THE DEVELOPMENT OF TECHNOLOGY READINESS ASSESSMENT FOR COMMERCIALIZATION INNOVATION AND PRODUCT DEVELOPMENT BASED ON DIGITAL BUSINESS ECOSYSTEM

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Technology assessment is needed to determine the technology is ready or not to be commercialized. An approach has been used to assess the readiness of technology, namely Technology Readiness Level (TRL) adopted from NASA. So to solve this problem, this research focuses on developing a model for assess technology readiness based on the Digital Business Ecosystem (DBE) that consists of 3 layers. The purpose of this paper is to develop a model evaluation of the product or technology based on DBE concept. From the results of this research can be implemented for measurement technological readiness based on DBE within 3 layers, business ecosystem, application environment, and infrastructure environment.
Key words: DBE, TRL, technology assessment.

1. INTRODUCTION

In the real world until now, many technology innovations is not fully transferred to public and not sold in the marketplace. In the simplest form of the technology commercialization process, technology is developed by an institution (researcher) and then commercialized for application in the marketplace. Cooper [1] summarized the commercialization process include idea generation, product definition, concept screening, prototype development, concept testing, diagnostic evaluation, preliminary marketing, financial analysis, product development, product testing, and simulated or actual test marketing. Failure to carry out one or more of these steps has been correlated to product failure.

The most crucial step of the technology transfer process is selection of the right technologies to start transfer process. According to Cooper [1] most new product failures are attributed to bringing the wrong product to the market or the right product at the wrong time. Heslop et al [2] states that picking winning technologies amongst other technologies is not easy and often a poorly managed process. Rogers et al [3] states that technological innovation is fully transferred when it is commercialized into a product that is sold in the marketplace. New technology or product that given benefit to people has been so many creates by researcher but not all succeed to be commercialized.

In order to avoid these failures, researcher starts to evaluate their invention from first step until their product ready to apply in the marketplace. The most widely adopted metric for assessing technology maturity is the scale with Technology Readiness Levels (TRLs) developed by NASA [4]. In recent years, based on TRL Heslop at al [2] developed an evaluation technology for Cloverleaf model. Oosthuizen and Buys [4] improved cloverleaf model from Heslop et al [2] for the assessment of technology readiness for commercialization.

Business environment as an ecosystem is need to be considered to develop products until commercialized. As well as in the natural ecosystem, each species depend on each other in order to continue to thrive and to reach a balance. Business ecosystem as it has been expressed by Moore [5], an economic community supported by a foundation of interacting organizations and individuals, the organisms of the business world. The economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also

include suppliers, lead producers, competitors, and other stakeholders. Organisms in the development of innovation and commercialization is an industry, researchers, inventors and others. Each of these actors interact with each other to develop and commercialize the products.

The addition of digital to business ecosystem (called Digital Business Ecosystem or DBE) involves a digital component to support interactions in the business ecosystem. Digital components can be application software, database components, hardware, and others. DBE concept in the innovation development and commercialization of each stakeholder will form a cluster which will be assessed on their performance throughout the process. The assessment used digital scope so it will be DBE performance management in the development and commercialization of product innovation. Ecosystem that designed is a digital representation of business ecosystems that exist in the development environment of products innovation and commercialization. Each actor is in the business ecosystem represented as a digital species in the DBE.

Therefore, the existence of problems that occur in the technology transfer then this paper aims to contruct technology assessment based on DBE with mapping requirement system identification with Business Process Modeling and Notation (BPMN) to represent activity flows of evaluation product or technology invention in the real world. Then with this model, we can assess the readiness technology or product invention.

2. THEORETICAL BACKGROUND

2.1. Digital Business Ecosystem

Synthesis of Digital Business Ecosystem appeared in 2002 by adding the digital to business ecosystem. Digital ecosystem is a technology that mimics natural ecosystems to help the collaboration of several actors for certain activities [6]. Digital ecosystem called the digital business ecosystem when applied in the business environment. Hadzic and Dillon [6] have designed a digital ecosystem to help collaboration in a hospital environment (named digital health ecosystem). Digital ecosystem affects the structure of the company and their social and business networks, while business ecosystem to modify the structure of the "organism" of the digital ecosystem. Digital ecosystem and business ecosystem, as they deserve, plus structurally and evolved to form a dynamic innovation ecosystem.

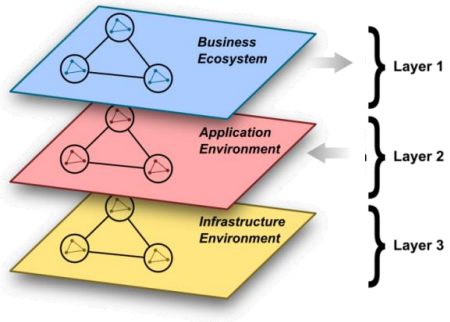

Figure 1. DBE concept for innovation and commecialization products [7]

DBE concept for innovation and commercialization products can be seen in Figure 2. Each stakeholder form a cluster which will be assessed on their performance in innovation development and commercialization (at Layer 1). The assessment used digital scope so it will be DBE performance management in the development and commercialization of product innovation.

The second layer is a representation of the first layer while the third layer is the infrastructure that supports the second layer in the form of hardware, networking and others.

2.2. Technology Readiness Level

Technological readiness (technology readiness) can be defined as how ready or mature a technology that can be applied. Definition of "readiness" is indicating a possible difference between "ready" and "not ready" of a technology or a difference "technology readiness levels" to be used or applied according to its usefulness. Technology Readiness Levels (TRLs) are a systematic metric/measurement system that supports assessments of the maturity of a particular technology and the consistent comparison of maturity between different types of technology [8].

One of the advantage of doing a technology readiness assessment is able to estimate the risks and costs for further product development and to decide when the technology is ready to be transferred to the market [9]. Technology readiness levels assessed in nine levels (Table 1) were divided into three categories or stages of the research section, namely basic research (level 1-3), applied research (level 4-6) research and development (level 7-9).

3. RESEARCH METHOD

3.1. Identification of Technology Readiness Parameters

TRL measurement parameters will be adopted from BPPT [10] and PU [11] which has been used previously for the measurement technology in Indonesia. Matrix technology readiness from PU and BPPT already categorized into nine readiness levels from initial studies, modeling, prototyping technology, the demonstration until the full-scale implementation.

3.2. Business Modeling and Notation

We have to conduct a business process model that implementing process flow in the evaluation TRL in the real world. In DBE business process analysis is located on the first layer where the stage in the analysis need to know the stakeholders involved, the role of each stakeholder, process flow occurs and others. We used Business Process Modeling and Notation 2.0 (BPMN 2.0). In BPMN, a "Business Process" involves capturing an ordered sequence of business activities and supporting information. Modeling a Business Process involves representing how a business pursues its overarching objectives; the objectives themselves are important, but at this point are not captured in the notation. With BPMN, only the processes are modeled. So in BPMN we can see business activities to develop a new product and process of evaluate technology readiness level.

3.3. TRL Evaluation

The second layer of DBE is constructed to digital with using Interval Type 2 Fuzzy Set (IT2FS). The implementation is using Java Program and the library is ready to use while using IT2FS.

As general the steps to develop IT2FS model can be seen in Fig. 2. The results of such a fuzzification process IT2FS input for the next set will be the inference to calculate the firing intervals are defined by rules. The output of the calculation is still a firing interval IT2FS, therefore the next step is to do so becomes IT1FS type reduction. The results of the calculation will result in the reduction of the type of number value in the interval [x_1, x_n]. The final step is to do so defuzzification generates output crisp value. Defuzzification is done by finding the average value of the interval.

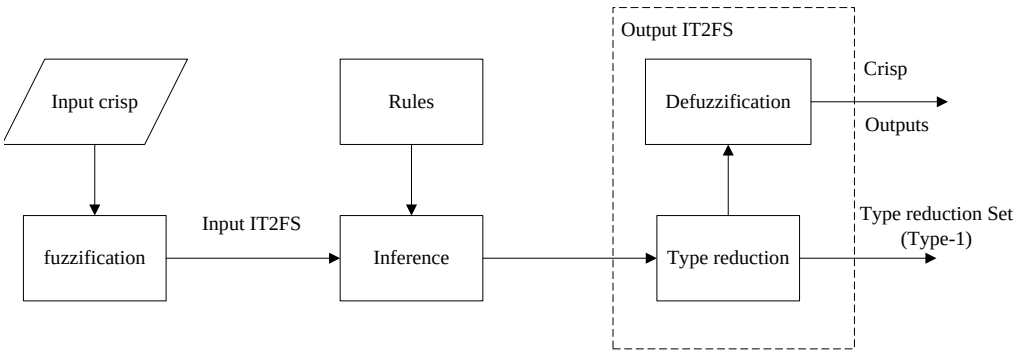

Figure 1. General steps to develop IT2FS for evaluate TRL

4. RESULT AND DISCUSSION

First layer on the DBE environment can be seen in business process flows that occur in the real world when develop product inventions that modeled by using BPMN 2.0. In a business ecosystem stakeholders have the function and each role. They will work

together to achieve a common goal in this regard to develop and commercialize products.

In a business ecosystem for the development and commercialization of product innovation stakeholders that involved consists of researchers, companies and research centers (part of researchers and evaluators). Technology evaluation begins when researchers develop products until transferring the technology from the developer to the customers who then produce a product to sell in the market.

The mechanism of evaluate new technology, for the first user or researcher has to assess his technology with Current TRL to determine the position or level of technology in the TRL. Then user verified his result. If the result is different from Current TRL then user asked to assess his technology in down level from Current TRL result. Then if the result is same with Current TRL then user is able to assess his technology to up level from Current TRL result.

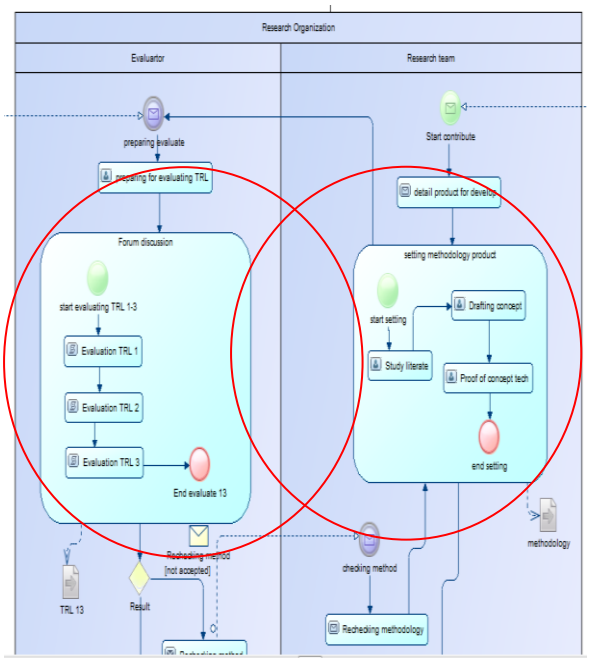

Figure 2. A capture BPMN for TRL evaluation

The second layer in the DBE is a digital representation of the first layer. The measurement method is widely adopted by researchers, companies and research centers is Technology Readiness Levels (TRLs) that was originally developed by NASA [8] where the highest level showed a complete prototype and higher system level verification.

Technology readiness can be interpreted as how ready or mature a technology to be applied. Technology Readiness Level (TRL) can essentially be defined as “indicators” that show how ready or mature a technology can be applied and adopted by users / potential users. TRL is a measurement system that supports systematic assessment of maturity or readiness of a technology certain maturity or readiness and comparison between different types of technology.

TRL which was originally developed by NASA is an indicator that shows the stages of success in achieving maturity or readiness in the form of nine technology readiness level, where between one levels to the other levels are interconnected, and became the foundation for the next level.

Table 1. TRL indicators for each level

Level TRL	Main Indicator	Number of linguistic evaluation	Range integer value
1	Basic principles observed and reported	3	[0 10]
2	Technology concept and/or application formulated	12	
3	Analytical and experimental critical functions and/or characteristic proof-of-concept	9	
4	Component and/or breadboard validation in laboratory environment (controlled)	10	

5	Component and/or breadboard validation in relevant environment	9	
6	System/sub system model or prototype demonstration in a relevant environment	8	
7	System prototype demonstration in an operational environment	15	
8	Actual system completed and qualified through test and demonstration	10	
9	Actual system proven through successful mission operations	8	

As we mentioned above, we use IT2FS to evaluate TRL. In the IT2FS model, fuzzification used to change crisp value into fuzzy input. Antecedent and consequent membership functions are Triangular membership functions. Membership Function (MF) for each variable is converted into a three ordinal scale of linguistic values, and in accordance with the provisions of IT2FS, MF has a value for each variable LMF and UMF.

Membership value for each indicator has the interval [0 10]. Inputs that will be given by user a value interval [0 10] in which the membership value for each variable that is smaller than10 will be 0 and a value greater than or equal to10will be equal to 1as shown in the Equation (6). Each MF is defined in equation (2) below will apply equally to each of the indicators at each level of TRL. Furthermore, the membership functions and rules are used to calculation of firing intervals according to Table 2

Table 2. Membership function for each indicators

MF lower	***MF Upper***
$\mu_{\underline{\text{fullfill}}}(x') = \begin{cases} 0 & x' < 8 \\ \frac{x'-8}{2} & 8 \le x' \le 10\, x' \\ 1 & x' = 10 \end{cases}$	$\mu_{\overline{\text{fulfill}}}(x') = \begin{cases} 0 & x' < 6 \\ \frac{x'-6}{4} & 6 \le x' \le 10\, x' \\ 1 & x' = 10 \end{cases}$
$\mu_{\underline{\text{unmet}}}(x') = \begin{cases} 0 & x' < 4 \text{ or } x' > 6 \\ x-4 & 4 \le x' \le 5 \\ 6-x & 5 \le x' \le 6 \end{cases}$	$\mu_{\overline{\text{unmet}}}(x') = \begin{cases} 0 & x' < 2 \text{ or } x' > 8 \\ \frac{x-2}{3} & 2 \le x' \le 5 \\ \frac{8-x}{3} & 5 \le x' \le 8 \end{cases}$
$\mu_{\underline{\text{not fulfill}}}(x') = \begin{cases} 0 & x' > 2 \\ \frac{2-x'}{2} & 0 \le x' \le 2 \\ 1 & x' = 0 \end{cases}$	$\mu_{\overline{\text{not fulfill}}}(x') = \begin{cases} 0 & x' > 4 \\ \frac{4-x'}{4} & 0 \le x' \le 4 \\ 1 & x' = 0 \end{cases}$

Furthermore, the membership functions and rules that have develop used in the firing intervals process according to Equation (3), the type of reduction process by using

Equation (4) and (5), and the process defuzzification by using Equation (6). Based on the model built, the final result (value default= y) is the value to the range [0, 10] which would then be converted in the form of linguistic values "fulfilled" or "unfulfilled". In Fig.4 we can see the interpretation of MF (for indicator in level 1) that has been establish in Java programming.

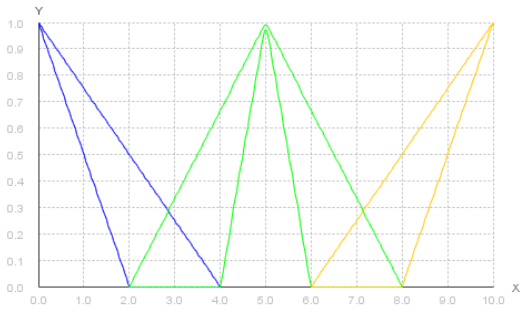

Figure. 3. Interpretation of MF in TRL evaluation

As we were mention above that the model IT2FS implemented in the Java programming language. Users (researchers or evaluators) will input technology name that will be evaluated. If a researcher who has just had new ideas and searching the information to develop their ideas then user will fill each indicator contained in the TRL level 1. If TRL 1 is fulfilled then the user can continue to vote until the user level is not fulfilled.

To find the model that has been created can be run in accordance with the needs so we try asking some researchers to assess their product inventions. There are 12 researchers with wide different product inventions. Table 3 shows the research name, category of product invention and TRL levels that have assessed with this model. Until now the category to product or technology invention classified into 3 parts, they are pharmacy, technology and food. The following will explain the test results according to some researchers TRL levels (1-3, 4-6, and 7-9). All the researchers assessed the linguistic value (Fulfilled and Unfulfilled). Investigators or examiners would be required to assess each indicator.

Table 3. Some researcher that has been used TeInvRL 1.0

No	Category	Invention products	TRL
1	Pharmacy	Essential Oil Hand sanitizer	8
2	Technology	Green paper	7
3	Technology	Bio insect technology process	5
4	Technology	Surfactant nonionic DEA based on CPO	7
5	Technology	Palm Oil Kernel Harvesting	9
6	Technology	Post-harvest Jatropha technology	4
7	Food	Innovative potatoes variety (named as JALA IPAM)	7

5. CONCLUSION

In this study, the first layer on DBE environment can be seen in business process flows that occur in the real world when develop product inventions that modeled by using BPMN 2.0. The mechanism for assessment evaluation technology starts with researcher has to evaluate his technology from determine current position his technology with assess Current TRL to determine the position or level of technology in the TRL. Then be verified to ensure the accuracy of the results of the current TRL.

The second layer on DBE is a digital representation of the first layer. Based on the analysis of business processes, digital base has designed and implemented to assess new technology in Java programming language by using IT2FS. The system is able to assess the results of product invention "fulfilled" and "unfulfilled".

There is still room to further improve the performance of the proposed model. For example, currently in the model-building

process we have made only TRL but for IRL (Investment Readiness Level) and MRL (Manufacture Readiness Level) has not done. In future studies, we should consider about that categories because IRL can measure a product "ready" or "not" to commercialized.

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