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Technology content assessment for Indonesia-cable based tsunameter development strategy using technometrics model

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A B S T R A C T

This research aims to calculate the value of the Technology Contribution Coefficient (TCC) and determine the priority of technology component improvement in the development of the Indonesia-Cable Based Tsunameter (INA-CBT) Tsunami Early Warning System (TEWS) conducted by the National Research and Innovation Agency (BRIN) Research Center for Electronics (RCE). In this study, the Technometrics model is used to calculate the technology contribution of technology components and TCC, while Analytical Hierarchy Process (AHP) is used to calculate the value of the technology contribution intensity of technology components. The results showed that the TCC value of the RCE is 0.55 (Good). With the state-of-the-art value of 1, the RCE still has the opportunity to make improvements, especially on Infoware components with the lowest contribution value, to increase TCC. In calculating the technology contribution intensity, Infoware obtained the highest score of 0.447 compared to other technology components, therefore Infoware needs to be prioritized for improvement so that it is expected that the management of RCE can increase the quality and accuracy of the engineering design and simulation stage because it is a critical point in the development of INA-CBT.

1. INTRODUCTION

The Indonesian archipelago is located between the Indo-Australian Plate and the Eurasian Plate, therefore, this area is seismically very active along the boundary between plates [1]. The phenomenon of plate shifts at the border causes frequent underwater earthquakes and has the potential to cause tsunamis [2]. There have been 69 tsunamis with a validity status of "definite tsunami" and 55 tsunamis with a validity status of "probable tsunami" in Indonesia from 416 to 2018 [3].

The 2004 Aceh Tsunami and the 2006 South Java Tsunami have triggered various studies on the importance of the Indonesian Tsunami Early Warning System or INA-TEWS [4]. Through Presidential Regulation No. 93/2019, the Agency for the Assessment and Application of Technology or BPPT received a mandate to support the operation of INA-TEWS to assist the community and other government institutions [5]. Therefore, in 2019, the BPPT Center of Technology for Electronics (CTE) built and developed INA-CBT, part of INA-TEWS [6].

A cable-Based Tsunameter is a series of one or more Ocean Bottom Units (OBU) with electronic, communication, and power equipment installed on fiber optic cables serially and then placed on the seabed [7]. Fiber optic cable is chosen because of its transmission capacity of up to 1 GB/s [8]. Electronic sensors in the OBU measure changes in underwater water pressure related to an increase or decrease in sea level due to a tsunami caused by tectonic earthquakes on the seabed or from underwater volcanic mountain activity [9]. Next, the pressure data is sent via fiber optic cable to the Landing Station (LS) on the coast and then transmitted via satellite network, GSM or fiber optic cable to the tsunami monitoring center or Read Down Station (RDS) [10].

Several countries have implemented CBT systems, including Japan, which has the Dense Ocean Floor Network System for Earthquakes and Tsunamis (DONET) and the Seafloor Observation Network for Earthquakes and Tsunamis Along the Japan Trench (S-NET) as deep sea tsunami sensor systems in the Southeast and East of Japan, respectively [11], [12]. Both systems are operated by the National Research Institute for Earth Science and Disaster Resilience (NIED) [13]. In addition, Taiwan also has a CBT system, namely the Marine Cable Hosted Observatory (MACHO), which is used to monitor active volcanoes and detect earthquakes and tsunamis occurrences off the coast in the Northeast of the country [14].

Research and development of 1st Generation of INA-CBT or INA-CBT G1 technology in Indonesia have been carried out since 2012, and at that time, INA-CBT technology still used copper cables [15]. In 2019, 2nd Generation of INA-CBT or INA-CBT G2 was developed using fiber optic cables with the concept of one LS and one OBU, which then were deployed in the Mentawai Islands area and Sertung Island area, but after operating for about 6 months, both systems stopped working due to lack of power supply [15]. In 2020, the development of the 3rd Generation of INA-CBT or INA-CBT G3 began by involving other work units related to marine surveys, coastal dynamics, structural strength, materials, informatics, and communication, as well as technology policy. The goal was to build INA-CBT with one LS and two OBU systems to be deployed in the waters of Labuan Bajo and Rokatenda, Flores, East Nusa Tenggara [16]. The involvement of other stakeholders is due to the need for human resources and infrastructure facilities owned by these units. Therefore, the management of all technological components is needed to develop this generation of Ina-CBT. In 2021, the construction of INA-CBT was continued by the BRIN RCE as the main work unit after the issuance of Presidential Regulation No. 78/2021, which mandates the merger of BPPT and three other Non-Ministerial Government Institutions into BRIN [17].

The success of INA-CBT cannot be separated from the application of technology in the form of utilizing a set of systemic and collaborative components from various disciplines throughout the development process to ensure that INA-CBT can be deployed at the planned place and time [18]. Understanding of technology should be interpreted in a broad scope and must be integrated effectively to be applied to meet the requirements of INA-CBT development. From this understanding, four technology components, namely Technoware (facilities), Humanware (abilities), Infoware (facts), and Orgaware (framework) or THIO, are based on the 1989 Technology Atlas Project of The UN Economic and Social Commission for Asia and the Pacific (UNESCAP), contribute to the transformation process to turn inputs into outputs [19], [20].

The use of THIO components as an integrated unit is needed in the transformation process so that an organization's extent of technological achievement and technology absorption can be known [21]. Technoware is at the core of the transformation process, which will only function properly if it is developed, installed, operated, and improved by Humanware based on the Infoware collected from time to time and the existing procedures at Orgaware [22]. Therefore, organizations need an analysis of the contribution of the THIO components in the product development process to increase productivity, efficiency, and added value of the output, which in turn will provide greater benefits for the community [23], [24], [25].

The analysis of THIO has been used to measure the intensity and contribution coefficient of three types of industries in the fields of petroleum, manufacturing, and mining technology in East Azerbaijan, where the Humanware

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component has the highest contribution value for success, such as hard work, cooperation and time management [26]. Then, Rumanti & Wirawan [27] conducted a technology assessment on CV Kajeye Food in Malang East Java Indonesia, which is engaged in processing fruit and vegetable chips. The results show that the technological components of Orgaware and info ware have the highest contribution level, and CV Kajeye's technology level is at the traditional level. Furthermore, the measurement of technology contribution coefficient values and the determination of priority for institution readiness in adopting technology in vocational education internal quality assurance system shows that Infoware and Orgaware are needed to become a priority to be developed [28].

This research was conducted to determine technology's contribution to developing INA-CBT, which has never been done in previous studies. The research object is focused on the RCE, which carries out INA-CBT development activities and is based on the complexity of using technology components, starting from the desktop study stage to the testing stage. The research subjects are 1) Technoware components which include equipment, machines, and office supplies, as well as laboratory and transportation facilities; 2) Humanware components, which cover all capabilities of employees involved in using Technoware in the development process; 3) Infoware and Orgaware components at the organizational level, namely the RCE. The analytical tool integrates the Technometric Model and the AHP method with a complete AHP hierarchical structure so that the criteria for determining the priority of developing technology components can be known. Previously, Fauzi *et al.* [29] used a model that combines Technometrics, AHP, and quality function development approaches to measure the readiness of production technology to meet government standards in the toy industry. Then, Muksin *et al.* [30] conducted research using Technometrics methods and AHP pairwise comparison matrix to calculate the technology coefficient contributions to obtain alternative technology components for the Indonesian Navy's Anti-Submarine Helicopters.

The Technometrics Model is part of the technology content assessment framework compiled by the UNESCAP and is used to calculate the contribution value of technology components and TCC, which shows the technology level of an organization in transformation processes. The TCC formula (1) is as follows:

$$TCC = T^{\beta_t} \times H^{\beta_h} \times I^{\beta_i} \times O^{\beta_o} \quad (1)$$

where: T, H, I, O: contribution of technology component, and β_t, β_h, β_i, β_o = contribution intensity of THIO

The AHP developed by Thomas L Saaty is a functional hierarchical framework that requires human perception as its primary input. This method is used to solve a complex and unstructured problem by splitting it into groups and arranging it into a hierarchy. The output of AHP is the values of the contribution intensity of technology components.

The development of INA-CBT is the only one in Indonesia, and previous research that calculated the value of technology contributions using the Technometrics Model in the development of CBT technology has never been found. In addition, there is a gap in the value of technology contributions in various industries and institutions from the results of previous studies, so research to calculate the value of technology contributions to the development of CBT technology needs to be done.

The research objectives are, first, to calculate the technology contribution values and determine the technology content or level status of the RCE in INA-CBT development. Second, the research intends to obtain a comprehensive technology component development strategy for improving THIO INA-CBT development. Third, the research also wants to provide empirical evidence that the Technometrics model can be applied to research institutions, especially research for developing disaster technology.

2. RESEARCH METHODS

The UNESCAP Technology Atlas Framework estimates technological sophistication and calculates the state-of-the-art (SOTA) values to obtain the technology level status in the INA-CBT development process. In turn, the technology level status will be used as input for the management of the RCE in planning, improving, and prioritizing the development of appropriate THIO components in the future [31].

The research focused on the use of THIO components, starting from the desktop study, survey, engineering design, model manufacturing, testing, supervision of the manufacture of components, and overall tests in electronics, telecommunications, and power. Primary data was collected through in-depth interviews and filling out questionnaires by selected experts of the RCE. Interview questions and questionnaires were designed to gather information about using THIO components. Interviewers also assist interviewees in obtaining complete and accurate data and information. Secondary data related to the best practices of CBT technology were obtained from the literature study. The data and information collected will be used to assess the technology level status in the INA-CBT development process as follows:

1. Identify the THIO components used.
2. Estimate the upper and lower limit of sophistication of THIO involved in the transformation process by assigning values in the range of 1-9 (Table 1).
3. Calculate each THIO component's SOTA or complexity level value based on (2). The calculation is based on the estimation of THIO indicators. A range of values from 0 to 10 is given for indicators with the lowest specification to the best one. Then the value of THIO is normalized by dividing it into 10 to get a number between 0-1 and has the same weight for all components using indicators for calculating SOTA values (Table 2) and the SOTA rating scale of THIO (Table 3).

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

Where k_t=the number of technoware component criteria. t_{ik} is the k^{th} criterion value of category, i techno ware

$$SH_j = \frac{1}{10}\left[\frac{\sum_i h_{ij}}{jh}\right] \qquad j=1,2,\ldots,j_t \qquad (3)$$

Where j_t=the number of humanware component criteria. h_{ij} is the j^{th} criterion value of category, i human ware

$$SI = \frac{1}{10}\left[\frac{\sum_m f_m}{mf}\right] \qquad m=1,2,\ldots,m_f \qquad (4)$$

Where m_f=the number of info ware component criteria. f_m is the m^{th} criterion value of info ware at the organizational level

$$SO = \frac{1}{10}\left[\frac{\sum_n o_n}{no}\right] \qquad m=1,2,\ldots,n_o \qquad (5)$$

Where, n_o= the number of orgaware component criteria. The n^{th} criterion value of orgaware at the organizational level

4. Calculate the contribution of THIO using the sum of the lower limit values with the multiplication result between SOTA and the difference between the upper and lower limits. The result is then divided by 9 so that the contribution of the components at the SOTA level equals 1.

$$T = \frac{1}{9}[LT + ST(UT - LT)] \qquad (6)$$

$$H = \frac{1}{9}[LH + SH(UH - LH)] \qquad (7)$$

$$I = \frac{1}{9}[LI + SI(UI - LI)] \qquad (8)$$

$$O = \frac{1}{9}[LO + SO(UO - LO)] \qquad (9)$$

Where, LT= technoware lower level; UT = technoware upper level; LH = humanware lower level; UH = humanware level; LI = infoware lower level; UI = infoware upper level; LO = orgaware lower level; LO = orgaware lower level; and UO = orgaware upper level.

5. Calculate the value of technology contribution intensity or importance (β) of the technology components by using the AHP method.
6. Calculate the TCC. The TCC is then classified to obtain the technology level status of INA-CBT development and will be used by the management of RCE to set goals and strategies for THIO improvement in the current and future development of INA-CBT [32] by the TCC classification and type of technology (Table 3).

Table 1. Criteria in the level of sophistication of THIO [20]

Technoware	Humanware	Infoware	Orgaware	Value limit LL		UL
Manual Facilities	Operating Abilities	Familiarizing Facts	Striving Framework	1	2	3
Powered Facilities	Setting-up Abilities	Describing Facts	Tie-up Framework	2	3	4
General Purpose Facilities	Repairing Abilities	Specifying Facts	Venturing Framework	3	4	5
Special Purpose Facilities	Reproducing Abilities	Utilizing Facts	Protecting Framework	4	5	6
Automatic Facilities	Adaptation Abilities	Comprehending Facts	Stabilizing Framework	5	6	7
Computerized Facilities	Improving Abilities	Generalizing Facts	Prospecting Framework	6	7	8
Integrated Facilities	Innovation Abilities	Assessing Facts	Leading Framework	7	8	9

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Table 2. Indicators for estimating the state-of-the-art value of technology component [21]

Technoware	Humanware	Infoware	Orgaware
Operational complexity	Creativity	Ease of information repetition	Leadership effectivity
Precision/Degree of accuracy	Achievement orientation	Connectedness	Autonomy of work
Handling of raw material	Teamwork	Data processing system	Organizational direction
Process control	Productivity orientation	Ease of communication	Organizational involvement
Contribution of operational engineering facilities	Ability for taking risks	Operational procedures	Innovation climate in organization
Image contribution	Responsibility and discipline	Speed of information access	Integrity of organization actions

Table 3. TCC classification and type of technology [33]

TCC Values	Rating Classification	Type of Technology
$0.0 < TCC \leq 0.1$	Very low	Traditional
$0.1 < TCC \leq 0.3$	Low	Traditional
$0.3 < TCC \leq 0.5$	Normal	Semi Modern
$0.5 < TCC \leq 0.7$	Good	Semi Modern
$0.7 < TCC \leq 0.9$	Very good	Modern
$0.9 < TCC \leq 1.0$	Highly sophisticated	Modern

3. RESULTS AND DISCUSSION

To obtain primary data, direct observation and in-depth interviews were carried out with the leaders of the Ina-CBT Program, namely the Program Head and Chief Engineer, who have had experiences since the development of Ina-CBT G1. The findings are a descriptive explanation from a qualitative analysis that explains and examines the collected data related to the transformation process. This process is a series of activities that are interconnected with one another. Each activity involves very detailed subprocesses, but basically, these subprocesses can be grouped into several stages that are considered important. 5 main stages must be carried out before deploying INA-CBT as the final product in the predetermined place. In addition, monitoring and evaluation are also carried out to ensure the success, accuracy, and completeness of the processes at each stage. These 5 main stages are as follows.

1. The development of INA-CBT begins with Desktop Study activities that aim to understand the characteristics of the assignment and then search for material in the form of theory, best practices, and secondary data needed to complete the activity. The data obtained is divided into two types: specifications for equipment at sea (wet parts) and specifications for buildings and equipment for the Landing Station (dry parts).
2. Nearshore, Offshore, and seabed topography surveys are conducted to obtain information for planning and preparing for underwater fiber optic cable deployment. The INA-CBT cable system has tsunami detection sensors on the OBU, so it requires information on the exact location of the cable route or path. Offshore survey operations are carried out using the Baruna Jaya IV Research Vessel with an operating area from a depth of 20 m to deep waters (more than 1000 m), while nearshore surveys use local vessels with a survey operation area from 0 m to 20 m. Positioning on the water surface, both offshore and nearshore surveys, uses real-time Differential Global Navigation Satellite System (D-GNSS) equipment with 24-hour L-Band type D-GNSS correction signal coverage.
3. Engineering design activities include designing and developing hardware and software for INA-CBT's wet and dry parts. These activities require the innovative ability of engineers for the study process in the early stages, which is then continued with the implementation process to ensure that the INA-CBT must be successful in operation and useful in its implementation. All engineers as Humanware components in developing INA-CBT are members of an engineering organization in the RCE.
4. Individual testing activities are carried out to ensure that each INA-CBT component meets the required specifications. Tests were carried out on fiber optic cables to determine the

strength of the cables and their connections by performing tensile tests, torsion tests, and submerge tests to determine the cable's resistance to seawater pressure. The next test is carried out on electronic devices, including operational tests to determine the performance of components and vibration tests to determine the strength of the devices against the vibration (impact) that occurs. Another test is a submerged test on the OBU canister by inserting the canister into the pressure chamber device. Then water is put into the pressure chamber using a pump, simultaneously giving it a pressure of up to 500 bar (50 kN). Monitoring of pressure values is carried out with a data logger instrument.

5. After individual testing on fiber optic cables, electronic devices, and canisters is completed, all these components are integrated into one system and retested. The integrated test includes the operational and submerged tests for the whole system. The submerge test is carried out by partners of the RCE using a pressure chamber with a pressure of up to 600 Bar to meet the requirements for installing OBU at sea depths between 4200 m - 6000 m.

3.1. Determination of TCC value using technometric model

3.2.1. *Identification of the details of the component technology (THIO) used*

The first step in measuring technology's contribution is to identify each technology component's details. This identification will be needed to estimate the upper and lower limits of the sophistication level and determine the technology components' SOTA values. Table 4 and Table 5 present details of the THIO components in developing INA-CBT, which are the focus of the research.

Table 4. Details of technoware component [31]

Operational Workflow	Equipment	Information System	Tools/Machines	Physical Infrastructure
Desktop Study	Computer, modem, printer, calculator	Web Browser, Search Engines, Maps System	-	Research Centre Offices, Internet
Survey	Laptop, modem, printer, camera, calculator	Global Navigation Satellite System, Solar Irradiance Logger, Spectrum Analyzer System, Drone Controller System	Research vessels, GPS, Drones	Internet
Engineering Design	Computer, modem, printer, calculator	Proprietary and open-source tools for electronic, communication and power design and simulation	Spectrum Analyzer, Testbed Router MPLS and server, Ethernet to an optic converter, Optic Amplifier	Research Centre Offices, Advanced Network Protocol Lab, Photonics Lab, Electronic Design Lab, Internet
Testing	Computer, modem, printer, calculator	Proprietary and open-source tools for electronic, communication and power design and simulation	An anechoic chamber, Antenna	Research Centre Offices, Advanced Network Protocol Lab, Photonics Lab, Electronic Lab, Electromagnetic and Compatibility Lab, Internet

Table 5. Details of humanware, infoware, and orgaware components [31]

Technology Component	Details
Humanware	Program Head and Chief Engineer Group Leaders Leaders Engineering Staffs
Infoware	Information systems and applications for data processing, design, and simulation SOP, Guidelines related to operating process equipment SOP, Guidelines related to service quality assurance Information on infrastructure facilities (Lab, Office, Network)
Orgaware	Organizational structure and relationships between sections Work Facilities Quality management Organizational Competency Improvement Planning

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Table 6. Summary of estimation results of technological component sophistication

Technology Component	Lower Level (LL)	Upper Level (UL)	Description
Technoware	4	6	**LL:** This level consists of desktop study and survey processes using equipment, systems, tools/machines and infrastructure equipped with automated special-purpose applications **UL:** This level consists of the engineering design process and testing of electronic circuits and sensors in the laboratory using equipment, systems, tools/machines and infrastructure controlled by the operator
Humanware	4	6	**LL:** Employees of the Research Centre for Electronics can use the devices provided, such as computers and measuring instruments. In addition, employees can also carry out work on operational activities according to the direction of employers. **UL:** Some employees have worked together to use and develop engineering designs of electronics and sensor circuits for OBU. In addition, during the testing process, several employees were able to analyze deficiencies and make improvements and innovations to the system.
Infoware	3	5	**LL:** BRIN RCE provides open source-based information to select and install Ina-CBT components **UL:** Some of the available information is already in forms that employees from BRIN RCE and partners can easily use to develop Ina-CBT designs
Orgaware	4	6	**LL:** BRIN RCE already has a standard quality management system. The accreditation obtained from KAN (SNI ISO/IEC 17025:2008 and 17025:2005) shows that the BRIN RCE Laboratory Facilities has fulfilled the mandatory document and record requirements in the ISO/IEC 17025 clauses. **UL:** BRIN RCE has been recognized by third parties, can identify potential needs, and has a network of Cooperation with BRIN intermediary units and strategic partners to market products resulting from its research activities

3.1.2. *Estimation of sophistication level of technological components*

The estimation of the sophistication level of THIO refers to the generic procedure of the UNESCAP Technology Atlas Framework by determining the upper and lower limit values of each technology component and then taking the median value of each limit. The estimation results indicate the position of the organization (or company) regarding the use of technology to generate innovation in product development [34]. When an organization increases the sophistication of its technological components, it also requires a proportional increase in operational complexity related to interactions between technology components [35]. Table 6 presents a summary of the results of estimating the sophistication level of THIO used in developing INA-CBT.

3.1.3. *Calculation of the state-of-the-art value of technology components*

Based on the lower and upper-level values of Technological Component sophistication (Table 6), then we calculate the SOTA value of THIO with the results: SOTA(T) is 0.7500, SOTA(H) is 0.7750, SOTA(I) is 0.7333 and SOTA(O) is 0.7625.

The SOTA value of Humanware of 0.7750 represents the highest level of complexity, indicating that human resources' ability is very good. The reasons are that employees already have Bachelor's to Doctoral degrees, often attend various training sessions in their fields, and are experienced in research, development, assessment, and application of technology activities. In implementing activities, employees can work based on certain SOPs consistently, analyze the shortcomings of the CBT system that has been built previously (both domestically and abroad), and then make improvements, developments, and innovations to produce the latest generation of better INA-CBT systems.

The SOTA value of Orgaware of 0.7625 indicates that the management's ability to formulate policies and strategies related to organizational strengthening, directing the achievement of BRIN's vision, motivating employees, and increasing product innovation has been carried out based on good planning.

The SOTA value of Technoware of 0.7500 indicates that the availability of physical facilities at the desktop study stage up to the testing stage, such as processor and board design facilities, optical system design, telecommunication system design, programming, and telemetry system design, as well as the power system design, has an adequate level of complexity, accuracy, and raw material handling, and can be used and controlled optimally.

The SOTA value of Infoware of 0.7333 represents the lowest level of complexity which indicates that, in general, the management is capable enough to provide informative data processing facilities, is available online, and can be accessed quickly. However, paying attention to the aspects of the storage system's order, accuracy, neatness, information catalogue, and SOPs used for various operational activities is necessary. In addition, the BRIN RCE does not yet have complete system information and applications to fully support its activities in the engineering design and simulation stage.

3.1.4. *Calculation of the contribution value of technology components*

The magnitude of the contribution of each technology component to the successful development of INA-CBT will help the management to make the right decisions about which components need to be prioritized to improve their quality. Table 7 presents the results of calculating the contribution value of the technology component using.

Table 7 shows that the contribution values of technology components are in the order of I<T<O<H where Infoware is the component that has the smallest contribution value of 0.4962, and Humanware is the component that has the largest contribution value of 0.6167 to the development of INA-CBT. The characteristics of the RCE's human resources can be presented as follows:

1. The ability of human resources in terms of creativity and productivity, performance orientation, Cooperation, as well as commitment and discipline to developing INA-CBT is in the very good category.
2. The BRIN RCE has human resources capable of innovating, deepening value-added processes, and updating production processes. This high level of human resource expertise has been proven in developing INA-CBT, which has reached its 3rd generation, as well as showing that the BRIN RCE is the leader in CBT technology nationally.

The technology component that contributes the second highest to developing INA-CBT is Orgaware of 0.6144. This value shows that the management of RCE can manage its resources, produce innovative works needed to detect the occurrence of a tsunami disaster and adapt to various external and internal organizational change demands.

Next is Technoware, with a contribution value of 0.6111 to developing INA-CBT. It states that the available technological facilities are sufficient to conduct the development process, starting from the desktop study, survey, engineering design, model making, and testing.

The technology component with the lowest contribution value is Infoware, with a value of 0.4962. it shows that the availability of Infoware is still limited and inadequate in providing development support, especially at the engineering design and simulation stages for the design of communication and power electronics on the INA-CBT Ocean Bottom Unit (OBU) component. Although the Infoware SOTA value of 0.7333 is still in the good category, this lowest value in technology contribution indicates that certain conditions of Infoware still require improvement, primarily to support the smooth development of INA-CBT. For example, they were increasing online information about the organization in an up-to-date manner that internal and external institutions can access. Then the organization needs to carry out or strengthen the management of knowledge in a structured manner through the Knowledge Management System so that all knowledge, skills, and experience of the human resources of BRIN RCE can be accessed by all employees. In developing INA-CBT, it is necessary to improve the quality of application programs to achieve a superior level of mastery of engineering design and produce products according to the specifications.

In principle, the role of Humanware supported by Infoware is to make Technoware more productive. Therefore, Infoware must be updated regularly in line with the rapid development of science and technology. If not done, then properly selecting and using Technoware will be difficult to do.

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Table 7. Calculation of technology contribution values

Technology Component	Lower Level	Upper Level	State-of-the-Art (SOTA)	Contribution Values
Technoware	4	6	0.7500	0.6111
Humanware	4	6	0.7750	0.6167
Infoware	3	5	0.7333	0.4962
Orgaware	4	6	0.7625	0.6144

3.1.5. *Calculation of the intensity value (β) of technology components*

The calculation of contribution intensity values (β) of technology components is based on the assessment of selected experts from BRIN RCE on the level of importance of technology components using AHP pairwise comparison matrix method. The instruments used to obtain information are questionnaires and interviews. The level of importance is needed in determining the priority of developing technology components in the future. Based on the results of data processing questionnaires and interviews using the AHP method, values of the contribution intensity of 4 (four) technology components can be seen in Table 8.

Table 8. Result of calculation of the intensity value of technology component contribution

Technology Component	Contribution Intensity Values
Technoware	0.345
Humanware	0.155
Infoware	0.447
Orgaware	0.053

Consistency Ratio: 0.04

The result of the calculation of the intensity values of technology components contribution in Table 8 shows that Infoware and Technoware are the technology components with the highest intensity values of 0.447 (I) and 0.345 (T), followed by Humanware and Orgaware components of 0.155 (H) and 0.053 (O). Sequentially, the value of the contribution intensity of each component is $\beta_I > \beta_T > \beta_H > \beta_O$. The AHP pairwise comparison matrix calculates the consistency ratio (CR) based on the principal eigenvalue, consistency index and the division of consistency index with random index. From those calculations, a CR value of 0.04 is obtained, indicating that the assessment of level of importance carried out by selected experts has been consistent because the CR value is < 0.1. The Fig. 1 presents an overview of these two values.

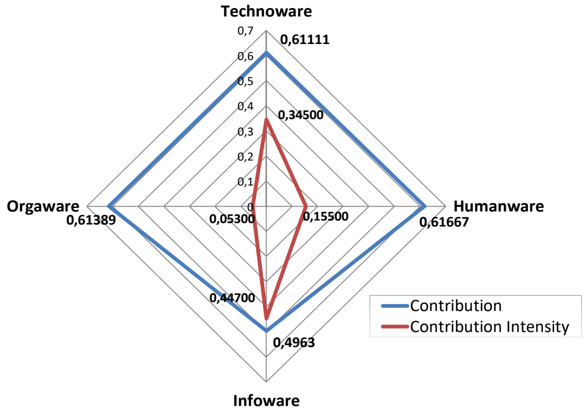

Fig. 1. Radar chart of technology contribution and technology contribution intensity

Fig. 1 shows that the Humanware and Infoware components have the highest and lowest values in the technology contribution values. In this case, Infoware is recommended as a technology component that needs to be improved. Furthermore, based on the opinion of experts at the RCE, Infoware components have the highest contribution intensity value. Therefore, Infoware is the most important component that needs management attention to be developed. Enhancement and improvement of Infoware is the key to improving the quality and accuracy of the INA-CBT development process, especially at the engineering design and simulation stages. Fig. 1 also shows that the Humanware component supported by highly qualified human resources is the main driver in developing INA-CBT.

3.1.6. *Calculation of the technology contribution coefficient value (TCC)*

The result of the technology contribution coefficient (TCC) calculation in Table 9 is 0.55. Referring to Table 3, this TCC value is in the range of 0.50<TCC≤ 0.70. Therefore, qualitatively, the technological level status of the RCE has reached a "Good" classification, and the type of technology is semi-modern.

Table 9. TCC Calculation Results

Technology Component (1)	Contribution Values (2)	Contribution Intensity Values (3)	(2)^(3) (4)	TCC (5)
Technoware	0.6111	0.345	0.8437	0.55
Humanware	0.6167	0.155	0.9278	
Infoware	0.4963	0.447	0.7311	
Orgaware	0.6144	0.053	0.9745	

The low value of Info ware's contribution of 0.4963 compared to other technology components can be caused by the following:

1. Currently, there is no good data documentation system. The reasons are due to the large volume of work at several stages (such as testing) that must be carried out by INA-CBT development personnel; sometimes, some work details are not well-documented. Apart from that, there is still a lack of good habits for documenting every activity.
2. The engineering design and simulation process runs slowly without support from application and information systems tools.

The situation concerning the absence of SOPs and Guidelines to support operational activities is due to the following:

1. Daily operations are more based on previous habits carried out without being accompanied by technical guidance documents to understand and know the machine's and equipment's working history.
2. Every operational activity related to technical work is only communicated verbally.

All technology components contribute to the acquisition of TCC scores. With the technology level status being classified as "Good" and the type of technology being at the semi-modern level, the management of the BRIN RCE has the opportunity as well as resources to enhance and strengthen the capacity and quality of Technoware, Humanware, Infoware, and Orgaware components to improve quality, accuracy, and efficiency of the INA-CBT development process, especially in the survey and engineering design stages. A review of the lower limit value of the technological component sophistication needs to be carried out. Furthermore, the value of the upper limit of technological sophistication and state-of-the-art also needs to be increased so that the value of the technology component contribution will improve the value of TCC.

3.2. Determination of priority for THIO improvement using the AHP method

Priority determination of technology component development is carried out based on the relevance of objectives, criteria, and alternatives and is arranged in the AHP hierarchical structure (Fig. 2). The criteria set under the objectives of prioritizing THIO improvement in INA-CBT development are:

1. Creation of Technology & Innovation. This is an effort to produce new products and improve the quality of the development and production stages with an emphasis on mastering capabilities in technological research and innovation.
2. Cooperation. It is an effort to realize the concept of an innovation ecosystem to improve performance and output. For this reason, relevant stakeholders need to collaborate to support the development process.
3. Financing is mobilizing financial resources to fund or procure certain goods/assets/services.
4. The urgency of need. It is a time-based criterion, immediate and absolute for the organization, so it needs to be done quickly because it will affect operational performance.

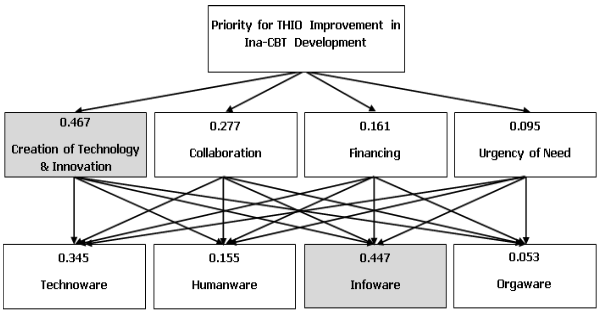

Fig. 2. Structure of THIO development priority

3.2.1. *Priority determination of criteria*

The weighting of each criterion indicates that the Creation of Technology & Innovation criteria is the first priority, Collaboration is the second

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priority, Financing is the third priority, and the Urgency of Need is the fourth priority. The Consistency Ratio (CR) value obtained is 0.04, so the importance level weighting based on interviews and questionnaires to experts has been consistent because CR < 0.1. Therefore, considering the Creation of Technology & Innovation criteria becomes the main determinant for selecting priority technology components to be improved in developing INA-CBT. In addition, the Cooperation criteria are the following determinant for selecting technology component priorities. The priority order of criteria is under the characteristics of INA-CBT development. The activity is a technological engineering process involving various scientific disciplines, such as electronics, mechanics, materials, coastal and marine dynamics, and technology policy. For example: To obtain a suitable submarine cable route under the characteristics of the seabed, a survey of submarine cable routes is needed so that the deployment and maintenance of fiber optic cables can be carried out safely. Another example is the placement of sensors and electronic devices that require competence related to suitable materials for the devices to be used as containers.

Cooperation and Collaboration in disaster technology development such as INA-CBT are increasingly needed in the future because monitoring for various events or threats in the ocean is very difficult and expensive, so there are weaknesses related to the data needed to model, understand, and deal with these threats. One solution to this problem is integrating electronic sensors into the underwater telecommunications cable network so that collaboration between disaster management institutions and telecommunications companies is needed [36].

3.2.2. *Priority determination of alternatives*

The use of the AHP method to synthesize data based on the consideration of all criteria shows that the order of priority of alternative technology components that need to be improved based on the Creation of Technology & Innovation criteria in the development of INA-CBT is: the first priority is Infoware with a weight of 0.447, the second priority is Technoware with a weight of 0.345, the third priority is Humanware with a weight of 0.155 and the fourth priority is Orgaware with a weight of 0.053. The CR value is 0.04, so the assessment of the level of importance made to experts has been consistent because CR ≤ 0.1. Based on these contribution intensity values, Infoware is the technology component with the highest priority, so it must be a concern of the management of BRIN RCE to be improved.

The improvement of quality and completeness of Infoware should positively impact the INA-CBT development process. For this component, the improvement needed is to increase the capacity of engineering design and simulation by adding (i) application programs for thermal and systems simulation, design and simulation of electronics, communication and power devices, design and simulation of submarine cables, and system reliability analysis; (ii) preparation of SOPs under the current flow of the INA-CBT development process; (iii) implementation of SOPs including documentation of activity results that must be complied with and implemented by all personnel involved. The availability of Infoware can provide new solutions to many problems that occur throughout the development process [37].

In addition, strengthening the Humanware and Orgaware also needs to be done because all types of Technoware (equipment, machinery, and infrastructure) require specific human resource capabilities (Humanware) for Technoware can be operated properly and correctly. Humanware needs adaptability and self-motivation to increase the ability and effectiveness of Technoware. On the other hand, the management and organizational framework or Orgaware must evolve continually to meet the requirements of the application of disaster technology in various activities such as development, monitoring, processing, analysis, preparation, and dissemination of early tsunami warnings. The theoretical implication of this research is empirical evidence of the Technometric Model to provide an overview of the technology content analysis in the current development of INA-CBT.

3.2.3. *Contribution of research results*

The use of the Technometric Model has been carried out in the implementation of technology content assessment in the overall INA-CBT G3 development activities to obtain the combined contribution of the four technological components in the process of transforming inputs into outputs. The contribution value of the technology component is used as recommendations to the management of BRIN RCE for managing large-scale activities.

The Humanware and Orgaware components significantly influence Collaboration between stakeholders, namely other work units within BRIN, Industry, Central Government and Regional Governments, where each stakeholder has specific competency advantages. This collaboration is able to encourage the Creation of Technology and Innovation, which has an impact on improving the quality of the system design of INA-CBT G3 compared to the previous generation.

The advantages obtained by the management of RCE from the research results related to the development of the INA-CBT G3 are knowing the role of technological components involved; knowing the magnitude of the contribution of each technology component; knowing the value of the gap in each existing technology component compared to the state of the art technology and knowing the technology components that need to be prioritized in increasing technology contribution. However, using a Technometric Model requires primary data collection and interviews as well as in-depth discussion with the research object so that it will impact the large size of labour and research costs.

4. CONCLUSION

The INA-CBT technology development has undergone several processes, from desktop studies, surveys, engineering designs, trials, and tests. All these stages have involved various parties who contribute according to their fields. From the calculation, the order of priority for the selected technology development criteria is Knowledge/Technology, Collaboration, Funding, and Urgency. The sequence states that the Knowledge/Technology criteria are the aspect with the highest priority because the technology components consisting of Technoware, Humanware, Infoware, and Orgaware need to be owned and controlled by the BRIN RCE to be able to realize the Ina-CBT development process. The lowest contribution value of the technology component was Infoware (0.49630), and the highest was Humanware (0.61667), while Orgaware was in second place (0.61389), followed by Technoware (0.61111) in third place. From these results, it can be seen that Humanware and Orgaware played an important role in developing the INA-CBT. Potentials such as good human resources, organizational structure, leadership, Cooperation between work units, and adaptive attitudes within the organization must be maintained and developed. Apart from that, the Technoware components also get quite high technology contribution values. It is due to the complexity of the technology used, and the facilities used are also quite qualified to support the development process being carried out.

The core of the transformation in developing INA-CBT is the existence of Technoware, where Humanware is the component that develops, installs, and operates Technoware so that without Humanware, Technoware components will be useless. In this case, Humanware makes Technoware productive. Improving Technoware requires higher Infoware and Humanware as well. On the other hand, the development and enrichment of Infoware by Humanware impact the optimal utilization rate of Technoware. The existence of qualified Humanware, good Cooperation, and direct leadership can boost the capabilities of Orgaware, Technoware, and Infoware.

In the future, a similar analysis will be carried out by comparing BRIN with other countries to identify what optimizations must be carried out to obtain maximum results in developing INA-CBT technology, which is relatively new for Indonesia.

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