A Guideline for Technology Commercialisation in the 4IR Era

Joe Amadi-Echendu

1 Introduction

As a preamble, it pertinent to state that discourse on technology commercialisation may be found under several extant subject areas such as entrepreneurship, innovation management, intellectual property management, knowledge management, new product development, new ventures and entrepreneurship, research and development (R&D), technology and innovation management, science and technology policy, systems of innovation, and related subject matters and topics. In this chapter, we draw from these subject areas and articulate a brief and concise guideline on technology commercialisation intended for both the novice and the experienced practitioner. Therefore, the content of this chapter complements well established discourse on the commercialisation of technology. Our discourse commences by combining intuitive and literary definitions of the terms 'technology' and 'commercialisation'.

1.1 Forms of Technology

'Technology' is defined from many perspectives [see, for example, a review by Wahab et al. 2012]. This is because the cross-, multi-, and trans-disciplinary nature of technology conjure up multifarious meanings in different contexts. We learn from history that earliest humans found *ways* and *means* towards satisfying basic needs. They developed techniques, invented and used tools for gathering food, and especially for hunting animals. They devised methods and developed materials for building shelters. As human needs and desires have become increasingly sophisticated (cf:

J. Amadi-Echendu (✉)
Department of Engineering & Technology Management, University of Pretoria, Pretoria, South Africa
e-mail: joe.amadi-echendu@up.ac.za

C. Daniels et al. (eds.), *Entrepreneurship, Technology Commercialisation, and Innovation Policy in Africa*, https://doi.org/10.1007/978-3-030-58240-1_7

Maslow 1943), the ways and means of satisfying the needs and desires have also become increasingly sophisticated. It seems that increased sophistication in the ways and means of satisfying human needs only leads to insatiable desires! In fact, the sequence of industrial revolutions bears testimony to the intertwined and symbiotic transformation of human society and technology.

In the context of this chapter, 'technology' encompasses the *ways* and *means* that extend human abilities, enhance livelihood, and improve living experience of human beings. So *ways* and *means* constitute two primordial forms of technology. A third and more sublime form of technology is inherently embedded in the two basic forms. We refer to this third and implicit form of technology as *knowledge* or *knowhow*. Hence, for the purposes of this discourse on technology commercialisation, we decompose technology into three basic co-existing and complementary forms as illustrated in Fig. 1.

- Form 1—'*ways*' translate into methods, processes, and techniques plus inherent knowledge of how to apply method/process/technique to doing something.
- Form 2—'*means*' translate into tangible physical artefacts plus inherent knowledge of how to use the artefacts to do something.
- Form 3—'*knowledge*' of how to do something, and the *knowhow* may be tacit or explicit.

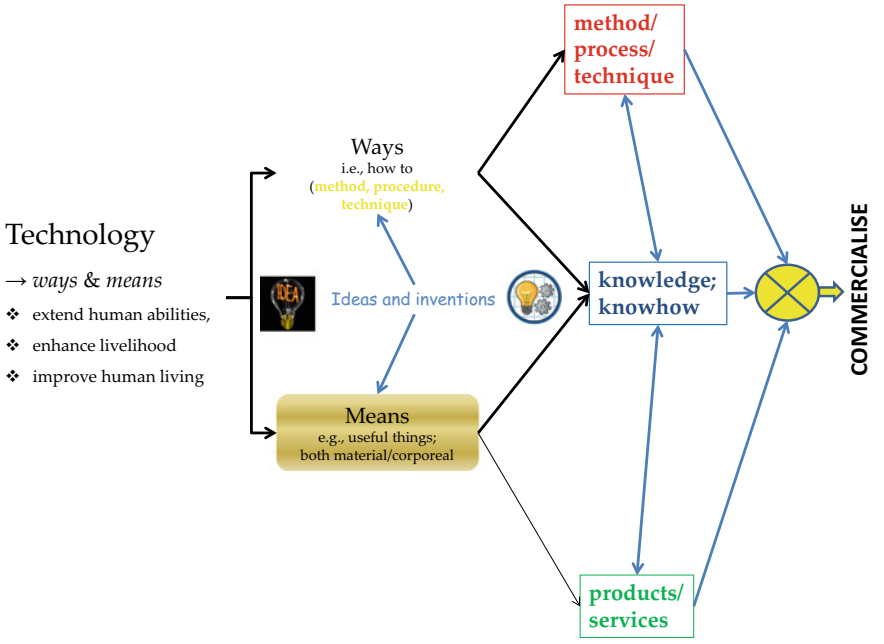

Fig. 1 Forms of 'technology'

Form 2 is better visualised in terms of products[1] and services. For instance, an aircraft provides the means to satisfy human desire to travel by air. An aircraft is manufactured as a product, while an airline operator uses aircraft to provide the service of air travel. Interestingly, in the modern era, a personal gadget like a mobile phone combines many 'technologies', thus making it possible to deliver a range of services well beyond satisfying the preliminary human desire to communicate. In fact, it is arguable that in the era of fourth industrial revolution (4IR) with corresponding trends in globalisation and globalism, commercialisation seems to be more about finding new combinations of many original technologies in order to provide solutions to seemingly insatiable human needs and desires.

1.2 Commercialisation

Although 'commercialisation' is also defined from many perspectives, however, the central tenet is commercial success which, in general, tends to be narrowly characterised by, or measured only in terms of financial gain. In this chapter, we shall adopt the definition that commercialisation is 'the process of transforming ideas, knowledge and inventions into greater wealth for individuals, businesses, and society at large[2]' (re: Australian Government 2003). This viewpoint allows us to redefine commercialisation in terms of the wider ethos of value well beyond the narrow focus on financial gain. The value ethos is inherent to the commercialisation of the various forms of technology. After all, why should anyone gain from *ways* and *means* (i.e., technologies) that do not extend human capabilities, or that do not enhance human livelihood, or that do not improve the lived experience of human beings? This does not vitiate the fact that there are positive and negative consequences of technology, that is, that technology may be commercialised for purposes that raise ethical issues. The discourse surrounding the commercialisation of somatic cell nuclear transfer (SCNT) or 'cloning' technology (cf: Lee et al. 2016) provides a good example of ethical concerns.

1.3 Outline of the Chapter

The rest of this chapter includes brief discourse on.

- commercialisation theory in terms of
  - innovativeness and commercialisation potential,
  - systems of innovation and commercialisation models;

[1] See extant literature on New Product Development for extensive discourse on the commercialisation of products.

[2] 'Society at large' encompasses human society and the natural environment.

- commercialisation practice in terms of
  - the entrepreneurial process coupled with
  - commercialisation knowledge areas and enablers; and
  - routes to market.

The chapter concludes with remarks postulating that commercialisation will increasingly involve the conflation of technologies directed towards instant gratification of human life styles.

2 Commercialisation Potential and Systems of Innovation

It is common practice to discuss technology commercialisation within the parlance of innovation,[3] albeit that the term gives rise to a range of ambiguities and different meanings to different disciplines and persons. In fact, *ways* and *means* (i.e., technologies) that extend human abilities, enhance livelihood, and improve living experience should inherently feature some element of *newness* or innovativeness. Notwithstanding the various meanings, there is a common understanding that innovation involves the creation and delivery of value in a manner that must not only motivate enterprise but also, must provide positive returns to sustain enterprise. After all, the goal of enterprise is to enhance human livelihood, extend human capabilities, and improve the living experience of human beings.

2.1 Commercialisation Potential

Innovativeness or ability to innovate is an inherent feature of technology (Bubou and Amadi-Echendu 2013), while commercialisation forms part and parcel of, and characterises innovation. That is, commercialisation is a process that not only demonstrates the ability to innovate but also, results in the realisation of innovation. Conceptually, an innovation index or the potential for commercialisation may be expressed as:

$$\text{Commercialisation potential, (CP)} = \frac{\text{value}}{\text{cost} * \text{time}} \tag{1}$$

[3] *Innovation is the process of turning new ideas into value, in the form of new products, services, or ways of doing things. It is deceptively complex, and goes beyond mere creativity and invention to include the practical steps necessary for adoption. New innovations tend to build on earlier versions and, in turn, to lay foundations for others. It is now widely accepted that innovation fuels the majority of the world's long-term productivity and economic growth—and that innovative firms significantly outperform non-innovators, in terms of both revenue and employment growth*—World Economic Forum.

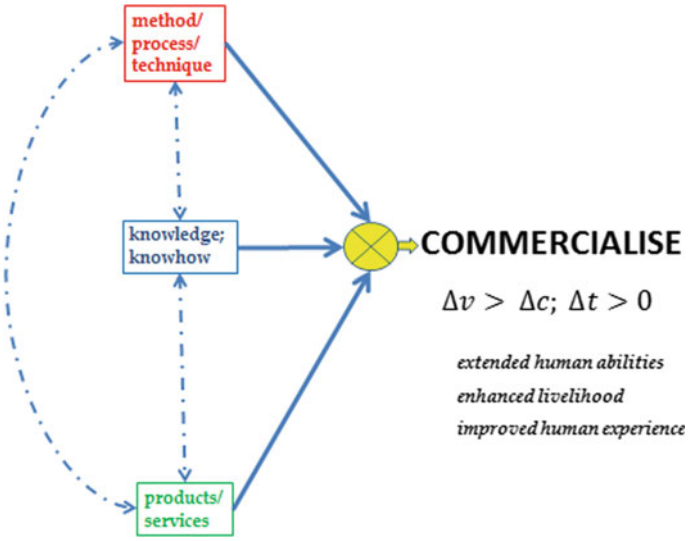

Fig. 2 Commercialisable forms of technology

In this expression, value may be defined either quantitatively, or qualitatively, or both. In the paradigm of commerce and economics, value and cost are both characteristically stated as financial quantities, i.e., in monetary terms. In socio-political paradigm, both value and cost contain quantitative and qualitative parameters such that commercialisation extends beyond pure financial gain. Often, the socio-political paradigm requires that technology should be commercialised for the so-called 'greater public good'. Paradoxically, the metrics for 'public good'[4] can be extremely fuzzy, and this presents an interesting conundrum for the 'social entrepreneur' and for policy makers.

Both value and cost are functions of time, therefore Eq. 1 can be restated as:

$$\mathrm{CP}(t) = \frac{v(t)}{c(t) * \mathrm{time}};\ \mathrm{CP}_{t_2 - t_1} = \frac{v_2 - v_1}{(c_2 - c_1) * (t_2 - t_1)};\ \mathrm{CP} \triangleq \frac{\Delta v}{\Delta c * \Delta t} \qquad (2)$$

Focusing on the last part of Eq. 2, the first issue is that, to be innovative, the process of commercialisation must create new value (Δv) within a given cost regime (Δc) and time frame (Δt). This implies that any technology to be commercialised must offer new value ($\Delta v > 0$) that corresponds to, and results in the extension of human capabilities, and/or enhancement of livelihood, and/or the improvement of living experience (see Fig. 2).

The second issue is a paradox because the creation of value comes at a cost, that is, Δv is correlated to Δc. For success, the cost of commercialising technology must be bounded ($\Delta c \leq \Delta v$) so as not to demotivate enterprise, diminish or vitiate the

[4] *Good or service that provides non-excludable and non-rival benefits to all people in the population.*

new value, or even eliminate enterprise altogether. Thirdly, there is a time frame or window of opportunity (Δt) for commercialisation to succeed. In short, there has to be a real need!

Suppose Δv equals Δc, i.e., strictly correlated, then, the potential for commercialisation is solely determined by the time window of opportunity. Although such situation may not readily appeal to private sector enterprise where the motivation is financial gain, however, it may pertain to public sector enterprise to commercialise the technology for the public good. In fact, the essence of commercialising the technology for public good could create an environment for private sector enterprise to flourish. Take for example, public sector commercialisation of technology that lowers or removes barriers that encourage private sector participation in highly competitive global markets.

The scenario where Δc perfectly tracks Δv presents very interesting challenges and conundrums for policy makers. Such policy issues are discussed throughout this book. Thus, it is appropriate here to consider the influence of the systems of innovation concept on the commercialisation of technology.

2.2 Systems of Innovation

It is widely acknowledged (e.g., Manzini, 2012) that the systems of innovation (SI) concept gained prominence sequel to Freeman (1982). A notable and significant antecedent to the SI concept is the 1962 OECD Working Party of National Experts on Science and Technology Indicators. The outcome resulted in the wide adoption of the OECD Frascati guidelines for collecting, measuring, and reporting scientific, technological and innovation activities (OECD Frascati Manual 2015). Another important antecedent is the United States Bayh-Dole Act (1980) dealing with intellectual property arising from publicly funded research. Edquist (1997) presented an overview and assessment of the SI concept which is still relevant and instructive. The SI concept is typically used to characterise the fostering of innovation, or more precisely, to encourage the commercialisation of technology.

As an extension of the SI concept, the 'national system of innovation' (NSI) construct has been defined as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies". This definition is common from the policy viewpoint as it characterises a country's collective effort to organise and holistically integrate science and technology endeavour towards economic and socio-political development. This stems from the notion that science and technology endeavour as formalised through educational and research institutions, or from other actors within a country, region or sector, result in ideas and inventions, or better still, in technologies that should be commercialised to create economic and social prosperity. The notion has long been strengthened by the wide adoption of the aforementioned and standardised application of OECD Frascati guidelines for collecting, measuring and reporting scientific, technological, and innovation activities.

The SI/NSI construct influences technology commercialisation. An understanding of the network of interrelationships between SI/NSI actors, agents and institutions in both the public and private sectors is vital for successful commercialisation of technology (e.g., van Zyl et a. 2007; Kirchberger and Pohl 2016). The network of interrelationships between SI/NSI actors, agents and institutions accentuates access to complementary resources that are crucial for the commercialisation of technology. In essence, the SI/NSI construct more or less conceptualises how the market interfaces with the network of interrelationships between actors, agents and institutions that facilitate the commercialisation of technology. The emphasis here is that the market predominantly determines the parameters of value, cost, and time. Therefore, technology commercialisation essentially involves a determination of the normative distance between the technology and the market (Amadi-Echendu and Abanum 2012). This normative distance shall be explained in terms of commercialisation models and framework discussed as follows.

3 Commercialisation Models: The TAPM Framework

The terms 'model' and 'framework' are used here as theoretical representations or depictions of a process that can only be actualised through practice. Thus, at best, the models and framework discussed herein illustrate how the commercialisation process may be imitated.

3.1 Commercialisation Models

Discussion of commercialisation models often dovetails towards activities of research and development (R&D) actors, agents, and institutions. This is more or less a policy tradition which derives from the OECD Frascati Manual definition of R&D as "creative and systematic work undertaken in order to increase the stock of knowledge—including knowledge of humankind, culture and society—and to devise new applications of available knowledge." By convention, the policy driven or R&D heuristic approach promotes linear transformation of ideas and/or knowledge into commercialisable products and/or services (see, for example, Amadi-Echendu and Alan 2008; Dorf and Worthington, 1987; Kelm et al. 1995). Whereas the policy driven approach largely created two patterns, however, empirical evidence indicates that there are at least three paradigms for commercialising technology, viz:

- *Market-pull*—where the technology commercialisation process commences with establishing the market need. This paradigm is perceived as the purview of the classical entrepreneur endowed with entrepreneurial flair (cf: Baron 1998), the cliché being that classical entrepreneurs possess special or instinctive aptitudes or ability to identify opportunities in the market space.

- *Technology-push*—where the commercialization process tends to focus on marketing what the technology can do. This paradigm tends to be the purview of the 'techpreneur' searching for the 'capable' technology to be accepted by the market. A contrary and arguable cliché is that the 'techpreneur' generally lacks entrepreneurial flair.
- *Functional paradigm*—this combines market-pull and technology-push, and should be the purview of most current generation entrepreneurs who are supposed to be 'tech-savvy', linked, networked, market-intelligent, and market-oriented. The functional paradigm demands concurrent development and exploitation of existing linkages and networks between actors, agents, and institutions so that the commercialization activities and functions are performed as necessary to track the vagarious nature of the value ethos. The functional paradigm is accentuated by 4IR technologies and new business models that are stimulated, triggered and fostered by trends in globalisation and globalism. The point is that the commercialisation of technology cannot be isolated from trends in globalisation and globalism because these macro factors exert extraneous influence on the variables shown earlier in Eqs. 1 and 2.

3.2 TAPM Framework

We adopt the functional paradigm to describe the ***t***echnology-***a***pplication-***p***roduct/service-***m***arket (TAPM) framework as illustrated in Fig. 3 (see also, Amadi-Echendu and Rasetlola 2011).

In the market-pull paradigm, the TAPM commercialisation process commences with evaluation of the conceived product/service configuration against the verifiable need. A verified need refers to the situation where there is proof that $\Delta v > 0$. The conception of the product/service configuration should be based on validated applications of combinations of complementary technologies which, in turn, must include the unique feature(s) of the particular technology(ies) selected. This implies estimating Δc within an acceptable Δt. On the one hand, the market-pull paradigm demands backward integration of functions and activities (i.e., technology management) implicit in the TAPM framework in order to provide credible estimates of Δv, Δc, and Δt.

On the other hand, in the technology-push paradigm, the TAPM commercialisation process stimulates forward integration of activities and functions. The process requires searching for the market that will provide the highest demand ($\Delta v \gg \Delta c$) for the candidate technology, i.e., searching for the need that will result in the highest level of technology acceptance. This process must also yield estimates of Δv within confidence limits that correspond to acceptable Δc and Δt.

The significance of the TAPM framework is that it facilitates determination of the normative distance between the technology and the market. Firstly, the TAPM framework presumes the existence of technology (in any of its forms, and stages

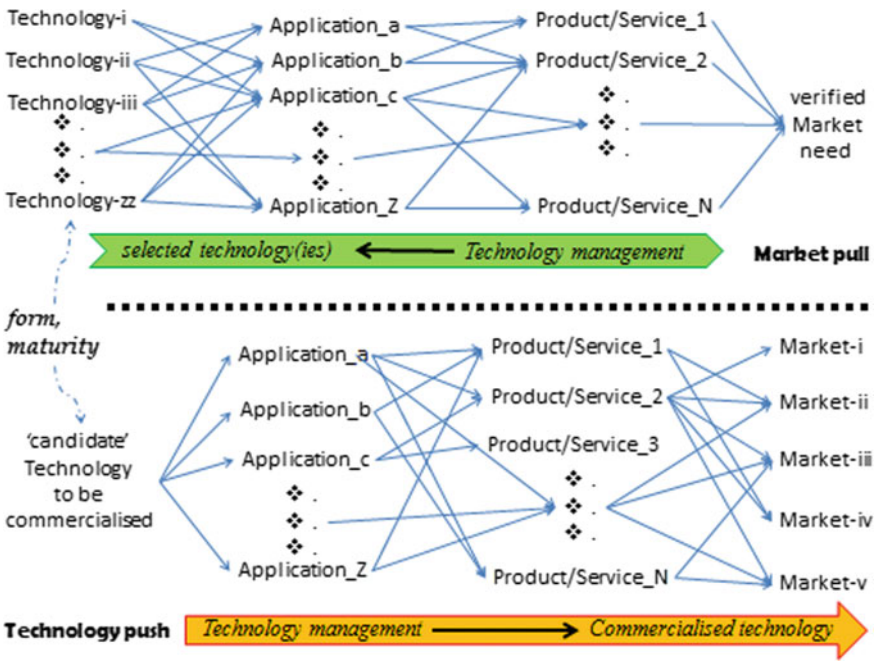

Fig. 3 TAPM framework for commercialisation

of maturity[5]). Secondly, the framework also assumes the existence of verifiable market need. Based on these two hypotheses, then, the primary challenge becomes how to package candidate or selected technology(ies) towards satisfying verified need(s). In essence, the functional paradigm demands that the verification of needs is symbiotically intertwined with development of candidate technology(ies).

4 Commercialisation Practice

In this section, we discuss some of the structural components or enablers implicit in the aforementioned paradigms and framework such as entrepreneurship, knowledge areas, and routes to market.

[5] *So called "s-curve" depicting performance of the technology against time.*

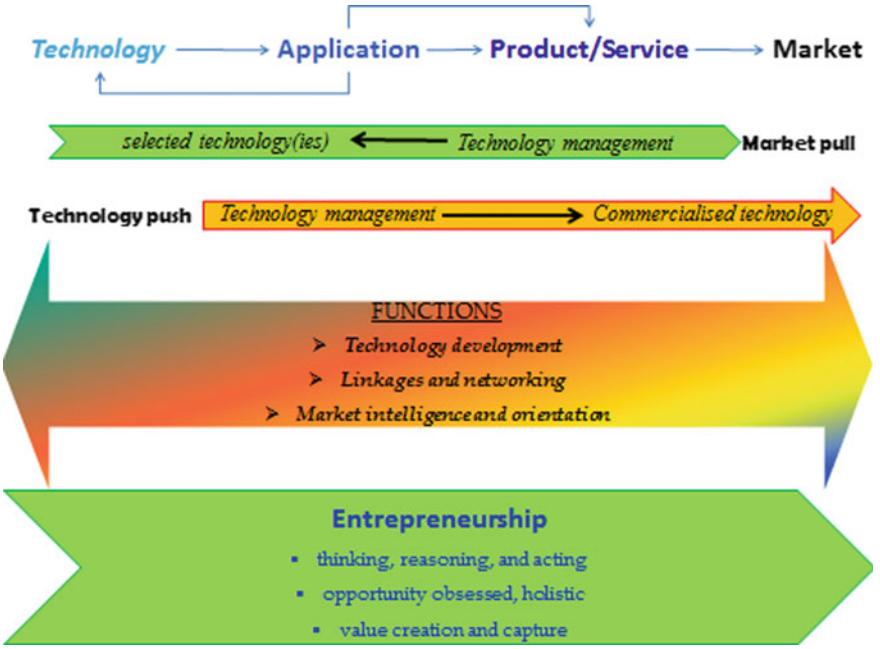

Fig. 4 TAPM framework and entrepreneurship

4.1 Entrepreneurship

Quoting Timmons and Spinelli (2009), "entrepreneurship is a way of thinking, reasoning, and acting that is opportunity obsessed, holistic in approach, and leadership [based on balancing risks] for the purpose of value creation and capture." As illustrated in Fig. 4, the TAPM provides a framework for the breed of entrepreneurs who must be (i) 'tech-savvy', (ii) linked, (iii) networked, (iv) market-intelligent, and (v) market-oriented. This brand of entrepreneurship[6] is vital in the era of 4IR technologies, pervasive globalisation and globalism.

Activities underpinning market orientation and intelligence, linking and networking of actors, agents and institutions, and technology development must be rapidly and concurrently performed so as to increase the likelihood of commercialisation success (Otejere and Amadi-Echendu 2015). Market-pull is established through intelligence and orientation activities while technology acumen and associated development activities provide the push. Activities which connect the actors, agents and institutions also establish linkages and networks that stimulate, facilitate and support 'techpreneurship' and the entrepreneurial process.

[6]*The capacity and willingness to develop, organize and manage a business venture along with any of its risks in order to make a profit. Entrepreneurial spirit is characterized by innovation and risk-taking, and is an essential part of ability to succeed in an ever changing and increasingly competitive global marketplace.*

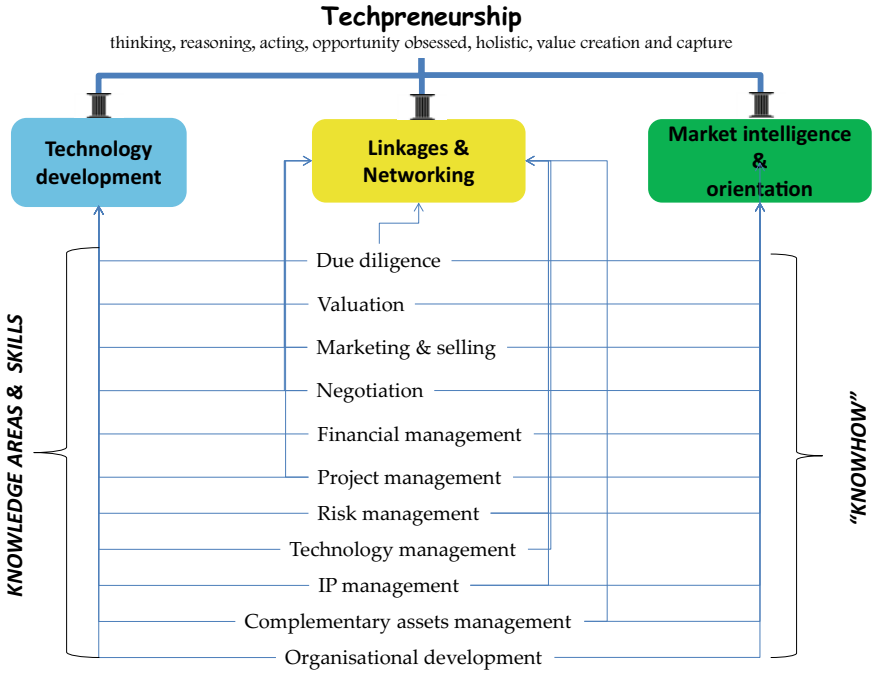

Fig. 5 Pertinent skills and knowledge areas for technology commercialisation

Each task or activity is underpinned by several areas or fields of knowledge, therefore, from an academic viewpoint, technology commercialisation inherently involves multidisciplinary endeavour. Thus, the entrepreneurial process demands a team composed of complementary skills to rapidly perform the concurrent functions, tasks, and activities necessary to commercialise technology. Some of the pertinent skills and knowledge areas are briefly itemised.

4.2 Knowledge Areas for Commercialisation

Given that technology commercialisation is multidisciplinary in nature, there are many knowledge areas, skills, and competencies required; thus the attempt here is to highlight a few of the pertinent knowledge areas and enablers, or better still, what might be regarded as high level team competencies.

First, it is vital that the team has capability to conduct due diligence[7] across the three broad functional areas depicted in Fig. 5. Second, the team must be able to

[7] *…reasonable steps taken by a legal person in order to establish claims, rights and privileges, especially before entering into an agreement or contract with another party, or an act within a legally certain standard of care.*

conduct valuation across the three functional areas in order to determine/estimate both the qualitative and quantitative aspects of value encapsulated within the technology commercialisation process.

Third, the process of technology commercialisation involves more than one person or legal entity, therefore, the ability to negotiate is a paramount skill that the team must possess. In the fourth instance, it is equally vital that the team possesses marketing and selling skills, not only to create awareness and publicity but also, to explain the commercialisation value proposition succinctly.

For the purposes of this chapter, it is useful to highlight some academic compartmentalisations of the extensive body of knowledge that is intrinsic to technology commercialisation. Whilst acknowledging that the aforementioned skills areas also depend on knowledge of respective academic disciplines, however, conventional disciplines include financial, project, risk, and technology management, as well as organisational development.

Financial management knowledge is required at least to determine and control Δc succinctly and to provide credible estimation of Δv. Matters such as cost of capital, capital allowances and taxation regulations need to be given due consideration. Project management knowledge is required, at least to order and track the sequence of tasks and activities to be carried to commercialise technology, so as to provide better estimation and management of Δt.

Commercialisation happens within the realm of uncertainties, risks and opportunities. Therefore, identification of sources of risks, as well as mitigation and treatment of risks are vital to commercialisation team capabilities, and should result in improved estimation of the parameters of the commercialisation potential. At least, the team should be able to carry out technology management activities such as scanning, forecasting, and roadmapping.

The formation of the commercialisation team and sustenance of team dynamics requires knowledge of how organisations learn and evolve. It is important that the entrepreneurial team should be able to conflate necessary knowledge areas from the many disciplines that are intrinsic to technology commercialisation. The ability of the team to synergise the complementary knowledge areas and skills increases assurance of the choice of the route to successful commercialisation.

4.3 Commercialisation: Routes to Market

With regard to routes to market, there are three unique areas of knowledge that may be specifically highlighted as follows. These are (i) technology transfer mechanisms and modalities, (ii) intellectual property (IP) management, and (iii) complementary assets management.

First, commercialisation invariably involves the transfer of technology in any form, or combinations of the forms discussed earlier. Therefore, an understanding of the mechanisms and modalities of transferring the forms of technology is crucial to the commercialisation process. For example, training is a classic mechanism for

technology transfer. The challenge is to determine how much or what aspect of the technology must be confidentially transferred during training in order to facilitate the commercialisation process. This challenge applies to any other mechanism and modality of technology transfer.

Second, IP management generally deals with issues such as confidentiality, invention disclosure, patenting, material transfer agreement, legal assignment, licensing, commission, royalty, and similar concerns that are usually embodied in contractual arrangements. IP management is strongly emphasised from the policy approach as a route to commercialise technology arising from *apriori* investment in R&D. In this regard, licensing tends to be a prominent route to market in both technology-push and market-pull paradigms. On the one hand, an existing firm with strong market presence may wish to outsource and licence an emerging technology to increase market presence and strengthen its competitive position. On the other hand, a technology developer may desire to outsource access to the range of complementary assets (resources) necessary to ensure that maximum value is realised and appropriated from the technology that is being commercialised.

It can be argued that the form of technology coupled with requisite complementary assets (i.e., intangible and tangible resources) primarily determine the commercialisation route to market. For example, the risk appetite of a commercialisation team will be influenced by the range of complimentary assets that the team can access. Consider a situation where the commercialisation team has very limited access to the range of complementary assets that are necessary to realise maximum value from the technology to be commercialised; and, suppose that commercialisation is initiated from the technology-push paradigm; then, it seems logical that to minimize the normative distance to market, the team should first search for areas where the candidate technology can be applied. In terms the TAPM framework, this translates into a business concept phase of the commercialisation process (see Fig. 6). Where there is access to internal complementary assets in relation to a particular area of application of the technology, the team may wish to start-up a business, or better still proceed to the full commercial phase, especially if the risks are manageable and the candidate technology proffers high growth opportunities. In general, technologies that exist in the form of product/service are regarded as near-market whereas so-called early stage technologies are often regarded as high risk from a market stance. The TAPM framework shows that the entrepreneurial team capabilities and concomitant organisational development should evolve through the business concept, start-up, and commercial phases.

A crucial matter about routes to market relates to how to apportion value from the commercialisation process. This issue, in conjunction with the mechanism and modality of technology transfer, IP regime, and access to complementary assets leads to other options or routes to market such as (i) franchising, (ii) management contracting, (iii) joint venturing, (iv) strategic alliancing, and (v) selling-off IP. Having mentioned licensing earlier, the significant challenge is to evaluate each option whilst considering that a hybrid of options may be feasible.

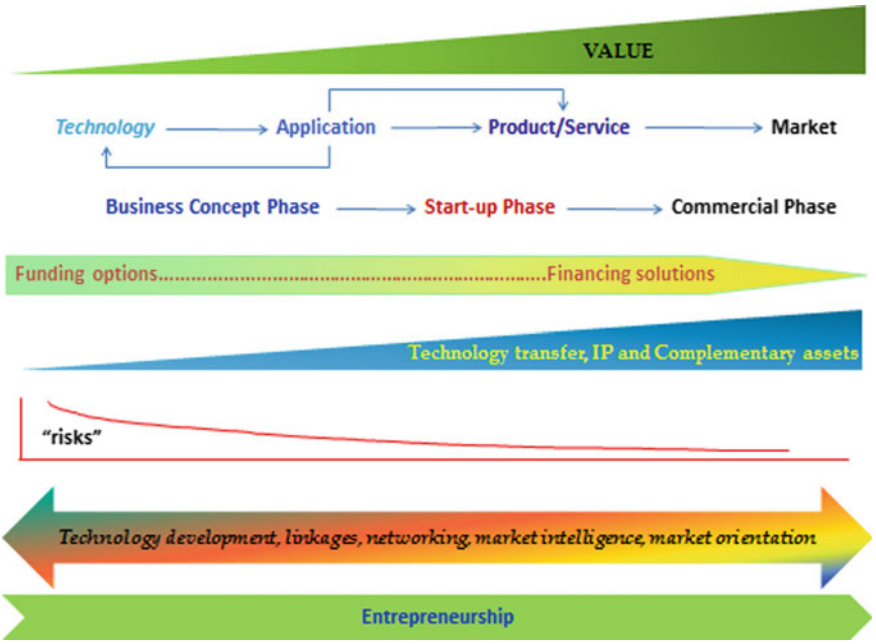

Fig. 6 Technology commercialisation and business development

5 Concluding Remarks

In this chapter, we have defined technology primordially as the *ways* and *means* that extend human abilities, enhance livelihood, and improve living experience of human beings. Also, we have adopted the value ethos to define commercialisation as a process that encompasses the packaging of one or more 'candidate' technologies towards satisfying human needs and desires in a manner that not only creates greater wealth for individuals and businesses but also, leads to sustainable development of society at large. Furthermore, we have posited commercialisation potential, TAPM framework and entrepreneurship as theoretical and philosophical foundations for the commercialisation of technology.

In reiterating the widely acknowledged paradigms of *market-pull* and *technology-push*, we have stated three categories of concurrent commercialisation functions as (i) technology development, (ii) linking and networking, and (iii) market intelligence and orientation. *Techpreneurs* of the 4IR era need to possess T-shaped knowledge[8] with interdisciplinary capabilities (cf: Amadi-Echendu 2007; Gwata 2019). Given that technology commercialisation is multidisciplinary in nature, we have emphasised a team approach whilst highlighting some crucial knowledge areas, skills, and competencies that may provide assurance towards success.

[8] *T-shaped person—one who has in-depth knowledge of a specific field, with sufficient knowledge in other fields outside her own specialisation.*

It is worth emphasising that every commercialisation process is peculiar (Amadi-Echendu and Mngadi 2015), so there is no magic wand that guarantees success. However, based on empirical evidence garnered from practitioners, we reiterate that the *market-pull* paradigm should be preferred over the *technology-push* paradigm in order to minimize the normative distance between technology and market. After all, if there is no need ab initio (i.e., if $\Delta v \leq 0$ in a quantitative sense), there is no motivation since no one will be willing to pay for technology commercialisation, let alone sustain the associated enterprise. The era of third industrial revolution gave rise to massive integration of technology into business and society, and further highlighted the social good tenet. This meant that commercialisation could no longer be measured only via the quantitatively narrow lens of financial gain.

We posit that the value ethos which promotes both financial gain and public good increasingly drives technology commercialisation in this era of 4IR and corresponding globalisation and globalism. Thus, an optimistic proposition is that commercialisation should be about the conflation of technologies that not only continue to improve business efficiencies and reduce the costs of goods and services but also, successful conflation of technologies must concomitantly and sustainably improve quality of human life styles for all members of society.

Policy making with regard to technology commercialisation has conventionally followed the SI concept and OECD Frascati approach where significant emphasis is placed on R&D expenditure particularly by public sector institutions and corporate businesses. Since the dawn of the third industrial revolution, commercialisation of technology has largely become the purview of small, medium and micro enterprises. It is generally acknowledged (cf: Solow 1956; OECD 2017) that this trend will increase well beyond the current era of 4IR, globalisation and globalism. The techpreneurship functions of technology development, linking and networking, plus market intelligence and orientation encapsulated in the TAPM framework allude to three paradigms for policy making and interventions, viz: market-pull, technology-push and functional paradigms. First, policy interventions based on the technology-push paradigm need to focus on avoiding, minimising or mitigating risk. Second, policy interventions based on the market-pull paradigm need to focus on maximising value. Third, policy interventions based on the functional paradigm need to balance value against risk.

References

Amadi-Echendu JE (2007) Thinking styles for technology management in the innovation, knowledge and learning economy paradigm. Technol Forecast Soc Chang 74(2007):1204–1214

Amadi-Echendu JE, Alan J (2008) On the commercialisation of "trailing" knowledge and intellectual property. In: Proceedings of PICMET'08, Cape Town South Africa, July 28–Aug 1, 2008

Amadi-Echendu JE, Rasetlola TR (2011) Technology commercialization factors, frameworks and models. https://doi.org/10.1109/ITMC.2011.5995939

Amadi-Echendu JE, Abanum NF (2012) On commercial exploitation of indigenous technology in developing countries. In: Proceedings of IEEE ITMC 2012, Dallas Texas USA 24–27 June 2012
Amadi-Echendu JE, Mngadi MF (2015) An examination of success criteria for technology-based start-ups in South Africa. In: Proceedings of IEEE TEMS-ICE, Belfast, Northern Ireland, 22–24 June 2015
Australian Government (2003) Mapping Australian science and innovation: main report, p 37
Baron RA (1998) Cognitive mechanisms in entrepreneurship: why and when entrepreneurs think differently than other people. J Bus Ventur 13(4):275–294
Bayh–Dole Act or Patent and Trademark Law Amendments Act (Pub. L. 96–517, 12 Dec 1980)
Bubou GM, Amadi-Echendu JE (2013) Measuring innovativeness of petroleum firms. In: Proceeding of XXIV ISPIM conference, Helsinki Finland, 16–19 June 2013
Dorf RC, Worthington KKF (1987) Models for commercialization of technology from universities and research laboratories. J Technol Transfer 12:1. https://doi.org/10.1007/BF02371357
Edquist C (1997) Systems of innovation: perspectives and challenges. In: Fagerberg, Mowery (eds) The Oxford handbook of innovation. https://doi.org/10.1093/oefordhb/9780199286805.003.0007
Freeman C (1982) The economics of industrial innovation, 2nd edn. Francis Pinter, London
Gwata M (2019) "The future employee will be an entrepreneur" We need to reconfigure our perception of education, employment and entrepreneurship. An article in World Economic Forum blog, 9 Aug 2019
Kelm KM, Narayanan VK, Pinches GE (1995) Shareholder value creation during R&D innovation and commercialization stages. Acad Manag J 38 (3), 770–786
Kirchberger MA, Pohl L (2016) (2016) Technology commercialization: a literature review of success factors and antecedents across different contexts. J Technol Transf 41:1077–1112
Lee JE, Chung YG, Eum JH, Lee Y, Lee DR (2016) An efficient SCNT technology for the establishment of personalized and public human pluripotent stem cell banks. BMB Rep 49(4):197–198
Manzini ST (2012) The national system of innovation concept: an ontological review and critique. S Afr J Sci 108(9/10), Art. #1038, 7 pages. https://doi.org/10.4102/sajs.v108i9/10.1038
Maslow AH (1943) A theory of human motivation. Psychol Rev 50:370–396
OECD Frascati Manual (2015) Guidelines for collecting and reporting data on research and experimental development, The Measurement of Scientific, Technological and Innovation Activities. OECD Publishing Paris. https://doi.org/10.1787/9789264239012-en
OECD (2017) Enhancing the contributions of SMEs in a global and digitalised economy
Otejere JA, Amadi-Echendu JE (2015) A study on innovation activities of SMEs in a developing country. In: Proceeding 13th Globelics, Havana, Cuba, 23–25 Sept 2015
Solow RM (1956) A contribution to the theory of economic growth. Q J Econ 70 (1), 65–94
Timmons JA, Spinelli S (2009) New venture creation: entrepreneurship for the 21st century. McGraw-Hill Education. ISBN 9780073381558
van Zyl A, Amadi-Echendu JE, Bothma TJD (2007) Nine drivers of knowledge transfer between universities and industry R&D partners in South Africa. SA J Info Management 9 (1) 2007
Wahab SA, Rose RC, Osman SIW (2012) (2012) Defining the concepts of technology and technology transfer: a literature analysis. Int Bus Res 5(1):61–71