Technology Assessment with Technometric Model in Small and Medium Industries: A Case Study at Traditional Textile "Kain Tenun Endek & Gringsing" Bali

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***Abstract*—Technology is one of the most important factors in the industry. Technology has a vital role to survive and compete with competitors so that industries can keep their sustainability. Technology is defined as knowledge, products, processes, tools, methods, and systems used in the manufacture of goods or services needed by humans. Technology consists of four components, technoware, humanware, infoware, and orgaware. Technology is also an important factor in the process of innovation in various industries including small and medium industries in Bali as well as the creative weaving industry. By knowing the current technological position of the industry, they can innovate to determine the strategy that will be carried out to achieve their competitive advantage. This study aims to measure the four components of technology in the small and medium industry (SMI) of the traditional woven textile industry (*pertenunan*) in Bali which produces "*kain tenun endek*" and "*kain tenun gringsing*". The results of this study will show the technological position of each SMI and determine the technology components that can be improved.**

Index Terms*—Technometric, small and medium industry, *Kain Tenun Endek*, *Kain Tenun Gringsin

I. Introduction

Technology has a crucial role and influence on company productivity. The benefits of technology in increasing productivity depend on the managerial ability to build a balance between various aspects related to technology components [1]. Assessment of technology in a company can be done to identify the strengths and weaknesses of the technology assets owned. It aims to determine the company's position in terms of technology, competitors, and state-of-the-art [2]. One model that can be used to determine the position of technology is technometric. Technometric includes measurements of technological quality, the sophistication of products, processes, product groups, in industries [3]. The basic components of technology that dynamically interact and together accomplish any transformation operation are, physical facilities/ technoware, human abilities/ humanware, documented facts/ infoware, and organizational frameworks/ orgaware [4]. These four components are needed as integrated components in the process of transforming inputs into outputs [5]. The technometric model produces a technology contribution coefficient value which can indicate the need for improvement of an organization or company against its current technological capabilities [6]. Technology assessment with a technometric approach aims to measure the contribution of the basic components of technology in the transformation process from input to output which can then be used to make the basis of technology planning [7]. After measuring technology and knowing the position of technology, then the company can make a strategy or plan to develop technology according to company needs [2, 8].

Technology has a very important role in all aspects of sustainable development [3], but in fact, most of the SMIs in Indonesia have not paid attention to the technology they have and even ignore it [7]. Bali Island is one of the islands in Indonesia, this island is widely known through its cultural tourism. One of the efforts made to maintain the existence of cultural tourism in Bali is to engage in the provision of various creative industry products as a characteristic of tourist attractions which are the hallmark or uniqueness of these places [9]. One of the products of the creative industry is *kain tenun* (woven fabric). In Bali, there are three types of *kain tenun*, namely *kain tenun songket*, *kain tenun endek*, and *kain tenung gringsing*. *Kain tenun endek* is a type of fabric that is often used in daily life. Meanwhile, *kain tenun songket* and *kain tenun gringsing* are generally used in traditional ceremonies and religious ceremonies. In the development of cultural tourism, this traditional fabric has not received the attention of development programs [10]. However, since *kain tenun endek* or traditional Balinese woven fabrics are listed as communal intellectual property of traditional cultural expressions with the inventory number EBT.12.2020.0000085 by the Directorate General of Intellectual Property by the Ministry of Law and Human Rights of the Republic of Indonesia and the enactment of the Governor of Bali Circular Number 04 of 2021 (*Surat Edaran Gubernur Bali Nomor 04 Tahun 2021*) regarding the use of balinese traditional fabric [11], the use of *kain tenun endek* and balinese traditional fabric has also begun to receive more attention. In addition, the use of *kain tenun endek* in 2020 by the famous brand Christian Dior at Paris Fashion Week, and *kain tenun gringsing* as souvenir for the G20 Presidency of Indonesia has made *kain tenun bali* (balinese woven fabric) increasingly known to the world. The holding of the G20 in Bali also give a positive impact on the Indonesian tourism sector where it is estimated that there will be an increase in the number of foreign tourists by 1.8 to 3.6 million with 600 to 700 thousand new jobs in the culinary, fashion, and craft sectors [12, 13]. Where this also has a good impact on the weaving industry in Bali which produces products that can be used as souvenirs from Bali tourism.

With the increasing interest in *kain tenun endek* and *kain tenun gringsing*, competition in the weaving industry has also increased. Therefore this study aims to measure the position

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of technology in SMI of traditional woven industries located in Klungkung and Karangasem Regencies using a technometric model. The results of this study are expected to be able to provide insight into the small and medium industry of traditional woven industries regarding their current technological position and which technological components need more attention as a basis for technology planning so that the traditional woven industries can continue to survive and compete with its competitors to achieve their competitive advantage.

II. Literature Review

A. Technology

Technology is defined as knowledge, products, processes, tools, methods, and systems used in the manufacture of goods or services needed by humans [2]. Technology is not just physical tools, but in an economic context refers collectively to any tool and related knowledge [4]. Technology can be considered a key factor that transforms certain inputs into desired outputs because it transforms natural resources into produced resources [5].

There are four basic components of technology:

1) Physical facilities/ technoware, are all physical tools and facilities needed in the transformation process such as equipment, machines, devices, factories, etc.
2) Human abilities/ humanware, are skills and experiences such as the ability to carry out transformation processes, creativity, perseverance, diligence, ingenuity, etc.
3) Documented facts/ infoware, are facts and information such as regulations, designs, observations, relationships, etc.
4) Organizational frameworks/ orgaware, are all the frameworks needed in the transformation process such as grouping, organization, systematizations, networks, management, etc. [4].

B. Technometric

Technometrics is a model within the Technology Content Assessment framework developed by the Technology Atlas Project under the auspices of the United Nations Economic and Social Commissions for Asia and the Pacific (UNESCAP) [14]. Technology assessment with a technometric approach aims to measure the contribution of the basic components of technology in the transformation process from input to output which can then be used to make the basis of technology planning [7]. The technometric model produces a Technology Contribution Coefficient (TCC) which is measured by the following formula.

$$TCC = T^{\beta t} \times H^{\beta h} \times I^{\beta i} \times O^{\beta o} \quad (1)$$

The TCC value shows the contribution of technology to the entire transformation process that occurs within the company from input to output. The TCC value can be interpreted as follows [3].

Table I shows the internal qualitative value based on the result of the TCC value. The classification of TCC values can be adjusted to the intervals of TCC values with six categories listed in Table I to find out in which category the technology currently owned by the company is.

TABLE I: Qualitative Value Interval of TCC

TCC Value	Classification
0 < TCC < 0,1	Very Low
0,1 < TCC ≤ 0,3	Low
0,3 < TCC ≤ 0,5	Standard
0,5 < TCC ≤ 0,7	Good
0,7 < TCC ≤ 0,9	Very Good
0,9 < TCC ≤ 1,0	Absolute Sophisticated

TABLE II: Technology Level

TCC Value	Classification
0 < TCC ≤ 0,3	Traditional
0,3 < TCC ≤ 0,7	Semi Modern
0,7 < TCC ≤ 1	Modern

Table II shows the technology level based on the result of the TCC value. The classification of TCC values can be adjusted to the intervals of TCC values with three categories listed in Table II to find out in which category the technology currently owned by the company is.

III. Research Method

The method used in this study is technometric which result will be the value of Technology Contribution Coefficient (TCC). The following is the procedure for determining TCC with a technometric model.

1) Describe the transformation process from input to output within the organization or company.
2) Determine the degree of sophistication by determining the value of the upper limit and lower limit of each technology component.
3) Determination of the state-of-the-art (SOTA), determining the value of state-of-the-art in this study was accomplished using the component criteria assessment matrix compiled by Achmad Fauzan, 2009 and the state-of-the-art calculation formula:

*Example for technoware component (T)

$$ST_i = \frac{1}{10}\left[\sum_k t_{ik}/k_i\right]; k = 1,2,3, \dots k_i \quad (2)$$

The assessment matrix criteria compiled by Achmad Fauzan consists of the following components [15].

TABLE III: Component Criteria for Technoware

No	Component Criteria for Technoware
1	Type of machine
2	Type of process applied
3	Type of operasion applied
4	Error rate
5	Frequency for machine maintenance
6	The technical expertise of the worker or operator required to use the tool
7	Inspection on every job
8	Measurements on each job
9	Work safety and security level

Table III shows the component criteria for calculating state-of-the-art technoware components.

TABLE IV: COMPONENT CRITERIA FOR HUMANWARE

No	Component Criteria for Humanware
1	Awareness in task
2	Awareness of discipline and responsibility
3	Creativity and Innovation in solving problems
4	Ability to maintain production facilities
5	Awareness of working in groups
6	Ability to meet due dates
7	Ability to solve problems that occur in SMI
8	Ability to work together
9	Leadership

Table IV shows the component criteria for calculating state-of-the-art humanware components.

TABLE V: COMPONENT CRITERIA FOR INFOWARE

No	Component Criteria for Infoware
1	Management information
2	SMI informs employees of problems and external conditions immediately
3	Information network within the company
4	Procedures for communication between workers in the SMI
5	Company information system to support SMI activities
6	Storage and retrieval of information

Table V shows the component criteria for calculating state-of-the-art infoware components.

TABLE VI: COMPONENT CRITERIA FOR ORGAWARE

No	Component Criteria for Orgaware
1	SMI autonomy
2	SMI vision
3	SMI's ability to create a conducive environment to make improvements and increase productivity
4	SMI's ability to motivate employees with effective leadership
5	SMI's ability to adapt to dynamic business environments and external demands
6	SMI's ability to maintain relationships with suppliers
7	SMI's ability to maintain relationships with customers
8	SMI's ability to obtain external resource support

Table VI shows the component criteria for calculating state-of-the-art orgaware components.

1) Determine the value of the contribution of technology components, determining the value of the contribution of the technology component can be done with the following formula:

*Example for technoware component (T)

$$T = \frac{1}{9}\left[LT_i + ST_i(UT_i - LT_i)\right] \quad (3)$$

*U = Upper Limit

L = Lower Limit

2) Measuring the intensity of the contribution of each technology component.

3) Calculating the Technology Contribution Coefficient (TCC) value using formula number (1).

IV. RESULT AND DISCUSSION

Data collection to create the technometric model was carried out through direct observation and interviews with three SMIs. The selected SMIs in this study are located in Klungkung Regency and Karangasem Regency because these two regencies are known for their creative weaving industries. The three SMIs are Pertenunan Astiti located in Klungkung Regency with *kain tenun endek* products, Pertenunan Pelangi located in Karangasem Regency with *kain tenun endek* products, and Pertenunan Sukerta located in Karangasem Regency with *kain tenun gringsing* products. The difference between *kain tenun endek* and *kain tenun gringsing* is in the making of the paterns, where in *kain tenun gringsing* patterns are made on horizontal and vertical threads, while in *kain tenun endek* the pattern is only made on horizontal threads.

Based on the calculations that have been done, the state-of-the-art, technology component contribution, and TCC values for each SMI are shown in the table below.

TABLE VII: STATE-OF-THE-ART

Technology Component	Pertenunan Astiti	Pertenunan Pelangi	Pertenunan Sukerta
Technoware	0,417	0,417	0,417
Humanware	0,722	0,833	0,722
Infoware	0,750	0,750	0,750
Orgaware	0,875	0,875	0,375

Table VII shows the state-of-the-art values based on the technology components currently owned by the industry. Data processing to produce state-of-the-art values in this study was obtained through an assessment matrix compiled by Achmad Fauzan, 2009 and calculations using formula number (2). The value of state-of-the-art shows the value of the technology components that can be achieved with the current technological conditions.

TABLE VIII: COMPONENT CONTRIBUTION

Technology Component	Pertenunan Astiti	Pertenunan Pelangi	Pertenunan Sukerta
Technoware	0,204	0,204	0,204
Humanware	0,753	0,852	0,753
Infoware	0,528	0,528	0,528
Orgaware	0,403	0,403	0,236

Table VIII shows the value of the component contribution of each technology component (THIO) obtained through calculations with formula number (3). The result of the component contribution calculation shows the current contribution value of each technology component.

TABLE IX: COMPONENT CONTRIBUTION INTENSITY

Technology Component	Pertenunan Astiti	Pertenunan Pelangi	Pertenunan Sukerta
Technoware	2,045	2,045	2,045
Humanware	0,959	0,978	0,959
Infoware	1,421	1,421	1,421
Orgaware	2,172	2,172	1,588

Table IX shows the value of the intensity contribution component which is a comparison based on the state-of-the-art value with the contribution of the technology component.

TABLE X: TECHNOLOGY CONTRIBUTION COEFFICIENT

SMI	TCC Value	Classification	Technology Level
Pertenunan Astiti	0,0016	Very Low	Traditional
Pertenunan Pelangi	0,0018	Very Low	Traditional
Pertenunan Sukerta	0,0012	Very Low	Traditional

Table X shows the TCC value of each SMI which shows the technological position of each SMI with its classification and technology level.

To make it easier to see the comparison between state-of-the-art and component contributions values, THIO diagrams are visualized as follows. Fig. 1. Represents the THIO diagram of Pertenunan Astiti, Fig. 2. Represents the THIO diagram of Pertenunan Pelangi, and Fig. 3. Represents the THIO diagram of Pertenunan Sukerta.

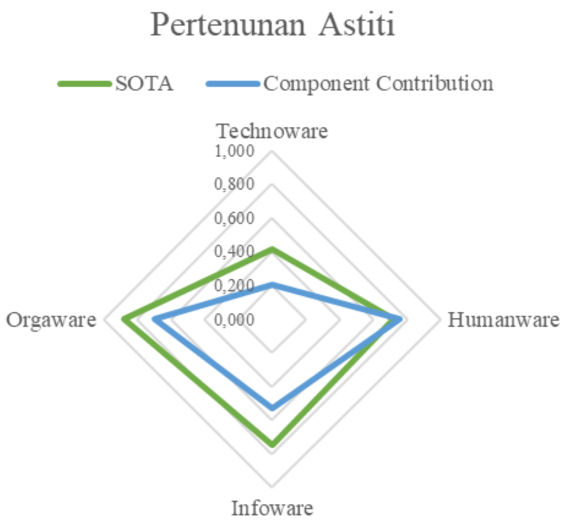

Fig. 1. THIO diagram of pertenunan astiti.

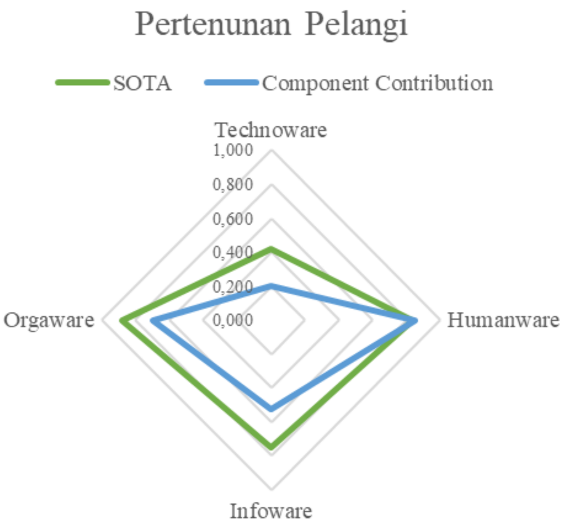

Fig. 2. THIO diagram of pertenunan pelangi.

Pertenunan Astiti and Pertenunan Pelangi have very similar SOTA values and component contributions, this is probably because both are weavers that produce *kain tenun endek*. The difference between the two is only found in one component, which is humanware. Fig. 1., Fig. 2., Table VII, and Table VIII show that the humanware component in SOTA and the contribution component have the closest values. Therefore the humanware component in Pertenunan Astiti and Pertenunan Pelangi is good, this can be caused by many involvements of humans in the process of making *kain tenun endek*.

Although there is a slight difference in SOTA and component contribution value which can be caused by slight differences in employee motivation. The technoware component still has a large gap between the contribution component and SOTA, this can be caused by the process of making *kain tenun endek* using traditional and non-machine tools (*Alat Tenun Bukan Mesin*). The infoware component still has a large gap between the contribution component and SOTA, this can be caused by the documentation process which is still manual and not yet integrated. In the organizational component, there is still a large gap between the contribution component and SOTA which can be caused by the lack of SMIs' ability to motivate workers and management systems.

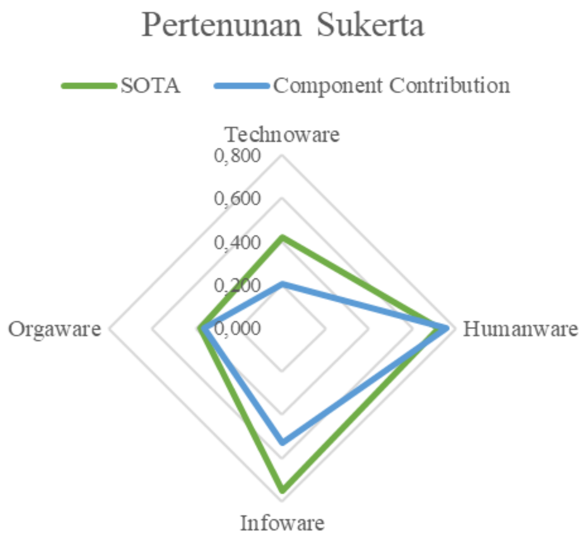

Fig. 3. THIO diagram of pertenunan sukerta.

Fig. 3., Table VII, and Table VIII show that the humanware component in Pertenunan Sukerta has SOTA values and component contributions that are very close, which means that the humanware component in Sukerta Weaving is good, this can also be due to the process of making *kain tenun gringsing* dominated by human involvement. The orgaware components in Pertenunan Sukerta also has a very close value of SOTA and contribution components, which means that the orgaware technology components in Pertenunan Sukerta are also good, this can be due to the weaving industry that produces *kain tenun gringsing* is fully managed by family members so that the management of worker motivation and business or system management is easier. Technoware components still have a large gap between component contributions and SOTA, this can be caused by the process of making *kain tenun gringsing* using traditional tools and not machines (*Cagcag*). And the infoware components also have a large gap between the contribution component and SOTA, this can be caused by the documentation process which is still manual and not yet

integrated.

V. Conclusions and Future Work

A. Conclusions

Based on the research that has been done, it can be concluded that the three SMIs are in the very low technology classification because the TCC results show a value of $0 < TCC < 0.1$ with the traditional technology level because they have a TCC value of $0 < TCC \leq 0.3$. From the THIO diagram, it can also be seen that the humanware components in the three SMIs have the closest position to the position they should be, this can be caused by many involvements of humans in the process of making *kain tenun endek* and *kain tenun gringsing*. The orgaware components in Pertenunan Sukerta are also in a position close to their position they should be, this can be due to the weaving industry that produces *kain tenun gringsing* is fully managed by family members so that the management of worker motivation and business or system management is easier. Therefore, based on Pertenunan Astiti and Pertenunan Pelangi technometric model, they can begin to develop strategies to make improvements to the technoware, infoware, and orgaware components. Meanwhile, in Pertenunan Sukerta, they can start developing strategies to make improvements to the technoware and infoware components.

This research has shown the current technological position of each SMI and which technology components must be given more attention so that SMI can survive, and compete with competitors to achieve a competitive advantage.

B. Future Work

This research has only been carried out up to the stage of creating a technometric model to determine the position of technology and technological components that need to be developed so that SMIs can determine strategies that can be taken for components that are not yet close to their state-of-the-art. Therefore, future research is expected to be able to provide suggestions related to strategies for example policy strategy, business strategy, or technology strategy that can be carried out by industries to achieve a better technological position so that SMIs can survive, compete with competitors, and be sustainable.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

N.P.A.L.P. and A.A.R. collected the data and information; N.P.A.L.P. and L.A. analyzed the data and information; N.P.A.L.P. calculated the data; N.P.A.L.P. analyzed and visualized the result; N.P.A.L.P. wrote, reviewed and edited the paper; L.A. and A.A.R. supervised the research process. All authors had approved the final version.

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