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A Measurement Model and The Techno-Economy Analysis for Traceability Technology Adoption: A Case Study of Melon Distribution in Indonesia

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ABSTRACT

Product traceability system is used to trace an item or group of items from one point to another within a supply chain/distribution. Implementing a traceability system will allow the prevention of potential risks that may arise due to contamination of horticultural products. This study focuses on melon. Melon is one of horticultural products which have a high output volume and export value and is expected to increase in the future. Potential increase in export volume and value coincide with the need for improving the quality and product quality standards. Therefore, it needs a system that supports an increase in volume and export value. The system is the traceability system. The importance of the product traceability system is driven by increasing consumer awareness on safety and quality agricultural products. The technology supporting it becomes important in a traceability system, and therefore this paper discusses assessment technology components within the distribution system of melon. The results will be used as a reference in the improvement aspect to support the implementation of traceability technologies. The techno-economic analysis is used to analyze the feasibility of implementing technology and economy models.

Keywords: *Traceability, technology component, techno-economic analysis*

1.0 INTRODUCTION

The agricultural sector in Indonesia has an important role in supporting the economy. Basically, the agricultural sector is divided into four sub-sectors; food crops, horticulture, plantation, and farms. Based on the four sub-sectors, horticulture plays an important role and is strategic as a major component in Pola Harapan Pangan. Horticultural commodities have the advantages of high value, diversity, availability of land resources and technologies as well as the potential for market uptake in the domestic and international continues to increase [1].

There are several types of horticultural products, such as fruits and vegetables. Fruit commodities are such as melon, sapodilla, bananas, and others. Vegetable commodities are such as chili, cabbage, carrots, and others. This study focuses on melon. The melon has a high commercial value in Indonesia, from traditional markets to modern markets, restaurants, and hotels [2]. Melon production spread across several areas ranging from West Java, Central Java, East Java, Sumatra and Kalimantan [2].

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Besides domestic consumption, melons are also exported to several countries, including Malaysia, Japan, Hong Kong and Singapore with high export value. However, there are some challenges when exporting melons, there are quality and product quality standards, selling prices, attractive appearance, and consumer confidence [3].

One of the efforts in facing these challenges is by applying traceability system. By using traceability technology, consumers can perform product tracking so as to increase consumer confidence in purchasing the product [4-6]. Thus, consumers who pay attention to the quality and safety of the product can obtain information about a particular product [6]. This is in accordance with the results of a survey conducted by the UK Food Standard Agency in 2000, which shows that 75 percent of consumers are very concern about the food quality and food security [7]. In addition, traceability can improve supply chain efficiency, reduce theft and fraud and realize significant cost savings [8].

In traceability, technology support should be considered such as alphanumerical code, barcode, and radio frequency identification (RFID) [9]. The alphanumerical code is a sequence of numbers and letters placed on the label, this will be placed on the product or on the packaging. Barcode contains a series of vertical lines with varying thickness placed on a label and is used to identify goods. Barcode technology has become very common and is widely used in traceability. It is also a technology that is easy to use. Barcode is also effective in performing its function as a tool of traceability [10]. In recent years, RFID technology has been widely accepted by many practitioners in managing assets. RFID technology is an identification technology based on radio waves. This technology is able to identify different objects without direct contact (or within a short distance). RFID technology enables the user to uniquely identify the object or person [11]. Hence, RFID technology becomes very popular and is widely applied in some countries such as Japan, China, Taiwan, the UK, South Korea, and others.

Unlike in some developed countries that already possess the appropriate technology infrastructure, technology to support traceability, this is still quite uncommon in Indonesia, particularly in rural areas. Therefore, there is a need of the performance measurement to know the adoption level of the technology in the current condition of traceability. In this study, the performance measurement in terms of the implementation traceability is conducted to the distribution system of melon. An analysis needs to be done to ensure the feasibility of implementating the traceability technology. The benefit cost ratio analysis was selected as the method of analysis used in this research and it is limited only to the use of barcode technology.

2.0 METHODOLOGY

Figure 1 shows the research methodology applied in the study. The techno-economic analysis of the melon's traceability system begins with identifying the distribution system of melon. The distribution system of melon consists of a number of processes related to ordering, weighing, sorting, packing, storing, and shipment. After the identification of melon's distribution system, the next step is to analyze the technology adoption model that is needed as a reference model to identify the relevant factor about technology adoption for traceability. The technometric model serves to assess the level of technology contribution coefficient (TCC) of the company. The components used in this model consists of technoware (T), humanware (H), infoware (I) and orgaware (O). The research instrument used in this study are questionnaires, interviews and direct observation. Questionnaires were distributed to the relevant parties that are considered necessary to support this research. Direct observations were also conducted.

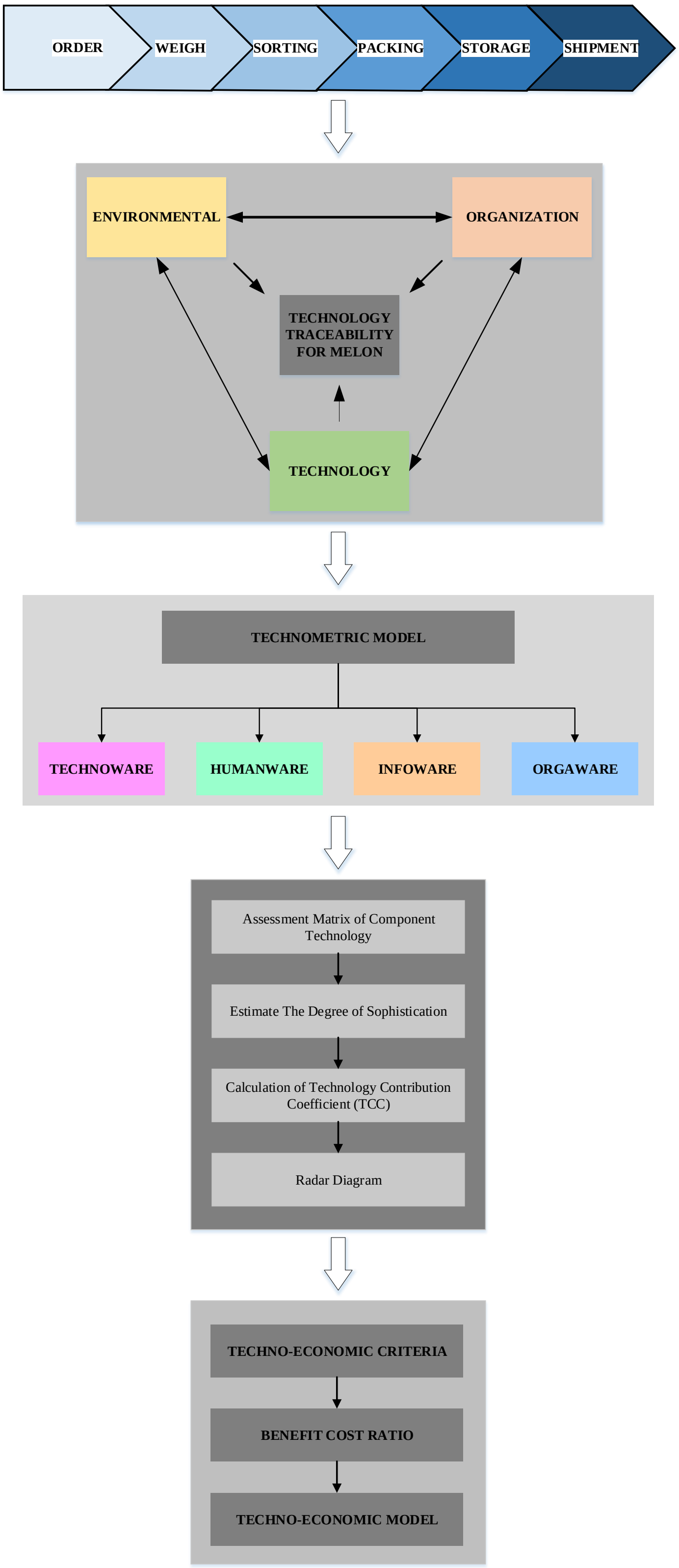

Figure 1: Research methodology

This research continues with the measurement of technology adoption based on feedbacks from questionnaires and direct observation with reference to the two case studies conducted on the two selected companies, namely, *Company 1* and *Company 2*. The first did not implement the traceability technology while the other actually implemented it. The result of this measurement can be used as an input to create the techno-economic model. This model is subsequently used to compute the benefit/cost (B/C) ratio.

3.0 RESULTS AND DISCUSSION

3.1 Business Processes

The business processes in dealing with the melons involve the followings:

a. Ordering

The ordering process of melon was done by company to collectors. The order was done after the company receives an order from overseas importer. The collectors will send that order in less than one day after company's order.

b. Weighing

The weighing process starts when melon comes to the company. Weighting is done to determine the total weight and the amount of melon sent by collectors.

c. Sorting

The sorting process aims to sort between defect and good melon. The other activity within sorting is making melon fruit look neat so it can be easy to pack.

d. Packing

The packing process is done by putting the melon into cardboard boxes.

e. Storing

The storing process aims to protect melon against shrinkage and spoilage. The room used in storage process must be have about 5 °C temperature. The melon is stored for 2-3 days while waiting for the shipping process.

f. Shipment

The melons are shipped by container through sea routes; it takes approximately two days.

3.2 Technology Adoption Measurement

The steps taken to measure the technology adoption are as follows:

1. Assessment matrix of the component technology

a. Technoware

Assessment matrix for technoware components which form the physical components of the company as a computer or a set of instrument technology used in the production process.

b. Humanware

Humanware assessment matrix components such as:

1) Human resource capability in doing his job.
2) The human resource capability to operate equipment production

c. Infoware

Infoware assessment matrix components such information source related to the technical understanding of the processes and functions of production equipment.

d. Orgaware

Assessment matrix for orgaware component such as organizational functions and work patterns within a company.

2. Degree of sophistication

In order to estimate the degree of sophistication, required a rubric assessment as reference. Assessment rubric used to estimate the degree of sophistication is shown in Table 1.

Table 1: Degree of sophistication

Component	Degree of sophistication	Definition
Technoware	Manual	The manual production equipment (human full control on running production machinery)
	Powered	The mechanical/electrical production equipment (human carried out process control of power engine)
	Automatic	Automated production equipment (machines as controller activity, human's task was ensured the machine work well)
	Programmable	Computerized production equipment (computers programmed to run production machine correctly)
	Zero Deviation	Integrated production equipment (production machines connected and sustainable from start to the end of the process)
Humanware	Basic	- Have standard skill on work's competence and ability - Capable to operate production equipment/machine
	Superior	- The competence and ability to work a little bit above the standard - Capable to install/stringing production equipment
	Advanced	- The competence and ability to work much better than standard - Capable to modify production equipment
	Extra-ordinary	- Have an unusual competence and ability to work - Capable to repair damaged production equipment
	Zero error	- Competence and ability to work are very high when did production activities - Capable to innovate the production equipment
Infoware	General	Information that useful to provide a general understanding in the operation and use of production equipment
	Special	The information serves to provide technical/fundamental understanding to use production equipment
	Unique	The information allows for selecting production equipment
	Frontier	Information can improve processes and production equipment function
	Zero unknown	Information can provide an assessment of the processes and functions production equipment
Orgaware	Adhoc	The company's organization which in quest of work patterns
	Orderly	Companies that have an orderly organization in production activities and has had settled work patterns
	Managed	Companies that have been able to arrange the organization well and were able to stabilize work patterns
	Optimized	Companies are able to optimize the functioning of the organization and work patterns
	Zero tolerance	A company's organization which can holding superior work pattern

The degree of sophistication evaluated within the two companies are shown in Tables 2 and 3. Note that *Company 1* does not implement the traceability approach while *Company 2* actually implements it

Table 2: Degree of sophistication for *Company 1*

Business Process	Technoware	Humanware	Infoware	Orgaware
Order	Powered	Extra ordinary	Spesial	Orderly
Weigh	Powered	Extra ordinary	General	Orderly
Sorting	Manual	Extra ordinary	General	Orderly
Packing	Manual	Extra ordinary	General	Orderly
Storage	Powered	Extra ordinary	Spesial	Orderly
Shipment	Powered	Extra ordinary	General	Orderly

Table 3: Degree of sophistication for *Company 2*

Business Process	Technoware	Humanware	Infoware	Orgaware
Order	Powered	Zero error	Special	Orderly
Weigh	Powered	Extra ordinary	Special	Orderly
Sorting	Manual	Extra ordinary	Special	Orderly
Packing	Powered	Extra ordinary	Special	Orderly
Storage	Automatic	Zero error	Special	Managed
Shipment	Programable	Extra ordinary	General	Managed

3. Technology contribution coefficient (TCC)

The calculation of the TCC value is typically done for every process in the company. The values used in each component are taken from the upper limit value in each component technology. TCC is calculated using the following formula:

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

where βt, βh, βi, and βo are the composition weights of each component in THIO with reference to the main technology components; i.e., the Technoware (T), Humanware (H), Infoware (I) and Orgaware (O), respectively. Note that $\Sigma\beta = 1$ and in this study, all the values of β were assumed equal, thus:

$$\beta t = \beta h = \beta i = \beta o = 0.25$$

α is a trend or a scale factor. Meanwhile, T, H, I and O are the contribution values of the main technology components. The technology component values were obtained from the results of the data collection in which each component is assumed to have an upper and lower limits. In order to determine the TCC, an upper limit of available value was used. The TCC results for the two case study involving both *Companies 1* and *2* are presented in Tables, 4 and 5, respectively.

Table 4: TCC results for *Company 1*

Business Process	Technoware	Humanware	Infoware	Orgaware	TCC
Ordering	1.189	1.414	1.189	1.189	0.476
Weighing	1.189	1.414	1.000	1.189	0.400
Sorting	1.000	1.414	1.000	1.189	0.336
Packing	1.000	1.414	1.000	1.189	0.336
Storing	1.189	1.414	1.189	1.189	0.476
Shipment	1.189	1.414	1.000	1.189	0.400

Table 5: TCC results for *Company 2*

Business Process	Technoware	Humanware	Infoware	Orgaware	TCC
Ordering	1.189	1.495	1.189	1.189	0.503
Weighing	1.189	1.414	1.189	1.189	0.476
Sorting	1.000	1.414	1.189	1.189	0.400
Packing	1.189	1.414	1.189	1.189	0.476
Storing	1.316	1.495	1.189	1.316	0.616
Shipment	1.414	1.414	1.189	1.316	0.626

4. Radar diagram

The radar diagram for the entire production process of the company is described in Figure 2.

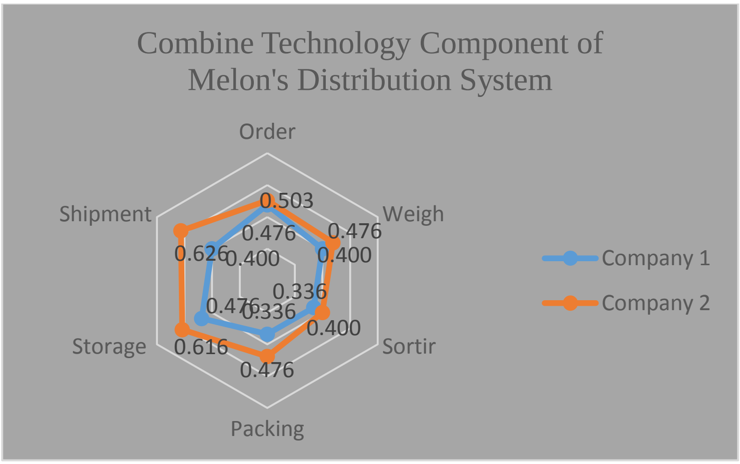

Figure 2: Radar diagram

3.3 Techno-Economic Model and Analysis

This involves the following procedures:

1. *Generalization of the techno-economic model*

The generalization of techno-economic model is based on the benefit and cost models. The results of the generalization of the techno-economic model is shown in Table 6.

Table 6: Generalization of the techno-economic model

Category		Definition	Source
Benefit model	Tracking and control	Labor reduction	- Direct observation - Gerber, 2011 [12]
		Sales improvement	
	Shrinkage reduction	Reduce the possibility of inventory loss	
	Quality savings	Reduction of recall products	
Cost model	Capital expenditure	The cost of obtaining the physical components of the technology system, including the software.	
	Implementation cost	Contractor-related costs that include the cost of installing each hardware and labor cost per hour.	
	Training cost	The cost of bringing in technology experts to train employees consists of training materials, expert fees and employee training costs.	

2. *Construction of the techno-economic model*

The construction of the techno-economic model is based on the benefit and cost models in which every component has a different formula.

A. *Benefit (B) model*

Based on the generalization model, the benefit model consists of tracking and control, shrinkage reduction and quality savings.

Tracking and control

Tracking and control consists of labor reduction and sales improvement. The formulation can be described as:

a. *Sales improvement*

It is calculated as:

$$B_S = a \times Q_S \times P_S \tag{2}$$

where:

B_S : benefit value of sales improvement

a	:	percentage of sales improvement (%)
Q_S	:	sales amount (kg/year)
P_S	:	selling price per kg

b. Labor reduction

This is given by:

$$B_{TK} = \Delta Q_{TK} \times C_{TK} \times m \quad (3)$$

where

B_{TK}	:	benefit value of labor
ΔQ_{TK}	:	changes in the number of labor before and after using the traceability technology
C_{TK}	:	wages of labor
m	:	working time

B. Cost (c) model

Cost model consists of the capital expenditure, implementation costs and training cost. The formulation is as follows:

i. Capital expenditure

Component cost of capital expenditure is related to the hardware and software with reference to the barcode technology. The hardware required in the barcode technology is the barcode printer, label, scanner and computer. It also includes the cost of the numbering system by GS1 Indonesia [13]. The cost of the physical components (hardware) and software depends on the required installation. The amount of capital expenditure costs is modeled as follows:

$$C_E = C_H + C_S + C_C \quad (4)$$

where

C_E	:	equipment cost
C_H	:	hardware cost
C_S	:	software cost
C_C	:	computer cost

$$C_H = (C_P \times Q_P) + (C_T \times Q_T) + (C_R \times Q_R) \quad (5)$$

where

C_P	:	cost of barcode printer
Q_P	:	number of barcode labels needed
C_T	:	tag barcode cost
Q_T	:	number of tags required
C_R	:	cost of barcode scanner
Q_R	:	number of barcode scanners required

ii. Implementation cost

Implementation cost is associated with the accumulated cost required in implementing the barcode technology that includes the installation of any physical components and fees required by GS1 Indonesia as a membership fee. The cost of installing a physical component is usually done by someone skilled in dealing with a barcode component technology installer. GS1 membership fee consists of registration fee, annual fee, dues numbering system that were paid every three years. The implementation cost is modeled as follows:

$$C_I = (C_N \times Q_N) + C_M \tag{6}$$

where

C_I	:	implementation cost
C_N	:	device installation cost
Q_N	:	number of devices that needs to be installed
C_M	:	GS1 membership fee

$$C_M = C_E + C_A + C_B \tag{7}$$

where

C_E	:	GS1 member registration fee
C_A	:	annual fee
C_B	:	cost of the GS1 numbering system

iii. Training cost

Training cost is related to train company employees in using the barcode technology properly and correctly. The training cost is also incurred to provide the payment to trainers who train the employees. It is expressed as:

$$C_X = (C_K \times \mathrm{Q_K} \times \mathrm{T_K}) + (C_L \times Q_L \times T_L) \tag{8}$$

where

C_X	:	training cost
C_K	:	wages of training expert
Q_K	:	number of experts who train
T_K	:	number of training hours
C_L	:	wages of employees who participated in training
Q_L	:	number of employees attending the training
T_L	:	number of training hours

iv Maintenance cost

The maintenance cost is to keep the function and operation of the device in good working order. It is given by:

$$C_m = c_m \times f \tag{9}$$

where

C_m	:	maintenance cost
c_m	:	maintenance rate
f	:	frequency of maintenance in one year

Based on the generalization of the techno-economic criteria, then the *B/C* ratio can be obtained as follows:

$$B/C = \frac{B_S + B_{TK} + B_E + B_I}{[C_E + C_I + C_X + C\mathrm{m}] + (O\&M)(P/A,\%,n) - SV(P/F,\%,n)} \tag{10}$$

where

B_S	:	benefit value of sales
B_{TK}	:	benefit value of labor
B_E	:	benefit values of product efficiency
B_I	:	benefit value of inventory
C_E	:	equipment cost
C_I	:	implementation cost
C_X	:	training cost
C_m	:	maintenance cost
O&M	:	operation and maintenance cost
SV	:	salvaged value

4.0 CONCLUSION

A development model of the technology adoption measurement and techno-economic analysis for traceability involving a case study of companies dealing with melon production has been presented. The main result of this research is the measurement of technology adoption level in a company. The main criteria for the two companies in the case study are that one of them has implemented the traceability technology while the other did not implement the approach. From the measurement results, it can be seen that there are differences in some technological components between the two companies. In addition, with reference to the technological adoption rate measurement, this study also produces a techno-economic analysis model that can be used to calculate the B/C ratio of the traceability technology implementation ratio for the companies that will start applying the technology in the near future.

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