Bridging Technometric Method and Innovation Process: An Initial Study

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Abstract. The process of innovation is one of ways utilized to increase the capability of a technology component that reflects the need of SME. Technometric method can be used to identify to what extent the level of technology advancement in a SME is, and also which technology component that needs to be maximized in order to significantly deliver an innovation. This paper serves as an early study, which lays out a conceptual framework that identifies and elaborates the principles of innovation process from a well-established innovation model by Martin with the technometric method, based on the initial background research conducted at SME Ira Silver in Jogjakarta, Indonesia.

1. Introduction

Human lives will never be apart from technology. Numerous studies have given contribution to the development of technology, and it is justifiable to say that humans and technology have a substantial interdependency, which makes them simply inseparable [1]. Mankind cannot survive without technology and on the other hand, technology will never exist without the hands of human race.

The feeling of dissatisfaction or the notion of “the pursuit of perfection”, is in fact a part of human nature, which is naturally invented as a response to their suffering in dealing with survival circumstance. This propensity of improvement becomes an important agent of improvement for technology and science in general [2].

If we analyze further on technology, there is a different perspective that is not as straightforward as we thought. Technology has four essential components i.e. technoware, humanware, infoware, and orgaware [3]. Each component plays a major role in an industry, be it big scale or small and medium enterprises (SME). Nevertheless there is a difference in managing these components that could lead to different level of maximization. Big industry in general has an adequate level of awareness regarding the components in management of technology aside from generous capital and a more structured organization, leading to lesser effort in increasing capabilities. In contrast, SME lacks this kind of wareness due to limited capital and human resources. A study on usage of information technology in Nigeria confirmed that lack of awareness, training, and infrastructure, contributed to underdeveloped fruition [4].
SMEs need to change in order to grow the organization, economy of nearby society, and eventually reduce poverty level. Indonesian SMEs have grown rapidly and been faced with various demand from consumers. In order to serve those diverse market, SMEs need a technology advancement i.e. innovation. The process of innovation is ingrained together with its components and this very process will be examined in this paper by measuring the capability of each component in management of technology, with SME as the research object. Despite how simultaneous these components are in applying technology, it is very likely to have certain component stands out compared to the other, in terms of having bigger impact to the innovation process. Prior to innovate, SMEs ought to know where they stand with respect to level of sophistication within each component, which can be measured by using technometric method [3]. This method encompasses technology (technoware), organization (orgaware), human resource (humanware), and information related to technology within the organization (infoware), and analyses the dynamic interaction among components to determine the level of sophistication.

1.1. The profile of SME Ira Silver
This research focuses on a silversmith in Kotagede, Yogyakarta. Every single touch of silversmith reflects the sheer culture that still exists. The birth of silversmith in Kotagede was in tandem with the genesis of Kotagede as capital city of Matam Islam in the 16th century. There is evidence that shows how silver, gold, and blacksmith have already been known to existence since the 9th century (the era of old Mataram/Hindu) with the finding of inscriptions in Central Java. The development of silversmith in Kotagede entered the golden age during 1930 – 1940, with the emergence of new enterprises, quality improvement, and discovery of new patterns.

After experiencing ups and downs, the silversmiths in Kotagede managed to survive and turned themselves into a tourist destination in Yogyakarta, but several problems rose as dollar became unstable causing high price for silver yet the selling price for used-silver remained low. This led to dwindling silver enthusiasts that put pressure on silver industries, including SME Ira Silver. Founded by Mr. Lesmanu in 1990, Ira Silver works through a form of cooperation between a group of silversmiths like cooperation Apikri, that extended their wings to cities even countries. The workers who were starting to alter their job toward becoming factory labor became a problematic part of silver industries. Moreover, the rising price of dollar affected negatively in Ira Silver’s sales. Mr. Lesmanu then started to make some adjustments by producing silver-coated copper and combining silver with stones, all with a hope to reduce the usage of silver. He hoped that with his innovation, the quantity of goods sold would rise, however his limitation on technology advancement diminished the effectiveness of the innovation itself. The applied changes did not bring substantial impact as he had expected because the change occurred only on product level without paying attention to other components.

The outcome could then be used to increase the capability of promising components to reach their maximum potential i.e. which components contribute significantly in the innovation process by using technometric method. Moreover the research should be extended to generate strategies that would improve the selected component(s), with the ultimate goal of increasing sales.

1.2. Research objective
Based on the circumstance of Ira Silver and theoretical framework, this research aims to lay out a preliminary study with respect to the relation between technometric and innovation process.

2. Theoretical Framework

2.1. Definition of technology
Technology can be defined as knowledge, product, process, equipment/tool, method, and system applied to generate goods and provide service [5]. In short, technology is how one does something to attain her goal. Technology is equally a practical implementation of knowledge to help humans in their work. The common perception of technology is hardware, machines, computer, or any sophisticated devices. In fact, technology is more than just a machine. There are several technology entity beside hardware such as software and human capability.
Hardware is a physical structure and logical arrangement of a device or machine-related things used to complete a task; Software is the knowledge on how to use the hardware; while Brainware is defined as the thinker, who creates and provides reasoning to use technology in a meticulous manner. The fourth aspect is know-how, which translates to knowledge or technical skill required to ensure the task is being done precisely and correctly, incorporates experience, knowledge transfer, and direct training.

Technology and knowledge are two spheres tied together strongly. Any application that entails technology advancement, shall follow the up-to-date knowledge. Knowledge is not information, but the result of thought process behind the information [5]. The vast development of technology information has broadened the spread of information across the world, resulting in what is called as knowledge explosion and astonishing progress in technology.

2.2. Technometric

The standard definition according to the Economic and Social Commission for Asia and Pacific (ESCAP) of United Nation classifies technology into four simultaneous components [6]:

- Technoware (T) = object-embodied technology = physical facility = technical device: includes tools, equipment, machines, vehicles, factory, and physical infrastructure, with which humans operate a transformation.
- Humanware (H) = person-embodied technology = human abilities = human resources’ capability: includes knowledge, skills. Wisdom, creativity, achievement, and experience of one or a group of persons in leveraging available natural or technology resources.
- Infoware (I) = document-embodied technology = document fact = information device: includes process, procedure, technique, method, theory, specification, design, observation, manual, and other facts revealed through publication, documentation, and blue print.
- Orgaware (O) = institution-embodied technology = organizational frameworks = institutional device: essential to accommodate physical facility, human skills, facts, and includes management practices, and organizational management to reach a positive result.

Technometric method as an analysis for the level of technology contain, aims to measure aggregate contribution of all four technology components within transformation process from input to output, which then can be described as technology contribution. Technology Contribution Coefficient (TCC) can be formulated in a multiplicative function as follows:

\[
TCC = T^{\beta_t} H^{\beta_h} I^{\beta_i} O^{\beta_o} \tag{1}
\]

T, H, I, O reflect contribution of Technoware, Humanware, Infoware, and Orgaware; \(\beta_t, \beta_h, \beta_i, \beta_o\) reflect the intensity of contribution for each component to TCC. There are five steps that serve as procedure to estimate the value of T, H, I, O, \(\beta\):

- Estimate the degree of technology sophistication
  - Data collection: degree of sophistication for technology component
  - Qualitative observation on T, H, I, O
  - Evaluation and give score to T, H, I, O
  - Define top and bottom limit of available technology sophistication
- Conduct assessment for State of The Art (SOTA)
  - Determine status of technology component against SOTA with the formula (2), (3), (4), and (5):

\[
ST_t = \frac{1}{10} \times \left[ \frac{\sum k_t T_{ik}}{k_t} \right] ; k = 1,2,\ldots,k_t \tag{2}
\]

\[
SH_h = \frac{1}{10} \times \left[ \frac{\sum i_h H_{ji}}{i_h} \right] ; i = 1,2,\ldots,i_h \tag{3}
\]

\[
SI = \frac{1}{10} \times \left[ \frac{\sum m_f m_{mf}}{m_f} \right] ; m = 1,2,\ldots,m_f \tag{4}
\]

\[
SO = \frac{1}{10} \times \left[ \frac{\sum n_o n_{no}}{n_o} \right] ; n = 1,2,\ldots,n_o \tag{5}
\]
• Capability: technical knowledge, in relation with the best condition within transformation facility.
• Criteria: scoring from 0 (lowest specification) to 10 (highest specification).
• Between score: interpolation approach.
• Determine component contribution
  • Define contribution by using the limitation of sophistication degree and SOTA.
  • \( T_i \), \( H_j \) = contribution of each item i technoware and item j humanware. The formulas to determine component contribution are shown below (6), (7), (8), (9):

\[
T_i = \frac{1}{9} \times [LT_i + ST_i(U_T_i - LT_i)]
\]

(6)

\[
H_j = \frac{1}{9} \times [LH_j + SH_j(U_T_j - LT_j)]
\]

(7)

\[
I = \frac{1}{9} \times [LI + SI(U_I - LI)]
\]

(8)

\[
O = \frac{1}{9} \times [LO + SO(U_O - LO)]
\]

(9)

• Assessment on the intensity of component contribution \( \beta \), whose format is a coupled comparison matrix.
• Calculate TCC using formula (1). TCC is the total contribution of operating technology transformation vis-à-vis output made by SME.

As TCC indicates the gap between technology content between input and output, therefore if there are two TCC values but one with higher output, then it can be said that the one with higher output will have the upper hand. The maximum value of TCC is 1, and TCC value represents the level of technology in an organization as shown in table 1 [7].

| Table 1. Qualitative assessment of TCC. |
|-------------------------------|-----------------|
| TCC Value | Classification |
| 0.1 | Very low |
| 0.3 | Low |
| 0.5 | Normal |
| 0.7 | Good |
| 0.9 | Very good |
| 1 | HighlySophisticated |

After following the aforementioned five steps, one can then position the organization’s technology level through a THIO Diagram. TCC value cannot be 0 as it translates to the absence of even the slightest advancement in each component contributing collectively. TCC value will then be compared to table 2 and 3, which are the more elaborated versions of table 1.
Innovation is defined as new discovery that differs from previous or existing one [8]. One can be deemed as innovative if she continues to make improvement and provide differentiation, which are paramount virtues to be a successful entrepreneur.

The process of innovation is a complex activity through a transformation from ideas and knowledge to physical form and tangible application. This process of actualization turns knowledge into advantageous products and service leading to a positive value for social and economy aspect of society. Within the process of technology innovation, there are several types of elasticity:

- Technology elasticity: shows the effect of change in quality of technology with respect to demand change over the technology
- Absolute elasticity: shows the responsiveness of total market demand due to dimension improvement in technology quality.
- Relative elasticity: shows the shift in market due to better introduction from competitor.

The advancement of innovation technology has several steps described as the Model of Technology Innovation Process [9].

- Scientific invention: an initial step in the innovation process where theoretical findings or new knowledge can support the success of innovation. Having said that, not all innovation came from this step as it requires huge amount of capital and long period of time.
- Engineering development: this step represents the creation of product, which also oversees the proficiency and anything related to manufacturing process.
- Entrepreneurship: innovation process in this step indicates how innovation has to be able to attract opportunity of new or more exciting subjects, which can also be associated with how to get consumers through marketing or fulfilling their desires. An entrepreneur plays an important role in innovation as she is the driving force for the business that has a vision to a better future state. Equally so, an entrepreneur can create jobs and boost nation’s economy.
- Entrepreneurial activities have a lot to do with innovation process because not only do they involve a set of management skills e.g. problem analysis or decision-making, they also require ideas, thoughts, and creativity in order to have the upper hand over the competitor.
- Management: this step shows the importance of management to achieve the goals through several activities: planning, organizing, actuating, and controlling, in order to have a structured, smooth, and sustainable business.
- Recognized social need: innovation process in this step examines the reason behind one’s need for a product and where it belongs within Maslow’s hierarchy of needs.
- Supportive environment: this is the last step of the innovation process where environment serves as an important supporting factor.

### Table 2. Quantitative assessment based on TCC interval

| TCC score | Classification |
|-----------|----------------|
| 0 ≤ TCC ≤ 0,1 | Very low |
| 0,1 ≤ TCC ≤ 0,3 | Low |
| 0,3 ≤ TCC ≤ 0,5 | Normal |
| 0,5 ≤ TCC ≤ 0,7 | Good |
| 0,7 ≤ TCC ≤ 0,9 | Very good |
| 0,9 ≤ TCC ≤ 1 | Highly sophisticated |

### Table 3. TCC-based technology level.

| TCC score | Classification |
|-----------|----------------|
| 0 ≤ TCC ≤ 0,1 | Traditional |
| 0,3 ≤ TCC ≤ 0,7 | Semi Modern |
| 0,7 ≤ TCC ≤ 1,0 | Modern |
3. Research methodology
The flow of thinking in this research is presented through the schemes below:

4. Result and review
Technometric model aims for measuring aggregate contribution of four technology components within a transformation process from input to output by firstly analysing the level of technology content in each component i.e. technoware, humanware, infoware, and orgaware. This calculation then will be presented in a form of THIO diagram, reflecting the position of each technology advancement. Visually, this diagram will portend which component that needs to be improved to stimulate innovation process. The aggregate technology score can also be classified into categories to mark the
state of an organization at that time, which can then be re-measured over time in a form of longitudinal study to examine the progress of technology enhancement.

Through his innovation model, Martin indicated the importance of having scientific, engineering, entrepreneurial, and management skills, which resonates with the elements assessed in technometric method i.e. human, technology, organization, and information. This resemblance is perceived as a justification on why the authors proposed to combine Martin’s model with this method. Moreover, the additional two spheres i.e. need and socio-politic environment, brings an interesting external aspect of innovation that is not covered in technometric, to the whole conversation with regards to enabling the innovation process itself. A well-rounded innovation road map can then be synthesized by leveraging the technometric assessment on how SME Ira Silver can work on elevating each innovation stage and equally engage with the externalities to realize a fruitful innovation.

5. Conclusion
Technometric method can be used to identify to what extent the level of technology advancement in a SME is, and also which technology component that needs to be maximized in order to significantly deliver an innovation. Furthermore, this study justified the collaboration between technometric and Martin’s innovation model through their clear similarity with regards to innovation scope, as well as additional aspects that can be used to extend the discussion to include the external state of the entity per se. As a continuation of this study, a questionnaire can then be utilized to measure the level of sophistication for each component, before extracting them into TCC value. Another important part is to have a better traceability for each innovation stage, which can be mitigated by establishing a strategy roadmap synthesized with the joint-inputs from both authors and SME owner. This approach will increase the feasibility aspect of the whole innovation effort.

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