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Technology Management Practices and Infrastructure in Nanotechnology Industry: The Malaysian Case

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Abstract

The nanotechnology industry continues to grow in size and importance around the world, with many countries of both developing and developed status taking action by launching their own National Nanotechnology Initiatives. With the increasing cost of maintaining the research and development (R&D), as well as commercialisation of such a promising field in a growing country like Malaysia, industry players, such as research centres and private companies, need to find ways to improve their profit margin as well as provide quality products for their customers. One cost saving aspect is in the management of the technology, i.e., technology management practices. Even though it has been discovered through literature that technology management is a system that improves competitiveness and performance of organisations, there are still problems related to it, such as the traditional issues associated with cost, delivery, and quality, as well as surrounding influences from the environment regarding the infrastructure, specifically the R&D and industrial infrastructure, human resource, and industry readiness. This paper presents the review of literature regarding technology management and infrastructure in managing the organisational performance of companies in the nanotechnology industry, specifically in Malaysia. Through this review, the issues and challenges have been revealed and a potential research model has been formulated in order to assist in overcoming the highlighted problems.

Keywords: Technology management practices; Nanotechnology management; Infrastructure; Organisational performance, Malaysia.

1. Introduction

Without waiting to watch its neighbours pass it by, the Malaysian government has taken up the challenge of exploring the vast potentials of nanotechnology by launching its own National Nanotechnology Initiative on 4 July 2005 in Johor Bahru, Malaysia (Asia Pacific Nanotech Weekly, 2005). In order to remain competitive, Malaysia has to have its own nanotechnology policies, as well as strategic plan to manage this viable technology, as extensively stressed by the then Deputy Prime Minister, in several of his public appearances regarding the research and management of nanotechnology.

The report by Asian Technology Information Program ATIP (2006) had identified the infrastructure components for supporting the nanotechnology industry, namely R&D infrastructure, human resource, industry infrastructure, and industry readiness. From the comparison performed in 2006, it was highlighted that the Malaysian nanotechnology industry still requires more development in R&D infrastructure and human resource development, as compared to the other ANF countries; ANF being a network organisation that is supported by 13 countries, including Australia, China, Hong Kong, India, Indonesia, Korea, Japan, Malaysia, New Zealand, Singapore, Taiwan, Thailand, and Vietnam.

1.1. Problem Statement

Hashim *et al.* (2009) had provided the outlook of the nanotechnology industry in Malaysia through their research. The study had concluded that the Malaysian scenario required much work in the management of such high technology. Some of the highlighted problems within the nanotechnology industry include lack of linkages between various projects, no central facility, there is no definitive plan to realise and develop the nanotechnology industry, there is no clear overall road-map for nanotechnology research, and lack of effort in promoting awareness of nanotechnology. Furthermore, Hashim et al. also revealed a Strength, Weakness, Opportunity, and Threat (SWOT) analysis of the nanotechnology industry in Malaysia, as formulated by the Malaysian Industry-Government Group for High Technology (MIGHT), which is placed under the supervision of the Economic Planning Unit (EPU) of the Malaysian Prime Minister's Department. Some of the weaknesses identified were, no dedicated policy for nanotechnology, need for human resource planning, lack of private sector investment and participation, lack of facilities, and lack of world-class companies to raise the standard. All these identified issues would not only have a detrimental impact on the R&D, but also retard the commercialisation process of promising products.

Therefore, "nanotechnology [based] organisations should be more flexible, productive, and fast in producing the product, in light of changes in customers' demand behaviour" (Zulhumadi *et al.*, 2010). Furthermore,

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competitiveness of these organisations is highly dependent on the level of effectiveness and efficiency of the technology management to cater for the changes and demands. As a result, nanotechnology organisations must prepare themselves through their technology management to be highly flexible and responsive to the changes in this competitive environment.

In response to this, the National Innovation Council (NIC) convened on 14 February 2011 and agreed that an agency was needed to monitor and facilitate the commercialisation of the nanotechnology industry. This resulted in the establishment of NanoMalaysia Berhad in 2011, as a company limited by guarantee (CLG), that is parked under the watchful eyes of the Ministry of Science, Technology, and Innovation (MOSTI). NanoMalaysia acts as a business entity to run nanotechnology commercialisation activities, with the specific roles of commercialisation of nano-R&D, industrialisation of nanotechnology, facilitation of investment and funding, and the development of human capital tosupport the nanotechnology industry (Nanomalaysia, 2018a).

One of the many programmes implemented to facilitate the growth of the nanotechnology industry in Malaysia, is the NanoVerify programme (a voluntary nanotechnology verification programme co-created with SIRIM QAS International with advice from Standards Malaysia), which resulted in the establishment of NanoVerify Sdn. Bhd. in 2015 (Nanomalaysia, 2018a). According to the market report by Nanoverify (2018b); there are over 500 nanotechnology products in the Malaysian market; however 34 products have been verified thus far. This illustrates the great potential of the nanotechnology industry can have if managed well, through technology management practices and infrastructure.

1.2. Research Objectives

The general objective of this research is to investigate the current development of the nanotechnology industry from the perspective of technology management practices and infrastructure. More specifically, the objectives of this study are to:

1. to define and investigate the current state of nanotechnology in Malaysia, from the perspective of infrastructure and technology management practices on organisational performance;
2. to develop a framework for the Malaysian nanotechnology industry from the perspective of infrastructure and technology management practices on organisational performance; and
3. to validate the framework for infrastructure and technology management practices on organisational performance in the Malaysian nanotechnology industry.

1.3. Significance of the Study

Since more and more interest is being directed to nanotechnology, there is a growing need for exploring the management side of nanotechnology, rather than just the technical and material aspect. More interest means that there is more funding being allocated to this high technology industry, which entails more risk in technically developing such high technology. Therefore, in order to minimise the risks and to facilitate the growth and development of such a potentially viable industry, there is a dire need to guide this growing industry to develop at a more rapid pace by avoiding the traps and pitfalls of (mis)managing previous technologies.

1.4. Scope of the Study

This study is expected to cover the nanotechnology companies in Malaysia, where the population of which may be ascertained from several sources, such as the Ministry of Science, Technology, and Innovation (MOSTI) and other government agencies, such as the Malaysian Industry-government Group for High Technology (MIGHT), and the Malaysian Industrial Development Authority (MIDA). However, in order to truly ascertain the actual companies that deal in nanotechnology and verifiably use nanotechnology-based material in their products, this study shall obtain a list of companies from NanoVerify Sdn. Bhd. (NVSB), a wholly-owned company under NanoMalaysia Berhad (NMB). NMB is an agency under the Minister and Deputy Minister of Energy, Technology, Science, Climate Change, and Environment, who have been given the responsibility of monitoring and facilitating nanotechnology research, development, and commercialisation in Malaysia. NVSB has been appointed by NMB to fully operate Malaysia's first and only nanotechnology verification and certification programme, which is known as the NanoVerify Programme. The reasoning behind this is that since this industry is heavily supported by the government, companies that wish to thrive in this industry would one way or another, be linked to these government agencies in order to receive some kind of support. It is anticipated that the field of study for this research effort would be related to technology management, specifically its practices and infrastructure. Justification for this would be that these are two possible key areas for facilitating the growth of the nanotechnology industry.

2. Literature Review

2.1. Nanotechnology Strategy in Malaysia

Closer to home, the Malaysian government had funded some pioneering work in nanotechnology during the Seventh Malaysia Plan which span the years 1996 to 2000 (National Nanotechnology Initiative NNI, 2010). Further reinforcement was of this nanotechnology research drive was seen with the emphasis of nanotechnology being one of 14 priority research areas in the Intensification of Priority Research Areas (IRPA), which was governed by the Malaysian Ministry of Science, Technology, and Innovation (MOSTI).Furthermore, National Nanotechnology Initiative NNI (2010) had stated the short term strategy for Malaysia was, geared toward identifying researchers in various areas of nanotechnology with specific expertise; upgrading and equipping nanotechnology laboratories with state-of-the-art facilities; and to prepare a comprehensive human resource development programme for producing nanotechnologists.

This is further reinforced by the National Science and Technology Policy II (Ministry of Science, Technology, and Innovation MOSTI, n.d.) which, specifically with regard to nanotechnology, desires to position Malaysia as a technology provider in the key strategic areas of nanotechnology; to ensure the widespread diffusion and application of nanotechnology, leading to enhanced market-driven research and development (R&D) to adapt and improve technologies by undertaking a detailed scrutiny of the industry; and to build competence for specialisation in key emerging technologies by developing a secure knowledge base in nanotechnology to sustain technology support for the Malaysian industry (MOSTI, n.d.).

The technology management practices (TMP) concept has been applied and proven successful empirically in the manufacturing sector, covering many industries including food, textile, and healthcare industries to name but a few. However, there were also some concerns raised over the applicability of such an approach in all the different industries. The variation of all the industries has perhaps caused doubt about the applicability of this concept. However, there are also efforts being made to explore its promising applicability in other viable sectors, such as the focus of this paper, the nanotechnology industry. NMB had identified four major sectors that nanotechnology has impacted upon, namelyelectronic devices and systems, food and agriculture, energy and environment, and wellness, medical, and healthcare. To date, NMB has successfully created and supported seven joint venture/start-up companies, which had resulted in the development 51 products, with 12 of them being successfully commercialised (Nanomalaysia, 2018b).

The successful companies of today continue to grow in size and operations, and with the advent of globalisation, more companies are facing greater challenges in trying to conquer a larger share of the market. In the industrial sector, companies are moving away from concentrating on just their products to a more holistic approach whereby they shift their focus on the processes internal and external to their company. No longer are successful businesses looking to improve just themselves, but also improve their immediate partners upstream and downstream of their. This is where technology management practice (TMP) has been touted as perhaps the next viable way of gaining this advantage (Mohtar *et al.*, 2010). A collaborative environment facilitates would facilitate communication among the nanotechnology work groups, with place and time becoming non-factors. Such an environment allows work groups to work simultaneously in planning and designing nano-related products, forecasting, and making decisions. Integration across disciplines or functional areas is needed in order to resolve the complexity of linkages in the supply chain. Moreover, players along the nanotechnology chain need to have close relationships with their upstream and downstream partners within the supply chain.

2.2. Infrastructure Factors (Independent Variable)

2.2.1. R&D Infrastructure

Infrastructure would definitely affect the nanotechnology industry, since certain fields of nanotechnology, such as semiconductors, would have special requirements regarding the electricity and water supply. Waste treatment also becomes an issue with certain nanotechnology fields. Infrastructure (facilities and technology) are the support structures that allow an organisation's work to proceed. These structures are often taken for granted in developed countries. However, where infrastructure is inadequate especially in the developing nations, this presents an organisational problem that warrants assessment.

The utilisation of information that flows within the organisation is an important process. Information that flows from one entity or functional area to another should be able to support the management in formulating the strategy. Furthermore, organisations should be able to develop a strategy that enables all members to share information, work together, and formulate common objectives to maintain the competitiveness of individual organisation (Mohtar *et al.*, 2010). Information and communication technologies (ICT) and its underlying infrastructure have fundamentally altered the nature of global markets, transforming social and economic interactions, and redefining work (Organisation for Economic Cooperation and Development OECD, 2017).

Technological change is occurring faster than policies are able to respond, more so in the nanotechnology where one is witnessing the discovery of new scientific fact that has a great impact on other fields and technology. However, information gaps continue to exist between the developed and developing countries, with the potential to disenfranchise entire communities on the edge of the information revolution. The technological resource of an organisation covers

all equipment, machinery, and systems (including the library, information systems hardware, and software) that are requisite for the proper function of the organisation. However, these instruments of technology are merely tools for enhancing services and products, thus ideas must still inspire the technology.

While Malaysia is rapidly moving towards developed countries, the need to put into place a sound and solid infrastructure to support R&D has become paramount. In order to answer this, the emergence of technology parks typically generates the expectations that they will contribute significantly to the industrialization process of R&D. The terms of "technology parks", "science parks", "research parks", "industrial parks" and "innovation parks", etc. have always been used interchangeably in past studies (Nanotechnology, 2018).

Generally, the terms refer to clustering of industries designed to meet compatible demands of different companies within one location. The physical layout can be described as tract of land developed and subdivided into plots or zones according to a detailed plan equipped with roads, transport and public utilities for the use of a group of industrialists. Given the necessary support of infrastructure and facilities in the technology park, the companies expected to obtain benefit from economic of scale. In addition, the comprehensive services provided will necessitate diversified effects on the surrounding region and finally, stimulate regional development.

The technology park basically will act as the catalyst that drive the start-up of newly established high-tech firms and guide the existing firms for advancement in process and product innovation. The broader roles of a technology park can be defined (Organisation for Economic Cooperation and Development OECD, 1999) as, has formal and operational links with a university or other higher education institution or major centre of research; is designed to encourage the formation and growth of knowledge-based businesses and other organisations normally resident on site; and has a management function that is actively engaged in the transfer of technology and business skills to the organisations on site.

Consequently, "Technology Park" in this study was defined as an area that allows benefits to individual firms located on the park (Chan and Lau, 2005). One of the critical benefits of technology parks is to encourage and facilitate the formation and growth of knowledge-based businesses, which are categorized as 'incubator'. The incubator, therefore, will assist entrepreneurs with business start-ups and development, and with possible involvement of the public, private and non-profit sectors (Organisation for Economic Cooperation and Development OECD, 1999). There is broad recognition today that entrepreneurial, knowledge-based enterprises are prime creators of economic growth and that such ventures need special business development services (QAA, 2018).

2.2.2. Human Resource

The human resource is one of the key factors that contribute to the growth and development of any industry, more so for the knowledge and skill demanding nanotechnology industry. Human resource management involves "human capital", which refers to the skill and knowledge levels of the workforce. The top level management is of the view that employees are the key source of an organisation's competitive advantage (Durany, 2016); especially in nanotechnology. Pertinent factors that affect human resource management is the development and instilling of core values throughout the organisation, which include integrity and honesty, commitment to the organisational mission, accountability for

and pride in one's work, commitment to excellence, and building trust (Gehman *et al.*, 2013). These core values form the basis for developing cohesiveness and teamwork, as well as for developing policies, procedures and programmes that focus on meeting the needs of customers or clients.

Meanwhile, human resource skill planning involves the forecast of organisational human resource needs, and following through to meet these needs. For this planning to be effective, it should be closely linked to the organisation's strategic objectives and mission. According to (CIPD, 2018); such planning is a challenge, even in regions of the world with a plentiful, well-educated workforce, because the needs of the organisation are constantly changing and sometimes do not converge due to various pressures from various sources.

Staffing is an important step in implementing a human resource plan is to recruit and train new employees to carry out the work of the organisation. With the various focussing and narrowing of nanotechnology fields that demand more specialised knowledge, staffing an organisation is becoming a challenge. Staffing an organisation means to source out, choose, and train individuals that are equipped with a suitable spectrum of knowledge, skills, behaviour, and values to assist the organisation in meeting the organisational needs. Staffing becomes even more of a challenge due to the changing labour climate which is due to pressures from the industry and the government.

Developing and enhancing human resource is always an important agenda in any organisation, which means increasing employee performance by improving their skills, knowledge, and attitudes through training. This enables the organisation to minimise performance deficiencies, make employees more flexible and adaptable, and increase staff commitment. Placing the right employees at the right time is a crucial aspect of human resource development. An effective and popular approach to develop human capital is staff training and development programmes (Engetou, 2017); however a good strategy would be to develop the human capital at earlier stages, such as at the pre-tertiary stages.

2.2.3. Industry Infrastructure

While human resources and financial resources are quite typically reviewed in most industrial assessments, more attention needs to be paid in developing countries to the state of the industrial infrastructure required to support organisational performance (Mohammed *et al.*, 2016).

Infrastructure refers to the basic conditions (facilities and technology) that allow an organisation's work to proceed—for example, reasonable space in a building equipped with adequate lighting, clean water and a dependable supply of electricity, as well as viable transportation to and from work for employees. In developed countries that have the wealth and the governmental structures to support adequate infrastructure, these conditions are often taken for granted. In some developing countries, however, inadequate infrastructure presents an industrial problem that warrants assessment.

Each industry has its own assets and liabilities with respect to infrastructure resources. If the industry has its basic infrastructure in place, this area will represent a small component of the assessment. If the infrastructure is deteriorated, however, with electricity and water found to be problem areas, then the infrastructure will become a major concern of the assessment.

2.2.4. Industrial Readiness

The role of technology in customer-company interactions and the number of technology-based products and services have been growing rapidly. Although these developments have benefited customers, there is also evidence of increasing customer frustration in dealing with technology-based systems, thus the question of readiness comes into question.

Technology readiness levels (TRLs) of industries, i.e., industrial readiness, are measures used to assess the maturity of evolving technologies (devices, materials, components, software, work processes, etc.) during its development and in some cases during early operations. Generally speaking, when a new technology is first invented or conceptualised, it is not suitable for immediate application. Instead, new technologies are usually subjected to experimentation, refinement, and increasingly realistic testing. Once the technology is sufficiently proven, it can be incorporated into a system/subsystem.

Based on the effort by the U.S. Department of Defence (Department of Defence, 2010); the TRLs can be described into nine different levels, ranging from the very basic level to the deployment level, namely 1) basic principles observed and reported, 2) technology concept formulated, 3) characteristic proof of concept, 4) component validation in laboratory environment, 5) component validation in relevant environment, 6) prototype demonstration in a relevant environment, 7) system prototype demonstration in an operational environment, 8) actual system completed and qualified through test and demonstration, and 9) actual system proven through successful mission operations. These can be adapted to reflect the readiness of an industry.

2.3. Technology Management Practices (Moderating Variable)

When it comes to defining the technology management practices, it was observed in the literature that a universally accepted census of this construct is few and far in between. Some of these works had included the term technology management practice under various conditions and focusing on different areas.

In the work by (Li-Hua and Khalil, 2006); they revealed several critical factors in technology management practices. These had been identified as key factors in technology management that must be considered by business executives and policy makers alike. These issues include technology transfer, changes in the global business environment, harnessing communication and information technology, organisational structure, business finance, and education and training.

Meanwhile, in the area of strategic technology management as published by (Sahoo *et al*., 2011); the technology management practice covers 1) technology strategy drivers, 2) business expansion strategy, 3) technology development strategy, 4) technology capability development, 5) technology implementation, 6) supplier development, and 7) manufacturing-technology capability development approach. They presented the results of several case studies set in the automotive component industry in India. The output of their research was the conclusion that, “in the dynamic and competitive automotive industry, organisations need to continuously keep ahead in terms of technology to remain competitive” (Sahoo *et al*., 2011).

From an alternative viewpoint, work by Larosiliere *et al.* (2013); attempted to investigate the technology management construct, by basing it on the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh *et al*., 2003); and Will, Skill, Tool (WST) model of technology (Knezek and Christensen, 2002) developed in the instructional technology research domain. Larosiliere *et al.* (2013) has established that technology management encompasses the campus leadership, instructional support, and planning regarding the integration of technology in the classroom. The components of technology management used in their study are as follows: leadership and vision, planning, institutional support, technology budget, and communication openness, all of which was based on Texas Education Agency TEA (2010). However, after careful deliberation, they established the technology management construct as consisting of 1) leadership and vision, 2) planning, 3) instructional support, 4) communication, 5) budget.

2.4. Organisation Performance (Dependent Variable)

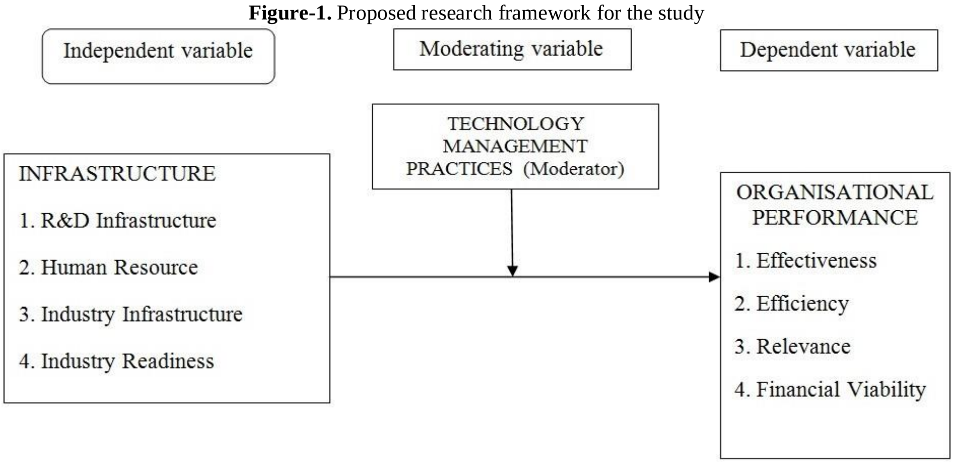
Companies operating in different competitive environments may have different performance objectives and their competitive strategy must fit the specific needs of the company and its customers. A stable environment enables reutilised operations focused on building efficient and lean operation flows. Their operations are dedicated to functional products with long life cycles and a low degree of innovation, such as in stable consumer goods industries.

Their performance priorities start with cost, followed by delivery, and quality. Companies in dynamic environments should focus on agility and market-responsiveness. They enable the production of innovative products with short life cycles, such as in emergent industries with rapid technological change (Da and Cagliano, 2006). Therefore, their major performance objective is flexibility, followed by quality, and delivery.

Considering these facts, for assessing the operational performance of organisations, researchers use the following as the major variables for investigation (Da and Cagliano, 2006): (1) cost; (2) quality; (3) delivery; and (4) flexibility. Cost is determined by the scale of economies, capacity utilisation, and inventory turnover. Delivery involves performance in lead times and supply reliability. Quality may involve both conformance and performance issues, appearing to suggest that stable operational system is aimed at quality sustainability (conformance) levels, which might not be as high as the quality supremacy (performance) levels of the system (Da and Cagliano, 2006). Cost, quality, delivery/dependability, and flexibility have become widely used as indicators of competitive dimensions of manufacturing. In each market in which the company operates, it should identify those criteria that win orders against the competition (Voss, 1995).

Figure 1 shows the research framework developed for this study.

Figure-1. Proposed research framework for the study



3. Conclusion

This initial review as well as the preliminary interviews with prominent players in the nanotechnology industry has revealed factors that may influence the practice of technology management. These factors can be investigated and confirmed through taking the next step in the research pathway, which is to perform a pilot study in order to identifyany problems with the survey instrument. Once the main round of investigation is underway, it is anticipated that the respondents would provide the feedback for confirming the research framework, which will then be a contribution to the body of knowledge, as well as become a guide for future policy makers and stakeholders in forging a pathway for this promising industry to thrive in Malaysia.

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