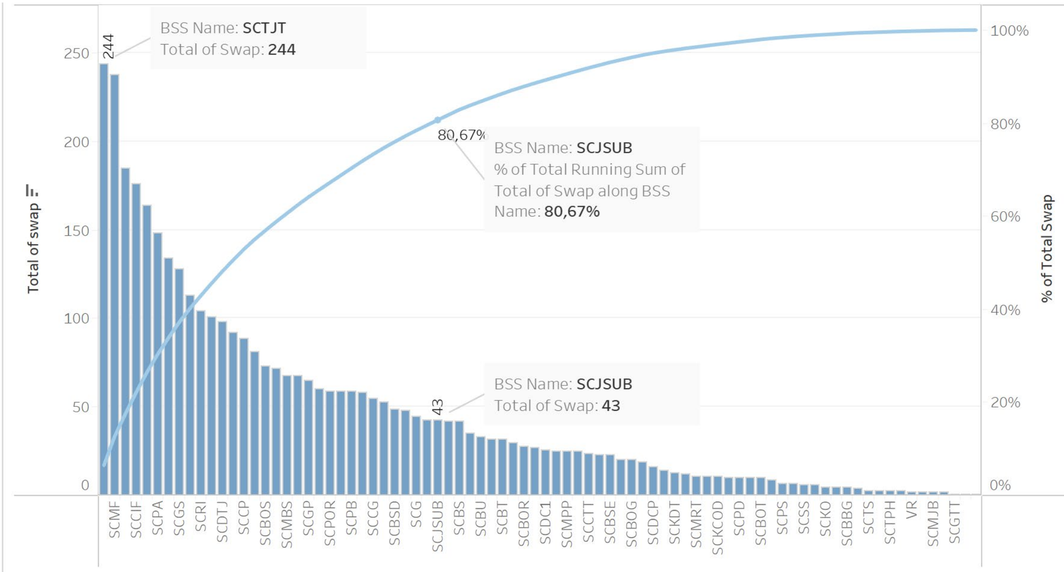


Figure 3. Pareto of the swap transactions categorized by location

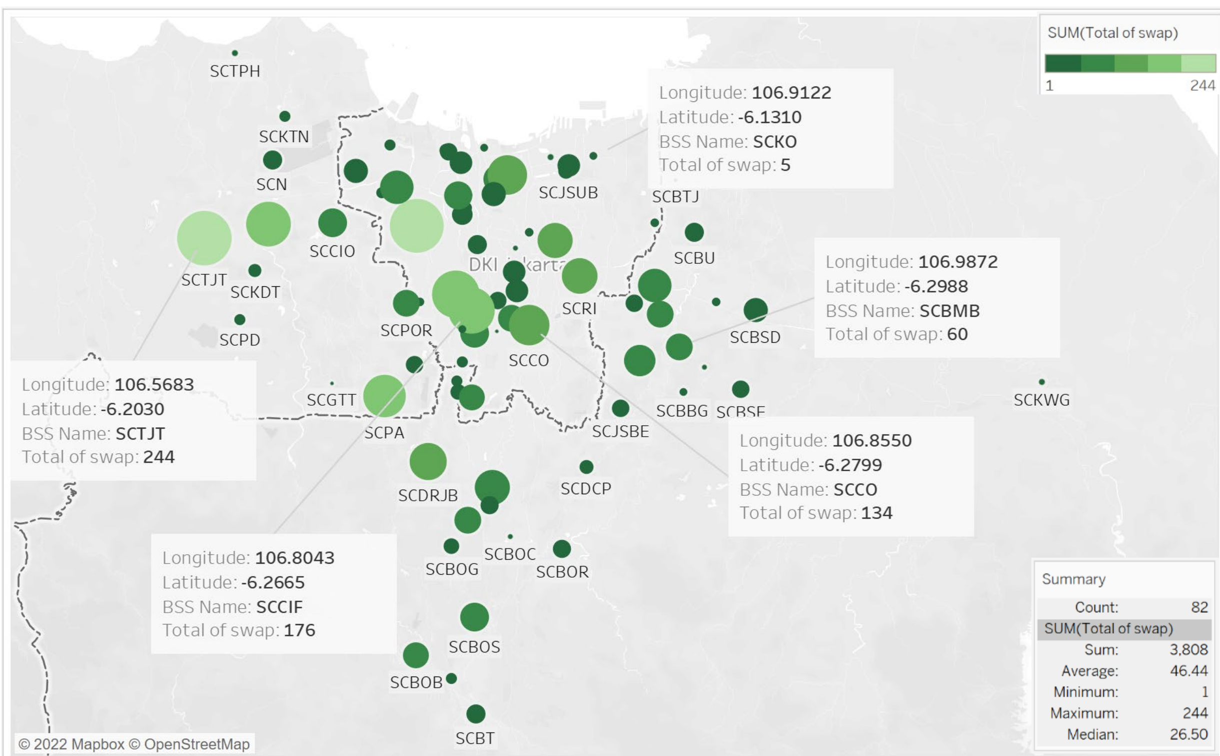


Figure 4. The number of Battery swapping based on the locations

At the top of Figure 5 is the number of batteries swapping at each location over 15 days sorted from largest to smallest. It can be seen that the location of SCTJT occupies the first position most battery exchanges occur. The below of Figure 5, illustrates the number of vehicles making swaps at each location and the average number of swaps per location. At the SCTJT location, 15 motorcycles have made battery-swapping transactions, so the average swapping is 16.27 times per vehicle per location in 15 days (244 batteries / 15 vehicles). In addition, insights were obtained that there is a correlation between the number of vehicles and the number of swaps. However, there are locations with a minimal number of motorcycles, but the number of swaps at these locations is quite large, for example at the SJBSUB location, there are only two vehicles making transactions, but the number of transactions is quite large, 43 times, so the average exchange is 21.5 times. On the other hand, there are also locations where the number of vehicles that exchange is large, but on average the swapping transaction is not large, namely at the SCKWC location with 22 vehicles and the number of battery swapping transactions 164 times, so that the average is 16.27 times. This insight leaves the question for companies whether there are other factors that companies can observe that affect the number of battery transactions? (Q4)

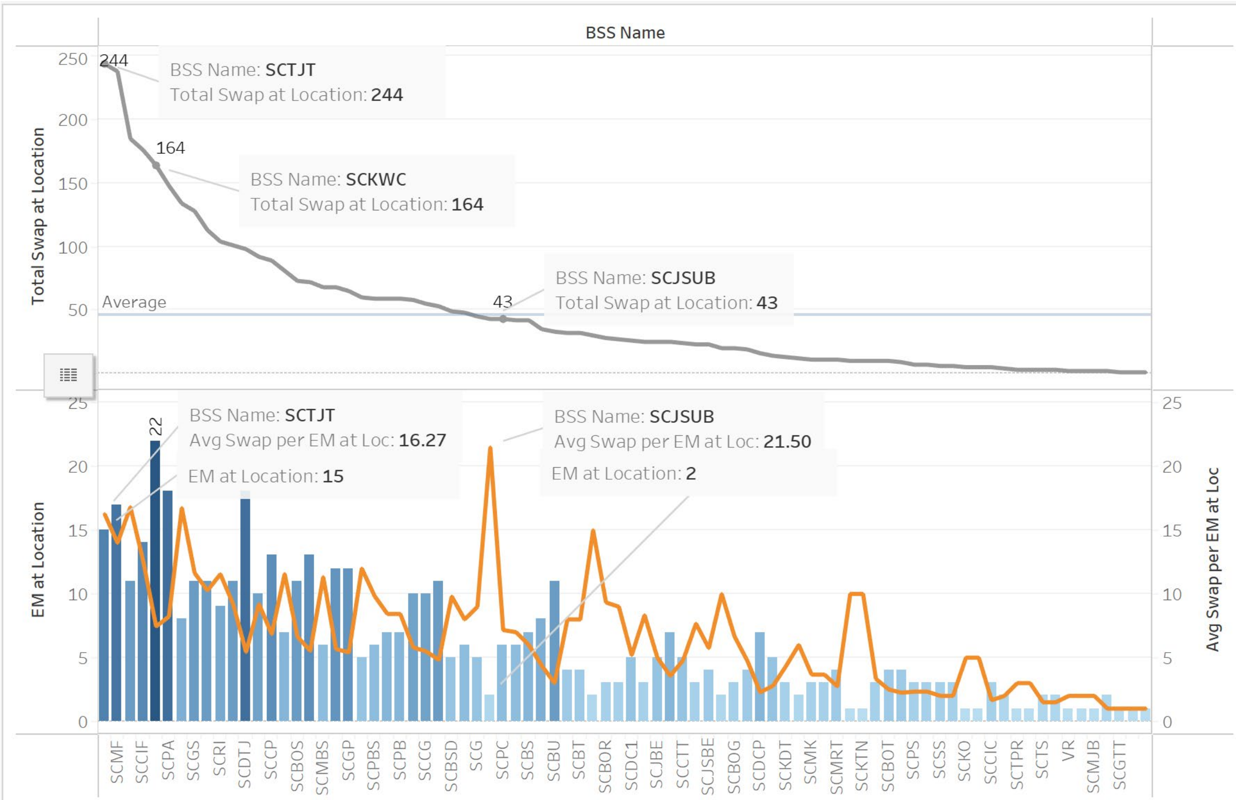


Figure 5. The number of Battery swapping categorized by the locations and EM

For more analysis, there are three BSS location clusters based on total battery exchange transactions and the number of vehicles redeeming, Figure 6. Characteristics of cluster 1 have a low number of battery-swapping transactions and a small number of vehicles; in cluster 3, the number of battery-swapping transactions is high, but the number of motorcycles is small. Cluster 2 is somewhere between clusters 1 and 3; the number of battery swapping transactions is relatively high and the number of vehicles making swapping relatively large. Cluster 1 is still very dominating, so it is necessary to pay attention to the company what is the expected number of swaps per motorcycle and per location? and what policies can be made to balance transactions at each location? (Q5)

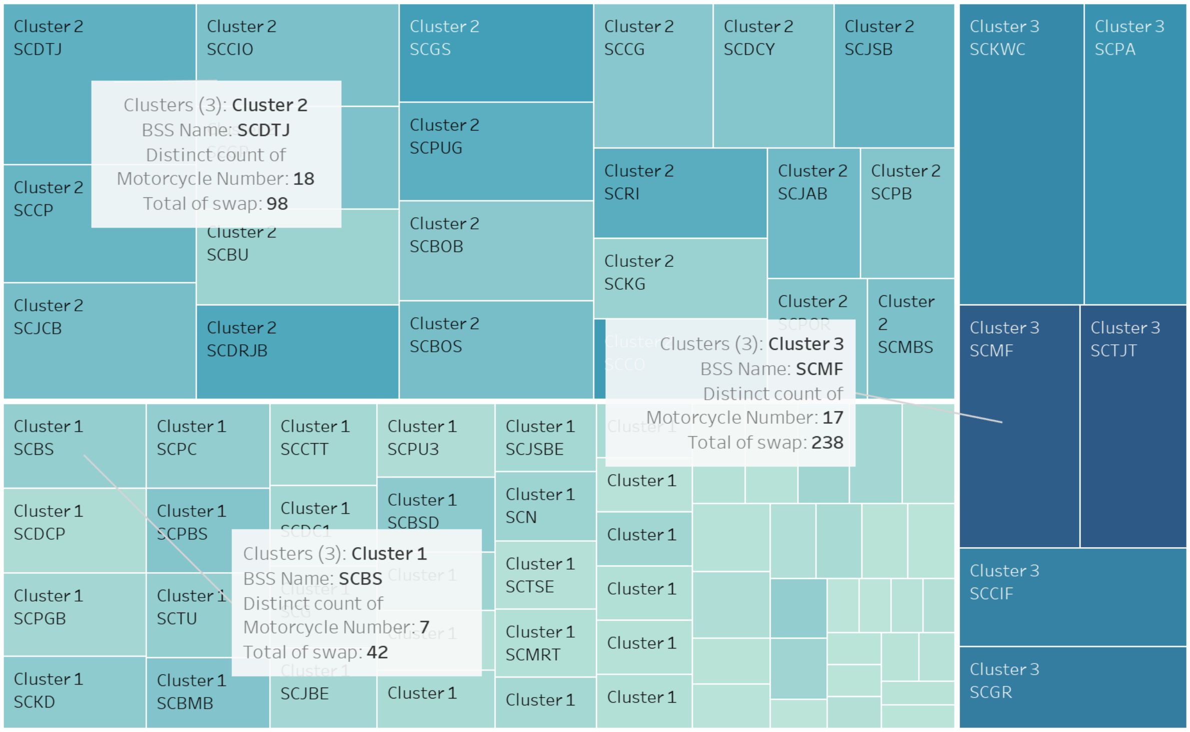
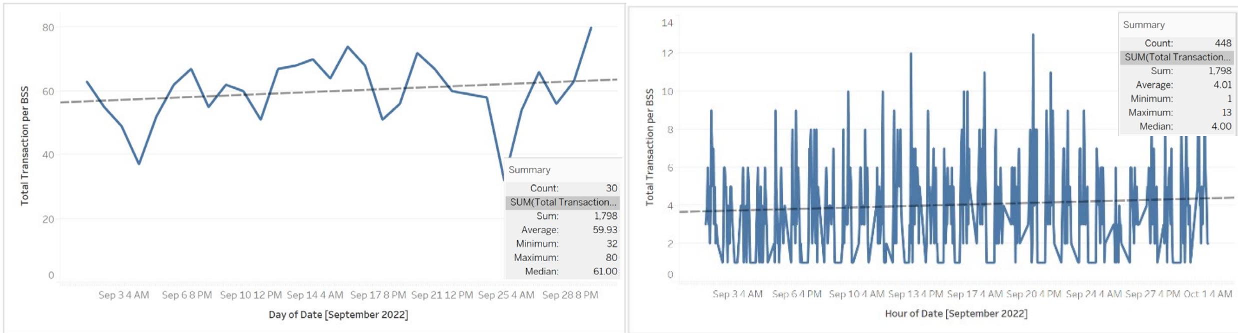


Figure 6. BSS clusters based on the number of EM and the swap transaction

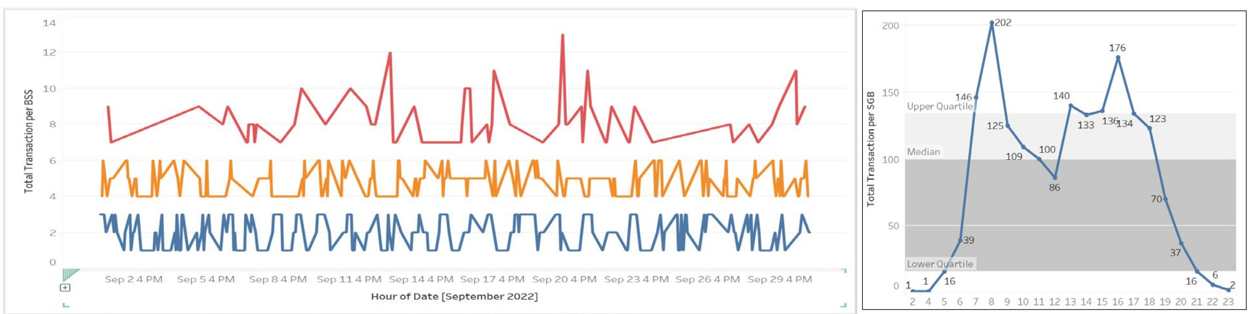
Descriptive analytics for the 2nd data.
The second data is battery swapping transactions from September 1 to September 30, 2022 at one BSS location. The attributes given are date (in timestamp), customer-name, chassis-number, motorcycle-number, and total-transaction (each row has one total-transaction value). The total number of rows is 1.798. Slightly different from the first data, the second data has a date attribute as a timestamp when a consumer carries out the battery swapping. Unfortunately, the location in the second data is a BSS location that has not been installed in the first data, so it cannot be compared vis-à-vis the previous data.

From 1 to 30 September 2022 at a BSS location, the swapping pattern follows the working day cycle; low swapping occurs on holidays, 4th, 11th, 18th, and, 25th September 2022, Figure 7 (a). The number of battery swapping per day is between 32 to 80 batteries, and an average of 60 batteries. The average per day at this location is already greater than the average number of exchanges from all locations in the February 2022 period of 46 batteries. The exchange trend for 30 days tends to increase, albeit very small. Battery exchange can be done within 24 hours, and the number of battery exchanges per hour is between 1 to 13 batteries, an average of 4 batteries per hour, Figure 7 (b). Assuming the number of on-site compartments is 11 batteries available, is this hourly average number of swapping already considered ideal for the company? (Q6).

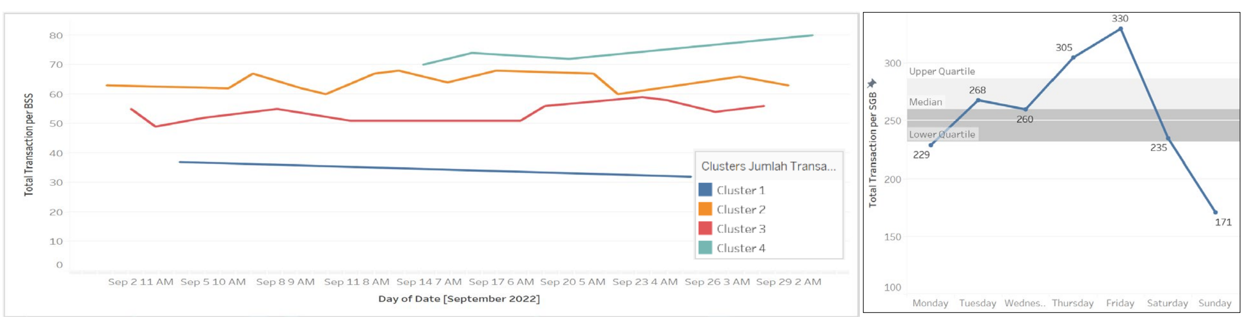


(a) (b)

Figure 7. Total transactions at a BSS location on September 2022



(a)



(b)

Figure 8. The cluster of the transaction at a BSS location on September 2022

Three groups are formed when grouping per hour (Figure 8 (a). The first group has a number of exchanges between 7 and 13 per hour. With the addition of the visualization on the right in Figure 8 (a), it can be seen that peak time occurs at 7 to 10 am, and 1 pm to 6 pm. If the group is carried out per day, four groups are formed, where the 4th group describes the couriers with many swapping transactions occurring from the middle to the end of the month, Figure 8 (b). Supported by the visualization on the right, the number of battery exchanges made by the couriers is mostly done on Thursdays and Fridays, and the lowest on Sundays. This insight provides a follow-up question for BSS managers, can IoT observe the occurrence of conditions when all compartments are in the process of charging? and there has ever been a courier who has to wait for the filling process? (Q7)

5. Recommendations

Descriptive analytics provides insight for the company on what happened to the electric motorcycle battery swapping transaction at BSS. The number of battery transactions at BSS locations on 15 observation days at the beginning of

2022 ranges huge, between 1 and 244 swapping, and 60% of them are below average. Based on descriptive analysis of secondary data for one BSS location with observations for 1 x 24 hours x 30 days, the peak time of battery turnover occurred at 7 to 10 a.m., and 1 p.m. to 6 p.m., and on Thursday and Friday.

To sum up, there is five decision that needs to be studied more deeply by the company. The five things are (1) What is the ideal target of the per-day transaction that the company expects to be associated with the charged battery change rate? (2) How to make a more profound observation of the factors that affect the number of battery swapping besides delivery tasks by the couriers? (3) How to increase the number of swaps in BSS? Is it necessary to relocate them? (4) What is the allocation of the optimum number of compartments at each location that provides ideal occupancy? (5) Is it necessary to redistribute a fully charged battery at peak time if it is ever observed in the IoT data, when all batteries are charging and the customer has to wait?

This research on battery swapping transaction data on BSS, with a minimal number of attributes and a small amount of data, has provided insight for the electric motorcycle manufacturer or the operator of BSS. This indicates the need for further research to create a more comprehensive SCA model that can present analytical results in descriptive, predictive, and prescriptive forms to support the supply chain operations of the electric motorcycle business based on battery swapping systems.

Acknowledgements
This research was funded by the Institution of Research and Community Services, Universitas Sebelas Maret, through the program "Penelitian Unggulan Terapan (PUT-UNS)", grant number 254/UN27.22/PT.01.03/2022, March 15, 2022.

References
Ageron, B., Bentahar, O., & Gunasekaran, A., Digital supply chain: challenges and future directions, *Supply Chain Forum*, vol. *21*, no. 3 , pp.133–138. , 2020. https://doi.org/10.1080/16258312.2020.1816361

Andryanto, S. D., *Kementerian Perindustrian: Target Motor Listrik 2025 Terpenuhi 1,76 Juta Unit*, Tempo.Co. , 2022. https://otomotif.tempo.co/read/1445120/kementerian-perindustrian-target-motor-listrik-2025-terpenuhi-176-juta-unit/full&view=ok

Bi, Z., Xu, L. D., & Wang, C., Internet of things for enterprise systems of modern manufacturing, *IEEE Transactions on Industrial Informatics*, vol. *10*, no. 2 , pp.1537–1546. , 2014. https://doi.org/10.1109/TII.2014.2300338

Büyüközkan, G., & Göçer, F., Digital Supply Chain: Literature review and a proposed framework for future research, *Computers in Industry*, vol. *97*, , pp.157–177. , 2018. https://doi.org/10.1016/j.compind.2018.02.010

Cao, G., & Duan, Y., The affordances of business analytics for strategic decision-making and their impact on organisational performance, *Pacific Asia Conference on Information Systems, PACIS 2015 - Proceedings*. , 2015.

Chae, B. K., & Olson, D. L., Business analytics for supply chain: A dynamic-capabilities framework, *International Journal of Information Technology and Decision Making*, vol. *12*, no. 1 , pp.9–26. , 2013. https://doi.org/10.1142/S0219622013500016

Davenport, T. H., & Harris, J. G., Competing on analytics: the new science of winning, In *Choice Reviews Online* (Vol. 44, Issue 11). , 2017. https://doi.org/10.5860/choice.44-6322

De Nardis, L., Mohammadpour, A., Caso, G., Ali, U., & Di Benedetto, M.-G., Internet of Things Platforms for Academic Research and Development: A Critical Review, *Applied Sciences*, vol. *12*, no. 4 , pp.2172. , 2022. https://doi.org/10.3390/app12042172

Erl, T., Khattak, W., & Buhler, P., *Big Data Fundamentals: Concepts, Drivers & Techniques*, Prentice Hall. , 2016.

Farooq, M. U., Waseem, M., Mazhar, S., Khairi, A., & Kamal, T., A Review on Internet of Things (IoT), *International Journal of Computer Applications*, vol. *113*, no. 1 , pp.1–7. , 2015.

financesonline, *What Is Business Analytics? Definition, Importance & Examples*, Financesonline.Com. , 2022. https://financesonline.com/what-is-business-analytics/

Gómez-Chabla, R., Real-Avilés, K., Morán, C., Grijalva, P., & Recalde, T., IoT Applications in Agriculture: A Systematic Literature Review, *Advances in Intelligent Systems and Computing*, vol. *901*, , pp.68–76. , 2019. https://doi.org/10.1007/978-3-030-10728-4_8

Hassan, N. R., The origins of business analytics and implications for the information systems field, *Journal of Business Analytics*, vol. *2*, no. 2 , pp.118–133. , 2019. https://doi.org/10.1080/2573234X.2019.1693912

IOT Analytics, *IoT Platforms Market Report 2021–2026*. , 2021. https://iot-analytics.com/

Jun, C., Lee, J. Y., & Kim, B. H., Cloud-based big data analytics platform using algorithm templates for the manufacturing industry, *International Journal of Computer Integrated Manufacturing*, vol. *32*, no. 8 , pp.723–738. , 2019. https://doi.org/10.1080/0951192X.2019.1610578

Lepenioti, K., Bousdekis, A., Apostolou, D., & Mentzas, G., Prescriptive analytics: Literature review and research challenges, *International Journal of Information Management*, vol. *50*, no. May 2019 , pp.57–70. , 2020. https://doi.org/10.1016/j.ijinfomgt.2019.04.003

Lu, Y., & Cecil, J., An Internet of Things (IoT)-based collaborative framework for advanced manufacturing, *International Journal of Advanced Manufacturing Technology*, vol. *84*, no. 5–8 , pp.1141–1152. , 2016. https://doi.org/10.1007/s00170-015-7772-0

McClelland, C., *What is an IoT Platform?*, Www.Iotforall.Com. , 2020. https://www.iotforall.com/what-is-an-iot-platform

Milligan, J. N., *Learning Tableau 2022* (5th ed.), Pack Publishing. , 2022.

Phillips-Wren, G., & Adya, M., Decision making under stress: the role of information overload, time pressure, complexity, and uncertainty, *Journal of Decision Systems*. , 2020. https://doi.org/10.1080/12460125.2020.1768680

Ramachandran, V., Ramalakshmi, R., Kavin, B. P., & Hussain, I., Exploiting IoT and Its Enabled Technologies for Irrigation Needs in Agriculture, *Water*, pp.1–20. , 2022.

Rezaei, M., & Faghihi-Nezhad, M.-T., Real-time supply chain performance management: An IoT-based framework for continuous improvement, *2022 Second International Conference on Distributed Computing and High Performance Computing (DCHPC)*, pp.8–14. , 2022. https://doi.org/10.1109/DCHPC55044.2022.9732086

Roihan, A., *Apa itu IoT Platform dan Perlukah Anda Menggunakannya?*, Nocola.Co.Id. , 2022. https://nocola.co.id/iot-platform-adalah/

Sahay, B. S., & Ranjan, J., Real time business intelligence in supply chain analytics, *Information Management and Computer Security*, vol. *16*, no. 1 , pp.28–48. , 2008. https://doi.org/10.1108/09685220810862733

Sorri, K., Mustafee, N., & Seppänen, M., Revisiting IoT definitions: A framework towards comprehensive use, *Technological Forecasting and Social Change*, vol. *179*, no. August 2021 . , 2022. https://doi.org/10.1016/j.techfore.2022.121623

Statista, *Number of publicly known Internet of Things (IoT) platforms worldwide from 2015 to 2019*, Https://Www.Statista.Com/Statistics/1101483/Global-Number-Iot-Platform/. , 2022. https://www.statista.com/statistics/1101483/global-number-iot-platform/

Tableu, *Business Intelligence vs. Business Analytics: What's The Difference?* , 2022. https://www.tableau.com/learn/articles/business-intelligence/bi-business-analytics

Wopata, M., *5 Things to Know About the IoT Platforms Market*, IOT Analytics. , 2021. https://iot-analytics.com/5-things-to-know-about-iot-platforms-market/

Biographies

Yusuf Priyandari is currently a doctoral student in Industrial Engineering Department. Faculty of Engineering, Universitas Sebelas Maret. He is also a lecturer at the Bachelor of Industrial Engineering Study Program, Faculty of Engineering, Sebelas Maret University (UNS) since 2003. He is a researcher in the Industrial Engineering and Techno-Economics (RITE) research group. He was a Head of the Industrial System Planning and Optimization Laboratory (2009-2019) and Head of the Information, Communication and Technology Center (ICT) at the Faculty of Engineering UNS (2013-2015). His research areas of interest are information systems analysis and design, decision support systems, enterprise information systems, and data analytics. His email address is priyandari@ft.uns.ac.id

Wahyudi Sutopo is a professor in industrial engineering and Head of Industrial Engineering and Techno-Economics Research Group, Department of Industrial Engineering, Faculty of Engineering, Universitas Sebelas Maret (UNS), Indonesia. His educational background is a doctor in industrial engineering & management from Bandung Institute of Technology (ITB) in 2011. He is the president of the industrial engineering and operations management (IEOM) society for Indonesia's professional chapter. His research areas of interest are in the areas of logistics & supply chain management, engineering economy & cost analysis, and technology commercialization. He has published articles over 180 documents indexed by scopus with H-index 11. His email address is wahyudisutopo@staff.uns.ac.id.

Fakhrina Fahma is a lecturer at the Bachelor of Industrial Engineering Study Program at Sebelas Maret University (UNS). She has been a Head of Quality Systems Laboratory since 2017. She is also active as a researcher in the Industrial Engineering and Techno-Economics (RITE) research group. She was a General Treasurer of the Central

Board of the National Standardization Education Forum (2018-2021). Her research area are standardization, statistic and quality control, and system quality.

Muhammad Nizam is a professor at the Department of Electrical Engineering, Sebelas Maret University, Indonesia. He received his Bachelor's and Master's degrees from Gadjah Mada University, Indonesia, and his Ph.D. from the National University of Malaysia (UKM). Currently, Professor Nizam is in charge of national research projects and multinational companies related to electric vehicles, batteries, and renewable energy in Indonesia. His research interests are Power Systems, Power Quality, Energy Management, Energy Storage Systems, Electric Vehicles, and Battery Management Systems. One of his research interests is energy storage systems and their applications. He has published more than 100 publications in indexed international journals and seminars. Currently, he has been appointed as an advisor and consultant for several start-ups in the fields of battery technology, electric vehicles, and renewable energy. He is a professional engineer and member of IEEE, PES, and PII..

Hendro Wicaksono is a professor of Industrial Engineering and Head of Reserch Group INDEED (Intelligent Data Management in Industry 4.0), Jacobs University Bremen (2018 – now). His educational background is a doctor-engineering in Mechanical Engineering, Karlsruher Institut fur Technologie, German (2016). He also was visiting professor/lecturer in TU Sofia (Bulgaria), MPEI Moscow (Russia), UNAIR, ITS, UNUSA, UIN Yogyakarta, UIN Malang, UM Malang, Unisma Malang and UNDIP. His research areas of interest are industry 4.0 maturity, sustainable assessment, supply chain, machine learning, semantic data management, and explainable artificial intelligent. His email address is h.wicaksono@jacobs-university.de.