Preventive Maintenance on Main Components of *PT KA Indonesia* Transportation Equipment

Tri Pujadi†
School of Information Systems
Bina Nusantara University
Jakarta, Indonesia
tripujadi@binus.edu

Bahtiar H. Simamora
Department of Management - Binus Business School
Bina Nusantara University Jakarta, Indonesia
bsimamaora@binus.edu

Vikas Kumar
Bristol Business School
University of the West of England
Bristol, BS16 1QY, UK
vikas_kumar@uwe.ac.uk

Harkat C Zamasi, Hendy Wijaya, Ernawaty, Lius Steven
School of Information Systems
Bina Nusantara University
Jakarta, Indonesia
harkat@binus.edu, hendy_wijaya@binusian.org, erna@binus.ac.id, lius.sanjaya001@binus.ac.id

Abstract

PT KAI is a company that provides mass transportation services, which must carry out maintenance to maintain the performance of its fleet. The company has implemented a preventive maintenance pattern, but it is not optimal and is still reactive. This study discusses the analysis of the application of these patterns on the Electric Rail Train and designing the information system. The research uses quantitative methods by performing calculations using historical damage data, damage intervals, and data on repairs or maintenance carried out in the January-December period 2020 and the business processes that occur during maintenance. From these data, calculations were made to find KRL and critical components, the value of availability, reliability, and downtime of each component. The analysis is carried out using the data from the calculation and then analyzing each critical component from a technical point of view. The result of the discussion is that Preventive Maintenance can increase the availability and reliability of the 8000 Series KRL components, namely carbon brush, brake pad shoe and SIV, but there is also an increase in downtime.

Keywords:
Preventive, maintenance, quantitative method, critical component

1. Introduction

The history of the railways in Indonesia began built during the government of the Governor-General of the Dutch East Indies, Mr LAJ Baron Slot van de Beele dated June 17, 1864. Construction of the state railway line through Staatssporwegen (SS), covering the route Surabaya-Pasuruan-Malang. This success has encouraged private investors to build the Semarang Joana Stoomtram Maatschappij (SJS), Cheribon, Pasoeroean, Kediri, Probolinggo, Modjokerto, Malang, and Deli railways. Until the end of 1928, the length of railroads in Indonesia reached 7,464 km, with government-owned rails being 4,089 km and private railways being 3,375 km.

After Indonesia proclaimed its independence on August 17, 1945, a few days later, the train station and headquarters in Bandung were taken over on September 28, 1945 (now commemorated as Indonesian Railways Day). It also marks the establishment of the Indonesian Railways Bureau of the Republic of Indonesia (DKARI). The government changed the structure of PNKA into a Railway Company (PJKA) in 1971. Perumka changed to PT. Kereta Api Indonesia (KAI) in 1998. Currently, PT KAI has seven subsidiaries, namely KAI Services (2003), KAI Airport (2006), KAI Commuter (2008), KAI Wisata (2009), KAI Logistics (2009), KAI Properti (2009), PT Pilar Sinergi BUMN Indonesia (2015).

KAI Commuter also known as Electric Rail Train (KRL) operates in Jakarta, Bogor, Depok, Tangerang, and Bekasi (Jabodetabek) areas. As a company in the field of mass transportation, PT KAI positions safety as a top priority. The company guarantees safety in its services by carrying out maintenance and checking of train facilities such as passenger trains, freight cars, and locomotives.

Facility officers are divided into two parts, namely train facilities officers and locomotive facilities officers. Routine work for train facilities officers is to inspect the underframe, bogies (frames that form a set of wheels with axles), push-pull devices (train couplings, carriages, or locomotives), braking devices, and safety equipment on trains or carriages.

The locomotive facility officers are devoted to maintaining locomotive components and ensuring that they function correctly. All parts such as wind, diesel, electrical and mechanical systems must be checked and repaired regularly. The maintenance and repair activities are carried out at the locomotive depot. After the officers check the trains, carriages and locomotives, the following process is an overall inspection until they are declared ready for operation (SO). Inspections are also carried out at stations where the train stops. The drive-through check, or the showing process, is a re-check to ensure that the train facilities are still up to standard. The components that were checked were braking equipment, coupling equipment, safety equipment, and electrical systems. Therefore, various requirements must be possessed by the facility officer before being placed in a depot or Yasa Centre".

In today's modern industrial world, the maintenance of transportation equipment has become a concern for companies. The strategy to carry out maintenance can result in savings in operational costs and increase the availability of the system or equipment used (Purnama, 2019). In the service industry, especially transportation service providers, the transportation equipment owned is the primary business tool in running a business and the business processes carried out. These tools are the primary source of income for the company, and the company must carry out routine maintenance for the tools they have. Nevertheless, sometimes maintenance can take a long time, so that it increases downtime (Duarte et all., 2006). If this happens, the company may lose business opportunities and suffer losses due to lost revenue.

Many companies are not aware of this. Planning for the maintenance of business tools can be one of the determining factors for the development or failure of a company's business. Maintenance often does not receive special attention from companies. Equipment maintenance is only carried out when damaged or planned before maintenance is carried out. It can cause losses for the company without realizing it and maintenance costs that will be higher.

The maintenance model applied by PT KAI, especially for KRL maintenance, is distance-**based** or time-based. Maintenance based on KRL mileage is only carried out for two years of maintenance (Qian and Dong, 2017). Meanwhile, maintenance based on the KRL maintenance time interval is divided into several daily, weekly, monthly, quarterly, semester and yearly. This method of treatment is included in preventive maintenance or carrying out maintenance that aims to prevent damage. However, its implementation is still general and has not identified KRL and which components have the highest level of damage (Sasitharan and Lazim, 2018). In addition, the replacement of components is still reactive or carried out only when the damage occurs.

The current KRL maintenance facility still adheres to a manual reporting system, where each file is stored locally and is not connected. It causes difficulties in reporting if historical data of a train is needed for evaluation and analysis purposes. When using an information system, it is hoped that this problem can be overcome and simplify documentation, grouping, and reporting (Singh and Kumar, 2015).

This study will discuss the optimal maintenance interval of KRL. Moreover, how an information system can make it easier to help documentation work to report historical data used to perform an analysis. The problem faced by PT. KAI is that planning is only based on specific units or references such as time-based or distance-based, which is not necessarily the best time to carry out maintenance because the two references do not consider other factors that also affect the work of KRL. The formulation of the problem obtained from the current condition of the company is:

1. Which KRL has the highest breakdown frequency and downtime? What components are classified as critical components of the KRL?

2. How does preventive maintenance affect the availability and reliability of KRL?
3. How do information systems support preventive maintenance?

2. Lirature Review

Preventive Maintenance

Planning is something that is often done for various purposes. There is no exception to maintenance, sound planning is the core and the advantage of preventive maintenance compared to other scheduling plans. Some conditions that allow using preventive maintenance are as follows (Hinggins, Mobley, & Smith, 2002, p.1.39):

a. Corrective maintenance cannot be justified.
b. Predictive maintenance cannot be applied.
c. The side effects of this type of maintenance repair are unacceptable.

Preventive Maintenance Scheduling

The measurement of active maintenance time includes time to study the damage that has occurred and data on the damage that has occurred to calculate the correct maintenance time and duration. Preventive maintenance performs simple preventive maintenance actions such as lubrication, cleaning or checking for existing problems. This treatment time can be measured by using the time when performing maintenance activities within a specific frequency (Jha, 2016). PM has scheduled downtime, usually periodically, consisting of several sets of activities, such as inspection and repair, replacement, cleaning, oiling, and alignment.

Prioritizing the order of maintenance is a crucial task in a production system, especially when the need for maintenance is higher than the technicians and resources needed to do it. Work sequences that are carried out randomly or specifically can waste the existing workforce and the resources used and increase the downtime that occurs to result in losses (Stritto and Schiraldi, 2013).

Maintenance schedules must be done based on the appropriate interval with the object of care. These interval units include (Basri et all., 2017) :

a. Land vehicles and trains: distance covered
b. Airplanes: flight hours, number of flights and landings.
c. Electronic devices: working hours, number of on and off.
d. Fixed system (radar, rail line, many more.): number of days.

Identification of Data Distribution

Data identification was carried out using the Least Square Curve Fitting (LSCF) method, which is a way to find the index of fit value from the existing TTR and TTF data. The distributions used in this method are Weibull, exponential, normal and lognormal. However, in this discussion, only two distributions are used, namely Weibull and lognormal. Here is how to find the value of r to choose the distribution to use. The highest r-value is the chosen distribution (Angius et all., 2016).

$$r=\frac{n\sum_{i=1}^{n} x_i.yi - (\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} y_i)}{\sqrt{[n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2][n\sum_{i=1}^{n} y_i^2 - (\sum_{i=1}^{n} y_i)^2]}}$$

$$F(t)=\frac{i-0,3}{n+0,4}$$

F(t) = cumulative distribution value
n = amount of damage data
i = 1,2, 3..., n
yi or zi = yi is used for Weibull and exponential distributions while zi is used for normal and lognormal distributions

The difference between these two distributions is in the way xi and yi/zi are calculated. The following is a calculation method to find these two variables for each distribution.

a. Weibull

$$x_i = \ln(t_i) \qquad y_i = \ln\left(\ln\left(\frac{1}{1 - F(t_i)}\right)\right)$$

y = value of the Weibull distribution table

b. Lognormal

$$x_i = \ln(t_i) \qquad z_i = \Phi^{-1}\left[f(t_i)\right]$$

$\mathbf{z_i}$ = value from the lognormal distribution table

Parameter Determination

After selecting the distribution using the index of fit, the next step is to calculate the parameters. This parameter is used to calculate the Mean Time to Failure and Mean Time to Repair values. Each distribution has different parameters.

a. Weibull (Ebeling, 1997, p. 368)

$$\beta = b$$
$$\theta = e^{-a/\beta}$$
$$b = \frac{n\sum_{i=1}^{n} x_i z_i - \left(\sum_{i=1}^{n} y_i\right)}{n\sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} x_i^2}$$

b. Lognormal (Ebeling, 1997, p. 371)

$$t_{med} = e^{-sa}$$
$$s = \frac{1}{b}$$
$$b = \frac{n\sum_{i=1}^{n} x_i z_i - \left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} z_i\right)}{n\sum_{i=1}^{n} x_i 2 - \left(\sum_{i=1}^{n} x_i\right)^2}$$

Calculation of Mean Time to Failure and Mean Time to Repair

Mean Time to Failure is the average value of the interval between damage from distribution of damage data, while the Mean Time to Repair is the average value of the time to repair the damage that occurs. MTTF and MTTR calculations require pre-calculated parameters (Mukhtar et all, 2009) (Hardt et all., 2021). The calculation method for each MTTF and MTTF differs depending on the parameters that match the existing data distribution

3. Methodology

The methodology in this research is descriptive analytic. Research is carried out in the unit in charge of procurement and storage. Figure 1 describes the sequence of activities in this study.

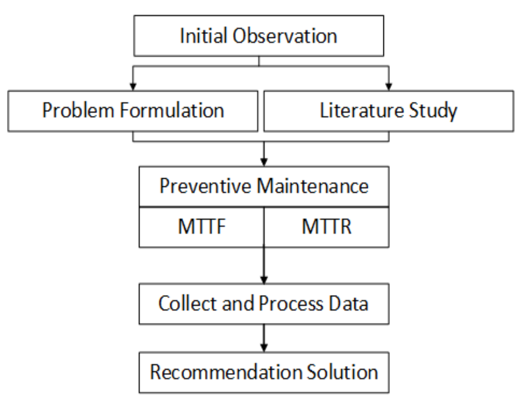

Figure 1. Methodology Research

In conducting this study, the flow chart used is as follows:
The initial observation process is carried out to find out the problems and what parts are related to the problem. After the data from the initial observations are obtained and already know the existing problems, the next step is to define the problem formulation in detail to minimize the scope discussed in this case study. The problems discussed are about maintenance intervals and the repair time on the PT KAI Electric Rail Train.

Furthermore, a literature study was conducted to find and obtain both articles and theories related to the problems discussed, namely preventive maintenance. The literature search focused on preventive maintenance and some supporting things such as searching for data distribution, mean time to failure, mean time to repair. After that, data collection that can support the process of solving this problem is carried out. Collected data such as business processes, breakdown interval data and repair duration.

After the data is collected, proceed to the data processing process. The data is processed into information that can support the complete process and can also meet the needs of the analysis carried out. Existing problems are solved by using preventive maintenance with the age replacement method. The analysis results carried out are also used in the design of information systems to facilitate the running process.

After data processing is done, system design is carried out to design a system that can help the preventive maintenance process. Finally, conclusions are made that can answer the formulation of the problem and provide suggestions for developing the company processes and case studies.

4. Result And Discusion

Parameter

Each component has different parameter values based on the type of distribution of TTF and TTR of each component. In table 1 the values of these parameters are used to calculate the MTTF and table 2 are MTTR values of each component.

Table 1 Parameters of Damage to KRL Components

Critical Component	Damage Distribution	Parameter
Carbon Brush	Lognormal	s=1,091
		tmed=2141,237
Brake Pad Shoe	Lognormal	s=1.2887
		tmed=3038,707
SIV	Lognormal	s=1.677
		tmed=2063,389

Table 2 Parameters for Repair of KRL Components

Critical Component	Repair Distribution	Parameter
Carbon Brush	Weibull	β=449,1565
		θ=1,0777
Brake Pad Shoe	Lognormal	s=0,3358
		t_{med}=1,156
SIV	Weibull	β=1,876
		θ=0,08204

MTTF and MTTR values

The MTTF value, in this case, is the average distance between the damage that occurs during the component operating. At the same time, MTTR is the average time needed to repair any damage that occurs to the component. The MTTF and MTTR values for each component are different because each component has a different distribution and parameter. The following table 3 and table 4 are the results of the MTTF and MTTR calculations for the three components.

Table 3 Data on MTTF Damage to KRL Components

Critical Component	Damage Distribution	MTTF

Carbon Brush	Lognormal	3883
Brake Pad Shoe	Lognormal	6791
SIV	Lognormal	8402

Table 4 MTTR Data for Repair of KRL Components

Critical Component	Repair Distribution	MTR
Carbon Brush	Weibull	1,08
Brake Pad Shoe	Lognormal	1,22
SIV	Weibull	0,73

The greater the MTTF value, the better the component will operate. It is because the higher the MTTF value, the less often the component will break down. By judging from the table above, the SIV component has the smallest number of breakdowns with 8402 km compared to the other two components, namely carbon brush with 3883 km and brake pad shoe with 6971 km.

Meanwhile, the smaller the MTTR value, the better. The smaller the MTTR, the smaller the total downtime that occurs. The table above shows that the SIV component has the smallest MTTR value with 0.73 hours compared to the other two components, namely carbon brush for 1.08 hours and brake pad shoe for 1.22 hours. SIV has a smaller MTTR value because the component is in an area that is relatively easy to reach when compared to the other two components.

Replacement and Inspection Interval

Preventive replacement is carried out to avoid sudden and unavoidable damage so that it interferes with the machine's work. The preventive replacement distance interval indicates the correct distance travelled to replace the component. It aims to avoid sudden damage that optimally may occur in the future.

The preventive replacement model is age replacement. The purpose of this model is to determine the optimal service life of a component. In this preventive replacement model, if there is damage before the optimal age of the component, the following replacement will still follow the optimal age of the component that has been determined. Table 5 below is the result of calculating the optimal age of each component.

Table 5 Data Interval Distance Replacement Prevention Components

Critical Component	Interval (km)
Carbon Brush	1400
Brake Pad Shoe	1750
SIV	350

Inspection is one of the activities carried out in preventive maintenance. It is done to minimize downtime that occurs because of component damage or component replacement. This inspection also aims to anticipate the occurrence of sudden damage. If symptoms of damage occur during the inspection, the components being inspected will be repaired, or if necessary, replacement components will be carried out to avoid further damage. It is hoped that with regular inspections, components can work optimally until the replacement period. Table 6 the results of the calculation of the inspection distance interval of each component can be seen below.

Table 6 Component Inspection Distance Interval Data

Critical Component	Interval (km)
Carbon Brush	8704
Brake Pad Shoe	10939
SIV	15564

***Availability* and Reliability**

Availability or level of availability is the probability that a component can work or function properly at a given time if operated under normal operating conditions. Below are the results of the availability calculation for each component. From the calculation of the availability level that has been done; several things can be identified that affect the value. Things that affect is the standard time of inspection and replacement of each component set by the company. The higher the standard replacement time applied by the company, the greater the level of availability of these components. Meanwhile, in the table 7 the smaller the inspection standard time applied by the company, the higher the availability level of the component will be.

Table 7 Component Availability Data

Critical Component	Availability when making preventive changes	Availability when checking	Availability Total
Carbon Brush	0,9998086	0,9798948	0,9797072
Brake Pad Shoe	0,9998747	0,9840023	0,9838791
SIV	0,9999387	0,9887563	0,9886958

Reliability is an opportunity for a system or, in this case, KRL components to function normally within a certain period during the period of use. The best level of reliability is 1 or 100%, so if the level of reliability is close to that number, the system or component will work optimally within a certain period.

In the table below, the level of reliability that exists in the current condition of the company is in column (R(t)), while for conditions after preventive maintenance is applied, it is in column (Rm(t)). Calculation of the level of reliability of each component is different, adjusted to a predetermined distribution. It is due to the different parameters and calculation methods of each distribution. Table 8 below is the data from the reliability calculations that have been carried out for each component.

Table 8 Component Reliability Data

Critical Component	MTTF (Km)	ti (Km)	R(t)	Rm(t)	Escalation
Carbon Brush	0,9998086	8704,21	29,27%	47,81%	18,55%
Brake Pad Shoe	0,9998747	10939,08	25,97%	44,64%	18,67%
SIV	0,9999387	15564,30	20,10%	85,51%	65,41%

With the increase in the reliability of these components, it is expected that the service life of the machine, especially these components, will be longer. In addition, it is also expected that the intensity of the damage unexpectedly can be reduced to a minimum level.

5. Conclusion

Based on the discussion and analysis that has been done in the previous chapter, several conclusions can be drawn relating to the implementation of Preventive Maintenance on KRL, including:

1. The critical type of KRL is the 8000 Series because it has a breakdown rate of 72 times and downtime of 69.08 hours, which is the highest among other types of trains.
2. The components of the 8000 Series KRL that often have disturbances and damage are the carbon brush with 31 times damage, which is 31% of the total damage, brake pad shoe with 19 times damage, which is 26% of the total damage, and SIV with 14 times damage, which is 19%. of the total amount of damage.
3. The implementation of Preventive Maintenance can increase the total availability value of the carbon brush component by 0.978, brake pad shoe by 0.983 and SIV by 0.988. While the reliability value, there is an increase

for each component. For carbon brush components, there is an increase of 32.94%, brake pad shoe there is 18.67%, and SIV, there is an increase of 65.41%.
4. The amount of downtime after preventive maintenance actions have increased. It is because of the number of actions performed for each component. The increase in downtime for the carbon brush component is 5.5 hours, the brake pad shoe component is 1.79 hours, and the SIV component is 11.29 hours.
5. The information system can support making a recapitulation of TTR and TTF values as well as in making periodic reports.

Acknowledgments.

This study is supported by RTTO (Research and Technology Transfer Office), Bina Nusantara University as a part of *Bina Nusantara University's International Research Grant* entitled **Influencing Factors to Minimizing Risk of Supply Chain in E-Commerce"** with contract number: No.017/VR.RTT/III/2021 and contract date: 22 March 2021

References

Angius,A., M. Colledani, L. Silipo, A. Yemane,"Impact of Preventive Maintenance on the Service Level of Multi-stage Manufacturing Systems with Degrading Machines," *IFAC-PapersOnLine*, vol. 49, no. 12, pp. 568–573, 2016, doi: 10.1016/j.ifacol.2016.07.696. 2016
Basri, E.I., I. H. A. Razak, H. Ab-Samat, S. Kamaruddin, "Preventive maintenance (PM) planning: A review," *J. Qual. Maint. Eng.*, vol. 23, no. 2, pp. 114–143, 2017, doi: 10.1108/JQME-04-2016-0014. 2017
Duarte, J.A.C., Craveiro, and T. P. Trigo,"Optimization of the preventive maintenance plan of a series components system," *Int. J. Press. Vessel. Pip.*, vol. 83, no. 4, pp. 244–248, doi: 10.1016/j.ijpvp.2006.02.016. 2006
Hardt, F., M. Kotyrba, E. Volna, R. Jarusek, "Innovative approach to preventive maintenance of production equipment based on a modified tpm methodology for industry 4.0," *Appl. Sci.*, vol. 11, no. 15, 2021, doi: 10.3390/app11156953 2021
Higgins, Lindley R, P.E. "Maintenance Engineering Handbook", 3rd Edition. McGraw-Hill Companies Inc., New York. p.1.39): 2002
Jha, C., "Supply Chain Optimization approaches and Market Demand Analysis of Petroleum Industry : A Case Study of ONGC," *Int. J. Sci. Res. Manag. Stud.*, vol. 4, no. 07, pp. 4461–4475, 2016, doi: 10.18535/ijsrm/v4i7.15. 2016
Mukhtar, M., N. Jailani, S. Abdullah,"A Framework for Analyzing e-Supply Chains," *Eur. J. Sci. Res.*, vol. 25, no. 4, pp. 649–662. 2009
Purnama, C.,"Analyze Machine Maintenance Cost With Corrective Method and Preventive Method To Increase Production Result," *Int. J. Bus. Rev. (The Jobs Rev.*, vol. 2, no. 1, pp. 1–8, 2019, doi: 10.17509/tjr.v2i1.15307. 2019
Qian, F., K. Dong, "The Open Cybernetics & Systemics Optimizing Preventive Maintenance of Used Equipment for Lease Abstract :," no. Cm, doi: 10.2174/1874110X0171101008. 2017
Sasitharan,D., H. M. Lazim, "Effect of Preventive Maintenance Practices and Supply Chain Management in Improving Manufacturing Performance," *Int. J. Innov. Res. Dev.*, vol. 7, no. 9, pp. 223–226, doi: 10.24940/ijird/2018/v7/i9/sep18079. 2018
Singh, S.R., T. Kumar, "Inventory Optimization in Efficient Supply Chain Management," *Int. J. Comput. Appl. Eng. Sci.*, vol. 1, no. 4, pp. 428. 2015
Stritto, G.D., M. M. Schiraldi, "A Strategy Oriented Framework for Food and Beverage E-Supply Chain Management Regular Paper," *Int. J. Eng. Bus. Manag. Artic.*, vol. 5, pp. 1–12, 2013, doi: 10.5772/57167. 2013

Biography

Tri Pujadi is an lecturer, in Information Systems in the School of Information Systems of Bina Nusantara University, Jakarta, Indonesia. He received the B.S. and M.S. degrees in information system management from the Bina Nusantara University, Indonesia, in 1998. From 2012 to 2019, he was a Research Coordinator with the School of Information Systems – BINUS University. Since 2010, he has been an Assistant Professor with expertise in Information Systems Plan and Design. His research interests include database management, e-commerce and e-business, disaster management.

Vikas Kumar is an Associate Professor in Enterprise Operations Management at Bristol Business School, University of the West of England. He has published more than 150 articles in leading international journals and international conferences. He serves on the editorial board of six international journals and serves on several scientific, technical, and programmed board committees of several international conferences. He is also co-founder and co-editor of the Int. J. of Supply Chain and Operations Resilience (Inderscience). His current research interests include sustainable supply chain management, process modelling, and service operations management.

Harkat Christian Zamasi is a lecturer, in Information Systems in the School of Information Systems of Bina Nusantara University, Jakarta, Indonesia. He received the B.S. and M.S. degrees in information management from the Bina Nusantara University, Indonesia, in 2006. From 2012 she was a Lecturer with the School of Information Systems – BINUS University with expertise in Data Warehouse Systems. His research interests include database management, data warehouse and data mining.

Hendy Wijaya is a lecturer, in Information Systems in the School of Information Systems of Bina Nusantara University, Jakarta, Indonesia. He received the B.S. and M.S. degrees in information management from Bina Nusantara University, Indonesia, in 2005. From 2012 she was a Lecturer with the School of Information Systems – BINUS University with expertise in Digital Business Technology. His research interests include digital marketing, blockchain and decision support

Ernawaty is a lecturer, in Information Systems in the School of Information Systems of Bina Nusantara University, Jakarta, Indonesia. She received the B.S. and M.S. degrees in information management from the Bina Nusantara University, Indonesia, in 2016. From 2018 she was a Lecturer with the School of Information Systems – BINUS University with expertise in Data Base Management Systems. Her research interests include database management, e-commerce, and e business.

Lius Steven Sanjaya is a lecturer, in Information Systems in the School of Information Systems of Bina Nusantara University, Jakarta, Indonesia. He received the B.S. and M.S. degrees in computer science management from the Nanyang Technological University, Singapore, in 2016. From 2018 he was a Lecturer with the School of Information Systems – BINUS University with expertise in digital business Management Systems. His research interests include enterprises system, e-commerce, and e business.