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Technological capabilities assessment by using Technometrics models in routine maintenance of commuter trains to increase service performance

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Abstract

Based on data on routine maintenance records for Indonesian Commuter Trains from 2015 - 2017, it is known that the number of realized train availability levels is still below the company's standards and targets. In addition, there is a potential risk of a backlog or train queues that are not handled properly in overhaul maintenance which is increasing yearly. The main objective of this research is to measure the technological capability of the routine maintenance of the Indonesian Commuter Train which is located at Dipo Depok. The method used in this paper is the Technometrics model approach which will produce a Technology Contribution Coefficient (TCC) value. The method describes the level of technology applied by routine maintenance of TCC obtained by identifying and assessing the technological components of Technoware (tool facilities), Humanware (HR), Infoware (information), and Orgaware (organization) involved in the routine maintenance operation process of commuter trains by measuring the Degree of Sophistication, State of the Art (SOTA) and Contribution Assessment, as well as the intensity of the contribution of technology components using an *Analytical Hierarchy Process (AHP). The results of this study identified 11 operating processes in maintenance activities. The SOTA values are T = 0.3857, H = 0.7750, I = 0.7111 and O = 0.633, with the contribution value being 0.4190, 0.6059, 0.5667 and 0.5862, and the contribution intensity is 0.301, 0.438, 0.132 and 0.030. Therefore, the TCC value for routine maintenance of Indonesian Commuter Trains with a value of 0.5 (TCC 0.3 ≤ TCC≤ 0.5) is categorized as low. With these results, the priority order of technology component development is humanware, technology, orgaware and infoware.*

Keywords:
Technology components;
Technology contribution coefficients;
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INTRODUCTION

Technology becomes one of the important things in the development of an operation [1][2]. By utilizing technology, operational activities can improve competitiveness and quality. In addition, technology facilitates transformation operations and provides infrastructure for integrated enterprise business development [3, 4, 5].

Conventional indicators of technology fail to provide a direct measure of technological progress [6][7]. The greater the contribution of the technology component to an operation will greatly affect the performance of the operation in terms of effectiveness, efficiency and quality [8, 9, 10]. The application of technology in maintenance activities is one of the important elements and significantly impacts operating activities [11][12]. Technology is seen from four dynamically integrated components: 1. Technoware (Hardware); 2. Humanware; 3. Infoware (information device); and 4. Orgaware (organization device) [13][14]. Sulistiyowat et al. [15] said the form of integration of the four components is the development and control of technoware components, carried out by humanware components, from infoware, all of which have been regulated by orgaware.

As companies in general, many factors related to production activities, especially in the application of technology, affect the company to achieve goals. Therefore, it is necessary to see the contribution of technology in the company's production system to know whether the application of technology is appropriate. Referring to the existence of four interrelated technological components, it is necessary to know the value of the contribution of each technological component [16]. By knowing these values, the right decision can be made about which components need to be prioritized for improvement.

Commuter trains are mass public transportation that can transport large numbers of people and can cover long distances in a short time, which are in great demand by people in the Greater Jakarta area of Indonesia. With the need for the availability of the fleet, Commuter Train Indonesia has increased the target number of passengers by 10% per year since 2019. Based on this, the Indonesian Commuter Train must prepare a train fleet in sufficient numbers and good condition so that it can constantly carry passengers every day. in a lot. Therefore, the increase in the target number of passengers crossing Jakarta must also be balanced with good train fleet maintenance management.

Companies need to measure their technological capabilities and contributions to achieve this target. The main objective of this paper is to measure the technological capability of routine maintenance of Indonesian commuter trains as a reference for companies to prioritize the evaluation of technology components.

The management of the maintenance of the train fleet in the process applies technology to produce a train fleet in prime condition, good quality, and insufficient quantity for traffic needs. Good application and mastery of technology will greatly affect the quality and quantity of available train fleets ready to operate [17]. Thus, the measurement of the application of technology in the maintenance of train fleet facilities can describe management regarding deficiencies in the fleet facility maintenance system. So that these deficiencies can be minimized or even eliminated and support the company's performance and targets [18][19].

Several empirical studies have been conducted to assess the role of technology in various industries. For example, the calculation of technology's contribution to the agricultural industry reveals that the components of technology that contribute the most to the transformation process are orgaware and infoware, while the components of technoware and humanware contribute the least [20, 21, 22].

Measurement of the application of technology in the maintenance of train fleet facilities can use several approaches [23][24], such as the technology audit model (GRACIA-ARREOLA), the technology audit model (SALADA-VELOSO), and the technometric model [25, 26, 27]. In this study, the level of technology application of Indonesian Commuter Train, train fleet facility maintenance system will be studied using a technometric model

METHOD

The value level of technological sophistication and artistic value on four components of Technoware, Humanware, Infoware and Organware (THIO) technology was determined using qualitative data. The use of quantitative data is carried out in order to obtain component contribution value technology through the use of an equation technometric model.

The first step is to classify the data from direct observations (observations) and interviews based on the type of technology component. Then, the stages of data processing to calculate the technology component's contribution coefficient value and the technology component's contribution intensity value based on the technometric model.

Before determining the level of sophistication, state of the art, the contribution of technology components, and the intensity value of the contribution of technology components, identification needs to be carried out. technology components (T, H, I, O) that exist in the process of transforming the research object. Technoware includes physical facilities, equipment, machines, means of transportation, and available infrastructure. Meanwhile, humanware is a technoware user in carrying out the process of operating container transportation. The availability of information that employees can utilize in carrying out operational processes includes the infoware component. Finally, the organizational component includes the framework available in the operation process such as management practice, organizational structure, and organizational arrangements (organizational arrangement).

The estimation method used is scoring to determine the technology components' level of sophistication. Testing and identifying all major techno items were and humanware while the components of inforware and organware are evaluated at the enterprise level.

The state-of-the-art assessment procedure is to use general criteria for each technology component that has been suggested as specific criteria that can be quantified and then these criteria are developed. Specific criteria were used to develop a rating system for the state-of-the-art. State-of-the-art ratings for Technoware, Humanware, Infoware, and Orgaware.

Based on knowledge of the sophistication level limit and state of the art rating, in this third step, the component contribution data is then calculated using the formula: Calculation of the contribution value of each technology component is carried out using the upper and lower limits of the degree of sophistication and the results of the calculation of the state of the art (SOTA). The intensity of the contribution of technology components is estimated using the AHP "pairwise comparison" method. The estimation procedure is that all companies under study are taken from pairwise comparison weight data and all companies must have a consistency ratio of 10%. If this condition has been met, then the calculation of the geometric mean of all the companies studied can be found.

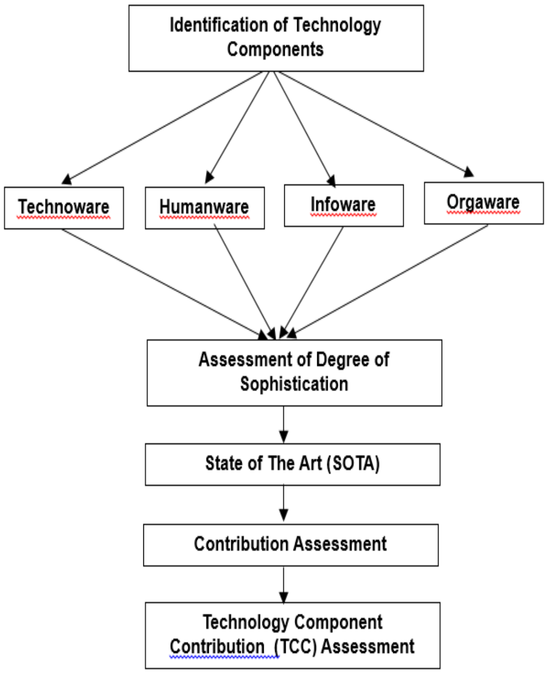

Figure 1. Step of Technometric

Technology Contribution Coefficient from a company showing the contribution of technology to the overall transformation operation, in this case, the train routine maintenance operation process. TCC is calculated using the values of T, H, I and O, that have been obtained. The flow of the steps for measuring Technometrics can be seen in Figure 1.

RESULTS AND DISCUSSION

The data that has been obtained is then processed and analyzed using the six steps contained in the Technometrics model. The results of the processing can be seen below.

Identification of Technology Components

The result of the identification process is operating the train routine maintenance. The process of routine maintenance of the train, which has been summarised, is shown in Table 1. Based on the above-operating processes, an assessment is made of the techno wave, humanware, infoware and orgaware components involved in the above operations.

Assessment of Degree of Sophistication

The value of Degree of Sophistication (DOS) or the degree of sophistication of technological components is shown in Table 2.

Components Technoware has a lower limit of 3 in the "Manual tools (1 2 3)" range. This is because there is still manual equipment used in the operation process. While the determination of number 3 is in the range of "Manual equipment (1 2 3)" because the available manual equipment is complete, organized, and organized to facilitate the operation process. Component technoware has an upper limit of 5, which is in the "Automatic equipment (5 6 7)" range.

Table 1. Process of operating routine maintenance

Num	Operation Process
1	Administration
2	Investigation
3	Preparation and Security
4	Lifting
5	maintenance of pneumatic and compressor
6	Interior and exterior
7	Bogie and wheel
8	maintenance Motor traction
9	maintenance Air Conditioning (AC)
10	Tests static and dynamic
11	Recording and reporting

Table 2. DOS Value

Technology Components	Sophistication Level	
	LL	UL
Technoware	3	5
Humanware	4	6
Infoware	3	5
Orgaware	4	6

The existing automatic equipment in the operation process is a crane. The value of the crane itself has reached number 6, meaning that the crane used is quite sophisticated. However, this number had to be shifted to 5 due to a lack of automatic equipment in other maintenance operations processes. As in the static test simulator tool and wheel lathe in terms of capacity and time for working on the wheelset.

The humanware component has an upper limit of 4 in the "Able to Take Care (3 4 5)" range. The maintenance ability possessed by humanware on facility technicians who are indeed required to take care of train maintenance equipment has a value of 5. But the overall maintenance ability is worth 4 because it is influenced by the ability to care for other humanware. While the bottom line for the humanware component is 6, which is in the range of "Ability to innovate with the help of external parties (6 7 8)". Employees generally fill the authority holders in the train maintenance department with a minimum experience of more than seven years. This experience, coupled with efforts to increase knowledge and insight made by the Indonesian Commuter Train, makes humanware able to innovate. The number 6 is obtained because of the different innovation abilities between the implementing technician and the authority holder. The difference in innovation ability is influenced by experience, educational background, training, and the breadth of authority possessed.

The infoware component has an upper limit of 3 in the range of "Able to provide and process general information (1 2 3)". Administrative documents are examples of general information that exists in the operation process. The value of 3 was chosen because this process has been carried out optimally with the help of the provided technoware. The infoware component has a lower limit of 6 in the range of "Ability to provide and process information for effectiveness and efficiency (4 5 6)". Infoware such as SOPs, Checksheets, maintenance history documents, technician data, spare parts data, and equipment data have been provided to make the operation process more effective and efficient. This document has gone through the revision, adjustment, and certification stages.

The organizational component has an upper limit of 4 and an upper limit of 6, both of which are in the range "The organization begins to have a network of cooperation that continues to grow, begins to have a standard management system, is recognized by third parties, can identify potential markets (4 5 6)". Indonesian Commuter Train has a growing partnership with Japan in procuring trains. Indonesian Commuter Train's management system is standardized and has been recognized by the parent company, namely Indonesian Commuter Train. The company sees the public's enthusiasm for commuter rail transportation as a potential market, so Indonesian Commuter Train has raised its passenger growth target to 10% per year, since 2017. standard management, recognized by third parties, able to identify potential markets". Following the guidelines of the technology development framework of the technometric model, if a component is in a range of values, then the lower limit value is taken from the lowest value of that range. While the upper limit is taken from the highest value of the range.

State of The Art (SOTA)

The State of The Art (SOTA) assessment is the next assessment of the technological components involved in the operation process. Based on the technology development framework, SOTA assesses the complexity of technology components. The SOTA rating range is from 0 to 10. Therefore, if DOS assesses the degree of sophistication of the technological components involved in the operation process, then SOTA assesses the level of sophistication of the sophistication.

The reference value of SOTA Technoware is based on the latest technology in similar industries. For example, one of the latest train depots that started operating in 2017 is the Singapore Tuas Depot. Since its inception, the Tuas Dipo in Singapore claims that they have the latest technology applied that they have not had at the other six Dipo in Singapore. The following equation can calculate Technoware's SOTA value:

$$\mathrm{ST_i} = \frac{1}{10}\left[\frac{\Sigma_k t_{ik}}{kt}\right] k = 1,2,\ldots\ldots k_t \quad (1)$$

$$ST_i = \frac{1}{10}\left[\frac{27}{7}\right] = 0{,}3857$$

k_t = the number of criteria for technoware
where t_{ik} is the value of the k-th criterion of technoware category i

The reference value of SOTA Humanware is the company's target for each maintenance unit in particular as well as on maintenance management in general. The SOTA value of Humanware can be calculated by the following equation:

$$\mathrm{SH_j} = \frac{1}{10}\left[\frac{\Sigma_i h_{ij}}{jh}\right] j = 1,2,\ldots\ldots j_h \quad (2)$$

$$SH = \frac{1}{10}\left[\frac{31}{4}\right] = 0{,}7750$$

I_h components humanware
where h_{ij} is the value of the i-th criterion of humanware category j.

For the SOTA Infoware assessment, the reference is the certification of SOP and Checksheet guidelines, ease of document access, document updates, and document management, which the following equation can calculate:

$$SI = \frac{1}{10}\left[\frac{\sum_m f_m}{mf}\right] m = 1,2, \dots \dots . m_f \quad (3)$$

$$SI = \frac{1}{10}\left[\frac{64}{9}\right] = 0{,}7111$$

where I_i is the value of the m-th criterion of infoware at the enterprise level

Meanwhile, Organware SOTA, according to the technology development framework for technometric models, is the most difficult SOTA to measure due to the many factors that can affect the organization. Organware SOTA value can be obtained from the following equation:

$$SO = \frac{1}{10}\left[\frac{\sum_n o_n}{no}\right] n = 1,2, \dots \dots . n_o \quad (4)$$

$$SO = \frac{1}{10}\left[\frac{38}{6}\right] = 0{,}6333$$

where n_o component criteria or aware and o_n is the value of the nth criterion of or aware at the company level.

In this study, the SOTA is the total number of trains that can be maintained per year in terms of overhaul maintenance. The overhaul treatment was chosen because the overhaul treatment is a comprehensive maintenance and represents other treatments from the side of the maintenance operation process. In addition to the number of commuter trains that carry out overhaul maintenance, it is also seen from the adequacy of technoware, humanware, and infoware provided by or aware. The SOTA value for the technology component involved in the routine maintenance operation process of the Indonesian Commuter Train fleet using (1), (2), (3) and (4) is shown in Table 3.

Table 3. The Values of the State Of The Art

Technology Component	Determination	Value
Technoware	3,857	0.3857
Humanware	7,750	0, 7750
Infoware	7,111	0,7111
Orgaware	6,333	0,6333

Table 3 shows that H>I>O>T indicates that humanware is a technological component considered the most recent that plays a role in train maintenance. These results are also directly proportional to the ability of humanware to meet the targets set by the company. Therefore, Humanware has made maximum efforts so that the target, namely the availability of a train fleet ready to operate for traffic needs, is still achieved.

After humanware, the most advanced technology component is the infoware. This is due to the completeness of the documents required at the treatment time. In addition, maintenance supporting documents such as SOPs and checksheets have obtained ISO 9001:2015 certification. The drawback lies in that these documents are not accessible on digital platforms when the operation is carried out, so when information is needed regarding these documents, they must go through several stages of the bureaucratic process first.

Contribution Assessment

The contribution value of the technology component is obtained through a formula. The formula is a calculation between the DOS value and the SOTA value. Changing the DOS value and SOTA value will impact the technology component's contribution value. The contribution value of the technology component describes the contribution of each technology component to the routine maintenance of the train fleet. The greater the value of the contribution, the greater the contribution of these components to the routine maintenance of the train fleet. The calculation of the contribution value of each technology component is carried out using the upper and lower limits of the degree of sophistication and the results of the calculation of the SOTA value which are formulated in the following equation:

$$T = 1/9\ [LT + ST\ (UT - LT)] = 0.4190 \quad (5)$$
$$H = 1/9\ [LH + SH\ (UH - LH)] = 0.6059 \quad (6)$$
$$I = 1/9\ [LI + SI\ (UI - LI)] = 0.4667 \quad (7)$$
$$O = 1/9\ [LO + SO\ (UO - LO)] = 0.5852 \quad (8)$$

Where:
LT = Lower limit technoware
UT = Upper limit of technoware
LH = Lower limit of humanware
UH = Upper limit of humanware
LI = Lower limit of infoware
UI = Upper limit of infoware
LO = Lower limit of or aware
UO = Upper limit of or aware
ST = SOTA technoware
SH = SOTA humanware
SI = SOTA infoware

SO = Sota or aware

The results of the calculation of the value of the contribution of technology components in the routine maintenance of the train fleet can be seen in Table 4. Table 4 shows that H>O>I>T. Humanware has the highest contribution to maintenance. This can be proven by the maintenance process that involves many technicians with certain abilities. However, Orgaware is a technology component that has the highest contribution after humanware. This is because although humanware is a component that is directly related to train maintenance, all decisions made by humanware regarding train maintenance must be approved by orgaware.

Such as the classification of the type of treatment or the use of vendor services. Technoware and infoware are the 2 lowest components contributing to fleet maintenance training. The mismatch between the number of humanware and the infoware references is one of the causes. Meanwhile, most of the available technoware has not been updated or added to support humanware work.

Contribution Intensity Assessment

Calculation of the contribution intensity value of technology components using the Analytical Hierarchy Process (AHP) method. The value of the intensity of the contribution of the technology component is obtained from giving a score through a questionnaire distributed to competent experts in the management of the technology component in Indonesian commuters.. The AHP hierarchy is composed of goals, criteria, and alternatives. The goal or goal of the AHP hierarchy is the priority of developing technological components in routine maintenance of Indonesian Commuter Train trains. Determination of criteria based on the objectives and needs of train fleet maintenance as well as discussions with several authorized train fleet maintenance officials, namely operational readiness, reliability, and ease of maintenance. While the alternatives are based on the technology components to be developed, namely technoware, humanware, infoware, and or awareness.

Table 4. Contribution Value of THIO

Technolgoy components	Contribution Value
Technoware	0.4190
Humanware	0.6059
Infoware	0.4667
Orgaware	0.5852

Table 5. Value of Intensity

Technology Components	Value of Contribution Intensity
Technoware	0.301
Humanware	0.438
Infoware	0.132
Orgaware	0.129
Consistency Ratio	0.09

The AHP hierarchy has been compiled along with the scores obtained with the expert choice 11 tools.

Based on the results of processing the questionnaire data for 15 respondents, namely 1 Technical Director, 1 Maintenance Manager, 4 quality control staff and 9 technicians, the intensity value of the intensity contribution to the technology component can be seen in Table 5.

The Consistency Ratio (CR) value in the AHP calculation must have a value of < 0.1. This value is a description of the consistency of the expert in answering the questionnaire given. The contribution intensity value shows how often the technology component contributes to training maintenance. The value of the contribution intensity in Table 5 shows that H>T>I>O. Humanware is the component that most often contributes to car maintenance. This form of contribution is supported by technoware which causes technoware to have the 2nd highest value in the value of contribution intensity after humanware. Humanware works with the help of technoware based on Infoware compiled by Orgaware.

Technology Component Contribution (TCC) Assessment

The value of the technology component contribution coefficient or Technology Contribution Coefficient – TCC is obtained through a formula. The contribution value of each technology component is raised to the power of the contribution intensity value of each technology component. The rank results are then multiplied with each other so that the TCC value is obtained. The following equation can calculate the TCC value:

$$TCC = T^{\beta t} \times H^{\beta h} \times I^{\beta i} \times O^{\beta o} = 0.5 \qquad (9)$$

Where:

TCC = technology contribution coefficient

T = contribution value of technoware component contribution intensity technoware

H = the value of the contribution of the humanware value of the intensity of the contribution of the humanware

I = the value of the contribution of the infoware

i = the value of the intensity of the contribution of the infoware
O = contribution value of or aware
B = the value of the contribution intensity of the or aware component

The calculation result of the Technology Contribution Coefficient (TCC) or the value of the technological component’s contribution coefficient on the routine maintenance of the Indonesian Commuter Train is 0.5 which is in the “enough” technology classification.

CONCLUSION

Based on the results, 11 operating processes in maintenance activities were identified. The SOTA values are T = 0.3857, H = 0.7750, I = 0.7111 and O = 0.633, with the contribution value being 0.4190, 0.6059, 0.5667 and 0.5862, and the contribution intensity is 0.301, 0.438, 0.132 and 0.030. Therefore, the TCC value for routine maintenance of Indonesian Commuter Trains with a value of 0.5 is categorized as low. With these results, the priority order of technology component development is humanware priority, and second priority is technology, third priority is orgaware and fourth priority is infoware. The condition happened because the maintenance process involves many technicians with certain abilities compared to other technological components.

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