System analysis and design of aromatherapy products for innovation performance assessment toward competitive commercialization phase

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Abstract. Many new essential oil-based aromatherapy products invented by researchers failed to be commercialized and ended up in scientific publication. In fact, many commercialized products were unable to survive in market. In order to avoid these failures, performance of technology has to be assessed. Technology readiness assessment for innovation of aromatherapy products or services represent assuredness to the products. Technological readiness levels (TRLs) are widely adopted to assess the maturity of new technology. The business process model of innovation performance toward commercialization is conducted using System Development Life Cycle (SDLC) method. Through SDLC, the innovation performance system entity and Business Process Modelling Notation (BPMN) were constructed. BPMN which constructs notation of business process shows that the stakeholders involved in innovation performance assessment are innovator, evaluator, research center and investor. TRLs system of aromatherapy products were then developed for innovation performance assessment. It was able to define criteria, attributes, and metrics for performance assessment based on the basic concept of TRLs and aromatherapy. Finally, validation was done using Fuzzy Inference System (FIS). The result shows that the developed TRLs system of aromatherapy products is valid for performance assessment. It is also conforming to TRLs and aromatherapy basic concept.

1. Introduction

Aromatherapy, nowadays has emerged as part of lifestyle trends [1]. The increasing popularity of aromatherapy in lifestyle is caused by its ability to reduce the symptoms of depression [2]. Aromatherapy is one of the compatible therapies that use essential oils as the main therapeutic agent for treating several diseases [3]. Indonesia has 39 potential plants as producers of high-quality essential oils [4]. Indonesia is one of the biggest exporter of semi-finished materials of essential oil. However, the import value of essential oil in Indonesia is bigger than the export. The imported semi-finished material is processed into finished good and exported back to other countries as products with higher added value [5].

Indonesian essential oil has a high productivity upstream but low productivity downstream. It happened due to direct export of essential oil production in large portion to downstream producer countries. Hence, the innovation of technologies and essential oil-based products must be improved to add higher value in essential oil agro-industry. University is the biggest innovation actor [6]. However, many of the university innovation ended in scientific publication. Nowadays, Indonesia is in the category of economic based on efficient production processes, but it is low in innovation capacity adopted by industries. Shortcoming adoption of innovation by industry is caused by low technology readiness [7].

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According to World Economic Forum (WEF) Indonesia ranks 77th among 139 countries in technology readiness [8].

Technology readiness represents the condition of assuredness toward a technology. It refers to people’s tendency in using new technology [9] or product in daily life to accomplish work effectively. In management and marketing theory, consumer personality is a combination of positive and negative beliefs toward technology. Through assessment of Technological Readiness Level (TRL), people’s beliefs are assessed to develop the products or services [10].

The most fundamental step in [11] assessing technology readiness is to decide which technology to transfer to market. Many new products produced by researchers failed to be commercialized. In fact, a lot of commercialized products were unable to survive in the market. In order to avoid these failures, technology performance has to be assessed. TRL is widely adopted to assess the maturity of new technology. There are four variables in technology readiness, i.e. optimism, innovativeness, discomfort and insecurity [10]. The combination of optimism and innovativeness increase individual technology readiness. While discomfort and insecurity reduce technology readiness.

Analysis of innovation performance of aromatherapy products describes the business process model of innovation performance toward commercialization. Whereas, system design for innovation performance assessment of aromatherapy products was a system that provides TRLs for aromatherapy products. TRLs help to manage the risk, communicate the development progress and specify the deliverables of new product [12]. In the beginning, TRLs were developed by National Aeronautics and Space Administration (NASA). Over many years, application of TRLs measurement spread across industries. TRLs share the guideline in enhancing efforts and technology handoff for stakeholders [12]. TRLs consist of 9 levels of technology maturity. It is divided into 3 stages. TRLs 1-3 were defined as laboratory scale, TRLs 4-6 as pilot scale and TRLs 7-9 as commercial scale [10, 13].

Based on motivations and challenges, there are two objectives in this research, to analyze the business process model of innovation performance system toward commercialization of aromatherapy product and to develop TRLs system for innovation performance assessment of aromatherapy products. Toward this, there is a better TRLs system to evaluate technology readiness of aromatherapy products.

2. Methodology

2.1. Analyzing the business process model of innovation performance system

The innovation performance system is analyzed using System Development Life Cycle (SDLC). System engineering is carried out for the new system development process and improvements to the development of the old system. SDLC is used as the engineering cycle in system development. SDLC consists of planning, analysis, design, implementation and maintenance [14]. Analyzing system using SDLC escalate the understanding of a system process which support business needs by supporting, building, and providing systems to users [15].

Then the mechanism of business process was analyzed to provide the flow of the overall business process in innovation performance system toward commercialization using Business Process Modelling Notation (BPMN). BPMN represents the notation of business workflow in business ecosystem and promotes the communication between stakeholders and its environment [16]. The business process model of innovation performance system is designed using Sybase-PowerDesigner 16.5. The research framework is briefly depicted in figure 1.
2.2. System for innovation performance assessment of aromatherapy

TRLs for aromatherapy product is designed according to Agency for the Assessment and Application of Technology (BPPT) regulation. Literature review is used in designing the TRLs. New TRLs values will be categorized as valid TRLs if they are in the 75-100 value range for its conformity to basic TRLs and aromatherapy concept. The range of the limit values specified in the technology assessment is 0-100 [17].

System for innovation performance assessment of aromatherapy products is validated using fuzzy logic. In the real world, humans are always faced with the decision to choose. The data available in the many problems in the real world are quite related with uncertainties [18]. In consequence of an inadequacy of information which may be imprecise, incomplete, or contradictory, fuzzy logic theory was developed to manage the uncertainty problems [19]. Fuzzy Inference System (FIS) shows good performance in validating the developed TRLs. FIS uses linguistic values which describe inaccuracies, uncertainties and unbiased [11]. The stage of inference process in FIS is shown in figure 2. The FIS design that will be carried out are:

2.2.1. Fuzzifier. The Membership Function (MF) type used is a triangular function. Fuzzy input was collected from expert analysis toward the developed TRLs of aromatherapy products based on its conformity to the basic concept of TRLs and conformity to aromatherapy concept. Meanwhile fuzzy output is used to ensure the system validity. Fuzzy input and output set for membership function is depicted in table 1 and 2. Degree of membership in fuzzy formulation follows the equation.

\[ A = \{ (x, \mu_A(x)) \mid x \in X \} \]
Table 1. Fuzzy input set.

| Variable                                               | Input set | Domain |
|--------------------------------------------------------|-----------|--------|
| Conformity to the basic concept of TRLs (CBC)          | Low (L)   | [1,3]  |
|                                                        | Middle (M)| [2,4]  |
|                                                        | High (H)  | [3,5]  |
| Conformity to aromatherapy concept (CAC)               | Low (L)   | [1,3]  |
|                                                        | Middle (M)| [2,4]  |
|                                                        | High (H)  | [3,5]  |

Table 2. Fuzzy output set.

| Variable                      | Input set     | Domain |
|--------------------------------|---------------|--------|
| TRL validity (PA)             | Not fulfilled (N) | [1,3] |
|                               | Unfulfilled (U)  | [2,4] |
|                               | Fulfilled (F)   | [3,5] |

2.2.2. Rules. In fuzzy inference process, If-Then rules form the deducing mechanism, which indicates how to project input variables into output. If-Then rules formulated as follow:

\[
\text{If } <A \text{ is } a \text{ and } <B \text{ is } b \text{ then } <C \text{ is } c >
\] (2)

Where A and B are the fuzzy input and C is fuzzy output. Decision rules for TRL verification shown in table 3 below.

Table 3. Decision rules for TRL verification.

| CBC | CAC | PA  |
|-----|-----|-----|
| If  | H   | H   | Then | F   |
| If  | H   | M   | Then | F   |
| If  | H   | L   | Then | U   |
| If  | M   | M   | Then | F   |
| If  | M   | M   | Then | U   |
| If  | M   | L   | Then | N   |
| If  | L   | H   | Then | U   |
| If  | L   | M   | Then | N   |
| If  | L   | L   | Then | N   |

2.2.3. Inferences Process. Inference is a key component of a fuzzy logic system. The results of the verification process are input sets for the FIS, and then it will be inferred by calculating the firing interval based on the rules set. Calculation of firing intervals can be done using equations:

\[
\mu_{A \cap B} = \min(\mu_A[x], \mu_A[y])
\] (3)

2.2.4. Defuzzifier. Defuzzifier is the opposite operation of fuzzifier. Defuzzification is the last step to get the final result. The formula for defuzzification for the centroid method follows the equation:

\[
z = \frac{\sum_{i=0}^{n} z_i \cdot \mu_C(z_i)}{\sum_{i=0}^{n} \mu_C(\theta_i)}
\] (4)
3. Result and Discussion

3.1. Business process model of innovation performance system analysis

Innovation performance system is an activity which plays important role in innovation ecosystem. The lack of commercialize innovation of essential oil-based products especially aromatherapy is the main focus in providing better solution for innovation performance system. The analysis of innovation performance starts from identifying the entity of system. The system entity is shown in figure 3. The system considers several entities that are built from inputs, stakeholders, controls, resources, goals, threats, and outputs [14]. This ensure all factors in system act properly in developing the system.

The stakeholders involved in system are innovator, evaluator, research center and investor. Research center and researcher can act as self-evaluator of the technology invention. Furthermore, the expert evaluator team conduct evaluations starting from compiling the concept of key product development. Interaction between evaluator and innovator continues until the research is completed and ready to be commercialized. BPMN diagram was developed to specify the processes of reality abstraction in system [20]. BPMN represent the relationships, processes, workflows, formulations and stakeholders in the system with real-life business situation [16]. Modeling a business process involves the representation on how a business pursues its objectives [11]. The BPMN of innovation performance assessment depicted in figure 4.

3.2. System design of innovation performance assessment toward commercialization

The measurement method adopted by researchers, companies and research centers is TRLs, which were originally developed by NASA [21]. Table 4 shows the TRLs developed by NASA. The TRLs system for assessing aromatherapy product performance is briefly depicted in table 5. In addition, TRLs are divided into three major functional categories; TRL 1-3 as proof-of-concept, TRL 4-6 as proof-of-principle, and TRL 7-9 as proof-of-performance [19]. The first stage of product development maturity is briefly pursued from data collection, related scientific reviews and analyses of tested hypotheses [22]. From development to demonstration, TRLs 4-6 act as bridge with scientific research in laboratory scale to engineering [19].

To advance from the first stage to the pilot plan stage, biological performance in laboratory are validated [22] to proof products quality and safety. Progressing from proof-of-concept stage to proof-of-principle stage requires manifesting manufacture capability for representative material at least in the laboratory scale [19].
Table 4. TRLs developed by NASA.

| TRL | Main Indicators [21] |
|-----|----------------------|
| 1   | Basic principles observed and reported |
| 2   | Concept and/or application formulated |
| 3   | Concepts demonstrated analytically or experimentally |
| 4   | Key elements demonstrated in laboratory environment |
| 5   | Key elements demonstrated in relevant environments |
| 6   | Representative of the deliverable demonstrated in relevant environments |
| 7   | Final development version of the deliverable demonstrated in operational environment |
| 8   | Actual deliverable qualified through test and demonstration |
| 9   | Operational use of deliverable |

Table 5. TRLs for aromatherapy technology.

| TRL | Main indicator for aromatherapy technology [2, 3] |
|-----|---------------------------------------------------|
| 1   | - Fundamental concept, innovation, or scientific principle that is key to the aromatherapy technology as therapeutic agent in treating medical ailment. |
| 2   | - Practical applications for the research or innovation of aromatherapy technology is developed. |
|     | - Hypothesis is generated. |
|     | - Target validation requires demonstration that the target is likely to have a therapeutic effect based on scientific paper studies. |
| 3   | - Hypothesis testing includes analytical and laboratory-based studies data of non-Good Laboratory Practice (GLP) to validate analytical predictions of aromatherapy effect in limited number of in vitro and in vivo research models. |
| 4   | - Validation should be consistent with the requirements of potential applications. |
|     | - Laboratory prototype been created that integrates all aromatherapy elements. |
|     | - Laboratory demonstration been conducted to proof-of-concept of products quality and safety. |
| 5   | - Aromatherapy prototypes are integrated with realistic supporting elements so that the aromatherapy technology can be tested and demonstrated in simulated or actual environments. |
|     | - Provide assays to ensure that aromatherapy product is in pharmacological potentials. |
| 6   | - Represents a major step in aromatherapy technology’s demonstrated readiness, include testing a prototype in a high fidelity laboratory environment. |
|     | - Validate assays to assess pharmaceutical effect from aromatherapy. |
| 7   | - Scale-up version/prototype of the technology is near or at the planned operational system. |
|     | - Studies of the Good Manufacturing Practices (GMP) in formulation, dosage form, and container consistent. Commence manufacturing process validation and consistency for large production. |
| 8   | - The Aromatherapy technology has been proven to work in its final form under expected conditions. |
|     | - Prepare and submit new aromatherapy products licensing application to International Federation of Aromatherapists (IFA) or Standar Nasional Indonesia (SNI) or Badan Pengawas Obat dan Makanan (BPOM). |
| 9   | - Application of the aromatherapy technology in its final form and those encountered in operational test and evaluation. |
|     | - Start post-licensure clinical trials to confirm safety and efficacy as feasible and appropriate. |
In the last stage, the engineering pilot plan must be demonstrated and be capable to perform all the function as aromatherapy products. At TRL 7, the prototype of products should almost be complete to reduce manufacturing risk. Products ready to be distributed and marketed if the technology is at the TRL 9 [22]. System of innovation performance assessment of aromatherapy products is able to define criteria, attributes, and metrics for evaluating and classifying technical standards and specifications based on their maturity.

The TRLs system is validated by testing the conformity of system to the BPPT’s TRL system and aromatherapy concept using Mamdani FIS. The fuzzification process in the FIS model is carried out by changing the input in the form of crisp values so that it becomes fuzzy input (figure 5). The model of fuzzification process is triangular model [11]. Membership value for each indicator has the interval [0 10]. The inference process maps the inputs which were fuzzified into fuzzy output. Hence, the relationship between fuzzy input and rules will be inference to define the firing interval. The last process was defuzzification (figure 6) which convert fuzzy output to single value output (crisp) [18].

![Figure 5. Fuzzy input.](image1)

![Figure 6. Defuzzification.](image2)

IF validity of TRL is equal and/or bigger than 8, then it fulfills as an indicator. The final result from FIS is confirming the performance of TRL in assessing aromatherapy products. System validation using FIS shows that, it was a very appropriate method to deal with uncertainty in deciding TRL indicators to assess new products. Modes value from expert validation is shown in table 6.

| TRL | CBT | CAC | PA  |
|-----|-----|-----|-----|
| 1   | 5   | 5   | 8,7 |
| 2   | 4   | 5   | 8,47|
| 3   | 4   | 4   | 8,47|
| 4   | 5   | 3   | 8,7 |
| 5   | 3   | 4   | 8,47|
| 6   | 5   | 4   | 8,47|
| 7   | 4   | 4   | 8,47|
| 8   | 5   | 4   | 8,47|
| 9   | 3   | 5   | 8,7 |
4. Conclusion and future work
System analysis using SDLC and BPMN was able to illustrate the business process in specifying the processes as the reality with real-life business situation in innovation performance assessment system. The system entity is constructed by inputs, stakeholders, objectives, controls, resources, threats, and outputs [14]. The TRLs system for innovation performance assessment of aromatherapy product is able to define criteria, attributes, and metrics for evaluating and classifying technical standards and specifications based on their maturity. Toward TRLs system performance, FIS is able to validate the system objectively for innovation performance of aromatherapy products toward commercialization based on TRLs conformity to basic concept. In future studies, FIS should be considered in assessing technology readiness of new aromatherapy products using TRLs system for aromatherapy.

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