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STRENGTHENING THE DISTRIBUTED TECHNOLOGICAL INTELLIGENCE OF INDUSTRIES IN SOUTH AFRICA

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Abstract

Organisations have to confront new technologies, or they might be disrupted when new technologies exceed the performance and functions of their current core competencies. Observing global technology developments is hard for any organisation to do alone, especially when potentially valuable or disruptive technologies may be developed in the obscurity of niche markets. Anticipating the potential of these technologies is important, and strategies need to be adjusted to develop new competencies, adjust existing competencies, and reconfigure the business model as the organisation learns about the possibilities of the new technology. As industries, technologies, supporting organisations and broader institutions co-evolve, it is not sufficient for a few companies to individually embrace new technologies. Competing with new technologies in new markets often requires complementary investments and co-specialisation beyond any given firm to be developed. Therefore, it is necessary to get more companies and their supporting organisations to develop a shared or distributed sense of key technological developments and what future investments and competencies are needed.

This paper considers two frameworks that TIPS could use to support industry collectives and their supporting organisations in strengthening their collective Technology Intelligence to coordinate strategic responses to emerging technology and market opportunities.

About the author

Dr Shawn Cunningham is a process consultant working in innovation and socioeconomic change. He supports a range of institutions, leaders, and advisors on topics such as making decisions under uncertain conditions, strengthening the resilience of institutional networks, or improving the dynamics of learning in societies. He has conducted diagnoses and supported improvement processes of economic and technological systems worldwide.

His practice is focused on technological and institutional change and how the dynamism of learning and innovation between stakeholders can be improved. He is passionate about building connections between different knowledge domains, disjointed institutions and between local, national and global actors.

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1. Introduction

The Technological Change and Innovation System Observatory was established in 2017 by TIPS. The project aims to support the Department of Trade, Industry and Competition (the dtic) and industry sectors in developing an integrated, strategic response to discontinuous technological change and disruptive innovation. It also aims to equip public and private organisations to become more sensitive to global technological shifts and the changing demands placed on the innovation system, the manufacturing sector, and its stakeholders.

Before COVID-19, the Technological Change and Innovation Observatory mainly disseminated information on how technologies changed and how companies and public officials could make sense of the popular concept of the Fourth Industrial Revolution. The Observatory published several research papers on technological change, disruption, and innovation (Cunningham, 2018a, 2018b; Deonarain, 2018; TIPS, 2018). The Technological Change and Innovation System Observatory webpage, developed on the TIPS website, contained publications and a map of technology intermediaries and meso organisations supporting the manufacturing sector.

During and after COVID, the popular conversation shifted from the Fourth Industrial Revolution to the broader topic of digitalisation. The Observatory's focus shifted towards unpacking key digital technologies and what they meant for industry. Technology profiles and case studies were disseminated to show how the industry could make sense of digital technologies. Several training events were held to assist the Department of Trade, Industry and Competition sector desks and other stakeholders in understanding how technologies change, how the innovation system supports learning and innovation, and how industries could be supported to explore new technologies.

TIPS published a policy brief about technological change and innovation to support the Department of Trade, Industry and Competition (Cunningham and Levin, 2021). Direct support was also provided to several sector desks and their industry stakeholders to discern the potential, hype, challenges and requirements of embracing technological changes.

In the current phase of the Technological Change and Innovation System Observatory project, the emphasis will shift to working with industry collectives to raise awareness of technological opportunities and collectively develop strategies to strengthen the institutions and public competencies that complement and enable innovation in the manufacturing sector. This paper shares what has been learned thus far and informs the next activities.

2. Confronting new technologies

Despite the hype about the promises of new technologies and the predictions of how fast they will change industries, shifting from established to newer technologies is not trivial. The late Clayton Christensen (2000) argued that established companies find it hard to confront new technologies for various reasons. While sustaining innovations may draw on existing competencies and past investments, disruptive innovations require abandoning the known for the unknown. In other words, many new technology developments are discontinuous for incumbents, disrupting the fundamental strengths of their existing arrangements and competencies. Even when a new technology offers significantly better performance, many companies may still find it hard to justify switching to an unfamiliar technology. The uncertainties may include the unclear business case, the unknown complementary investments needed, competence requirements, and the return on investments. Larger companies may also hesitate because of the distance from specialists, and concerns about inadequate support and maintenance capacity of new technology vendors.

The abilities of South African manufacturers to learn about and master new technologies are varied. In almost every manufacturing subsector, there is a common pattern of a handful of innovators interacting close behind the technology frontier while most companies lag behind. This is not to say that the technology laggards are not innovating per se; their innovation efforts may be focused more on serving mature markets by improving logistics and distribution, or process enhancements, or integrating into client operations.

Confronting new technology is not only a challenge for the private sector. The public sector, civil society, and citizens must also confront technology for their operations. Of course, the public sector doesn't only use technology; it also shapes the landscape wherein technology is deployed through regulations, investments in technological infrastructure, business services, and technology dissemination efforts.

Due to the physical distance from where many technologies originate, South Africans also have to scan more technology horizons than other countries. Companies that trade internationally also have to scan the technology horizons of the markets they are active in, while even companies serving only domestic or local markets have to pay attention to important changes that may affect their near-term competitiveness. For many, the unstable global geopolitical landscape adds another horizon that must be monitored, as global shifts can disrupt access to technology, intermediary inputs and markets.

3. Strengthening the competence of organisations to confront new technologies

The concept of competencies resulted from Edith Penrose's early work, which differentiated between resource-based and capability-based theories of the firm (Penrose, 1959). Penrose noted that "resources" sounds like a fixed state. In contrast, capabilities suggest an activity that could be done well or poorly, and management can decide whether to modify these capabilities. Richard Nelson and Sidney Winter (Nelson and Winter, 1982) formulated an evolutionary perspective and placed the emphasis on routines as the evolutionary building blocks of a firm. The evolutionary perspective emphasises how the competencies developed within firms co-evolve with those in their broader environment. The work of Nelson and Winter brought into focus the co-evolution between physical and social technologies, both within an organisation and between organisations. Their research laid the foundation for the emergence of the scholarly fields of modern evolutionary economics, innovation systems, technological change and broader societal changes.

Several scholars applied the evolutionary view of technological change to competencies. Thomas Durand defines the competence base of the firm as partly tacit, i.e., not formally codified, and thus not easy to describe and transfer. Durand argued that competence may be decomposed into three dimensions: a) knowledge, b) practice (know-how) and c) behaviour (Durand, 2004:66).

Michael Tushman and Philip Anderson expanded the concept of competence-enhancing and competence-destroying innovations to explain why innovations disrupt some firms, while other firms in the same industry may even become stronger (Tushman and Anderson, 1986). Anderson and Tushman took this further by explaining how discontinuous innovations occur (Anderson and Tushman, 1991). They argue that discontinuous innovations are so disruptive because they obsolesce the existing know-how; *"Mastery of the old does not imply mastery of the new"* (1991:27).

Gary Hamel and C.K. Prahalad popularised the concept of core competencies in terms of strategic competitive advantage. In their terminology, to be "core", the competencies have to meet three criteria, namely (1) offer real benefits to customers, (2) be difficult to imitate, and (3) provide access

to a variety of markets (Prahalad and Hamel, 2009). The combination of these core competencies can generate a unique competitive advantage. These core competencies may protect a company in an existing market, but technological disruptions often come from beyond existing market competitors (Anderson and Tushman, 1991:29). Companies still have to find ways to figure out how new technologies could be used by newcomers and which additional competencies might have to be developed to remain competitive.

Monitoring the firm's competence base is about being aware of what the firm can achieve based on its current competencies (and incompetence) which includes relations with clients, suppliers, and partners (Durand, 2022:66). However, this may appear to be inward-looking and very similar to what successful technology managers are supposed to be doing.

The next sections will describe two approaches to managing and adjusting technical competence strategically to avoid disruption and enable innovation.

3.1. Technology Intelligence

Technology Intelligence (TI) is a broad term that includes gathering and compiling technical information; developing technology foresight; monitoring the advancement of science and its anticipated consequences for subsequent technology development; and identifying and analysing technical choices made by competitors (Durand, 2015:1). It serves both to inform strategy and to guide innovation efforts. In other words, it considers how the technology selections the firm (and potential competitors) has made meet the needs it was selected for and how new technologies used or developed by others may meet those needs. Therefore, it must assess both current, emerging, and potential future technologies and anticipate changes in needs. It is important to emphasise that TI builds on technology management, but it goes beyond technology and innovation management as it is more strategic. Some instruments used in TI include surveying suppliers of mature technologies (investment, performance, new features), monitoring changes in the cost and performance of key technologies (both used by the firm and used in other industries), conducting foresight exercises, scanning patents and technology road mapping.

One of the promises of digitalising manufacturing and operations is that better data may make it easier to assess whether (and at what cost) existing technologies meet the firm's stated needs. However, this does not address the challenge of imagining how emergent or unproven technologies may offer solutions or threaten the firm's existing competencies.

A challenge in the Technological Change and Innovation System Observatory project is that very few manufacturers have the underlying technology and innovation management competencies on which technical intelligence could be built (TIPS, 2021). Furthermore, evaluating potential new technologies is very hard when the current performance of the chosen technologies is not measured against the needs they were chosen to meet. In our experience, many manufacturers are not selecting from technologies at the frontier, they are selecting from proven (and often older) technologies (Mokoena, 2022; TIPS, 2021). For example, a study conducted for the Manufacturing, Engineering and Related Services Sector Education and Training Authority (merSETA) found that most manufacturers rely mainly on industry-based information sources or the media, and that most manufacturers have only a vague idea for competence requirements of emergent technologies (TIPS, 2021). Of course, the research also shows a few exceptional manufacturers in almost every manufacturing subsector that are not only closely following global technology trends but are actively engaged in mastering and assimilating new competencies into their organisations.

3.2. The Dynamic Capabilities Framework

Dynamic Capabilities is *"the firm's ability to integrate, build and reconfigure internal and external competencies to address rapidly changing environments"* (Teece, Pisano and Shuen, 1997). Like TI, it draws from the capability-based view of the firm and is shaped by evolutionary scholars such as Nelson and Winter (Nelson and Winter, 1982). Small adjustments have been made to the framework, but the essence remains unchanged.

In a recent reflection on the framework's evolution, Teece defines a capability as a set of learning processes and activities that enable an organisation to produce a particular outcome (Teece, 2023:118). There is a distinction between ordinary capabilities and dynamic capabilities. Ordinary capabilities are needed for an efficient operation and can be learned from university or training courses, consultants, or experts. Operational capabilities enable an organisation to earn a living in the present by using and incrementally adapting existing routines and behaviours (Winter, 2003:993). With the rapidly decreasing costs of sensors and data processing, digital monitoring and management of manufacturing and logistics operations are becoming ordinary capabilities (Lansiti and Lakhani, 2014). While companies that have embraced these technologies may not have a competitive advantage, companies without it may have an increasing disadvantage.

In contrast, Dynamic Capabilities involve changing in anticipation of possible future needs. They describe an organisation's capacity to create, extend, or modify its resource base purposefully (Helfat, Finkelstein, Mitchell, Peteraf, Singh, Teece and Winter, 2007). According to Teece, the basic assumption of the Dynamic Capabilities Framework is that core competencies should be used to modify short-term competitive positions that can be used to build longer-term competitive advantage.

The high-level elements of the Dynamic Capabilities Framework can be summarised as sensing, seizing and transforming.

- **Sensing** is about observing and learning about new competencies, threats and changing needs. It is focused both internally (what do we have that can be adjusted? How do we build on what we have, and what is missing?) and externally (What is becoming possible? How are needs and technologies changing?).
- **Seizing** is about adjusting existing competencies (processes, products, resources) to learn about new technologies, competencies, and developments, and intentionally seeking feedback as early as possible. Complementary assets within and beyond the organisation should be identified, integrated and leveraged. Completely new routines, competencies, management models and markets have to be imagined and developed alongside new management and value-creation systems.
- **Transforming** is about reconfiguring the organisation based on learning and strategically positioning it in preparation for the future. It may be necessary to work with other organisations to develop co-specialisation or a broader ecosystem to enable co-investment. It may also involve figuring out how to reposition or redefine existing competencies, resources and networks.

While the Dynamic Capabilities Framework initially focused on firms, it was gradually replaced or used interchangeably with "organisation" in later publications. The framework is increasingly used to shape innovation missions (Spanó, Monnerat, Pacheco and Bonacelli, 2023), industry evolution and transformation (Radosevic, 2022; Malerba, Nelson, Orsenigo and Winter, 2016), entrepreneurial ecosystems (Petit and Teece, 2020) and public policy (Puttick, 2024; Kattel, 2022; Begovic, Kattel, Mazzucato and Quaggiotto, 2021).

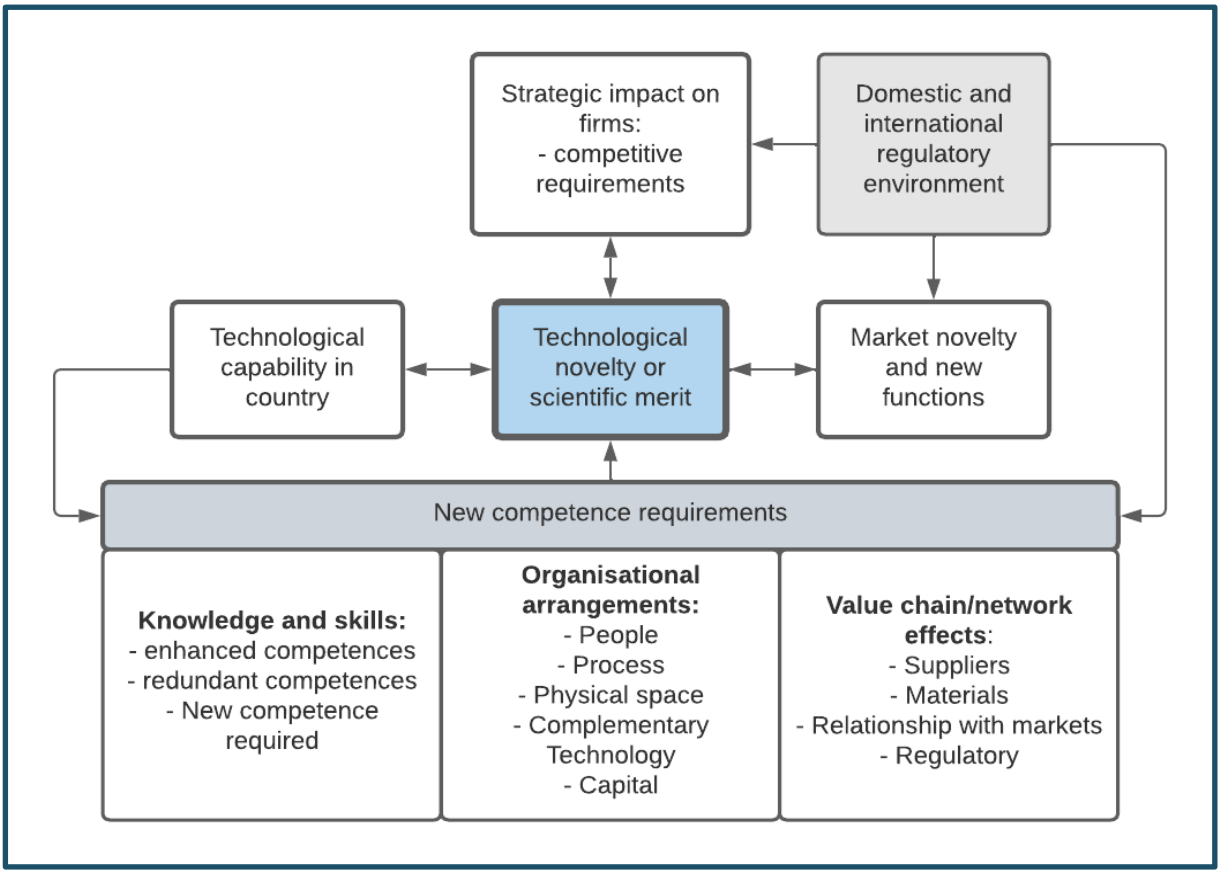
The Dynamic Capabilities Framework recognises the ecosystem and networks beyond any organisation (Petit and Teece, 2020; Teece, 2018). This does not mean that any organisation should constantly reinvent itself, but that it should constantly observe and learn about what is becoming possible internally, within the broader ecosystem it is part of, and beyond the ecosystem.

4. Sharing the learning of strengthening the shared Technology Intelligence in sub-sectors

Early in the Technological Change and Innovation System Observatory project, it was realised that many public officials and business leaders struggled to untangle ambiguous labels such as the Fourth Industrial Revolution (Cunningham, 2018b). Since COVID, the attention has shifted towards another vague term: digitalisation and, more recently, Artificial Intelligence. While digitalisation and Artificial Intelligence are easier to deconstruct into sub-elements that can be explored, these terms often mean everything and nothing for decision-makers. To guide the different public and private stakeholders through a process of considering the broader strategic and competence requirements of new technologies, a framework was developed. The framework must assist leaders to decompose the characteristics and competence requirements of a specific technology to enable more effective decision-making. Based on the Technology Intelligence literature, a generic technology profile was developed that was unpacked (See **Figure *1***):

- **The merit of the technology:** What is the need the technology meets? What is it about, and how does it relate to other technologies?
- **Competence requirements:** What is needed to make this technology work effectively within an organisational context? What are the new knowledge, additional skills, organisational arrangements, capital, supplier networks, complementary technologies and infrastructure that need to be secured?
- **Market effect:** What does this new technological capability mean for markets? What expected new functions/features are being offered to the market?
- **Strategic impact on the organisation's competitive position**: How will this ability influence the organisation's position, and what will it take to continue innovation if others follow? How will the changes we make trigger change in other organisations?
- **Supporting technological capability in the ecosystem**: Who can we rely on for technical assistance, problem-solving, testing or other technological support? Where is there hidden or deep expertise that we can leverage?
- **Anticipated regulatory adjustments:** Which regulations will be required, or will already have changed elsewhere and will most likely have effects here at some point? Can we support dialogue about how regulations would have to change based on experiences in other countries and our local context?

Figure 1: The Technology Profile used in the Technology Change and Innovation System Project



Source: Cunningham, 2022.

Based on this framework, a series[1] of technology profiles was developed to show how it could be used to unpack a technology and anticipate the competence requirements and strategic decisions needed to exploit it.

However, it often proved difficult to shift the conversation from the technology's features and merits to how organisations could improve their Dynamic Capabilities of sensing, seizing, and transforming. The industry stakeholders we engaged with were keen to disseminate the technology profiles to their members but were not so eager to bring them together to explore the technologies' opportunities and consequences.

The Technological Change and Innovation System Observatory identified and engaged with the public technology intermediaries that could promote new technologies and competencies to the manufacturing sector. We found that most of these intermediary organisations could not clearly articulate their offering to the industry and, in fact, also had little incentive to promote technological intelligence or upgrade at the collective or sectoral level. Most public funding for technology promotion is incentivised to support individual firms. In many cases, the technology intermediaries were unknown to the industry and its representative associations. It is important to clarify that there were exceptions. For instance, the Technology Station in Clothing and Textiles in the Western Cape was credited by many clothing manufacturers as a source of information, knowledge and inspiration.

[1] Technology Profiles were published for Additive Manufacturing and 3D printing; the Internet of Things; Information Processing: AI, Machine Learning and Big Data; Augmented Reality in the Manufacturing Sector; Robotics in the Manufacturing Sector; and Large Language Models like ChatGPT and the workplace. Available at: https://www.tips.org.za/projects/technological-change-and-innovation-system-observatory/profiles

Another example is the publicly funded efforts to promote additive manufacturing in South Africa through well-known technology centres at the Central University of Technology, Vaal University of Technology, North-West University, Stellenbosch University and the CSIR. The additive manufacturing competencies in the public sector are already known in the medical, defence and advanced manufacturing sectors.

Lastly, in sub-sector strategy processes, such as the development of sectoral master plans or the formulation of sectoral skills plans, technological change is often discussed but often not prioritised as a collective strategic priority. Technology is often treated as an object or process that individual companies can master. It is assumed that technological change is mainly about training workers and installing new equipment while neglecting the strategic, organisational and inter-organisational learning and competence development must take place to make new technologies effective and competitive. Without a coordinated technology strategy between different organisations, it is hard to share risk, develop complementary competencies, and encourage co-specialisation and co-investment.

A challenge is that in some areas where South Africa has a unique market position (e.g. natural fibres) it will take more than training or investing in off-the-shelf technologies to exploit the global demand opportunities. Coordination across multiple domestic and international companies, public sector support organisations, and specialised service providers is required to enable co-investment. Complementary competencies and co-specialisation, as well as market channels, have to be developed, and an instrument like the Dynamic Capabilities Framework, or at the very least a more strategic view of technology intelligence, would be essential.

4. Conclusion

This paper explored the Technology Intelligence and the Dynamic Capabilities approaches to raising awareness and strategically responding to technology development. While both approaches originate from evolutionary economics, they are slightly different in their emphasis. Technology Intelligence is more focused on the strategic ability of organisations to identify and evaluate new technologies in comparison to the current and anticipated needs of the organisation. It is future-oriented and goes beyond the management of technology and innovation.

The Dynamic Capability Framework concerns organisations' strategic ability to build and reconfigure internal and external competencies. It offers a simple heuristic: sense, seize, and transform, which can enable dialogue and exploration between different companies and their supporting institutions.

The objective would be to strengthen the collective strategic responses to technological changes. However, the extent to which the participating organisations can participate in these explorations and assimilate the insights from this process will depend on their respective abilities to improve their internal technology intelligence and their ability to adapt their business and technology strategies.

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