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DEPARTMENT OF TRADE AND INDUSTRY

MAPPING THE MESO SPACE THAT ENABLES TECHNOLOGICAL CHANGE, PRODUCTIVITY IMPROVEMENT AND INNOVATION IN THE MANUFACTURING SECTOR

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TIPS is a research organisation that facilitates policy development and dialogue across three focus areas: Trade and Industrial Policy, Inequality and Economic Inclusion, and Sustainable Growth

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ABOUT THIS PUBLICATION

This paper*, Mapping the meso space that enables technological change, productivity improvement and innovation in the manufacturing sector,* was commissioned by the Future Industrial Production Technologies Chief Directorate of the Department of Trade and Industry (the dti). This unit is focused on preparing South African industry for the fourth industrial revolution.

It is the third paper in a series and focuses on meso organisations and policies that strengthen the technological capability of the country or an industry to enable change, adaptation and economic resilience.

Other papers in the series are *Framing the concepts that underpin discontinuous technological change, technological capability and absorptive capacity; World Economic Forum and the fourth industrial revolution in South Africa;* and *Technological change and sustainable mobility: An overview of global trends and South African developments.*

Saul Levin (TIPS) directed the project, and Dr Shawn Cunningham of Mesopartner was the lead researcher and author.

"The first rule of any technology used in a business is that automation applied to an efficient operation will magnify the efficiency. The second is that automation applied to an inefficient operation will magnify the inefficiency." Bill Gates

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ABBREVIATIONS

CSIR	The Council for Scientific and Industrial Research
CCRED	Centre for Competition, Regulation and Economic Development
DST	Department of Science and Technology
dti (the)	Department of Trade and Industry
DPRU	Development Policy Research Unit at the University of Cape Town
ICT	Information and Communication Technology
IDC	Industrial Development Corporation
IPAP	Industrial Policy Action Plan
MCEP	Manufacturing Competitiveness Enhancement Programme
MerSETA	Manufacturing, Engineering and Related Services Sector Education and Training Authority
NACI	National Advisory Council on Innovation
NDP	National Development Plan
NGP	New Growth Path
NMISA	National Metrology Institute of South Africa
NRCS	National Regulator for Compulsory Specifications
OECD	Organisation for Economic Cooperation and Development
SABS	South African Bureau of Standards
SANAS	South African National Accreditation System
SANEDI	South African National Energy Development Institute
SPII	Support Programme for Industrial Innovation
TIA	Technology Innovation Agency
THRIP	Technology and Human Resources for Industry Programme
TSP	Technology Stations Programme

EXECUTIVE SUMMARY

This working paper is focused on the meso level, especially those policies, organisations, and programmes that affect the performance of the manufacturing sector, and especially those that support or promote technological change.

The meso level is the sphere in the economy where organisations and programmes are created for specific industries, regions, economic activities, or patterns of underperformance. This level is defined by policies from several government departments that target particular temporary or permanent market failures or structural issues. The policies are in turn implemented by a variety of organisations.

In this paper, particular attention is paid to meso organisations and policies that strengthen the technological capability of the country or an industry to enable change, adaptation and economic resilience. Two groups of organisations in the meso layer are examined in more detail, namely those that enable technological change and adaptation, and those that enable education and skills development.

The paper provides an approach to mapping the different meso organisations in South Africa that are relevant for improving the technological capability of the country. Some pointers on measuring the performance of these organisations are provided. The challenge of identifying and responding to missing public institutions is also explored.

1 INTRODUCTION

"The future is already here – it's just not evenly distributed" – attributed to William Gibson

This working paper is focused on the role of the meso level in enabling and promoting technological change, knowledge diffusion, innovation, and knowledge intensification in the South African manufacturing sector. This is in the context of a perceived acceleration in global technological change, convergence, and digitalisation under the popular banner of the Fourth Industrial Revolution. Even if we disagree with the methodologies and policy recommendations of many international organisations' assessment of South Africa's readiness for technological change, more credible local and international assessments and reports confirm that South Africa's technological capability and readiness for technological change is lagging those of our peers (TIPS, 2018). Discontinuous technological change is visible in the world around us, and many companies, governments and civil organisations are concerned about job losses, increased competition from new sources and disruption to current production networks.

This working paper will not cover the whole economy and all the meso organisations that exist. It is focused mainly on those policies, organisations, and programmes that affect the performance of the manufacturing sector, and especially those that support or promote technological change. This paper will not examine the evidence of the increasingly disruptive nature of global technological change, or the fears about that change, but will be focused on the role of meso organisations and how they enable the private sector to adapt, upgrade and prepare for the future.

This paper is organised as follows. In chapter two, the concept of the meso level is introduced. A distinction is made between meso policies, meso organisations and specific programmes. The purpose of the meso level is also clarified.

In Chapter three, the role of the meso level in strengthening technological capability is unpacked. Two groups of meso organisations are emphasized: those technological institutions that enable problem solving, technology dissemination and technological upgrading; and the broad network of education institutions that formally upgrades skills and management capabilities.

In Chapter 4, the process of identifying meso organisations is explained. A typology for classifying distinct types of organisations is proposed for South Africa.

The concluding chapter is a short conclusion outlining some recommendations and next steps.

2 WHY DO WE NEED MESO POLICIES, ORGANISATIONS AND PROGRAMMES?

"We can only see a short distance ahead but we can see plenty there that needs to be done." Alan Turing

2.1 What is the meso level about?

The idea of the meso level draws from the research around the concept of Systemic Competitiveness that is briefly summarised in Textbox 1.

The meso level is the sphere in the economy where organisations and programmes are created for selected industries, regions, economic activities, or patterns of underperformance. This level is defined by policies from several government departments that target specific temporary or permanent market failures or structural issues. Macro policies are often generic in that they often address many sectors of the economy (such as trade policy fiscal, policy, monetary policy or exchange rate policies). Meso policies are known for their selectivity. Meso policies may set certain regulations, laws or standards of compliance that target specific regions, sectors, or patterns of behaviour. Or they may define certain organisations, programmes or initiatives and set targets.

Some meso organisations are permanent, such as the South African Bureau of Standards (SABS). Other programmes may be temporary, such as the Manufacturing Competitiveness Enhancement Programme (MCEP) of the dti that sought to encourage enterprises to upgrade their production facilities, processes, and products. The MCEP is also an example of a meso programme or initiative that was implemented by an organisation that also sets policies at a macro and the meso levels, the dti. The implication is that an organisation can be described as both a macro level organisation (because of its generic policies) and a meso level organisation with several regulations, programmes and activities that are selectively focused on sectors, initiatives or systemic issues.

Meso organisations can also emerge from the private sector. For example, an industry association that takes on developmental tasks, like lowering entry barriers into the industry, or setting transparent standards, can be classified as a meso organisation. In technology transfer and innovation, equipment suppliers that offer demonstration facilities (reducing information asymmetry and reducing adverse selection) can also be seen as fulfilling a meso function.

Textbox 1: Systemic Competitiveness in brief

Changing economic performance requires diverse institutional changes that go beyond interventions on micro-level interactions between companies and individuals and macro-level framework conditions. Two other levels of institutional interactions can be defined. Firstly, societies need to be open to change in general and open to change that favours economic evolution in particular. If, for example, a society does not tolerate failure, companies will not take the risk of experimenting with new ideas as this might threaten their very existence. A society's disposition to create a favourable environment for economic development can be described as the "meta-level". Further, specialised supporting institutions are needed to tackle persistent patterns of underperformance in economies that cannot be solved by individual actors.[1] One such institution would emerge, for instance, from a broad agreement that a performance issue or pervasive pattern of behaviour should be dealt with. This institution then results in organisations, programmes, projects, or infrastructure being created to take up this issue. An example of persistent underperformance that slows economic evolution is an underinvestment by the private sector in, for instance, skills development. An institution could emerge whereby it is agreed that skills development is lagging and should be improved. This could be done by investing in public education and integrating vocational training with on-the-job training. Non-governmental organisations may become involved in helping to re-train workers who have lost their jobs due to outdated skill sets. Even some private initiatives to upgrade worker's families may be set up, and the government might create an incentive for companies to absorb young learners as interns. This layer is called the "meso-level", which consists of initiatives that emerge to address patterns of underperformance at the micro level. This framework reveals that dynamic development is not the result of isolated interventions, but of the way many factors, priorities and policies interact on the micro, meso, macro and meta levels to shape economic performance. Central to this process are organisations, programmes, and interventions in the meso layer that connect the patterns observed at the micro level with generic policies originating from the macro layer, within a socio-cultural context created by the meta level orientation of the society.

Source: Summarised from Esser, Hillebrand, Messner and Meyer-Stamer (1996)

For certain services to be delivered, it is necessary to create a dedicated organisation or add a mandate to an existing one. Such services are often not supplied naturally by the market, either because markets typically do not supply public goods or because trust in an institution needs to be established first. For all these reasons, individual businesses have little or no incentive to invest in these services.

The functions in the meso level are shaped by many different public and private organisations. Some functions may be basic, such as the provision of advisory services aimed at start-ups, or technical training. Other services may be more advanced, such as a specific programme aimed at technology transfer or specialised training to upgrade workers skills. Specialised functions could include technology extension to assist companies in an industry to upgrade or absorb new technology, or specialised research to exploit a particular technological opportunity in a region or a knowledge domain (see Table 1).

Table 1: Examples of services offered by meso organisations

	Technology	Education and training	Finance	Infrastructure	Foreign trade	Entrepre-neurship	Business membership associations
Basic functions	Measurement, standards, norms, quality assurance	Secondary and higher education in basic disciplines	Credit, Investment capital	Basic infra-structure: roads, water, electricity, telephony	Basic foreign trade transactions	Awareness raising on potential of entrepreneur-ship	Elementary services Ad hoc lobby
Advanced functions	Technology transfer	Vocational training in specialised disciplines	Development banking Micro-finance Collateral banking	Reliable, efficient, high-quality infrastructure	Export financing Export credit insurance	Entrepre-neurship training, business skills training BDS market facilitation	Specialised services Business networking
Specialised functions	Specialised R&D	Highly specialised, high-quality training courses	Specialised, innovative financing Venture capital	Specialised, innovative infrastructure	Advice and support for market research, design, packaging, etc.	Business incubation, business acceleration	Comprehen-sive services Active role in locational policy

Source: Meyer-Stamer (2005)

The first two columns (marked in yellow) in Table 1 show the services offered by meso organisations related to technology and education. However, other organisations offer services that affect technological change and upgrading. For instance, under infrastructure there is quality infrastructure like telecommunications networks and connectivity. Under entrepreneurship there is business incubation and acceleration. The implication is that not only mapping of narrow technological and educational institutions exists, but also an understanding of the current patterns of performance, gaps, and technological change – at the level of enterprises. From this one can then work back to what kinds of institutions are missing, underperforming or working well.

While the examples of typical activities in Table 1 are directed towards firms, meso organisations also play an important role in advocating for policy change and shaping public sector strategies at the policy level based on their insight into the incentives and behaviours of enterprises. Often these organisations must balance the requirements of the micro-level actors with the priorities of policy makers or funders.

To find opportunities for improvement, or to address binding constraints, meso organisations must typically work with other stakeholders, conduct diagnostic processes, and formulate improvement processes over the short, medium, and longer term. An example is a standards body that helps enterprises meet international and national standards.

2.2 The purpose and emergence of the meso level

Governments set meso policies and create meso organisations and programmes because they want to influence the structural change process in the economy, overcome persistent and temporary market failures, and enable upgrading, modernisation, and employment in the economy.

Hausmann, Rodrik and Sabel (2008) argue that structural change must overcome three main types of failure that hamper economic development:

a) **Self-discovery externalities**: Learning between different agents about which new products can be produced profitably in an economy, and how.
b) **Coordination externalities**: New local economic activities are often required simultaneously by different investors – upstream, downstream and in parallel or in related industries. For instance, to promote a circular-value logic would need stakeholders who may not even be aware of each other's existence or interests to develop new concepts along a new value chain that does not yet exist.
c) **Missing public inputs**: Private production typically must have highly specific public inputs – legislation, accreditation, R&D, transport and other infrastructure specific to an industry – of which government institutions often have little up-front knowledge.

Technological upgrading is particularly prone to market imperfections. Many technological changes are costly and require economies of scale beyond an enterprise's management, organisational and market capacity. These kinds of technologies are scarce, indivisible, and often prone to imperfect market structures such as monopolistic or oligopolistic behaviour by those that can afford to overcome the upfront investment.

Enterprises would often choose rather to optimise profits in the short term than invest in technological change and innovation that introduces risk, uncertainty, and variation into their organisations. There are also external effects, both positive and negative, that shape the decisions of entrepreneurs. An example of a negative externality is where entrepreneurs hesitate to send their staff for training due to a fear that employees may demand more pay or find employment elsewhere. An example of a positive externality is where young graduates that were exposed to newer technology at university bring new knowledge into a business, for which the employer does not have to pay directly.

New technologies, knowledge and the impact of developments elsewhere can be costly to remain abreast of, figure out, experiment with and master. This is especially the case where the technological change appears to be widespread and pervasive, like the rapid pace of digitalisation and its effects on many industries and knowledge domains. Many entrepreneurs might simply be overwhelmed or paralysed and may choose not to invest and to just wait and see what happens. While this may save risky investments in the shorter term, at an aggregate level it harms the economy if incumbents that can invest and try new ideas do not do so; consequently, new technologies are not tried, adapted or adopted in the economy. At the same time, it is critical to promote start-ups, which are not as path dependent as incumbents, to try new technological combinations, and to challenge the dominance and inertia of incumbents through a process of creative destruction.

Textbox 2: An example of the interplay between physical technologies and social technologies

Printing a new component on a 3D printer may require not only new equipment, a carefully controlled manufacturing environment, and new raw materials. It most likely will require a change in the architecture that the component forms part of, changes in regulations, testing and certification, as well as new engineering skills. Furthermore, it may require a new organisational form, a different relationship with research and development organisations, and a more integrated relationship with both the equipment supplier and the final user of the equipment.

A few factors typically inhibit the dissemination of new knowledge and technologies to firms. One is the fixed cost of the new technology itself. This could both be the cost of finding the right solution, or

the cost of acquiring, integrating, and mastering the new technology or knowledge. All other investments needed to optimise or leverage a new technology could also put the investment out of reach. A second aspect is related to the social costs and complementary institutional or physical infrastructure needed to fully use a new technology. With increased and often converging technological change; the sheer amount of information that must be processed and options that must be considered; and many competing technologies and solutions, enterprises can easily become overwhelmed. This is not only a function of the physical technology in a narrow sense. There is a cost within and between organisations to process all the information and to make sound decisions. While much of the attention is drawn to physical technologies, such as artificial intelligence or 3D printing, the social technologies that allow new business models to emerge, new network arrangements to be tried, and new collaborations between different social actors, is often overlooked (see Textbox 2). Nelson (2003:20) stresses that *"Some of our most difficult problems involve discovering, inventing and developing the social technologies needed to make new physical technologies effective"*.

Businesses that can generate or recognise modules that work better and that can be repeated elsewhere by drawing on their past experiences have a huge advantage over businesses that cannot do so (Beinhocker, 2006; Nelson and Winter, 1982). Schumpeter argued some time ago that innovation consists of *"the carrying out of new combinations"*, with many of these combinations depending on past knowledge or understanding of physical, social or economic properties (Schumpeter, 1934:65-66). Dosi and Nelson (2010:103) argue that the ability of firms to learn, adapt, and innovate is generally highly heterogeneous, idiosyncratic, and unevenly spread. What is often overlooked is that the knowledge and technology ecology that firms form part of are critical to their ability to absorb the latest ideas, adapt their technologies, and enter new markets.

Organisations in the meso level typically emerge when groups of stakeholders collaborate to overcome some form of structural issue or market failures, or when a policy formulation process needs an implementing organisation to implement, monitor or coordinate some strategy or plan. This firstly requires some recognition that an undesirable or costly pattern is repeating that should be reversed, or that underperformance in the private sector should be corrected. While some meso organisations may be copied or imported from abroad due to international agreements, many organisations are created through public-private dialogue and deliberation to tackle pressing issues affecting the performance of enterprises, industries, and economic regions. Some organisations may be formal and may respond to specific issues in a sector or region. Other organisations may be informal and exist mainly because a group of stakeholders have a common interest in achieving some developmental goal. The meso level emerges as actors in a society develop the ability to look beyond their own narrow interests or to mobilise around issues that are affecting a broad range of stakeholders and issues. When the private sector is involved, it takes time, resources, and attention away from day-to-day operational issues. When the public sector is involved, it typically entails changes in policies, regulations, priorities and budgets. This process of institutional adjustment often needs mediation, collaboration, dialogue and negotiation between competing priorities, different ideologies, and different timescales. It entails trust building and the willingness to search for common ground, and for different actors to work together.

To conclude this section, the meso level emerges as a policy response in the public sector, or as a strategic response in the private sector, to structural issues and patterns of underperformance that are detected at the level of markets, business networks and hierarchies. The emergence of activities in the meso level may require different stakeholders in the public and private sector to work together, share information, collaborate and agree on priorities and resource allocations. Or it may remain informal, when different stakeholders all do what they think is necessary in an uncoordinated way.

Formal organisations typically emerge out of some sort of recognition that something must be done, or that a certain structural change should be achieved. The challenge is often that the patterns are shifting or unnoticed, key stakeholders are not involved, or the costs of a certain pattern of underperformance is unclear. In developing countries, the challenge is often that the meso level is dominated by a supply- driven public sector policy, while issues that lower barriers to entry, and increase innovation and competitiveness or investment are not attended to in a systemic or transparent way. Finally, the dynamics in the meso level and the performance of formal and informal organisations are shaped by the explicit and implicit framework conditions and incentives in a society. These incentives are not necessarily financial, but could be political, social or value-driven. For example, in societies where learning is highly valued, and where failure is tolerated or even encouraged, a different set of institutions and organisations will emerge to encourage and support both winners and losers of this learning by failure approach.

"As for the future, your task is not to foresee it, but to enable it." Antoine de Saint Exupery

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3 THE MESO LEVEL AND TECHNOLOGICAL CAPABILITY

With the increasing sophistication of technology, the ability of organisations to have all the relevant knowledge in-house diminishes.[1] Knowledge is being increasingly distributed among larger numbers of actors, spread over organisational and even territorial boundaries, who need to work together dynamically to produce and transact. Knowledge tends to flow more easily where there is a certain density of diverse actors that have complementary interests, capabilities, or knowledge.

A diverse range of actors, publicly funded organisations, key suppliers, and demanding local and international buyers, all contribute to making this technological capability possible (TIPS, 2018). It is also important to note that knowledge does not only flow through formal structures during business hours, but also through social networks and events, both domestically and internationally. This is one explanation of why innovation is increasingly an urban phenomenon: it is greatly enhanced by the diversity of the urban economy.

3.1 Technological capability

While it is easier to track and criticize the performance of the private sector, the technological capability of the country is not only determined by good framework conditions and competition at the level of enterprises. These are necessary but not sufficient. Hillebrand *et al.* (1994) argue that technological capability is built on four pillars:

1. The skill of the producers to imitate and innovate at product, process, and business model levels. This is largely dependent on pressure to compete as well as pressure to collaborate with each other.
2. The economic, political, administrative, and legal framework conditions determine whether there are incentives to develop technological capability. In the past, it was often not recognised that these incentives were lacking in many developing countries.
3. Direct support by technology-oriented state organisations or specific types of knowledge-intensive service companies depends on the existing level of development, the competition situation, and the characteristics of a technology branch in the given country. These organisations disseminate technical and expert knowledge between different actors, knowledge domains and industries, and play a critical role in the use and application of tacit and explicit knowledge.
4. Indirect support by the public and private educational systems. In addition to a sound basic education, it is important that technical training of a suitable quantity and quality is available at secondary school level and in the universities. The private sector often plays a role in short-term training aimed at particular technology applications. Overall the education sector must be able to identify and respond to changes in the application, development and use of technology in society.

The close interaction between these four pillars creates technological capability. Of the four bullet points, the third and fourth are really about the meso level and its ability to encourage or shape the innovative efforts of enterprises.

[1] See for instance Hidalgo (2015)

These two groups of meso institutions will be explained in more detail under the next two sub-headings[2].

Before discussing these two groups of institutions it is important to explain what is meant with the term "institutions" and how it relates to "organisations". Institutions are often thought of as organisations. For example, universities are referred to as institutions of higher learning. But there are also social norms, cultural practices, informal forms of collaboration, more formal networks, regulations, standards and then the more easily identifiable formal organisations. Societies, as they develop and evolve, are constantly tinkering with their institutional landscape, which means they are adjusting incentives, organisational mandates, are shifting budgets to agreed priorities, developing consensus, debating alternatives, and responding to external change. So "technological institutions" is a broad term that includes all the different ways a society is trying to make sense of technological change or technology broadly, just as educational institutions enable a society to educate, train, retrain and develop its citizens and its formal knowledge stock.

In some cases, organisations emerge because of global pressure to have certain kinds of organisations in place (think of the South African National Accreditation System). In other cases organisations emerge out of local needs, such as a technology incubator.

3.1.1 Technological institutions

The third group in the earlier list (see 3.1) are collectively referred to as the technological Institutions of the society. Of these institutions, the easiest to find are the formal organisations that are established through public funding, or the organisations created or supported by industry as a means to enhance their competitiveness. Of particular interest for improving the technological capability of an industry or a region are those organisations that disseminate technological knowledge in the society and assist enterprises to solve problems, master new technologies, and make scarce or specialised knowledge and technology available to the society. Technological Institutions can be publicly funded, mixed goods, or private sector activities. These organisations reduce entry costs, reduce risks, promote new concepts, compare alternatives, save search and evaluation costs, and encourage improvement. In general, they respond to temporary or persistent market failures such as overcoming indivisibilities, reducing information asymmetry, reducing adverse selection, and overcoming barriers to entry. For instance, by giving access to an expensive laboratory, a technology centre reduces barriers to entry and overcomes economies of scale. The result is that a small or medium-size enterprise that cannot afford, or cannot justify creating and maintaining, a lab of its own can benefit from a professionally managed facility.

Mostly, technological organisations supply services in the form of access to scarce equipment or human resources or technological advice.

Some functions performed by technological institutions include:

- Technical infrastructure, such as organisations involved in standards, measurement, and testing;
- Quality assurance, certification, compliance;
- Technology consulting and management consulting;
- Technology and knowledge dissemination, technology demonstration;
- Technology and manufacturing extension;

[2] These next two headings will draw on the experience of the author in diagnosing meso level organisations and facilitating the closure of these gaps over 15 years and spanning more than 30 countries.

- Research and development consultancies, centres, and contract research organisations;
- Intellectual property protection;
- Research and development financing, venture capital;
- Technology assessment;
- Technological and trade journals focused on technology dissemination, evaluation, and technical journalism;
- Access to scarce or specialised equipment on a pay-per-use basis;
- Technological or production technology trade fairs and exhibitions; and
- Prototyping, simulation, and design services

While some may be supply-push (like compulsory standards, certification, or technology demonstration), others may be more demand-oriented (like technology and management consulting, technology extension services and contract research organisations).

Some organisations may not even identify with the topic of technology extension, and may simply be fulfilling a regulatory requirement. The development or compliance assessment with standards could be an example. Yet standards (or even patents) transmit valuable information about performance, processes, systems, and minimum specifications, and in this way play an important role in disseminating knowledge, technology, and innovation.

Often a surprise is the importance of equipment suppliers in disseminating new technology, knowledge, and innovations. Equipment suppliers providing technology demonstration, comparison or even trial use can be critical players in encouraging upgrading and reducing risks.

Common challenges faced when working with technology institutions are:

- Technology-oriented organisations are often technically brilliant but communicate poorly. Offerings are often inadequately described; costs of solutions are hard to understand; and upgrading pathways or use cases are not documented. Many different forms of market failures emerge around these organisations.
- These organisations often narrowly focus on physical technologies, processes and systems, and are sometimes insensitive to understanding change in enterprises or neglect helping develop adequate social technologies.
- There is a tendency for a strong supply-push approach, especially when public funding is used. These organisations are often deficient in measuring the impact or value of their solutions (especially when publicly funded).
- While working with high-tech clients and sophisticated technology is rewarding, some basic technological concepts and offerings that reduce barriers to entry or upgrading must still receive attention.
- In many instances there is a strong linear orientation and not enough attention is paid to sense-making, understanding trade-offs, and preparing for multiple or alternative futures.
- Organisations could be hidden (within larger organisations) and inaccessible behind acronyms, technological jargon, or high security barriers.
- Organisations that are critical in the landscape may not even identify with technological upgrading, improving competitiveness or disseminating knowledge. They may simply think of themselves as “supporting small enterprises” or regulating standards or providing a certain service.
- Technology organisations are often funded by national public funds yet are focused on a local client base with insufficient attention to creating more accessible public-good services aimed at reducing access costs for enterprises far away. Institutions hosted by universities may be

hard to access for enterprises due to a lack of parking, inadequate signage, or disturbances on campus.

3.1.2 Education Institutions

The fourth group in the earlier list (see 3.1) are collectively referred to as the "education institutions". Again, formal organisations are the easiest to identify and mainly disseminate formal knowledge to the economy in the form of education, courses and academic research. This group includes public as well as private organisations involved in education, schooling as well as higher education and vocational training. Often, little attention is paid to the informal networks that exist between alumni and organisations, or the importance of researchers being able to raise funds to enable academic exploration and research into niche areas.

The ability of individuals and organisations to learn difficult and abstract concepts is largely dependent on this group. These organisations often also encourage informal knowledge dissemination through social networks and personal relations. Through research, development, analysis and publications, these institutions also signal and disseminate information that enable better decision-making in the society.

Some of the functions performed by education institutions include:

- A comprehensive primary education.
- Appropriate technology-related secondary schooling.
- Exposing children and youth to emerging technologies, scientific thinking, abstraction, and logic.
- Vocational skills.
- Higher education, especially
    - scientific, technology, innovation, and engineering-related qualifications,
    - management, problem-solving, strategic leadership, technology, and information management qualifications.
- Ongoing education, workforce development, and retraining.
- Academic research.
- Providing interns, researchers, and instruments to industry.
- Developing, formalising and organising industry, domain, and specialised knowledge, pools of expertise, researchers and knowledge.
- Attracting public and private funding to enable searching, deliberation and exploration of new topics, and the development of new forms of knowledge.

These organisations must be accessible, flexible and responsive to the ever-shifting needs of the society.

Common challenges often faced when working with education institutions are:

- In South Africa, a strong emphasis is placed on the youth and first-time graduates. Often insufficient public funding is available for further education, retraining or adult education.
- Academic departments are often narrowly focused on a discipline, knowledge domain or a qualification. Multi-disciplinary research and transdisciplinary research (within faculties and between faculties) are valuable to industry, but extremely hard to manage, design, fund or even justify in the public higher education space.
- Compared to other countries, South Africa has low mobility of private sector experts moving into the academic space, or senior researchers and academics rotating into the private sector.

Knowledge transfer between academia and the private sector often takes the form of people moving between the two, and this phenomenon is limited in South Africa.

- The systems to develop, accredit or approve new qualifications, programmes, disciplines, and academic programmes are often tedious and prolong the process.
- What academics and policy makers sometimes forget is that when the private sector expresses a need in a collective way, this is often based on the lowest common denominator or compromise. The implication is that a new course that is strongly supported by the private sector may in fact be five years too late and not addressing the current or near-future demands of the private sector.
- Many of our higher education organisations are underfunded, overly bureaucratised, overly controlled yet under-managed. The merger of many universities and colleges has led to large universities spanning several campuses, cities, and towns and which are hard to manage.
- Out of frustration with the slow responsiveness and incompetence in many institutions, the private sector often resorts to creating its own training and certification programmes in parallel to formal institutions. While this solves the problems of industry in the short term, it does not improve the performance of the systemic capability of institutions to identify a new need, nor does it create an appropriate response in partnership with the private sector and implement a new programme in collaboration with industry.
- While regulating training providers and skills providers, the current system is perceived to be overly complicated and rigid, and not responsive to the emerging and complex needs of the private sector.

3.2 Assessing the performance of the meso level

While technological capability can be described in highly aggregated terms and measured with high-level indicators, the national technological capability consists of many overlapping and complimentary technological capabilities that exist in certain regions, around certain industries or shaped around certain markets.

For example, the Western Cape has developed a strong technological capability in food processing that is different (yet complementary to) the food production systems around eThekwini and in Gauteng. The same can be said of the South African tooling sector, the automotive sector, or the wind power industries in South Africa. Technological capability is neither about the existence of a particular organisation or programme nor about the performance of a handful of enterprises. Rather, it is about a dynamic relationship between policies, programmes, organisations, and incumbent as well as emerging enterprises. This capability must also be able to adapt, new organisations must be created, and performance must be measured and managed.

Therefore, it is not possible to measure all the organisations and programmes involved in technological capability in the same way. The Technology and Education institutions in the meso level that have the greatest institutional effects on technological change are easier to measure and assess because their effects are revealed at the level of the enterprises. The responsiveness and quality of the Educational Institutions is much harder to measure and quantify directly.

In general, meso organisations should not only be measured in how well they deliver services, solutions, or value to enterprises. They should also be measured in how well they are governed, and in how well they develop synergistic relations with other institutions and partner organisations or networks. Furthermore, meso level organisations also play a crucial role in channelling feedback from the level of enterprises (the micro level) to policy makers and decision makers.

Lastly, meso organisations cannot only respond to what is expressed as a need by the private sector or insights gained from analysing statistical data. The meso level also needs to be assessed on how well it is preparing the society and enterprises for the future.

3.3 Responding to missing or inadequate public goods in the meso landscape

Finally, it is hard to identify missing public goods and inadequate public organisations. Missing public goods could be the result of many various factors such as:

- The poor performance and governance of an existing organisation.
- New technological developments that may need organisations, policies and capabilities.
- Inadequate resources being allocated to a specific topic or issue, or organisations simply being spread too thin.
- Poor policy design and measurement of impact.
- Public policy mismatch with needs of industry.
- Overlapping fragmentation within the public sector, both within and between departments.
- The excessive costs of coordination between the fragmented public and private sectors as well as a lack of trust between different actors.
- A lack of data and analysis of factors that are shaping the behaviour of the private sector and its incentives to innovate, invest and upgrade.
- Too many competing demands on a limited public budget.
- An insensitivity to weak signals or demand within particular sub-regions or sub-industries.
- The pressure on the public sector to show results in the short term while technological change and capability development may necessitate a longer-term strategy and effort.
- Pressure from lobbying groups to protect their interests, resulting in marginalised groups not being heard or considered when deciding how to allocate resources.
- Situations where an agency seeks its own survival and interests, and consequently either pretends to be compliant with a mandate, or organisational creep takes place into domains that the organisation is not designed for nor effective in.
- A lack of management capability in the public sector to manage meso policy in an adaptive yet efficient manner.

From the moment a missing public good is identified to the time that it takes to fill the gap could be measured in many years. This is probably one of the main reasons for institutional scope creep, where an existing organisation designed for a specific purpose is repurposed or tasked with additional functions that do not fit its culture, capabilities and governance structures.

"Slow adaptation is driven by forces such as evolution. Fast adaptation is driven by forces such as insight." Gary Klein

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4 IDENTIFYING SOUTH AFRICAN MESO ORGANISATIONS THAT STRENGTHEN TECHNOLOGICAL CAPABILITY

In this section the approach to identifying and mapping meso organisations and programmes will be explored. The initial maps developed during the research for this project are attached as separate Annexures 1 and 2.

Various typologies have been proposed to classify, measure, and manage the performance of those organisations involved in technology dissemination or building technological capability. For instance, the OECD often refers to four types of technology diffusion programmes based on operational focus:

- **Supply-driven**: programmes to transfer and commercialise technology from government research programmes to private enterprise, both high-tech and low-tech. It also involves education, skills development, and standards.
- **Demand-driven**: these initiatives start with a diagnosis or the perspective of enterprises and aim to respond to the challenges or opportunities faced by private enterprises. These could be aimed at plugging specific performance, technology, and capability gaps in the enterprises, and is often focused at smaller businesses.
- **Network-based**: these are often sub-national or regional, and are aimed at creating or strengthening bridging effects, inter-firm partnerships in promoting information flows, and the diffusion of technology. Examples are cluster promotion, strengthening of industry or business associations, and fostering collaboration around skills development, research and development, or the development of shared infrastructure.
- **Technological capability dialogue, adaptation, and socio technical infrastructure building**: these intentional initiatives are aimed at working on a system-wide level to upgrade the technology diffusion capability of the national system of innovation within the context of global and regional economic and technological change and opportunities. This is often in the form of dialogue and reflection about why certain initiatives are not yielding the expected results, or why certain industries are not striving to increase their innovation, use of technology or competitiveness. An example is the effort by several government departments to collaborate around a national digitalisation strategy, or the effort around the Mining and Ocean Economy in the last few years.

Some organisations are created by international or national regulations, such as compulsory standards, agreements, and laws, and should be measured against set performance indicators in a public or transparent way. Examples are the South African National Accreditation System (SANAS) and the organisations involved in South Africa's technical infrastructure.

A challenge that many developing countries face is that meso organisations have to work hard on creating capabilities that should have existed already, while trying to remain abreast of new international and domestic shifts that require new management capabilities, human resources, technologies, and strategies. Not only the private sector that can be overwhelmed or paralysed by competing technological choices. The public sector management can suffer from the same symptoms.

While some organisations may be more important for improving the productivity and competitiveness of incumbent firms, others may be more relevant for lowering entry barriers to new start-ups and investors. Even if new start-ups lack market access or technological experience, in a dynamic environment their different knowledge and unique technological capability may put them at less of a disadvantage than the incumbents (Nelson, 1995).

Some meso organisations may be hard to classify because they offer differently valued services to different beneficiaries. For instance, universities play an essential role in lowering the costs of gaining access to new knowledge, codified knowledge, and research. At the same time, a university may offer industry access to scarce equipment on a pay-per-use basis, while a laboratory may offer certification or analytical services to another group. At the same time, a research programme based at a university may be a sophisticated client to a private enterprise that specialises in advanced equipment, while the same enterprise may be dependent on post-graduate students from the university. Some of these relationships and interdependencies are impossible to map without deep insight into how knowledge, technological ideas, and people, flow between organisations in the public and the private sectors.

4.1 Identifying supply-driven organisations created by laws, regulations or strategies

Supply-driven organisations and programmes created by laws, regulations or strategies are largely established to transfer and commercialise technology from government research programmes to private enterprise and include both high-tech and low-tech. They also involve education, skills development, and the promotion of environmentally friendly manufacturing technologies or other social imperatives. The supply side of technological capability also refers to organisations that promote regulatory compliance, technical infrastructure, labour, or other standards. In effect, these organisations or programmes lift the bar and encourage upgrading in a supply-push manner.

These organisations are often created through acts of parliament, regulations, and budget votes in different spheres of government.

- The most easily identifiable organisations report to the dti (budget vote 34) and the) (budget vote 30) or receive significant funding from these departments.
    - This includes programmes of the dti and the DST, for instance the Technology Localisation Implementation Unit (hosted by the CSIR) that is funded by the DST, the Technology Innovation Agency (TIA) or the SABS, or the Intsimbi Future Production Technology Initiative of the dti
- A second group are organisations relevant to technological upgrading and innovation, such as the Innovation Hub in Pretoria (Gauteng Province) or the Silicon Cape initiative.
- Many organisations reporting to other departments or spheres of government may also be strengthening technological capability.
    - For example, the South African National Energy Development Institute (SANEDI) is a Schedule 3A state owned entity that reports to the Department of Energy. In the 2018 financial year, SANEDI has been implementing several programmes to improve local innovation and applied research, improve technology demonstration around battery and solar photovoltaic technology, and to increase local content.

4.2 Identifying demand-side organisations and programmes

Demand-side organisations and programmes would be identified through their approach in conducting either a diagnosis from the perspective of enterprises and their responding to the challenges or opportunities faced by private enterprises. These organisations could be aimed at addressing specific performance, technology, and capability gaps in the enterprises, and are often focused on smaller businesses. While some of the organisations may be publicly funded, in many countries these organisations could also be privately owned. For instance, technological or management consulting service providers; or providers of knowledge intensive services may also fall in this category.

Identifying the demand-side institutions could involve:

- Finding public and private organisations that the dti, DST and others frequently collaborate with (or have collaborated with in the recent past) to upgrade technological capability, support knowledge or technology transfer, or help enterprises and industries improve their performance. It would be easier to identify these demand-side meso organisations in areas, sectors or even localities in which the dti and the DST are already deeply engaged. One approach would be to survey the dti sector desks and programmes to find which organisations are working to disseminate knowledge, encourage upgrading or to promote innovation in industry. Such an approach could be complemented by an assessment of how public funding flows from the departments to a range of organisations involved in improving the use and adaptation of technology, and innovation in industry.
- Engage with enterprises through industry associations and business membership organisations to determine who they turn to for advice when they have to solve a technological or complex problem. The approach will reveal the most obvious organisations that are close to the industry and that are promoting, enabling, or supporting technological change. However, this approach may be less effective in finding organisations that play a critical role behind the scenes or indirectly, but whose absence would reduce the ability of local enterprises to engage with new technologies, knowledge, and new markets created by new technologies. Examples could be the organisations involved in South Africa's technical infrastructure, or the funding available from the Technology Innovation Agency to fund a patent application. These organisations only become apparent if a sector, industry, technology and its competitive pressures are understood or are well known, or if a sudden problem or opportunity emerges that requires a particular public input. Some organisations may therefore only be identified by a deeper understanding of the changes, industry and technology lifecycle, and competitive pressures, that specific industries, technologies or markets face.
- Engage with dynamic legislative organisations (such as the Manufacturing, Engineering and Related Services Sector Education and Training Authority – MerSETA) which span demand-stimulation and responsiveness with strengthening the quality of supply. Organisations like the MerSETA can also identify centres, programmes or organisations which can help the manufacturing sector solve problems, increase their use of knowledge, or enable technological upgrading.
- Lead firms know of critical meso organisations that exist or should exist. Often, the leading enterprises with international exposure have a higher absorptive capacity and are often better resourced to experiment with new technologies. These enterprises are often the most sophisticated users of public goods (domestically and abroad) such as research and development infrastructure, certification labs or testing facilities.

Some of the challenges with undertaking a review of the demand-side organisations include:

- These organisations may not be known to all actors in each industry, as some only indirectly work with industry.
- Depth of information would be required, as it would not be sufficient to map organisations and their programmes only by name. It would be necessary then to understand what specific programmes or sub-programmes, facilities and projects are being implemented. Take the CSIR as an example. The name of a division (like Material Sciences) already transmits a lot of information. But the fact that there is a unit promoting technology development and application in the medical-devices domain may be a surprise to some. Surprising too is that

this same unit is also one of the few places in South Africa where an entrepreneur can see how printable electronics work.

- Demand-side technology dissemination is often done by consultants and experts who may be unwilling to share their insights.

4.3 Network-based

Network-based organisations are often sub-national or regional, and are aimed at creating or strengthening bridging effects, inter-firm partnerships in promoting information flows, and the diffusion of technology. Examples are cluster promotion, strengthening of industry or business associations, and fostering collaboration around skills development, research and development, or the development of shared infrastructure.

The cluster programme of the dti and the Technology and Human Resources for Industry Programme (THRIP) programme are examples of network-programmes. Several of the export councils that receive funding from the dti are also examples of programmes where networks are developed to share insight, market information and to collaborate around common interests.

In the last 10 years there were also several successful clustering initiatives in the Western Cape. A current initiative is the Silicon Cape initiative. Another, the Agrifood Technology Station at the Cape Peninsula University of Technology, is a good example of a technology centre that has established a wide network of food producers, processing companies, research and certification labs and a research organisation.

The Mining Precinct project in Johannesburg and the Tshimologong Precinct are hybrid technology-push, technology-pull and networking projects.

In general, publicly funded organisations aimed at technology dissemination are incentivised through their measurement frameworks to work on a one-on-one basis with enterprises. This means that excellent infrastructure is often used by a handful of companies. An incentive to promote more broad knowledge and technology dissemination as well as networking will use existing infrastructure; and it will encourage upgrading, experimentation, and improved competition in the private sector. It also strengthens feedback into the hosting organisations of these technology centres and meso programmes.

4.4 Intentional technological capability dialogue, adaptation and infrastructure building

Technological capability dialogue, adaptation, and infrastructure-building initiatives are aimed at working on a system-wide level to upgrade the technology diffusion capability of the national system of innovation. This upgrading would be done within the context of global and regional economic and technological change. This activity is not supposed to be academic, but about dialogue on the innovation system, economic performance, the identification of technological gaps, institutional gaps, and missing sociotechnical infrastructure.

Recent examples are:

- The current effort by several government departments to collaborate around a national digitalisation strategy.

- The work of the DST and other departments with the mining Phakisa[3] and the implementation of improvement projects emanating from that process.
- The current Foresight exercise that the DST is involved in.
- The process of reflection, debate, research, and deliberation in assessing the 1996 White Paper on Science and Technology over the last two years.
- South Africa's participation in the World Manufacturing Forum.
- The SA-EU Dialogue facility that organises dialogue events.

The performance of the innovation system, the performance of the manufacturing sector, and technological capabilities are addressed at many events, even if these events have a different main objective. For instance, the research, conference, and dialogue events of organisations such as the Centre for Competition, Regulation and Economic Development (CCRED), the Manufacturing Indaba, TIPS, the Development Policy Research Unit at the University of Cape Town (DPRU) and other organisations that the dti and DST participate in, all highlight or allude to the performance of parts of the system, trends in industry, and identify policy recommendations or hold up a mirror to the system.

4.5 Developing and maintaining a detailed map of technological and educational institutional capability

For existing and potential manufacturers to recognise and identify appropriate meso organisations that can provide support or enable technological upgrading, a more detailed map would need to be created and maintained. One such high-level directory that is focused on the science and technology institutional landscape is maintained by the National Advisory Council on Innovation (NACI).[4] Rather than replicating these efforts, the dti should consider mechanisms to incentivise or encourage the private sector not only to consult the map or directory, but to have companies reach out to these centres[5] and to foster collaboration around technology demonstration, adaptation and development.

At the same time, directing businesses to organisations which cannot respond, articulate their offering, explain their value add, or make their services available to manufacturers, is not helpful. Therefore, the dti should consider ways to encourage these meso programmes and centres to reduce barriers to business accessing their services, advertise their offers clearly, explain their value and capability in accessible terminology, and even become more pro-active in reaching out to industry in a collective form. A secondary benefit of incentivising these organisations to pro-actively reach out to industry is that it will encourage more competition between companies to access, and make better use of public goods. A first attempt at mapping meso institutions at a more detailed level during this research is documented in Annexure 2.

These efforts would need to overcome an inertia whereby highly specialised equipment or expertise that exists in a university is not accessible or oriented towards industry.[6] This lack of visibility is sometimes caused by the research interests of the academics, or by a lack of funding to invest in the complementary assets and people needed to make a research centre provide services to industry.

[3] For more information see http://www.tips.org.za/projects/past-projects/green-economy/item/3050-mining-phakisa.
[4] http://www.naci.org.za/nstiip/index.php/sti-institutions.
[5] In Germany, as part of the Industrie 4.0 high technology strategy, all centres that provide technology extension, demonstration and prototyping services are listed on a searchable public website.
[6] Author's own experience in working on closing the gap between technological support capability in universities and industries.

Table 2 below is based on work of the OECD during the 1990s and offers a tool to map and classify programmes involved in disseminating technology, new knowledge, and improved business practices.

Table 2: A typology for mapping programmes that disseminate technology and knowledge

Goal	Programme or organisation type	Objectives
At the highest level, the meso functions improve the adoption and adaptation of specific technologies, business practices (such as particular standards or levels of certification) or new kinds of knowledge	Technology or knowledge-domain specific	To diffuse specific technology or kind of knowledge to a wide range of firms and sectors
	Institution specific	Promoting technology transfer or dissemination from a specific institution such as a university or a research and development programme
	Sector specific	To diffuse technology or knowledge and practices to a particular industrial sector or sub-sector
	Demonstration	To demonstrate the practical implementation and adaptation of technologies
At the intermediary level, to improve the general technology reception or absorption capacity of enterprises	Technical assistance	To help enterprises to diagnose technology needs and solve problems
	Information networks	To make information exchange between enterprises and public knowledge bases easier, or to foster collaboration and information sharing
	Assistance for small-scale R&D projects and innovation processes	Build capacity for autonomous technology development and innovation within companies
At the level closest to firms, build the innovation, learning and technology-adaptation capability of enterprises	Participatory sector-wide technology roadmaps	Systemic exploration and planning for future strategic technology investments
	Promote the use of diagnostic tools and use cases	Help firms develop innovation-oriented management systems, and overcome adverse selection and information asymmetries
	Benchmarking	Transmit good practices and learning from elsewhere
	Academic programmes and or research and industry collaboration (university-industry collaboration)	Upgrade the knowledge base of the firm and leverage publicly funded infrastructure

Adapted from (OECD, 1997)

This table combines well with the typology described in the introduction of the chapter. A further refinement of this table would be to capture the institutional arrangements, for instance a technology demonstration programme hosted by a university versus a technology demonstration programme of a key equipment supplier.

5 CONCLUSIONS AND RECOMMENDATIONS

This working paper focused on the meso level as it relates to the manufacturing sector and building technological capability that enables technological upgrading, as well as improving access to these institutions. These are key areas to be understood as part of a measured response to the challenges of technological change.

A first insight is that the dti is only one of many government departments involved in this strengthening of technological capability in industry and the broader ecosystem. However, the dti plays a significant role in shaping the performance of the manufacturing sector through regulations and technical infrastructure and through a diverse range of meso programmes aimed at specific industries, target groups and patterns of behaviour that require structural change or market failures to be addressed. The dti is close to the organised private sector and many sector desks and programmes work with the private sector through network organisations. The dti is in alignment identifies with sectors, industries, and specific technological or market domains. Even if other departments may be channelling more funding to technological and scientific institutions, the dti is closer to the demand-side, international markets, trade, and large buyers. The dti has experience in funding programmes to foster collaboration and information-sharing through its current programmes and through its past programmes, such as THRIP, MCEP, the Support Programme for Industrial Innovation (SPII) and the Workplace Challenge Programme.

A second insight is that many of the demand-side elements of the innovation system can be dealt with by the dti. The dti is in a strong position vis-à-vis other departments to foster industry-academia-public sector collaboration around problem solving, learning by doing, and local technological infrastructure development. Furthermore, the dti is in a position to work with multinational companies to develop their supply networks, upgrade demand, and identify and co-develop missing critical technological infrastructure.

This paper illustrated how meso organisations and programmes can be identified. Many such organisations exist and some receive funding from the state; their effectiveness in promoting technological upgrading is not always evident. The value of these organisations in encouraging technology and knowledge dissemination, encouraging innovation, or enhancing competitiveness and agility in the private sector is hard to detect from a desktop perspective and entails active engagement with them.

The technological capability and offerings of this network of publicly funded meso organisations to industry are not always clear to the external observer. Highly specialised equipment or expertise in a university is in many instances inaccessible or not oriented towards industry, with little incentives in place to lower the barriers to access. This low visibility or inaccessibility is sometimes created by the research interests of the academics and their lack of interest in technology dissemination. Alternatively, this inaccessibility is caused by a dearth of funding to invest in all the complementary assets and people that necessary to make a research, technology or innovation centre provide services to industry.

Based on our research we recommend the following priority interventions:

1. Using the existing network of meso institutions to support technological upgrading. Active effort is needed through mechanisms such as:
    a) an accessible database (detailed enough to be valuable); such a measure would go beyond a directory and would require a searchable database for firms to identify meso

programmes that meet their needs of technological expertise with product, process technologies and scarce equipment.

b) Engaging with meso institutions to be more business-centric, and

c) Developing and using case-studies of how technologies can be applied in different contexts.[7]

2. Leveraging existing meso programmes by providing additional incentives to encourage technology dissemination, networking and a more demand-sensitive or pro-active approach to strengthening technological capability. Publicly funded technology-promotion and industry-support programmes tend to be measured by short-term indicators with a bias towards helping individual enterprises. However, it is clear not enough programmes target networks or collaborative arrangements to focus on upgrading sectors, technological domains, or industries. Few meso organisations and programmes have any incentive to promote technological concepts to industry.

3. Strengthening the dynamics, networking and feedback loops between meso organisations, the private sector, and public sector decision-makers. This can be seen where meso organisations were ineffective, and the delay in response by public sector decision-makers to intervene hampered the support provided to firms.

4. Building meso-level institutional capability to identify or detect technological threats or accelerated technological change. Finding ways to identify technological shifts in the manufacturing sector or keeping track of important technological shifts and their impact on manufacturing and the meso level must be developed. Collaboration between the dti, DST, and relevant industry associations as well as technological institutions and educational institutions would be beneficial in taking such an intervention forward. Such an approach would also consider issues of reskilling and address the threat of new technologies destroying both low-skilled and high-skilled jobs.

There would be merit in the Industrial Policy Action Plan (IPAP) articulating the interventions to build and strengthen meso institutions, make them more accessible and accountable, and support industry-wide engagements. Incentivising publicly funded meso programmes to become more responsive to the current and expected future needs of the private sector would contribute to structural transformation and therefore forms part of South Africa's industrial development ambitions.

The task of supporting meso institutions that respond to industrial upgrading and technological change does not sit with the dti alone. The DST has a core role within this framework, which requires coordination around upgrading and continuously improving the technological capability of the industry and the innovation system. The review of the White Paper on Science and Technology highlighted that there is not enough focus on innovation through learning by doing, technology demonstration and problem solving.

Further, industry associations, large private sector firms, and multinational companies also have a role to play in supporting meso institutions, including by encouraging transfer of technology, investment in technological capability, or in collaborating with the dti and the DST to identify missing public goods and technological infrastructure.

[7] For an example of an use case for blockchain, see https://www.weforum.org/whitepapers/blockchain-beyond-the-hype

"There are three characteristic responses to error: to deny it, to externalise it or to embrace it. Every individual has some tendencies toward each, but organisations develop norms reinforcing one or the other tendency until it becomes a dominant characteristic." David Korten (Harvard)

ANNEXURE 1:
LIST OF ORGANISATIONS AND PROGRAMMES OF THE DTI AND DST

This list is made up of organisations that directly report to the dti and the DST as well as organisations that are critical to the delivery of the strategies of these departments and that receive significant funding from these departments.

This is not an exhaustive list. Not all the organisations and programmes in budget votes 30 and 34 are included here.

Organisations reporting directly to the dti.

- National Regulator for Compulsory Specifications. The NRCS is responsible for the administration and maintenance of compulsory specifications and the implementation of a regulatory and compliance systems for compulsory specifications.
- National Metrology Institute of South Africa. NMISA is responsible for connecting the national measurement system to the international measurement system. The institute also provides reference analysis in the case of measurement disputes and maintains and develops primary methods for chemical analysis to produce and certify reference materials for South Africa, SADC and Africa.
- South African Bureau of Standards. The mandate of the SABS in terms of the Act is to be the national institution for the development, promotion and maintenance of standardisation and quality related to commodities and the rendering of related conformity-assessment services.
- The South African National Accreditation System. SANAS is responsible for carrying out accreditations in respect of conformity assessments mandated through the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act (Act 19 of 2006).

The Industrial Development Corporation

Industrial Development Corporation (IDC). As a key implementing agency of industrial policy, the IDC's activities currently centre on the National Development Plan (NDP), the New Growth Path (NGP) and IPAP. The IDC has several Strategic Business Units that focus on the following sectors:

- Agro-processing and Agriculture
- Automotive and Transport Equipment
- Basic Metal and Mining,
- Basic and Speciality Chemicals
- Chemical Products and Pharmaceuticals
- Clothing and Textiles
- Heavy Manufacturing
- Industrial Infrastructure
- Light Manufacturing and Tourism
- Machinery and Capital Equipment
- Media and Audio-Visual
- New Industries

Organisations and programmes reporting to the DST

This is not an exhaustive list. Not all the organisations and programmes in budget votes 30 and 34 are included here.

The National Research Foundation

Research support and promotion and especially the programmes on Research Chairs and Centres of Excellence.

Technology Innovation Agency (TIA)

TIA structures its offerings into two areas called Portfolios and Programmes. Some of the relevant programmes for this project include:

- The *Advanced Manufacturing Sub-Programme* "The role of the Unit in the AM NSI is to utilise technological innovations as a driver to support the development of a knowledge economy in manufacturing, by accelerating both the manufacturing capability and the knowledge intensity of the industry, to increase and sustain the competitiveness and innovation in South Africa's manufacturing industry."
- *The Energy Unit* supports technological innovations that strengthen security of supply or supports the transition to a low carbon economy through clean energy and climate change adaptation and mitigation technologies.
- The *ICT Business Unit* aims to help South African innovators apply their skills to create new ICT services and products with a high potential of establishing sustainable social or commercial enterprises. The unit will support information and communication technology projects likely to contribute to stimulating and intensifying innovation.

TIA also have portfolios in health, agriculture, and natural resources.

The relevant TIA Programmes include:

- The Seed Fund Programme
- Youth Technology Innovation
- Innovation Skills Development
- The Technology Stations Programme
- The Technology Platforms Programme
- The Technology Innovation Cluster Programme
- The Global Cleantech Innovation Programme

ANNEXURE 2:
A FIRST ATTEMPT AT A DETAILED MAP OF MESO ORGANISATIONS PROMOTING TECHNOLOGICAL CHANGE AND UPGRADING HOSTED AT HIGHER EDUCATION INSTITUTIONS

The list below is a first attempt at mapping meso organisations aimed at promoting technological upgrading in industry.

Hosting institutions	Centre, programme, organisation	Sector/domain focus and function
Cape Peninsula University of Technology (CPUT)	Agrifood Technology Station	
	Technology Station in Clothing and Textiles	
Council for Scientific and Industrial Research (CSIR)	National Laser Centre	
	National Cleaner Production Centre (NCPC)	
	Technology Localisation Implementation Unit	
	Product Life Cycle support initiative	
Central University of Technology (CUT)	Centre for Rapid Product Manufacturing (CRPM)	Focused on making additive manufacturing technology available to manufacturing, aerospace, and medical industries
	Product Development Technology Station	Assisting entrepreneurs with product design and prototyping; strong focus on design for additive or hybrid manufacturing
Nelson Mandela University (NMU)	InnoVenton Downstream Chemicals Technology Station	
	eNtsa	Focused on automotive components, alternative energy and manufacturing
University of Johannesburg	Resolution Circle	
	Metal Casting Technology Station	
	Process Energy and Environmental Technology Station	
Stellenbosch University	Institute for Advanced Tooling	R&D and technology transfer
Tshwane University of Technology (TUT)	Technology Station in Electronics	Electronics and electrical engineering, mechatronics

	Institute for Advanced Tooling	Training and SME tool and die-making support
	Technology Station in Chemicals	Chemistry and chemical engineering
Vaal University of Technology (VUT)	Casting Simulation Network	Focused on introducing simulation technology and services to the metal casting industry
	Technology Station in Materials and Processing Technologies	Additive manufacturing, hybrid manufacturing and design for 3D printing
Walter Sisulu University of Technology	Institute for Advanced Tooling	Tool design
Wits University	Tshimologong Precinct https://tshimologong.joburg	Incubation of digital entrepreneurs, commercialisation of research and the development of high-level digital skills for students, working professionals and unemployed youth

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