

Factors that Influence Successful Technology Commercialization

Ayodeji Sulaiman Olawore, Kuan Yew Wong and Azanizawati Ma'aram

School of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Malaysia
olawore@graduate.utm.my, m-wongky@utm.my, niza@utm.my

Wahyudi Sutopo

Department of Industrial Engineering, Universitas Sebelas Maret, 57126 Surakarta,
wahyudisutopo@staff.uns.ac.id

Abstract

Technology commercialization (TC) is crucial to companies' survival and progress in the rigorous and competitive market environment. Thus, it is vital to understand the factors that impact the successful commercialization of developed products. This paper presents a systematic analysis of literature on TC. The transformation of ideas to marketable products or technology encompasses the steps involved in TC. This study also focuses on the incubators or channels for commercializing developed technologies. The contributions of incubators such as universities and research institutes, start-up firms, and established firms in developing the technologies and selling the products are explicitly presented. The systematic literature review was conducted on factors that influence technology commercialization through the means of analysing relevant indexed and peer-reviewed journal articles. The purpose of this technique is to make the process of gathering the literature data more apparent and minimize the inconsistency of the researchers concerning the analyses. This paper adds to the knowledge by analysing the major factors that impact the success of TC in an industrial firm and aids the researchers to establish the theoretical and empirical analysis of TC.

Keywords

Technology, Commercialization, Incubator, Startup firm and Success factors.

1. Introduction

Technology development (TD) has been well known as the driving force behind the production of goods and services, market competitiveness, improved standard of living of the populace, and prospects of enhanced trade especially during the era of the reliant global economy (Balachandra et al., 2010). Nevertheless, technological development can promote the growth of the economy only if the technologies or products are commercialized (Van Rooyen et al., 2020). Many stakeholders such as the government, researchers, marketers, and entrepreneurs are involved in determining the future successes of TC (Afful-Dadzie et al., 2017). Determining the success of TC is significant to the stakeholders or decision-makers to grasp the likely growth potential of a technology or product in a vigorous and competitive environment. Invested products or technologies with high TC contribute to the economy and growth of the nation (Altuntas and Dereli, 2012). Numerous benefits are being derived from the successful commercialization of a new concept or idea such as job creation, job security, financial incentives, contribution toward the company's long-term stability, generation of revenue, and profit among others (Dhewanto and Sohal, 2015).

Technology commercialization (TC) is defined as the means of transferring technologies or innovative products from the conception phase to the markets for acceptance and usage. It is one of the basic aspects of technology management purposes (Ravi and Janodia, 2021). Newly developed technologies are considered necessary to be transferred and integrated into the market through organizations such as technology start-ups, established firms, and universities and research institutes that can either function as technology developers and/or business entities that bring the technologies to the market (Kirchberger and Pohl, 2016). TC is a two-phase process that entails the technology-based phase which involves the production of products or technologies (Jiang et al., 2020), and the marketing phase that involves the marketing and commercialization of the produced technologies (Mukhtarova et al., 2016). The production of new products or technology involved R&D which spans from the development of the idea that undergoes basic and applied research to the technology manufacturing phase. The developed technologies are commercialized through different

strategies using different modes of incubators to meet consumers and market demand (Do et al., 2018). Technology or product has the propensity to be adopted swiftly by prospective consumers if it is highly dependable, inventive, as well as well-suited with existing products. Effective diffusion of technology facilitates TC (Noh et al., 2018a).

In the past decade, there are limited research that solely focused on encompassing the various dimensions and factors that contribute to the success of TC based on diverse factors in different sectors, processes, and technologies in the manufacturing industry. Previous studies on the significance of incubators towards the success of TC and the phases of TC were not explicitly explained.

This research aimed to explicitly analyse the steps involved in TC and various dimensions with diverse factors that influence the success of TC by exploring the available literature for in-depth knowledge. This study addresses the significance and contributions of incubators to the success of TC. The paper is organized as follows; Section 2 presents the theoretical background of the stages of TC and channels or incubators for commercializing the technologies. The research methodology on the literature review and the factors that influence TC are addressed in Section 3 and the technology commercialization success factors are described in Section 4. The problems of TC and conclusion are discussed in Section 5 and Section 6 respectively.

2. Theoretical background

2.1 Stages of technology commercialization

Generally, the concept of TC encapsulates the entire process involved in the production of products initiated via the creation of ideas with complementary knowledge, design, prototyping, and testing stages to efficient marketing of the manufactured products (Hung et al., 2011; Park and Rhee, 2013). The development of concepts/ideas involves initiating innovation by identifying the problems that are transformed into concomitant needs and creating ideas to satisfy a particular need. Researchers involved in concept development for successful TC must possess specific traits such as business-minded opinion, ingenuity, and inspiration (Van Rooyen et al., 2020). The ingenuity of rigorous and thorough research aids to ameliorate ideas development to innovation and transformed the innovative products or technologies to be commercially feasible (Ravi and Janodia, 2021). The R&D involves academic scientists that are engaged in different forms of innovative activity spanning from the transfer of knowledge to technology transfer (TT) as the process to transform intellectual research into values creation (Abd Rahim et al., 2021). The success of R&D in an organization is attributed to the transfer of knowledge by employing scientific skills/know-how and boosting the commercial value of the new or improved cutting edge technologies produced through the utilization of knowledge transfer and technological diffusion to the market (Baron, 2021).

According to Dhewanto and Sohal (2015), TC is divided into three stages namely: *research, development and design, and wealth development*. The *research stage* involves basic and applied research. The *development and design stage* involves the development of technology, evidence of idea creation (design), development of model or prototype, and manufacturing on three different scales: laboratory, pilot, and factory. *Wealth development* involved marketing, unveiling the product and selling to end-users, licensing or trading of the intellectual property to established firms and start-up firms; as well as creating spin-offs.

2.2 Technology commercialization incubators

A business incubator is an innovator approach aimed to offer support to activities associated with technology and management to aid businesspersons in developing recent business enterprises (Games et al., 2021). The incubators or channels can be seen as a mechanism for connecting physical services and a diversity of commercial services such as technology, capitalists, small-scale and large-scale companies, and sources of investment for development technology and commercialization with better likelihoods of subsistence at the initial phase of development (Wonglimpiyarat, 2010). The innovator or technology developer that brings technologies to market and commercializes the new technologies originates from organizations such as universities and other research institutes, established firms, and technology startups (Connors et al., 2021). These TD organizations can collaborate to transfer new technologies into commercial organizations (Kirchberger and Pohl, 2016). The marketing strategies of the incubators involved in the development of technology are presented in Table 1. These incubators or channels are subsequently explained in the subsequent subsections.

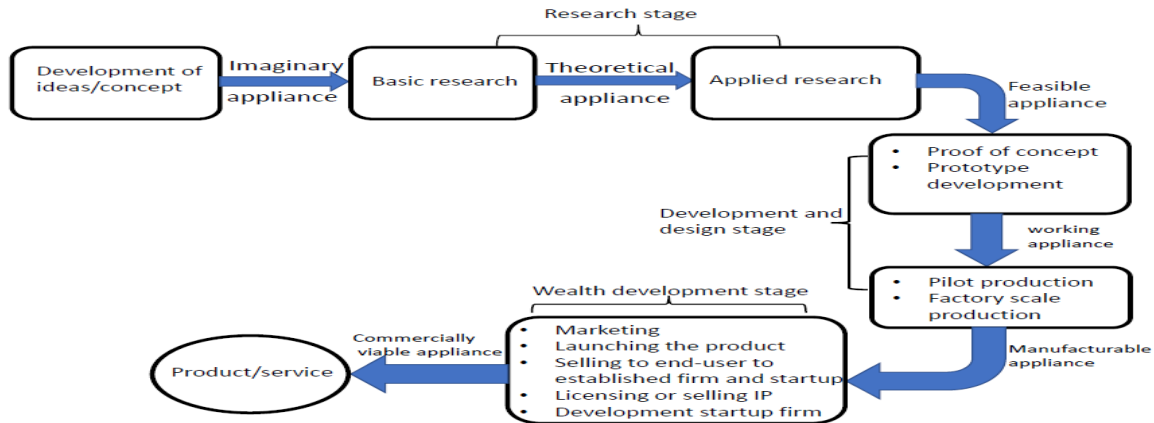


Figure 1. Steps involved in TC

Table 1. Marketing strategies of the incubators involved in the development of technology.

Universities and research institutes	Startup firms	Established firm
Joint ventures and through third parties (Corporate partnership)	Selling or licensing their technology to established firms	Licensing and patenting their intellectual property right to the established companies and public research institutes
Establishment of spin-off firms	Entering the market with new products	Creation of new organization unit
Selling, exchanging, and licensing of patent	Spin-in into government agencies	Entering the market with new technology

2.2.1 Universities and government-funded research institutes

Universities perform crucial functions in the transitioning of technology since the means of studying and acquirement of innovative knowledge are the bedrock for the best leading edge of discoveries throughout the globe (De Moortel and Crispeels, 2018). In addition, universities with superior capability to efficiently transfer information have greater TC performance and financial stability or sustenance (Fadeyi et al., 2019). The mutual understanding and cooperation between universities (research institutes) and firms have immensely improved in recent years. Industries collaborate with universities for enhanced research synergy and widen their scientific knowledge in a related field of their operation (Ahamat et al., 2021). The viewpoint of the industries towards collaborating with universities appears as prerequisites of firms concerning the universities' superior commitment to certify technologies produced from extensive research and knowledge transferred (Andrews et al., 2021; Roncancio-Marin et al., 2022).

Commercialization of technology developed by universities, government-funded laboratories, or research institutes can be implemented via selling, exchanges, and licenses, using certain physical facilities such as spin-off companies (Fadeyi et al., 2019; Mukhtarova et al., 2016), incubators (Games et al., 2021), start-ups (Hamilton and Philbin, 2020; Zhao and Ziedonis, 2020), strategic alliances (Leischnig and Geigenmüller, 2020; Van Rooyen et al., 2020), joint business enterprise (Adams and Link, 2018) as well as via the mediators (license of IP resources and contracts) (González et al., 2018). The establishment of spin-off companies from universities frequently happens when the emerging company has discovered that the preliminary market is unavailable for the developed technologies or when the firms in the market are incapable of employing the latest technology (Kim, 2020a). The establishment of spin-off firms is also frequently advocated as the desired process for transferring the technologies and scientific knowledge obtained by the research firms to the private sector for commercialization which consequently provides jobs and improves productivity (Jung and Kim, 2018; Messina et al., 2022).

2.2.2 Technology startups

A technology start-up is a form of entrepreneur that initiates the latest business enterprises via the process of converting a commercial concept into technologies as well as building the technologies with great modernization techniques (Taweasangrunroj et al., 2021). Start-up firms have sprung up job opportunities due to the government or university laboratory spin-offs. Likewise, start-up firms can hasten the economic development and industrial innovation in the areas in which they are situated (Kim, 2020b). Technology start-ups that are involved in invention activities are usually small in size, young firms, and not well versed with the nature of the potential market that would engage their new technologies. Small and medium-sized start-up firms are characterized by impresario's skills, knowledge, and proficiency, and is also referred to as start-up technology. These firms can commercialize the developed technology through different possibilities or mediums; by selling or licensing their technology (intellectual property (IP)) to reputable firms in the market, by moving into the market with their technology, and to spin-in into government agencies (Kim, 2020b; Kirchberger and Pohl, 2016).

2.2.3 Established companies

Established companies can market their developed technologies in the labs through different routes or channels. These include licensing and patenting their intellectual property right (IPR) to interested founded firms or public research organizations, the creation of new administrative or organizational units, and entering the market with their new technologies (Kirchberger and Pohl, 2016). There are some cases in which the established companies do not commercialize the developed technologies by themselves because the technologies might not affiliate with the company's main business model or aim of the firm. Nonetheless, the developed technology may add immense value to the firm if other commercialization alternatives are contemplated. This kind of circumstance is referred to as the commercialization of misfit technology (Anokhin et al., 2011).

3. Research methodology of the literature review

A systematic literature analysis was conducted on the factors that influence TC through the means of analysing relevant indexed and peer-reviewed journal articles. The purpose of this technique is to minimize the inconsistency of the researchers concerning the analyses and make the process of gathering the literature data more apparent.

A wide-ranging literature review was conducted with a comprehensive search on relevant literature associated with TC for assessment due to the broad application and significance of TC in promoting the economy of the globe. The keywords used during the process of searching for literature are “technology commercialization”, “success factors”, “performance factors”, “indicators”, “technology commercialization success factor”, “commercialization incubators, and “ commercialization channels”. Initially, the number of papers that were primarily obtained was 102 but later screened and trimmed down to 64 Web of Science and Scopus indexed articles. The pieces of literature obtained were published between 2003 and 2022. The number of the reviewed papers that are published between 2003 and 2022 is presented in Figure 2. The reviewed articles were also obtained from major electronic databases such as Springer, Elsevier, IEEE, Emerald, Taylor and Francis, Sage, among others.

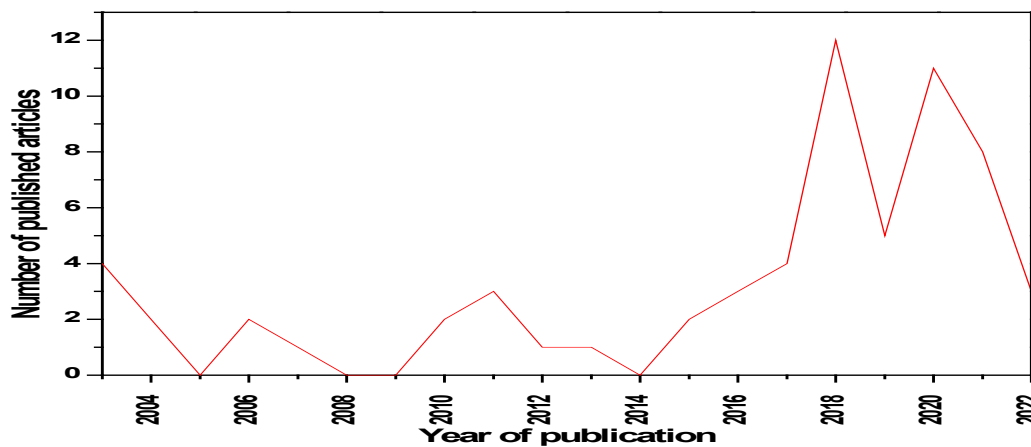


Figure 2. Number of published articles per year

3.1 Technology commercialization success factors

A comprehensive insight is necessary to explore the factors influencing successful TC. Literature in the past decades has identified some of the factors that impact TC. The dearth of accord concerning the factors that affect the success of TC has led to the suggestion made by some researchers such as Noh et al. (2018b) and Zemlickienė and Turskis (2020) that there might not be any generic success factors due to diverse technologies and sectors. In the research conducted by Yazdimoghaddam et al. (2018), a fuzzy expert system was developed to forecast the TCS and four dimensions were put into consideration during the analysis; technical evaluation, economic, financial and market evaluation, and rules and regulations. Kirchberger and Pohl (2016) reviewed several journal articles on success factors of TC and twelve (12) factors were highlighted in the reviewed literature. The factors are industry nearness, innovation culture, intermediaries' support, management techniques, networking activities, property rights, characteristics of the individual researcher, resource availability, team structure, technology application value, TT strategy, university policy and structure, and technology suitability for commercialization.

Taweasangrunroj et al. (2021) analysed the factors that affect the funding of technology start-ups in Thailand. The entrepreneur's features, product features, market features, and financial considerations were considered as the factors that support the government organization to assess or appraise the prospective candidates' business propositions and evaluate the worthiness of being supported to develop new creativities that would make them endure the rigorous market competition. However, economic, institutional, and regulatory environments do not affect government organizations' judgments in choosing prospective start-up firms to assist since these attributes negate the objectives of the agencies for helping technology start-ups. The success factors that influence TC in the early phases of TD were considered by (Noh et al., 2018a) from three viewpoints namely; technology characteristics, organization capabilities, and opportunity characteristics. They performed a logistic regression analysis on the indicators and recognized the market-associated factors (market potential, commercialization strategy, and situation of the market) as important in driving TC success. The research outcomes revealed that opportunity-associated indicators have a superior influence on commercialization success than the others. In another research, Noh et al. (2018b) conducted a systematic process to examine and enhance the accuracy of technology assessment models. In their research, technology-based dimension (technology capability, R&D and production risks, and commercialization likelihood), market-based dimension (market capability, market prospect, and economic outcome), and organization-based dimension (management capabilities, R&D proficiencies, and IP capabilities) were considered as criteria that influence the performance of TC.

Zemlickienė et al. (2017) also studied the factors that influence the commercial potential of developed technology using an expert approach. The degree of significance for the ranking factors was ranked in this descending order: value for the consumer, technology features, competitive environment, situation of the market, competency of technology developers, financial environment, circumstances relating to the inventor, legal environment, and internal policy of the institution. The feasibility of the commercialization of information technology and biotechnology was evaluated by Zemlickienė and Turskis (2020) using the MCDM technique. The factors enumerated by Zemlickienė et al. (2017) were also considered for the assessment of the commercialization of both information technology and biotechnology. Chung and Hyun (2019) used the meta-analytic structural equation model to analyse the success factors for TC. The success factors considered in the research were R&D competency, CEO competency, absorptive capacity, commercialization competency, technology sources, and social capital resources. Yazdimoghaddam et al. (2019) recognized the factors that impact the performance of TC and the ranking of the factors based on their significance to the success of TC using fuzzy Delphi and Analytic Network Process (ANP) respectively. They identified thirty-two factors that were classified into four indicators namely, technical characteristics, financial characteristics, market characteristics, and rules and confirmations. The literature reviewed in this article for diverse factors that affect the success of TC in different sectors and technologies are enumerated in Table 2.

4. Technology Commercialization Success Factors

Technological developments are regarded as the key driving force for innovation under the purview of technology push, whereas the market pull focuses on marketplace requirements as the impetus of innovation through research and development, thus private-sector financing to fulfil market needs (Ravi and Janodia, 2021). The technological dimension can be regarded as one of the major drivers of TC because they aid the organization to understand and develop ground-breaking technologies, stimulating organizational know-how, and enabling swift product or TD (Jiang et al., 2020). Nevertheless, a firm's competitive edge is both technical and non-technological based characteristics (Chung and Yoon, 2020).

The market dimension is concerned with the sector of the technological market to which the proposed technologies fit in terms of market demand together with the customers' view on similar technologies in the market in comparison to the capability of such prospective tech. The assessment of the success of TC required critical attention at various potential possible actions from the decision-maker in terms of cost, results, and consequences before committing money to the proposed tech (Bandarian, 2007; Taweasangrunroj et al., 2021). (Table 2)

Table 2. Review of factors that affect the success of TC

Dimensions	Factors	References
Technology	Technical features	Bandarian (2007), Altuntas and Dereli (2012), Afful-Dadzie et al. (2017), Yazdimoghaddam et al. (2019), Chen et al. (2011), Kumar and Jain (2003), González et al. (2018)
	R&D capabilities	Noh et al., (2018b), Yazdimoghaddam et al. (2019), Chen et al. (2011), Kumar and Jain (2003), Kumar and Jain (2003), González et al. (2018)
	Acceptability of Technology	Bandarian (2007), (Noh et al., 2018b), Altuntas and Dereli (2012), Afful-Dadzie et al. (2017), Yazdimoghaddam et al. (2019), Galbraith et al. (2006), Zemlickienė et al. (2017), Kirchberger and Pohl (2016), Taweasangrunroj et al. (2021), González et al. (2018)
	Technology transfer strategy	Yazdimoghaddam et al. (2019), Kirchberger and Pohl (2016), González et al. (2018)
	Resources availability	Yazdimoghaddam et al. (2019), Kumar and Jain (2003), Kirchberger and Pohl (2016)
	Patentability of technology	(Noh et al., 2018b), Afful-Dadzie et al. (2017), Yazdimoghaddam et al. (2019), Chen et al. (2011), Kumar and Jain (2003), Kirchberger and Pohl (2016), González et al. (2018),
Market	Marketing capabilities	Bandarian (2007), (Noh et al., 2018b), Afful-Dadzie et al. (2017), Yazdimoghaddam et al. (2019), Zemlickienė et al. (2017), Kumar and Jain (2003)
	Market potential	Bandarian (2007), (Noh et al., 2018b), Altuntas and Dereli (2012), Afful-Dadzie et al. (2017), Yazdimoghaddam et al. (2019), Zemlickienė et al. (2017), Taweasangrunroj et al. (2021)
	Perception of technology	Bandarian (2007), Altuntas and Dereli (2012), Afful-Dadzie et al. (2017), Yazdimoghaddam et al. (2019)
Organizational	Management capabilities	(Noh et al., 2018b), Altuntas and Dereli (2012), Chen et al. (2011), Kumar and Jain (2003), González et al. (2018)
	Innovation culture	Yazdimoghaddam et al. (2019), Zemlickienė et al. (2017), Kirchberger and Pohl (2016), González et al. (2018)
	Traits of individual	Kumar and Jain (2003), Kirchberger and Pohl (2016), Taweasangrunroj et al. (2021), González et al. (2018), Yazdimoghaddam et al. (2019)
	Team structure	Yazdimoghaddam et al. (2019), Galbraith et al. (2006), Zemlickienė et al. (2017), Kumar and Jain (2003), Kirchberger and Pohl (2016), González et al. (2018)
	Intermediaries' support	Kumar and Jain (2003), Kirchberger and Pohl (2016)
	Networking activities	Galbraith et al. (2006), Chen et al. (2011), Kumar and Jain (2003), Yazdimoghaddam et al. (2019)
	Educational qualification of the entrepreneur	Altuntas and Dereli (2012), Galbraith et al. (2006), Kumar and Jain (2003), González et al. (2018), Yazdimoghaddam et al. (2019)
	Location of the firm	(Noh et al., 2018b), Altuntas and Dereli (2012), Kumar and Jain (2003) Kirchberger and Pohl (2016)
	Licensing strategies	Chen et al. (2011), González et al. (2018)

Table 2. Review of factors that affect the success of TC Continue

Dimensions	Factors	References
Organizational	Legal oriented capabilities	Bandarian (2007), Altuntas and Dereli (2012), Afful-Dadzie et al. (2017), Yazdimoghaddam et al. (2019), Chen et al. (2011), Zemlickienė et al. (2017), González et al. (2018)
Financial	Cost of investment	Bandarian (2007), Afful-Dadzie et al. (2017), Galbraith et al. (2006), Taweasangrunroj et al. (2021)
	Capital return strategy	Bandarian (2007), Afful-Dadzie et al. (2017), Kumar and Jain (2003)
	Funding potential	Bandarian (2007), (Noh et al., 2018b), Altuntas and Dereli (2012), Afful-Dadzie et al. (2017), Yazdimoghaddam et al. (2019), Zemlickienė et al. (2017), Kumar and Jain (2003)
Societal	Employment creation	Afful-Dadzie et al. (2017)
	Environmental Protection	Afful-Dadzie et al. (2017), Zemlickienė et al. (2017), Kumar and Jain (2003)
	Competitive environment	Yazdimoghaddam et al. (2019), Zemlickienė et al. (2017)

In the financial dimension, the funding of a product does not only aid the R&D, marketing, liquidity, and intellectual patent protection but also the start capital and risk investment. This dimension assesses the potential firms' overall fiscal situation in terms of financial benefits and drawbacks (Kowalska-Pyzalska, 2018). The organizational dimensions are concerned with individual or organizational capabilities that contribute to the effectiveness and efficiency of the company's technology or R&D-related events. The organization dimension also addresses the benefits of tech as a resource, as well as business strategic alternatives to technologies (Noh et al., 2018b). The primary goal of the social dimension is to establish the influence that any proposed technology might have on their location of operation, and hence on the country where the firm would be situated (Kakati, 2003).

The common factors cited at least in six different articles that are enumerated in Table 2 are discussed in the subsequent sub-sections.

4.1 Technical features

The technical features assess not only the ability of the technology in satisfying its aims but also its constraining aspects and the level of intricacy of the technology or product (Altuntas and Dereli, 2012). They are important means for encouraging and establishing a firm's innovation plan as well as viable success with the vital outcome of innovation activities (Bakhtiar et al., 2020). It also necessitates and promotes the firms to deploy different technologies to produce new products and improve on the existing products via the acquired skills or technical knowledge from the organization. This consequently facilitates the success of TC (Pek et al., 2018).

The traits of technology affect the market potential by identifying prospective users owing to specific reference to particular technological traits such as the genericness, innovativeness, compatibility, and intricacy of technology (Chen et al., 2011).

4.2 R&D Capability

This is a critical factor in improving new product development success by decreasing the developmental duration of new goods. R&D capability is critical in drastic innovation with technical professionals, and it is a significant factor in technology developments (Kirkley, 2016). The existence of firm-affiliated research institutes and qualified R&D personnel have beneficial impacts on the advancement of technology innovation competence in terms of technical effectiveness (Park and Shin, 2017). The potential benefits of R&D capabilities on TC success criteria are also based on the culture of the company, familiarity with innovations, diverse nature of the R&D team, as well as clear awareness of the collaborative nature of the innovation process (Chiş and Crişan, 2020).

4.3 Acceptability of Technology

Technology acceptability evaluation focuses on the adaptation and adoption of new technology or product into prevailing techniques or the means that involve the technology substituting both the technical and process evaluation (Altuntas and Dereli, 2012). The new technologies or products must possess distinctiveness and get competitive

benefits over other challengers in the market (Taweasangrunroj et al., 2021). This factor also assists in evaluating the degree of the technical quality of the developed product in regard to the simplicity of application to the selected market and its capability to be incorporated into current operations are involved (Afful-Dadzie et al., 2017).

4.4 Patentability of Technology

The legal bottlenecks that would prevent competitors from introducing intellectual properties (IPs) to the market need to be analysed when considering the success of commercializing new products or technologies (Afful-Dadzie et al., 2017). This factor describes the prospect of the technology developer to use a patent for the protection of research as well as the capability to acquire property rights of new tech. The protection of patents also reduces the possibility of the new technology from being imitated (Kirchberger and Pohl, 2016).

4.5 Marketing capabilities

The marketing capabilities help not only the company to promote and analyse the market requirements, but also provide value to existing and new technologies or products, and fulfil client demands through marketing strategy, finding niches, and structuring product offerings (Arunachalam et al., 2018). These capabilities provide links between the consumers and the markets through organizational competencies. The latest developed products are launched to the marketplace by the firm through superior marketing strategies (Nerkar and Roberts, 2004). Marketing strategies are utilized to assess the likelihood of technology diffusion into the market by developing both market and customer acknowledgment of the products with advertising strategies, distribution network tactics, competitive benefits, and market infiltration strategies (Taweasangrunroj et al., 2021).

4.6 Market potential

The potential of the market on a produced product or technology can serve as a moderator in the links between technological aspects and the prospect of successful commercialization (Chen et al., 2011). A market analysis is necessary for TCS especially when breakthrough innovations are considered. The breakthrough or cutting edge techs alter the entire structure of a market, perhaps eliminating existing contending technologies or producing an entirely new technological niche (Bandarian, 2007). This factor involves the identification and evaluation of the market need for the proposed tech, identifying the market's existing requirements, the technology's compatibility with market demands, and the technology's ability to expand and enter the market (Yazdimoghaddam et al., 2019).

4.7 Management capabilities

Management capabilities involved administrative or individual characteristics such as managerial experience in related sectors, managers' capacity to commercialize, commitment and involvement of managers in TT, and managers' specialty that enable a company's technology or R&D associated operations to be successful and efficient (Noh et al., 2018b). The management capabilities cover not only risk and project management but also the governance and transfer capabilities, absorptive capacity, and knowledge management (Kirchberger and Pohl, 2016).

4.8 Team structure

The team structure of a firm has an impact on the commercialization of technology when considering the size, competence, and experience of TC crews. The experience of the team member is crucial and related to past industrial or commercial skills, marketing, and managerial abilities (Kirchberger and Pohl, 2016).

4.9 Legal oriented capabilities

The accessibility of new technology or product needs to be considered to determine the legal impasse that would prevent the unveiling of the new technology or product and its consequent accomplishment in other countries (Afful-Dadzie et al., 2017). Government agencies are supposed to enact and revise the laws, regulations, and policies governing the establishment and activities of technology transfer or TC channels for an enabling environment and sustainability (Fadeyi et al., 2019; Taweasangrunroj et al., 2021). The legal and administrative capabilities deal with the laws and regulations, physical needs, and cultural coherence (Yazdimoghaddam et al., 2019).

4.10 Funding potential

This factor evaluates the financial position of the company, especially the financial depths and limitations. The funding potential of the firm is a crucial factor in assessing business by both private and public equity investors, so the fiscal strategy has to be clearly stated and most likely involve projected expenses in each company activity (Taweasangrunroj et al., 2021). Inputs from financial organizations, as well as policy assistance (infrastructure and

incentive-based) from government organizations and donors, are equally critical to the product development and commercialization process (Oyebola et al., 2018).

The availability of funds for TC is critical for venture capital (VC) for firms and the funding of qualified personnel and infrastructure. In addition, the expenditures of technology implementation, operation, maintenance, and commercialization are to be taken into consideration for successful TC to occur (Bandarian, 2007).

5. Challenges of TC

The survival of firms due to intense competition to thrive in a challenging environment is important in boosting the economy (Lenzer and Kulczakowicz, 2021). However, success in commercializing new products in the market is difficult because there are various restrictions and hitches about commercialization that fail many commercialized products (Datta et al., 2015). The major problems associated with failed TC are the flaws in the process of commercialization, rigorous business environment, ineffective management of the project, ineffective collaboration with private sectors and stakeholders, fragile organizational structure, and conflicting political behaviours (Khalil et al., 2017).

Technological challenges are often worsened by the inadequate implementation of other factors such as the fiscal state, government policy and regulation, accessibility to knowledge, and market potentials which were frequently explained in the literature (How et al., 2019). Financial constraints occurred when technology developers lacked the required financial resources to fund the acquisition of necessary equipment, facilities, and technology to enter the competitive market (Salm, 2018). The capital-intensive businesses have high entry obstacles that minimize competition within the industries, but it is somehow difficult for technology developers to obtain funds for the R&D stage to the commercialization stage and endure during the repayment period.

Another major impediment to the success of TC is the lack of expertise and technical knowledge of the personnel engaged in the production of technologies along with transferring them to the market (Afful-Dadzie et al., 2017). However, there are a small number of employees that are entrepreneurs with technical skills or engineers with business-oriented skills and this consequently impedes the expansion of technological complexity. Most VCs handled by the government are overseen by unskilled civil officials and government workers serving as fund managers, who are less encouraged than their private counterparts since they do not actively participate in the sharing of profit that is amassed to the venture (Leleux and Surlemont, 2003).

Also, weaknesses in marketing capabilities and the incompetency of entrepreneurs in understanding the needs of the market impede the success of TC. Market inclinations triggered by inadequate knowledge of new technologies, competitive valuing, and prospects of existing product efficacy make the market competition extremely unfavourable for upcoming firms competing with established firms (Meijer et al., 2019). Nevertheless, Lichtenthaler (2006) clarifies that to achieve the best economic advantage from the commercialization of techs, a firm should create a scheme for TC, and not simply operate impromptu activities with the optimism of accomplishing success.

6. Conclusion

In this paper, several research papers on TC were systematically reviewed. The steps involved in TC were explicitly presented in this paper. The steps range from the development of ideas to the marketing of the developed products. The marketing strategies of the developed products or technology include licensing or selling of IP to established firms, creation of start-up firms, selling the products to end-users, and launching of the products or technologies.

Also, the channels or incubators for effective TC were presented and described in the paper. The contributions of universities and research institutes established firms, and start-up firms towards TC were mentioned. The factors that impact the TCS were identified through extensive and comprehensive reviews of the literature. Nevertheless, there are no universally considered factors that impact the commercialization of developed products or techs because of diverse sectors, processes, and technologies.

This literature review aids researchers to achieve the synopsis of hitherto published research papers focusing on technology developers and end-users along with their relation to commercializing newly developed technologies. This can be beneficial for researchers to establish and enhance the theories and empirical outcomes of evaluating the degree to which each factor contributes to the success of TC in different industrial sectors.

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