**International Journal of Electrical and Computer Engineering (IJECE)**
Vol. 15, No. 1, February 2025, pp. 129~145
ISSN: 2088-8708, DOI: 10.11591/ijece.v15i1.pp129-145 

# Technology performance of Indonesia tsunami early warning system: technometric approach

**Satrio Utomo, Gani Soehadi, Budi Setiadi Sadikin, Jaizuluddin Mahmud, Irawan Santoso, Hardono, Fitriana Tiolita, Helen Fifianny**
Research Center for Process and Manufacturing Industry Technology, National Research and Innovation Agency (BRIN), Jakarta, Indonesia

**Article Info**

***Article history:***

Received May 28, 2024
Revised Sep 13, 2024
Accepted Oct 1, 2024

***Keywords:***

Analytical hierarchy process
Early warning system
Technology innovation
Technology components
Infoware

**ABSTRACT**

Indonesia tsunami early warning system (Ina TEWS) is used for detecting earthquakes and tsunamis. The system currently is still under development and the government really needs information regarding the technological capabilities of the system in order to provide protection to the community from the threat of tsunamis and earthquakes. To produce the system and its components on an industrial scale, it is important to assess the extent of performance and readiness for technological development. The assessment used the technometric method which groups technological components into technoware, humanware, infoware, and orgaware, integrated with analytic hierarchy process. The results showed that the highest technology component contribution is technoware, and the lowest is infoware. Based on the magnitude of the contribution of technology components and intensity of technology, the priority order is technoware, humanware, orgaware, and infoware. The technology contribution coefficient is 0.522 (Good). The technology level is semi modern. Infoware is the lowest technological component, therefore improvement efforts are needed, namely structuring an integrated document system and improving standard operating procedures for manufacturing operational activities, especially in the testing and data validation.



***Corresponding Author:***

Satrio Utomo
Research Center for Process and Manufacturing Industry Technology, National Research and Innovation Agency (BRIN)
Jakarta, Indonesia
Email: satr003@brin.go.id and satrioutomo2030@gmail.com

## 1. INTRODUCTION

Indonesia's geographical location in the Southeast Asia region is very vulnerable to earthquakes and tsunamis because it is on three tectonic layers, namely: Indo-Australia, Eurasia, and the Pacific. Indonesia's territory is also surrounded by the Indian Ocean and the Pacific Ocean, and also has many active volcanoes. The occurrence of an underwater earthquake due to the movement of those tectonic layers has the potential to cause tsunamis. In Indonesia, there was a very powerful earthquake measuring 9.3 on the Richter scale in Aceh province in December 2004 which was caused by seismic activity in the Indian Ocean [1]. In September 2018, there was another large earthquake measuring 7.4 on the Richter scale which triggered a tsunami and liquefaction in the cities of Palu and Donggala, in Central Sulawesi Province [2]. In December 2018, Mount Krakatoa erupted, triggering tsunami waves in the Sunda Strait [3].

The extraordinary natural disasters result in loss of life, environmental and infrastructure damage, and psychological impacts. This is very urgent for the Indonesian government to build an early warning system to detect earthquakes and tsunamis. Therefore, a thorough emergency planning policy is needed to deal with various threats of natural disasters and emergencies such as earthquakes, volcanic eruptions and tsunami [4].

This government policy is strengthened through Presidential Regulation no. 93 of the year 2019 concerning the strengthening and development of earthquake and tsunami early warning information systems to build a tsunami early detection system as well as placing equipment between estimated tsunami sources and coastal communities that are vulnerable to being affected by tsunamis [5]. The agency for the assessment and application of technology (BPPT) was appointed to develop a tsunami early warning system next called Indonesia tsunami early warning system (Ina TEWS) [6]. Now, BPPT is one of the research institutions that has been merged into a research organization under the National Research and Innovation Agency (BRIN). Ina TEWS is Indonesia's early warning system for detecting earthquakes and tsunamis [7]. In 2019, a pilot project system trial was conducted to see the product quality test and ensure its function meets standards at four points, including Bali, Malang, Cilacap, and the Sunda Strait.

The Ina TEWS system combines satellite and terrestrial communication networks, to support real-time data communication between the control center and warning sirens. There are three types of Ina TEWS technology, including: Ina Buoy, Ina cable based tsunameter (Ina CBT) and Ina coastal acoustic tomography (Ina CAT) [8]. Ina CBT is a tsunami detection technology based on submarine cables equipped with sensors to measure extreme changes in sea pressure, which indicate tsunamis. The sensor will then send data via satellite to the tsunami monitoring center. The process of making Ina CBT facilities requires a very expensive investment compared to Buoy. Due to urgent needs, Buoy-based Ina TEWS is a more feasible choice to be built in the short term while preparing to develop a cable-based tsunami early detection system at the next stage. Ina TEWS consists of two parts, namely the surface Buoy and ocean bottom unit (OBU) [9]. The OBU component is tasked with detecting changes in water pressure during a tsunami through pressure sensor technology. This equipment is installed near the estimated potential tsunami sources in the middle of the sea, so that when a tsunami occurs, it can be identified quickly. Shortly after detecting a potential tsunami, indicated by a sudden change in seawater pressure, the sensor will send data notifications as an early warning sign via the underwater acoustic modem to the Buoy, which floats above the sea surface [10]. The Buoy component also detects and measures conditions for changes in sea level rise and fall that can potentially cause a tsunami. Next, Buoy immediately sends data from the OBU via satellite communication to the read down station (RDS) tsunami monitoring control center. The analysis results from monitoring on the seabed are immediately sent to the decision support system (DSS) at Meteorological, Climatological, and Geophysical Agency (BMKG). This DSS system will integrate all monitoring data and information originating from system devices such as buoys, seismographs, tide gauges, global position system (GPS), and also simulation systems from tsunami databases and geospatial data [11]. If the data has the potential to cause a tsunami, then BMKG will issue tsunami warning information to the public. BMKG is the focal point tasked with coordinating the handling of earthquake and tsunami disasters [12].

The development of early warning systems currently adopts various technological advances including artificial intelligence (AI), machine learning (ML), internet of things (IoT), GPS sensors to accelerate data transmission and detect risks if damage occurs [13]. In the industrial era 4.0, a part from being a tsunami monitoring and observation system, Ina TEWS can be used more widely such as navigation, telecommunications facilities and meteorological monitoring. The development of Ina TEWS technology design based on science and research is adjusted to the character of earthquakes and tsunamis and geographical conditions in Indonesia.

In addition to Indonesia, Japan is also a country prone to earthquakes and tsunamis. Japan has implemented a better system and has succeeded in developing sophisticated earthquake early warning (EEW) technology [14]. This EEW technology is able to detect early vibrations generated by earthquakes, conduct rapid analysis, and send earthquake warning information in a short time of less than 20 seconds. During this period, the community is expected to be able to take evacuation measures or protect themselves, which ultimately minimizes the risk of damage and loss of life. Meanwhile, Ina TEWS technology is still not as fast as EEW information because it is still constrained by many technical matters such as the availability of infrastructure technology, semiconductors, sensor technology, and finance. However, the development of Ina TEWS continues to be carried out to meet important needs as a tsunami disaster mitigation program in Indonesia. Improvement of technology with a shorter detection flow is a priority and needs to be taken seriously in addition to implementing mitigation and socialization regarding Indonesia's earthquake-prone conditions.

Currently, Ina TEWS is in the research development stage on a pilot plant scale. In the product development stage, there is a process of design maturity and control of the industrial manufacturing process. To support the production process and mechanical design development, the most essential component needs such as batteries, global position system, acoustic modem, transducer, bottom pressure recorder and other supports still depend on imports obtained from a foreign supplier because there is no domestic electronics industry capable of meeting these needs [15]. Ina TEWS technology includes high technology and high capital. This has an impact on low manufactured local content levels and low industrial competitiveness.

The potential need for Ina TEWS is quite urgent in supporting Indonesia's tsunami disaster mitigation program [16]. The Government of Indonesia really needs information regarding the technological capabilities and performance of the system in order to provide protection to the community from the threat of tsunamis and earthquakes. For this reason, Ina TEWS needs to be analyzed in order to be able to move towards the product development stage with achievements directed at the industrial production scale. As an effort to encourage industrialization of domestic production, it is necessary to identify, observe, and measure the extent of readiness for technological development.

For this reason, research is needed that can explain and assess technology and things that need to be prioritized immediately to support future technological progress, such as product quality related to durability tests and risk of damage, facility and infrastructure needs, human resource capabilities, availability of data and information; so that it becomes a collection of scientific data as a guide and a critical stage in the process of transferring cutting-edge technology. The results of the recommendations become strategic planning direction to determine development steps through better utilization of Ina TEWS technology and updating technology management, operations management, and technology-based human resources management. It is expected that the proper use of technology can optimize the potential of domestic industry to help accelerate the growth of the manufacturing sector and increase its competitiveness.

This article is structured as follows: section 1 presents the introduction. Section 2 explains the series of performance assessments of technology components using the technometric method which includes the degree of sophistication, state of the art of technology, and contribution of technology components. The intensity values of technological components are determined using the analytical hierarchy process (AHP) approach, serving as a basis for additional calculations to obtain technology contribution coefficient (TCC) values. Section 3 presents the application of a combination of technometric and AHP methods to determine the level or status of the TCC value. Finally, Section 4 presents the overall conclusions and recommendations for improving the development of Ina TEWS.

## 2. METHOD

The application of technology is an important element in efforts to improve industrial performance so that it can develop and compete. One way to discover technological capabilities is to understand the performance of the technology. Technological performance can be enhanced by improving the performance of each technological component. Performance analysis includes identifying factors that can encourage or hinder performance and then recommending innovations based on the problems.

To determine the degree of technological content, it is therefore required to conduct both qualitative and quantitative examination, analyzing and mapping the extent of technological strengths and weaknesses using an integration approach of two methods: technometric (THIO) and AHP. The technometric method was developed by The United Nations Economic and Social Commission for Asia and the Pacific (UN-ESCAP) [17]. Technometric or THIO is used to measure the combined contribution of the four components of technology: technoware, humanware, infoware, and orgaware [18]. The combination of technology components determines the results of technology performance [19].

The form of integration of the four components of technology is that the development and control of technoware is carried out by humanware based on data and information sources from infoware. Meanwhile, the relationship between the three components is regulated and controlled by orgaware. The combination relationship between technology components is presented in Figure 1.

Technoware is technical devices or production equipment includes equipment, supplies, machines, capital and other physical infrastructure. Humanware is production resources from the workforce includes abilities, education, skills, policies, creativity, knowledge and expertise in managing and utilizing technology. Infoware is information or documentation related to procedures, techniques, methods, product design specifications, observations, and relationships. Orgaware is the organizational and regulatory tools needed to reward experts panel, human resource capabilities, and information devices that includes management practices, linkages and organizational arrangements [20]. The value of technological sophistication and the state of the art in four different technology components is determined using qualitative data. Technometric model equations are utilized to derive the contribution value of technical components from quantitative data. Meanwhile, the contribution intensity value of technology components is measured using the AHP method. AHP is a decision-making model to help formulate a priority from various options using several criteria or multi criteria. The selection of priorities is done with a logical and structured procedure. The AHP method relies on the opinions of experts with strategic roles and deep knowledge of the research field for determining technology component development priorities can be known [21].

Primary and secondary data collection methods are done by direct field observation to validate the data, discussions and interviews with experts panel (head of project, chief engineer, program manager, group leaders, leaders, and engineers). Meanwhile, the AHP questionnaire instrument was used to collect data on the intensity of the contribution of technological components. In addition, this process is also supported by obtaining secondary data from internal documents, literature such as books, journals, research reports, and government policies related to disaster mitigation and disaster technology in Indonesia.

The novelty of this study is the integration of two methodologies and data analysis, namely technometrics and AHP to assess the development of Ina TEWS technology which is expected to obtain a priority list of technology components that can be improved. In addition, the results of the mapping of the identification of strengths and weaknesses related to the product and process can be used as an initial reference in evaluating and improving the device and as a basis for policy making for stakeholders in this case the government as a regulator and facilitator. There are five stages in assessing technology performance as shown in Figure 2, namely [22]: i) Estimating of the level of sophistication of technological components (degree of sophistication), ii) Determining state of the art of technological components (state of the art), iii) Determining the contribution of technological components (contribution of technological component), iv) Determining the intensity of component contribution (intensity of importance), and v) Determining the technology contribution coefficient (technology contribution coefficient).

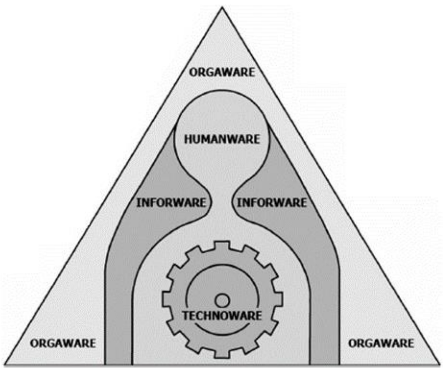



Figure 1. The component of technology

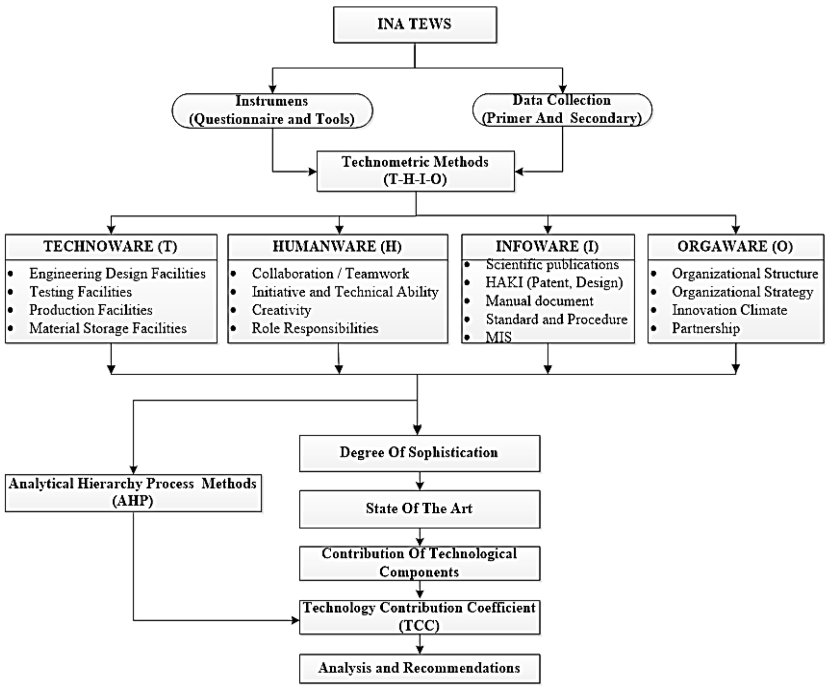



Figure 2. Flowchart for assessing the contribution of technology components

### 2.1. Degree of sophistication

To assess the estimated level of technological sophistication, UN-ESCAP has established a table that can be used as a reference for the criteria for determining the lower limit (LL) and upper limit (UL), shown in Table 1. LL is the minimum level required, and UL is the maximum possible level for the technology component [23]. The level of technological components is measured using a qualitative assessment range (score 1-9). These values are used to determine the contribution value of each technological component.

Table 1. Degree of sophistication of technological components

| Level of sophistication | | | | Lower | Middle | Upper |
|---|---|---|---|---|---|---|
| Technoware | Humanware | Infoware | Orgaware | limit (LL) | limit | limit (UL) |
| Manual facilities | Operating abilities | Familianzing facts | Striving framework | 1 | 2 | 3 |
| Power facilities | Setting-up abilities | Describing facts | Tie-up framework | 2 | 3 | 4 |
| General purpose facilities | Repairing abilities | Specifying fact | Venturing frameworks | 3 | 4 | 5 |
| Special purpose facilities | Reproducing abilities | Utilizing facts | Protecting framework | 4 | 5 | 6 |
| Automatic facilities | Adaptation abilities | Comprehending facts | Stabling frameworks | 5 | 6 | 7 |
| Computerized facilities | Improving abilities | Generalizing facts | Prospecting framework | 6 | 7 | 8 |
| Integrated facilities | Innovation abilities | Assessing facts | Leading frameworks | 7 | 8 | 9 |

### 2.2. State of the art

State of the art assesses the complexity level of each technology component [24]. This evaluation requires in-deep understanding of the technical aspects of performance specifications and input from technicians and specialists familiar with operational aspects. Determination of value is based on the results of identifying conditions in the field and interviews. State of the art is a description of the company's current condition based on a reference score from the criteria provided. The state-of-the-art assessment is as (1):

$$S = \frac{1}{10}\left[\frac{\Sigma_k t_{ik}}{k_t}\right]; k = 1, 2, 3, \ldots, kt \quad (1)$$

where, $S$ is state of the art, $t_{ik}$ is criterion value of the $k$ technology component, and $k_t$ is number of technology component criteria variables. The questionnaire is based on UN-ESCAP to assess each technology component through its operational activities. State of the art assessment starts by determining assessment indicators, where each indicator is given a scale range (0-10), where 0 (0) is the minimum and 10 is the maximum specification. If the assessment is not stated in the reference, then we interpolate the upper and lower values.

### 2.3. The contribution of technological components

The contribution of technological components uses Values derived from evaluating the level of sophistication and State of the Art ranking are used to calculate the contribution of technological components [25]. By providing a value contribution to each technology component, it will help organizations obtain an overview of existing technology. To obtain the contribution value of technology components, the formula is used:

$$T = 1/9[LT + ST(UT - LT)] \quad (2)$$

$$H = 1/9[LH + SH(UH - LH)] \quad (3)$$

$$I = 1/9[LI + SI(UI - LI)] \quad (4)$$

$$O = 1/9[LO + SO(UO - LO)] \quad (5)$$

where, $LT, LH, LI, LO =$ Lower limit of technology components $(T, H, I, O)$; $UT, UH, UI, UO =$ Upper limit of technology components $(T, H, I, O)$; and $ST, SH, SI, S0 =$ State of the art technology components $(T, H, I, O)$.

### 2.4. Determining the intensity of component contribution (β)

The contribution intensity of the technological component (β) determines the scale of importance for obtaining priority as an effort to increase technological capabilities. This data is processed using expert choice software, a decision support system application that helps in making decisions based on multiple criteria and evaluates alternatives using the AHP method [26]. With expert choice, hierarchical diagram results and the weighting values of the criteria will be obtained. The priority of each technology component is selected by considering the weight of the criteria and alternatives and adjusting them to the goals and interests the organization had to achieve [27]. The preference scale used is a scale of one which indicates the lowest level or equally importance to a scale of nine which indicates the highest level or extremely importance.

### 2.5. Technology contribution coefficient

Technology contribution coefficient (TCC) is a method that aims to measure the contribution of four technological components: technoware, humanware, infoware, and orgaware. The TCC result is the sum of the multiplication of intensity and contribution to each technology component [28]. TCC values can be categorized based on qualitative assessment of TCC interval and technology level presented in Table 2.

$$TCC = T^{\beta t} \times H^{\beta h} \times I^{\beta i} \times O^{\beta o} \tag{6}$$

where $TCC$ is technology contribution coefficient; $T, H, I, O$ is contribution of technological components; and $\beta t, \beta h, \beta i, \beta o$ is contribution intensity of technology components. The TCC value illustrates the magnitude of contribution of technology in creating added value in an industry. The TCC value is in the range of 0.0-1.0. The results of the analysis can be used to make recommendations to determine better strategies for improving Ina TEWS technology in the future.

Table 2. TCC's level of technology

| TCC | Classification | Technology level |
|---|---|---|
| 0.0 < TCC ≤ 0.1 | Very low | Traditional |
| 0.1 < TCC ≤ 0.3 | Low | |
| 0.3 < TCC ≤ 0.5 | Moderate | Semi modern |
| 0.5 < TCC ≤ 0.7 | Good | |
| 0.7 < TCC ≤ 9.0 | Very good | Modern |
| 0.9 < TCC ≤ 1.0 | Excellent | |

## 3. RESULTS AND DISCUSSION

### 3.1. Degree of sophistication (estimation of technology components sophistication level)

The LL and LL of each technological component are used to calculate the Ina TEWS system's degree of sophistication. Data collection for the level of sophistication of technology components was carried out through qualitative observations, in-depth interviews to collect information relevant to the use of technology. The estimation of each technology component must be determined by the UL and LL. The level of sophistication of each technological component is shown in Table 3. The four-dimensional model as shown in Figure 3 has been developed to describe the level of sophistication of Ina TEWS.

Table 3. Estimation of technology components sophistication level

| Technology component | Information | Level of sophistication | LL | ML | UL |
|---|---|---|---|---|---|
| Technoware | Design and production facilities are already available for the development of Ina TEWS. However, the production facilities are still in the R&D stage and do not yet meet industrialization standards.<br>The lack of a supporting industrial supply chain for raw materials and imports are the reasons for the unpreparedness for mass production.<br>The production process is mainly mechanical. But it is not ready for mass production because there is no supporting industrial supply chain that can prepare raw materials and currently it depends on imports | Special purpose facilities | 4 | 5 | 6 |
| Humanware | Human resources have experience in participating in transfer of technology activities related to the development of Ina TEWS.<br>There are technical advisory activities including technical discussions on the results of modifications and manufacturing designs.<br>Human resources have experience in participating in transfer of technology activities related to the development of Ina TEWS.<br>There are technical advisory activities including technical discussions on the results of modifications and manufacturing designs. | Reproducing abilities | 4 | 5 | 6 |
| Infoware | The work culture currently lacks standardized instructions for various activities from operational stages, maintenance to device handling during production system integration, engineering design, and testing.<br>The information process is still manual, leading to less effective use of company facilities. For monthly demand data there are only production records which are processed manually by engineers. | Specifying fact | 3 | 4 | 5 |
| Orgaware | Management builds communication and partnerships with local industries<br>There is currently no policy to allocate funds for improving product quality. Ina TEWS development still depends on the state revenue and expenditure budget (APBN). | Venturing frameworks | 3 | 4 | 5 |

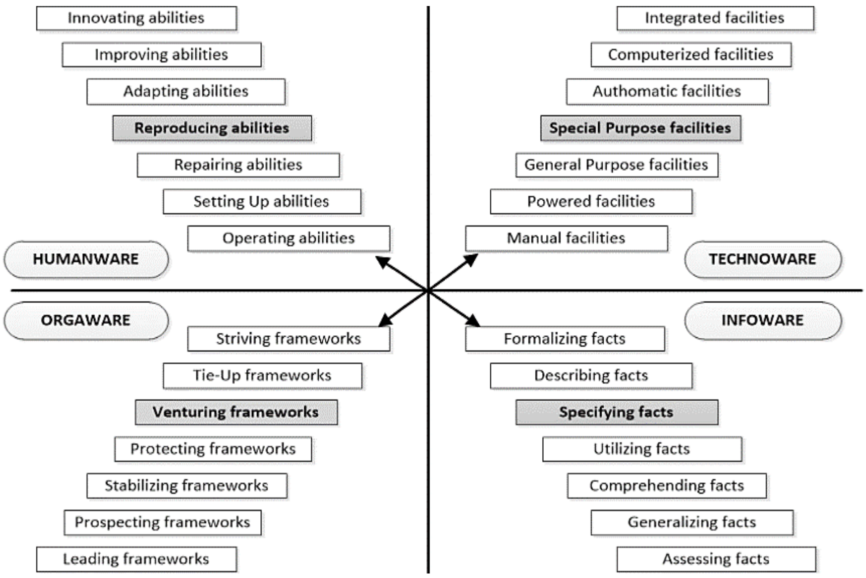



Figure 3. Degrees of sophistication of Ina TEWS in four dimensions

Table 3 and Figure 3 show the approximate position of each technology component. Technoware at the level of special purpose facilities ($LL = 4, UL = 6$) from the highest level (integrated facilities). Humanware at the level of reproducing ability ($LL = 4, UL = 6$) from the highest level (ability to innovate). Infoware at the level of determining facts ($LL = 3, UL = 5$) from the highest level (assessing facts). Orgaware at the level of venturing framework ($LL = 3, UL = 5$) from the highest level (leading frameworks). It can be seen that the higher the level of technological sophistication and the further away from the midpoint, the greater the sophistication of the technological components. If all technological components are enhanced simultaneously, the technology developed will be more sustainable. Based on the in-depth interview with the experts panel, the following section describe degree of sophistication of each technological component.

### 3.1.1. Degree of sophistication of technoware

The sophistication level of technoware components is estimated in the special purpose facilities classification, which is currently only used specifically for equipment in the development of Ina TEWS. The important things to consider in choosing the Special Purpose Facilities classification are:

– Most of the machines in the production unit are still mechanical and have not yet moved towards an automation system.
– Most of the machines in the production unit are still mechanical and have not yet moved towards an automation system. Therefore, control of the machines is still fully carried out by educated and experienced engineers who have high skills in operating machine devices.
– The need for component materials as much as 90% is still in the form of imported components from Wuhan (China) so that technology is still very dependent on supplies from abroad. This is because the supporting industry for domestic component suppliers has not been able to provide the needs of Ina TEWS. For example: when the need for batteries can be provided by the local industry, this will have an impact on the high percentage of domestic component level (TKDN) calculations.
– The technology performance testing process has used modern machine facility equipment such as ultraviolet-visible Spectro photometer for ultraviolet testing, calculating material structure fabrication using computer numerical control (CNC) machines, using universal testing machines to test material strength as well as controlling and testing material structures using radiography or x-ray systems.
– Production and storage facilities for raw materials do not yet use industrial standards. Many of the work processes are still manual because the equipment used is not yet intended for mass production needs.
– Currently, Ina TEWS facilities for production, engineering design, testing, to material storage are only for research development activities, and have not yet reached industry standards. The raw materials used are imported from foreign countries (China and the United State)

### 3.1.2. Degree of sophistication of humanware

The sophistication level of humanware components is estimated in the reproducing abilities classification, namely the ability to manage or reproduce equipment. Engineers are able to manage the devices used so that they can operate more optimally. Although most components are imported from abroad (China and USA), there are no additional devices as a result of modifications or upgrades to existing systems. The important things that are considered in the reproducing abilities classification are:

- The expertise of engineers has reached the level of device setting, component assembling to obtain quality improvements in terms of materials, and device construction to the prototype finishing stage. Engineers also have the ability to conduct quality assessments in the form of checking and testing through standard control of shape, dimensions, and other parameters.
- Engineers have participated in training of trainers (ToT) programs abroad but are not updated regularly. Technical advisory activities include technical discussions on the results of modifications and manufacturing designs of Ina TEWS. Currently, only a few know and master the electrical system and operational system of Ina TEWS.
- The availability of personnel to handle testing is still insufficient, so many engineers are working on various tasks. Therefore, there needs to be a clear division of tasks and responsibilities according to competence, qualifications and experience proven by certification.
- In addition, experts are still needed who are able to provide direction on the design of models and data integration systems so that the minimum level of material inventory required can be estimated more precisely and make the process of ordering resources and implementing supply chain models more efficient.
- The number of human resources in the operational section is partly outsourced. This shortage is caused by the process of transferring personnel between technical work units or those who are on study assignments.
- Professional skills are not yet fully evenly distributed, so there needs to be strengthening of the capabilities of technical personnel before entering industrial-scale work.

#### 3.1.3. Degree of sophistication of infoware

The sophistication level of infoware components is estimated into the specifying fact classification, which means that the work activities carried out by following previous habits without referring to supporting documents as a guide in understanding the history of the machine's work. Engineers have not yet become accustomed to the work culture of having standard instructions, both operational, maintenance to handling related to machinery both during system integration, engineering design, testing, and other activities. the engineering process for the tsunami buoy, including: the electronics and communication system integration section is responsible for integrating the Buoy; the electronics and communication systems engineering section is responsible for handling the design, construction and installation of the electronics and communications system; the power supply engineering section is responsible for handling the design, construction and installation of the power supply system; the electronics system validation section is responsible for handling the testing of the Buoy's electronics system functions; the technology and regulation study section is responsible for handling the study of future technology and regulations.

Based on the assessment results, the infoware aspect is still a supporting component in operational management and has not been a concern for management for the development of Ina TEWS. Therefore, it is necessary to immediately build an integrated information system application to support manufacturing operational activities as the main supporting tool for the system in each sub-organization to determine the results of the organization's performance value itself. One effort to survive and improve product quality is to create good technology management.

#### 3.1.4. Degree of sophistication of orgaware

The sophistication level of orgaware components is estimated to be in the venturing framework classification. Currently, the Ina TEWS production facility is still limited to research activities and has not yet reached industrialization standards. The implementation of mass production is not yet ready to be carried out as an industry in a long production cycle, because there is no supporting industrial supply chain that can prepare raw materials and is currently still very dependent on imported components. In addition, a business partnership has also been built with the PT. PAL (state-owned enterprise industry) to explore the development of the Ina TEWS industry, namely those related to efforts to produce domestically made Buoys. The important things to consider when choosing the Venturing Framework classification are:

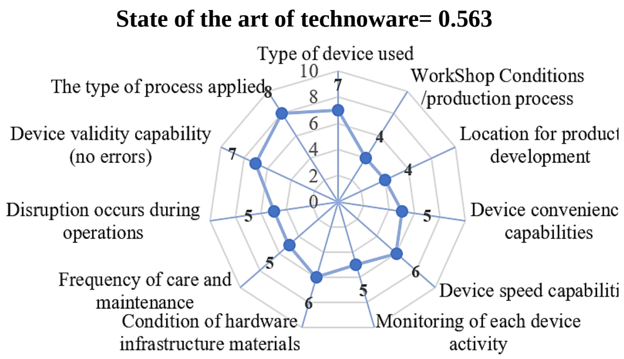
- The organization is already able to make and deploy its own Ina TEWS products, but the organization is not ready to carry out procurement with a long production cycle.
- The organization has not implemented a quality control and quality assurance unit that is responsible for supervising each stage of the process to ensure product quality, product standards, processes, and procedures at each stage.

– Reorganizations often occur so that there are no professional managers who specifically master Ina TEWS products.

## 3.2. State of the art
### 3.2.1. State of the art of technoware

The result of the accumulated criteria in technoware is 62 with a total of 11 criteria, so the state-of-the-art value of technoware is 0.563, as shown in Figure 4. The technoware criteria average assessment is 5.63, indicates that equipment types, machinery, and infrastructure have supported manufacturing engineering activities. There are indicators that need to be considered (<5), namely the physical location for product development, lab conditions or production process units, device capabilities, monitoring of each device activity, frequency of care and maintenance, and operational disruptions at Ina TEWS.

This condition shows that manufacturing development activities are still ineffective. The scattered physical location of equipment is affecting productivity. Procedures for structuring facilities are needed to increase production efficiency and safety, therefore the smooth production process, testing, engineering design, and material storage. Increased supervision, regulation reinforcement, and training can minimize negative potential. The completeness and functionality of machines and equipment are crucial for the manufacturing process. The monitoring schedule and maintenance frequency need improvement. Maintenance plays a vital role in ensuring the smoothness and stability of production activities.




Assessment accumulative totals:

$$(7+4+4+5+6+5+6+5+5+7+7)=62$$

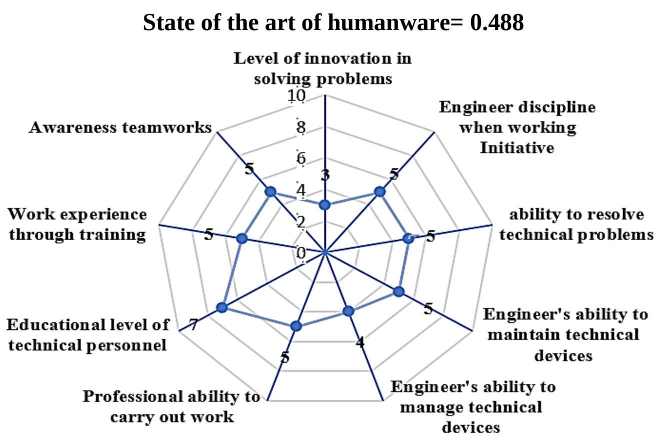
Technoware component criteria = 11
Score average = 62/11 = 5.63
State of the art technoware is:

$$ST_i=\frac{1}{10}\left[\frac{\Sigma_k t_{ik}}{k_t}\right]=\frac{1}{10}\left[\frac{62}{11}\right]=0.563$$

Figure 4. State of the art of technoware

### 3.2.2. State of the art of humanware

The result of the accumulated criteria in humanware is 44 with a total of 9 criteria, so the state-of-the-art value of humanware is 0.488, as shown in Figure 5. The humanware criteria average assessment is 4.88, indicating a need for attention as it is below the average (<5). There is a lack of training, teamwork, managerial, and innovation, especially in design and technology. This is related to the support level of professionalism human resources, creative and innovative especially innovation in design and technology.




Assessment accumulative totals:

$$(3+5+5+5+5+5+7+5+5)=44$$

Humanware component criteria = 9
Score average = 44/9 = 4.88
State of the art humanware is:

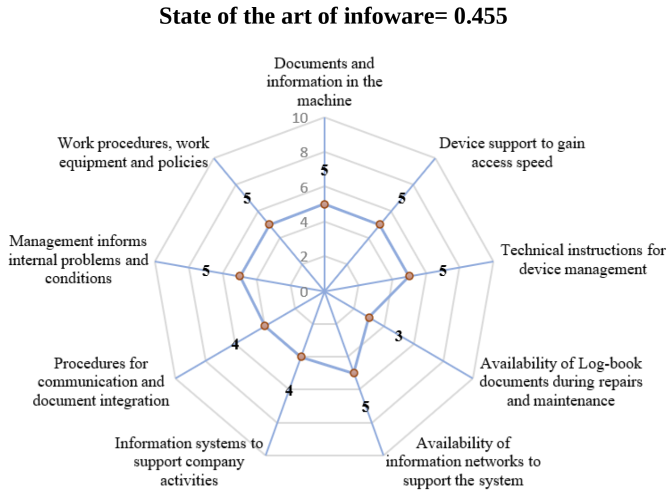
$$SH_i=\frac{1}{10}\left[\frac{\Sigma_k h_{ik}}{k_t}\right]=\frac{1}{10}\left[\frac{44}{91}\right]=0.488$$

Figure 5. State of the art of humanware

For the reason, A comprehensive strategy is needed, including motivation, training, expertise certification, and the sharing of best practices. So, engineers do not just focus on assembling components, but also contribute to moving the product value chain higher. Engineers also think about how to continue operating equipment by prioritizing effectiveness and efficiency in work. Highly competent human resources are one of the factors that increases the productivity of organizational performance.

### 3.2.3. State of the art of infoware

The result of the accumulated criteria in infoware is 41 with a total of 9 criteria, so the state-of-the-art value of infoware is 0.455, as shown in Figure 6. The infoware criteria average assessment is 4.55, indicating a need for attention as it is below the average (<5). Specifically, there is a lack of technical guidance documents for device management, minimal availability of logbooks or technical document notes for improvements, minimal or no integrated information system, and no standard procedures for communication with each technical unit.




Assessment accumulative totals

$$(5+5+5+3+5+4+4+5+5) = 41$$

Infoware component criteria = 9
Score average = 41/9 = 4.55
State of The Art Infoware is:

$$SI_i = \frac{1}{10}\left[\frac{\Sigma_k I_{ik}}{k_t}\right] = \frac{1}{10}\left[\frac{41}{9}\right] = 0.455$$

Figure 6. State of the art of infoware

To improve information services, a strategic decision-making policy must be implemented and use the information system outlined in the strategic plan. This allows for continuous monitoring, assessment, and evaluation. The focus is on equipment, consumables, spare parts, workshop tools, and equipment supplies. The documentation logbook serves as a tool for periodic performance assessment, covering processes, activities, and constraints like cost requirements. It helps identify potential problems. Additionally, it facilitates quick dissemination of information from management to all employees, including efforts to achieve the company's vision and mission.

### 3.2.4. State of the art of orgaware

The result of the accumulated criteria in orgaware is 38 with a total of 8 criteria, so the state-of-the-art value of orgaware is 0.475, as shown in Figure 7. The orgaware criteria average assessment is 4.75, indicating a need for attention as it is below the average (<5) namely the organization's ability to adapt to a changing business environment and according to external demands. Also, the organization's ability to receive support from outside resources. This shows that there is still a lack of effort to adapt to the business environment and external demands of the organization. The organization should focus on adapting to a changing business environment and external demands, as well as receiving support from external resources.

Management is working to maintain a conducive organizational climate for improvement and increased productivity. It is important to maintain good partnerships with suppliers, businesses, academics, and government regulators to inspire creative and innovative ideas. Additionally, the organization needs to provide the right equipment and support to engineers for expressing creative ideas in the form of innovative behavior.


Assessment accumulative totals:

$$(5+3+5+5+5+5+3+7)=38$$

Orgaware component criteria = 8
Score average = $38/8 = 4.75$
State of The Art Orgaware is:

$$SO_i = \frac{1}{10}\left[\frac{\Sigma_k O_{ik}}{k_t}\right] = \frac{1}{10}\left[\frac{38}{8}\right] = 0.475$$

Figure 7. State of the art of orgaware

### 3.3. The contribution of technological components

The purpose of determining the contribution of technology components is to find out how much each technology component contributes. The calculations are presented as:

- Technoware contribution: $T = 1/9[4 + 0.563(6 - 4)] = 0.569$
- Humanware contribution: $H = 1/9[4 + 0.488(6 - 4)] = 0.552$
- Infoware contribution: $I = 1/9[3 + 0.455(5 - 3)] = 0.432$
- Orgaware contribution: $O = 1/9[3 + 0.475(5 - 3)] = 0.439$

Table 4 presents the results of assessing the contribution of technology components. It can be seen that the highest contribution of technology components is technoware, and the lowest is infoware. The technoware (T=0.569), followed by the humanware (H=0.552), and the orgaware (O=0.439), and the lowest is the infoware (I=0.432). According to the priority order, the contribution value of the technology components is: (T>H>O>I).

Table 4. Determination of the contribution of technological components

| Technology component | Sophistication level | Lower limit (LL) | Upper limit (UL) | State of the art | Contribution |
|---|---|---|---|---|---|
| Technoware (T) | Special purpose facilities | 4 | 6 | 0.563 | 0.569 |
| Humanware (H) | Reproducing abilities | 4 | 6 | 0.488 | 0.552 |
| Infoware (I) | Specifying fact framework | 3 | 5 | 0.455 | 0.432 |
| Orgaware (O) | Venturing framework | 3 | 5 | 0.475 | 0.439 |

### 3.4. Intensity of technology components contribution (β)

The organization uses the AHP method and expert choice to determine priorities and improve product quality by creating a hierarchical structure to simplify decision-making and using expert choice to assist in making decisions with multiple criteria. There are seven criteria that influence technology development: research and development (R&D), financial, raw materials, policies and regulations, technology transfer, industrial partnerships, and innovation and industrial design. These criteria are used to evaluate alternatives based on four aspects of technology components: technoware, humanware, infoware, and orgaware. The next step involves creating a pairwise comparison matrix to determine the relative weights between criteria and alternatives. This is done by comparing the importance of elements to each other based on the judgment of the decision maker as shown in Table 5.

Table 5. Weighted criteria matrix

| Criteria | Regulatory | Financial | Raw material | Innovation and industrial design | Industry partnership | R&D | Technology transfer |
|---|---|---|---|---|---|---|---|
| Regulatory | 1 | 1/5 | 1/7 | 1/5 | 3 | 1/5 | 5 |
| Financial | 5 | 1 | 1/3 | 5 | 3 | 5 | 3 |
| Raw material | 7 | 3 | 1 | 2 | 3 | 5 | 5 |
| Innovation and industrial design | 5 | 1/5 | 1/2 | 1 | 3 | 3 | 5 |
| Industry partnership | 1/3 | 1/3 | 1/3 | 1/3 | 1 | 3 | 3 |
| R&D | 5 | 1/5 | 1/5 | 1/3 | 1/3 | 1 | 1/3 |
| Technology transfer | 1/5 | 1/3 | 1/5 | 1/5 | 1/3 | 3 | 1 |

With expert choice software, the process of weighting criteria on technology components can be automatically calculated. The results in Figure 8 show that the criteria for availability of raw materials is the largest criteria in the development of Ina TEWS, namely 25.3%, whereas the lowest criterion is R and D activities of 7.2%. Technoware is dominant at 48.3%, while infoware is the smallest at 13.2%.

A dynamic sensitivity analysis was conducted using Expert Choice to assess how changes in each of the main criteria would impact the outcomes. The purpose of this analysis is to understand how these changes would influence the priorities of the chosen alternatives. The analysis was based on seven criteria: availability of raw materials (25.3%), financial (21.7%), innovation and industrial design (15.1%), industrial partnerships (13.4%), technology transfer (9.5%), policy/regulation (7.8%), R&D activities (7.2%). The criterion with the highest priority is the availability of raw materials. The technology components are technoware (48.3%), humanware (22.3%), orgaware (16.2%), and infoware (13.2%). The results showed that the highest technology component contribution is technoware, and the lowest is infoware. The priority of the technological components from highest to lowest is technoware, orgaware, humanware, and infoware (T>O>H>I), with technoware being the main priority. The results of the hierarchy diagram and criteria weight values from Ina TEWS technology development priorities are shown in Figure 9.

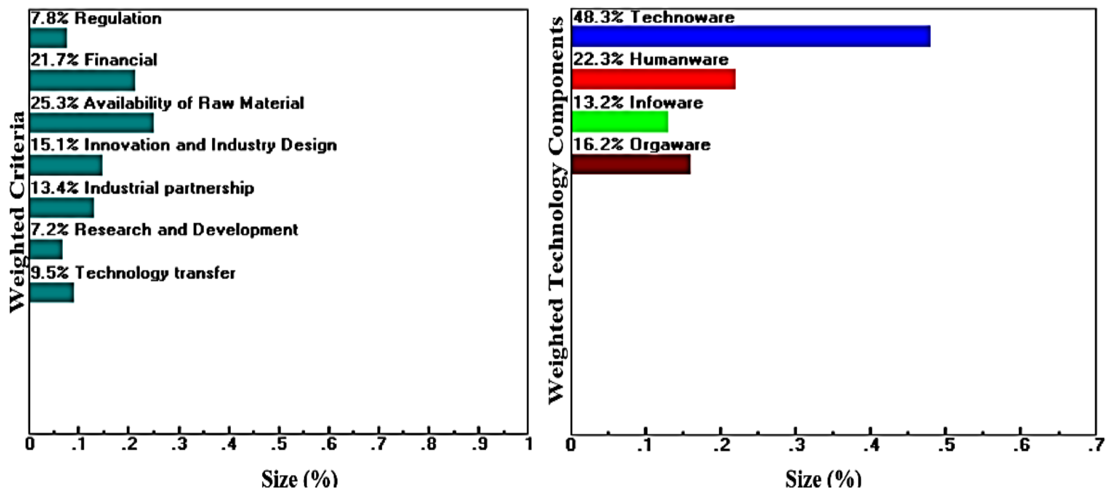



Figure 8. Dynamic sensitivity analysis

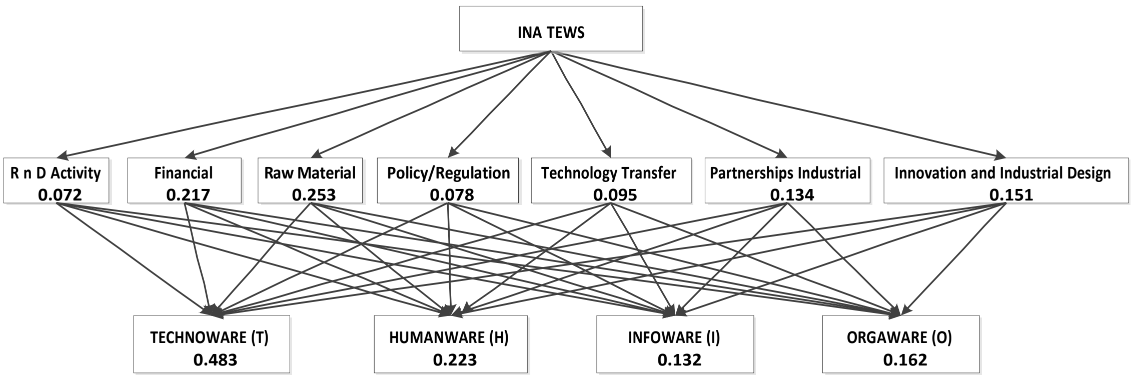



Figure 9. AHP with weights of criteria and alternative

## 3.5. Technology contribution coefficient

Next, the technology contribution coefficient (TCC) is calculated as:

$$TCC = T\beta t \times H\beta h \times I\beta i \times O\beta o$$
$$TCC = 0.5690.483 \times 0.5520.223 \times 0.4320.132 \times 0.4390.162$$
$$= 0.522$$

The value of TCC can indicate the technology level of Ina TEWS. The results in Tables 6 and 7 show that Ina TEWS has a TCC of 0.522, in the interval 0.5<TCC≤07, falling in the "Good" classification and "Semi Modern" technology level. This shows that the overall performance of Ina TEWS, both technological components have met the needs for mitigating the impact of earthquakes and tsunamis in Indonesia.

The results in Figure 10 show that the Ina TEWS technology component mapping, the highest contributing technology component is technoware (0.569), followed by humanware (0.525), then orgaware (0.439), and the smallest contribution comes from infoware (0.432). The ranking of contribution is $T > H > O > I$. Infoware's lower contribution is due to the absence of a good data documentation system, lack of manufacturing standard operating procedures (SOP), and sub optimal management information systems. The technology intensity rankings are as: technoware (0.483), humanware (0.223), orgaware (0.162), and infoware (0.132). So, the intensity values are sorted as: $\beta T > \beta H > \beta O > \beta I$. Infoware has the lowest intensity and is relatively weak compared to the other components. Management still considers infoware as a supporting component in operational management and has not yet become a focus of attention for management in developing Ina TEWS.

Table 6. Technology contribution coefficient (TCC) Ina TEWS

| Technology component | Lower limit (LL) | Upper limit (UL) | State of the art | Contribution | Intensity (β) | TCC |
|---|---|---|---|---|---|---|
| Technoware (T) | 4 | 6 | 0.536 | 0.569 | 0.483 | 0.522 |
| Humanware (H) | 4 | 6 | 0.488 | 0.552 | 0.223 | |
| Infoware (I) | 3 | 5 | 0.455 | 0.432 | 0.132 | |
| Orgaware (O) | 3 | 5 | 0.475 | 0.439 | 0.162 | |

Table 7. Technology contribution coefficient (TCC) levels

| TCC | Classification | Technology level |
|---|---|---|
| 0.5<TCC<=0.7 | Good | Semi modern |

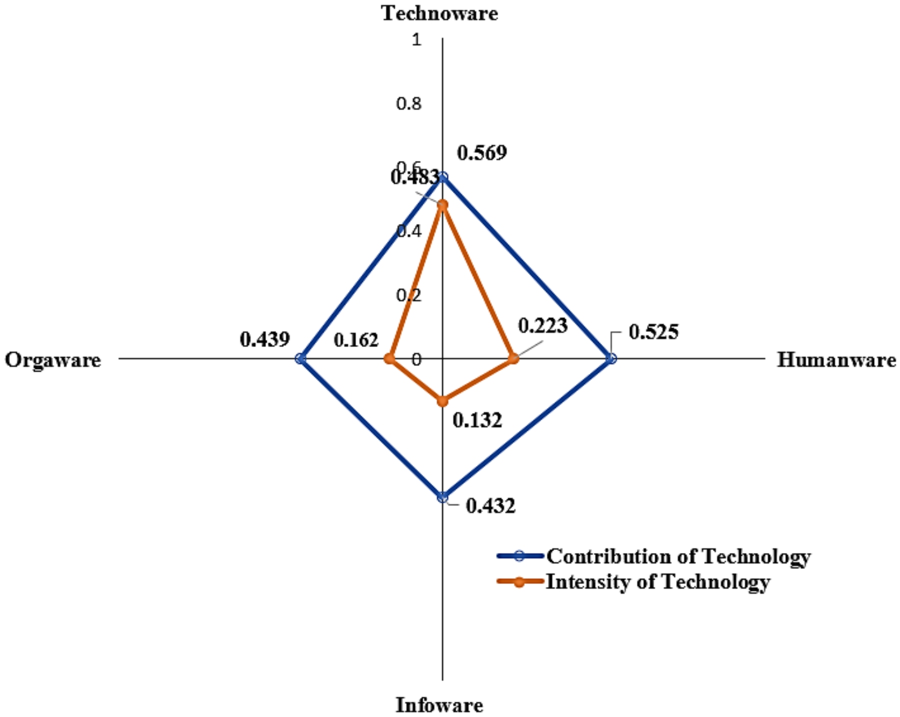



Figure 10. Diagram radar of Ina TEWS technology component

So immediate handling and improvement are needed, especially in the infoware component. For that, it is necessary to immediately build an integrated information system application to support manufacturing operational activities, including: an integrated documentation management information system application, a financial information system integrated with logistics, improvement of SOP in the production, testing, and data validation sections. In addition, increasing the competence of human resources in developing Ina TEWS needs to be continuously carried out. An effort to improve product quality is to create good management.

There are improvements needed for the overall technology components as:

– Improvements to technoware components need to be focused on infrastructure through continuous maintenance for device efficiency, and upgrading the equipment used. In addition, preparation related to maintenance scheduling is also needed to improve machine reliability.
– Improvement of humanware components is carried out by providing the broadest possible knowledge regarding the transferred product, whether in the form of training, internships, job guidance, or joining the core technology development team.
– Improvements in the infoware component are made by providing more detailed information on imported products including blueprints, designs, procedures, and all other information so that engineers are able to develop existing designs and are able to make similar products by relying on the available information. The minimum information that needs to be provided includes block diagrams, assembly manuals, component lists, standard operating procedures from purchasing materials to packaging, and other supporting assembly documents.
– Improvements in the orgaware component are carried out through strengthening research and development on disaster mitigation and building network initiatives with industry to create market cooperation.

The TCC of 0.522 is in the “Good” classification. However, this should be a concern for the organization’s management to continue to make improvements to all technology components because the TCC is on the threshold between the “Medium” classification ($0.3 < TCC <= 0.5$) and the “Good” classification ($0.5 < TCC <= 0.7$). Activities related to planning, monitoring, production improvement, testing, engineering design, and material storage must still be improved, because they are the key to the success of the quality management system.

## 4. CONCLUSION

This shows that overall, the performance of Ina TEWS has met the needs for mitigating the impact of earthquakes and tsunamis in Indonesia. To encourage the creation of Ina TEWS component product innovation, it needs to be accompanied by transfer of technology activities. Basically, Innovation cannot run well without transfer of technology. It is also important to build a conducive environment in Ina TEWS technology innovation activities, one of which is by collaborating with higher education institutions. Effective management is important for creating innovative products and processes to increase competitiveness. Continuous technological innovation is necessary to create breakthrough product innovations, processes and strategies to improve capabilities and produce valuable products. The level of dependency of components for Ina TEWS on imports is very high because there is no domestic component industry with quality and competitive prices. Therefore, the strategies needed so that various devices can be installed properly include preparing a financial information system integrated with logistics, building a documentation system, providing a centralized material warehouse, preparing a technical advice team, and preparing an integrated workshop. The results of the assessment of the technology components, management needs to be consistently committed to following up on the recommendations given by the assessment team so that the Ina TEWS development process can be carried out more efficiently and with better quality because stakeholders and the community need prediction results related to earthquakes and tsunamis.

In the future, the results of the assessment of the technology components in the development of Ina TEWS will help management in determining the priority of technology components based on the criteria that are the focus of technology development. The results of the assessment also help management in allocating its resources to areas with the greatest potential impact more effectively while identifying the risks of using new technology and minimizing its negative impacts. The most important thing is awareness and support from public to always be prepared for earthquakes and tsunamis, which ultimately becomes an important part of mitigation to reduce the risk of loss of life and damage to public service facilities and infrastructure.

## REFERENCES

[1] F. Ishak Aksa, “Investigating the role of geography education in enhancing earthquake preparedness: evidence from Aceh, Indonesia,” *International Journal of GEOMATE*, vol. 19, no. 76, Dec. 2020, doi: 10.21660/2020.76.90006.
[2] A. V. Simangunsong, R. Priadi, A. A. I. Dwilyantari, and A. Marsono, “Determination of temporal value of a-value and b-value to identify the level brittle of rock and seismic activity in the Palu region,” *Journal of Physics: Theories and Applications*, vol. 3, no. 1, Mar. 2019, doi: 10.20961/jphystheor-appl.v3i1.39431.

[3] A. Annunziato, G. Prasetya, and S. Husrin, "Anak Krakatau volcano emergency tsunami early warning system," *Journal of Tsunami Society International*, vol. 38, no. 2, pp. 68–95, 2019.
[4] Benazir and R. S. Oktari, "Assessing tsunami risk along the Aceh coast, Indonesia: a quantitative analysis of fault rupture potential and early warning system efficacy for predicting arrival time and flood extent," *Natural Hazards*, vol. 120, no. 5, pp. 4875–4900, Mar. 2024, doi: 10.1007/s11069-024-06401-x.
[5] Syugiarto, "Disaster management system in Indonesia," *Sumatra Journal of Disaster, Geography and Geography Education*, vol. 5, no. 2, pp. 87–96, 2021, doi: 10.24036/sjdgge.v5i2.377.
[6] G. Soehadi *et al.*, "Technology content assessment for Indonesia-cable based tsunameter development strategy using technometrics model," *Jurnal Sistem dan Manajemen Industri*, vol. 7, no. 1, pp. 15–29, Jun. 2023, doi: 10.30656/jsmi.v7i1.5748.
[7] D. H. F. Pradana, E. A. Wiguna, A. Rusdiutomo, A. N. Saputri, M. Wibowo, and W. Hendriyono, "Development of real-time tsunami early warning system dashboard based on Tunami-F1 and machine learning in Sunda Arc, Indonesia," in *2022 IEEE Ocean Engineering Technology and Innovation Conference: Management and Conservation for Sustainable and Resilient Marine and Coastal Resources (OETIC)*, Dec. 2022, pp. 23–29, doi: 10.1109/OETIC57156.2022.10176243.
[8] K. Priohutomo, W. H. Nugroho, and R. D. Yulfani, "Strength analysis and assessment of Ina-TEWS wave glider," *International Journal of Natural Science and Engineering*, vol. 4, no. 3, pp. 140–151, Dec. 2020, doi: 10.23887/ijnse.v4i3.29873.
[9] W. H. Nugroho, Arifin, N. J. H. Purnomo, and B. Ali, "Investigation of buoy hydrodynamic damping based on model testing data series of Indonesia tsunami Buoy," *IOP Conference Series: Materials Science and Engineering*, vol. 1052, no. 1, pp. 1–7, Jan. 2021, doi: 10.1088/1757-899X/1052/1/012009.
[10] S. Husrin, A. Annunziato, G. S. Prasetya, and R. Hidayat, "IDSL for tsunami early warning system in Indonesia," *IOP Conference Series: Earth and Environmental Science*, vol. 1117, no. 1, pp. 1–8, 2022, doi: 10.1088/1755-1315/1117/1/012028.
[11] Madlazim and T. Prastowo, "Evaluation of earthquake parameters used in the Indonesian tsunami early warning system," *Earthquake Science*, vol. 29, no. 1, pp. 27–33, Feb. 2016, doi: 10.1007/s11589-016-0143-6.
[12] Y. S. Manurung, J. Widjayanto, and H. Saragih, "Institusional role in analysis of installation of tsunami natural disaster detection equipment using analytical hierarchy process (AHP) and cost benefit analysis methods," *Technium Social Sciences Journal*, vol. 30, pp. 589–601, Apr. 2022, doi: 10.47577/tssj.v30i1.6207.
[13] V. Henao-Céspedes, Y. A. Garcés-Gómez, and M. N. Marín Olaya, "Landslide early warning systems: a perspective from the internet of things," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 13, no. 2, pp. 2214–2222, Apr. 2023, doi: 10.11591/ijece.v13i2.pp2214-2222.
[14] F. Tajima and T. Hayashida, "Earthquake early warning: what does 'seconds before a strong hit' mean?," *Progress in Earth and Planetary Science*, vol. 5, no. 1, Dec. 2018, doi: 10.1186/s40645-018-0221-6.
[15] A. Y. Herwindya, A. Dannari, A. B. Nugroho, and W. W. Pandoe, "Indonesia tsunami buoy," in *Joint Convention Balikpapan 2015*, 2015, pp. 1–6.
[16] M. M. Sakalasuriya, H. Rahayu, R. Haigh, D. Amaratunga, and I. I. Wahdiny, "Post-tsunami Indonesia: an enquiry into the success of interface in Indonesian tsunami early warning system," in *Post-Disaster Governance in Southeast Asia*, Singapore: Springer Singapore, 2022, pp. 175–200.
[17] S. Antesty, A. E. Tontowi, and A. Kusumawanto, "Mapping the degree of technological capability in small and medium industry of automotive components," *ASEAN Journal of Systems Engineering*, vol. 4, no. 1, pp. 13–19, Jul. 2020, doi: 10.22146/ajse.v4i1.59066.
[18] A. A. Rumanti and V. Hadisurya, "Analysis of innovation based on technometric model to predict technology life cycle in Indonesian SME," *International Journal of Innovation in Enterprise System*, vol. 1, no. 01, pp. 29–36, Dec. 2017, doi: 10.25124/ijies.v1i01.7.
[19] B. G. Irianto, A. Rahman, and H. Andayani, "Technology content analysis with technometric theory approach to improve performance in radiodiagnostic installation," *TELKOMNIKA Indonesian Journal of Electrical Engineering*, vol. 14, no. 2, pp. 353–362, May 2015, doi: 10.11591/telkomnika.v14i2.7676.
[20] F. H. Sukma, E. T. Handayani, and S. Supriyono, "Technological capabilities assessment by using technometrics models in routine maintenance of commuter trains to increase service performance," *SINERGI*, vol. 27, no. 1, Jan. 2023, doi: 10.22441/sinergi.2023.1.007.
[21] A. U. Khan and Y. Ali, "Analytical hierarchy process (AHP) and analytic network process methods and their applications: a twenty year review from 2000-2019," *International Journal of the Analytic Hierarchy Process*, vol. 12, no. 3, Dec. 2020, doi: 10.13033/ijahp.v12i3.822.
[22] A. A. Rumanti, R. Reynaldo, T. M. A. A. Samadhi, I. I. Wiratmadja, and A. C. Dwita, "Bridging technometric method and innovation process: an initial study," *IOP Conference Series: Materials Science and Engineering*, vol. 319, Mar. 2018, doi: 10.1088/1757-899X/319/1/012005.
[23] W. Sulistiyowati and R. B. Jakaria, "Assessment of technology content level with integrated technometrics and Analytical Hierarchy Process (AHP) methods in small and medium enterprises," *IOP Conference Series: Materials Science and Engineering*, vol. 434, Dec. 2018, doi: 10.1088/1757-899X/434/1/012246.
[24] R. Z. Aziz and H. C. Wahyuni, "Strategy to increase technological sophistication to increase helmet productivity with technometric methods and 5W1H," *Indonesian Journal of Innovation Studies*, vol. 23, Jul. 2023, doi: 10.21070/ijins.v23i.1045.
[25] A. Khoryanton, Pratikto, S. S., and P. B. S., "The analysis of the level of technology contribution to determine the strategy of quality standard achievement in the small and medium enterprise of ship components," *ARPN Journal of Engineering and Applied Sciences11*, vol. 11, no. 17, pp. 10618–10623, 2016.
[26] K. A. Aziz, S. Abdullah, M. A. Jabar, R. N. Haizan Nor, and N. I. Ismarau Tajuddin, "How analytical hierarchy process prioritizing internet banking influencing factors? a research study," *International Journal of Electrical and Computer Engineering*, vol. 13, no. 6, pp. 6646-6653, Dec. 2023, doi: 10.11591/ijece.v13i6.pp6646-6653.
[27] D. Herdhiansyah, Sudarmi, Sakir, Asriani, and L. O. Midi, "Analytical hierarchy process (AHP) in expert choice for determining superior plantation commodities: a case in East Kolaka Regency, Indonesia," *Songklanakarin Journal of Science and Technology*, vol. 44, no. 4, pp. 923–928, 2022, doi: 10.14456/sjst-psu.2022.123.
[28] M. Damdinsuren and B. Ishdamba, "Application of the AHP in choosing project manager," *International Journal of English Literature and Social Sciences*, vol. 2, no. 4, pp. 155–160, 2017, doi: 10.24001/ijels.2.4.19.

## BIOGRAPHIES OF AUTHORS

**Satrio Utomo** received his bachelor of engineering degree in informatics engineering from Telkom College of Technology (Now: Telkom University), a master's degree in educational technology from Jakarta State University. He currently works as a researcher at the Research Center for Process and Manufacturing Industry Technology, National Research and Innovation Agency (BRIN). His research interests include audit technology, Technometric, Industry 4.0, information system, technology management, smart city management. He can be contacted at email: satrioutomo2030@gmail.com and satr003@brin.go.id.

**Gani Soehadi** received his B.Eng degree in electrical engineering from Sepuluh November Institute of Technology (ITS), Indonesia, a master degree in information science from The University of New South Wales, Australia, and a doctoral degree in information system from IPB University, Indonesia. He currently works as a researcher at the Research Center for Process and Manufacturing Industry Technology, National Research and Innovation Agency (BRIN). His research interests include technology management, technology foresight and system dynamics. He can be contacted at email: gani001@brin.go.id.

**Budi Setiadi Sadikin** actively participates in research group activities. Currently, He is a doctor student at Padjajaran University (UNPAD). He also works as a researcher at the Research Center for Process and Manufacturing Industry Technology, National Research and Innovation Agency (BRIN). His research activity includes technology management, electrical vehicle machines, and renewable energy. He can be contacted at email: budi018@brin.go.id.

**Jaizuluddin Mahmud** received his doctoral degree in Industrial Technology from IPB University, Indonesia. He actively participates in research group activities. He currently works as a researcher at the Research Center for Process and Manufacturing Industry Technology, National Research and Innovation Agency (BRIN). His research activity includes technology management, foresight technology, technology clearing house, Technopark, electrical vehicle machines, and renewable energy. He can be contacted at email: jaiz001@brin.go.id.

**Irawan Santoso** received his B.Eng. degree in statistics from Padjajaran University (UNPAD). Indonesia, and a master's degree policy science from Saitama University, Japan. He currently works as a researcher at the Research Center for Process and Manufacturing Industry Technology, National Research and Innovation Agency (BRIN). His research interests include foresight technology, science statistics, technology management and system dynamics. He can be contacted at email: iraw002@brin.go.id.

**Hardono** received his master's degree in industrial engineering from University of Indonesia (UI). He currently works as a researcher at the Research Center for Process and Manufacturing Industry Technology, National Research and Innovation Agency (BRIN). His research interests include product-service systems, information systems management, information technology, and technology foresight. He can be contacted at email: hard007@brin.go.id.

**Fitriana Tiolita** received her bachelor of engineering degree in chemical engineering from University of Indonesia (UI). She actively participates in research group activities. She currently works as a researcher at the Research Center for Process and Manufacturing Industry Technology, National Research and Innovation Agency (BRIN). Her research activity includes technology management, electrical vehicle machines, and renewable energy. She can be contacted at email: fitr027@brin.go.id.

**Helen Fifianny** received her bachelor of engineering degree in electronics engineering from University of Andalas, Indonesia. She actively participates in research group activities. He currently works as a researcher at the Research Center for Process and Manufacturing Industry Technology, National Research and Innovation Agency (BRIN). Her research activity includes technology management, renewable energy, technology foresight, and Technopark. She can be contacted at email: hele001@brin.go.id.