Bridge to Opportunity: TAFE as Key Partners in Innovation Ecosystems

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TAFE Directors Australia

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Foreword: Is Innovation Now Mainstream Activity for Economic Growth?

Australian firms face challenges of renewing their production or service processes to take advantage of new technology. Many are exploring new markets opened-up by an online consumer world, which at the same time is taking their traditional domestic customers off-shore.

Most areas of our economy will be touched by technology and automation. Grading of roads is guided by GPS, mechanised brick-laying is being trialled, sensors allow for remote monitoring of equipment, mechanical work is more diagnostic than fine-tuning, and just-in-time logistics management is transforming warehousing and transport.

At the same time expectations of consumers are on the rise. Customers want bespoke solutions, preferably now! Artisanship, whether the quality of the crema on the coffee, sensory impacts on the palate, or the finish on furnishings underpins the viability of many businesses. Personalised service is the norm. The success of the National Disability Insurance Scheme rests on the capacity of support workers to meet the unique needs of each client.

The OECD sees innovation as mainstream and far more than new ideas. It measures product, process, marketing and organisational innovation as the building blocks of innovation.

This is the backdrop for TAFE Directors Australia sponsoring this report from the LH Martin Institute study mission of senior TAFE and University officials to The Netherlands and Italy in early 2017.

The mission and this report is an important step in showing the potential for TAFE to contribute directly to innovation. Australia risks that innovation is seen as the domain of the elites in society, whether it is big business, the research community or the academy. This report shows otherwise.

The tour found that new institutional structures established by government created the right environment for grasping innovation opportunities. Collaboration across the tertiary education sector and with local business was the ingredient for success. And focus on applied research, complementing the equally important initial research, bridged the ‘valley of death’ often faced in innovation ecosystems.

TAFEs deliver industry relevant skills, particularly high level technical and business skills, in close partnership with business and employers. Senior TAFE practitioners and leaders bring a unique blend of education and training expertise with a deep knowledge of industries. TAFEs can offer the bridge to business to help them on the innovation journey. TAFEs can offer all Australians the opportunity to engage in, and benefit from, the changes sweeping through the economy.

I thank Professor Leo Goedegebuure and Associate Professor Ruth Schubert of LH Martin for organising the tour and providing this report.

TAFE Directors Australia, on behalf of its members, takes up the challenge to capitalise on the opportunities presented in this report.

Craig Robertson

Chief Executive Officer
TAFE Directors Australia

Executive Summary

The established concept of innovation has focussed on process and internal control within enterprises and organisations. This paradigm is no longer fit for purpose in a rapidly transforming global economy; innovation is now best described as a network. Australia has long recognised the need to innovate, and the launch of the National Innovation and Science Agenda (NISA) continues this tradition, heralding the way for significant changes in our innovation system. However, the NISA has some significant limitations. Although it recognises the internationally well-established concept and practice of innovation ecosystems, it essentially fails to recognise the role of higher vocational education in these systems.

Canada, Europe and other places in the world have transformed their economies particularly when key parties in regions have collaborated to create innovation ecosystems. These systems are frequently underpinned and initiated by Tertiary Education Institutions (Universities, Universities of Applied Sciences, Colleges, Institutes, and Dual Sectors) along with local and provincial governments. During our 2017 study mission, Novel-T (Enschede), Brainport (Eindhoven), and Polihub (Milan) were all identified as examples of networks that capitalise on pure and applied research; specifically, the talent of staff and students as they form cross disciplinary research groups in open innovation models with enterprises, including spin-offs and start-ups and established companies. It is the dynamic collaboration between these actors and the co-location and facilitated interaction of the partners that further develops the capacity to collectively use the intellectual property generated by the different partners, resulting in the achievement of compressed timeframes in the race to commercialise ideas and products. The social and economic growth of these three regions is self-evident as is the ongoing commitment by all parties to these models.

National governments in Canada and the Netherlands have recognised the need to involve higher vocational education institutions in innovation systems, partly as a means of engaging the capacity of these institutions (and their staff and students), and partly as a mechanism to involve small and medium-sized enterprises. The Netherlands has an innovative and pragmatic national vision for its Tertiary Education sector, particularly in relation to higher vocational education. The first reform was bringing together a disparate sector of 400 plus higher vocational institutions (HBOs) into a more streamlined group of 37 Universities of Applied Sciences (UAS). In the second reform, UAS have been supported in building their applied research capacity by the creation of a new type of researcher, the Lectors, who bring both research and industry expertise. While initially 60 Lectors were appointed, this has grown to 600 plus Lectors in the system by 2017. These reforms were followed by the establishment of an independent foundation to manage a grants process to support applied research projects, and finally, the UAS have been recognised as having a network of strategic Centres of Expertise. Small and medium-sized enterprises were identified as not sufficiently engaged in the innovation system, mainly because they were unable to navigate large complex institutions to reach university researchers and access their expertise. SMEs have become the key target for UAS engagement with industry, with significant overall impact on the innovativeness and effectiveness of both the SMEs and the UAS. In Canada over the last 12 years, a similar reform for the Colleges and Institutes has built a highly effective, yet relatively low cost applied research capacity, supported by national funding grants and with in-kind contributions from enterprises both small and large. The results are remarkable and underpin real economic growth.

In the Australian context, traditional TAFE Institutes have in recent years developed capacity in the delivery of niche and targeted higher education, particularly at the Bachelor degree level. A different situation exists for Dual Sector Universities who for much longer have been bridging both the vocational and higher education domains, and who also have a much stronger history of basic and applied research (see further) compared to TAFE. Yet the involvement of TAFE in Higher Education is important for their capacity to develop the kind of T-Shaped graduates who have both broad capabilities and in-depth higher technical vocational skills needed in the fast changing world of tomorrow. In addition, in the last two years, several major TAFE Institutions in a number of jurisdictions have supported the development of an applied research capacity. It is this combination of higher vocational skills and applied research with SMEs where TAFE Institutes, and Dual Sector Universities through their TAFE programs, can make an invaluable contribution to Australia's innovation system. Victoria is the only State government to have an open competitive application round to fund applied research projects, although some TAFE Institutes have committed own source funds for select projects.

Compared to the vision and commitment shown internationally in Europe and Canada to develop and fully capitalise on their tertiary education systems, Australia is still bedevilled by national debate around:

- The quality and financial probity of the VET private provider sector, especially in relation to VET FEE HELP.
- The role of TAFE as being central to the vocational education system, with a lack of a national bipartisan vision about how to re-engineer this.
- The inadequacy of existing training products to deliver the skills needed by graduates in a rapidly transforming global market confronted by automation and digitalisation.
- Uncertainty and indecision about reform in higher education.
- The current Commonwealth Minister announcing that "mainstream" universities will be funded to deliver sub-degree programs (when Dual Sector Universities have been doing this for many years) and also possible changes to the Higher Education classifications.

The question then for TAFE Directors Australia as the peak body representing TAFE Institutes and Dual Sector Universities nationally is: how to capitalise on both the challenge and opportunity that this report represents? The following actions are recommendations for consideration.

Recommendations

1. TDA to develop a detailed vision and action plan for TAFE Institutes and the TAFE divisions of dual sector Universities outlining the road map for change.
2. TDA to commit professional development funds to support the development of applied research capacity and creation of dedicated positions, i.e. Lectors, across TAFE Institutes and the TAFE divisions of Dual Sector Universities.
3. Capitalise on the current economic challenges (national and region-specific) by supporting place-based initiatives that demonstrate innovation ecosystems in action, thereby building the case for change.
4. TDA and LH Martin Institute to develop a range of policy and strategy options, which will be presented to stakeholders at a series of roundtables organised in each State and Territory. These roundtables will allow TDA and the LH Martin Institute to share findings and advocate for the proposed approaches on the key themes of this report. For these events, a selected group of experts from the study mission host organisations in the Netherlands and Milan would be invited to participate.
5. TDA and the LH Martin Institute to co-host a series of roundtable meetings with political leaders, key stakeholders, and national influencers to discuss the policy implications of this report.
6. Develop options for the implementation of Lector positions, outlining their roles and responsibilities and proposing funding modalities for them.
7. Develop a brand and marketing campaign to promote the applied research capacity of TAFE Institutes and TAFE divisions of dual sector Universities with industry and enterprises across Australia.
8. Lobby the Commonwealth and State Governments for the creation of initial demonstration funds for competitive applied research projects separate from existing research funding streams.
9. Develop an integrated campaign to lobby the Commonwealth Government about creating a new category of higher education provider for TAFE Institutions, i.e. an Australian version of the Dutch Universities of Applied Sciences, able to deliver and be funded for vocational education, higher education and applied research.

From Innovation to Open Innovation

Whilst the concept of innovation always has received significant attention in both the policy and the research literature, in the wake of the rise of the digital revolution and associated changes, the concept of open innovation has risen to the fore. Traditionally, innovation has been defined as "the implementation of a new or significantly improved product (good or service), a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (OECD, 2005). Although this definition still is in common use throughout much of the developed world, in a way it is a limited view of innovation. It does not have much to say on the processes through which innovation is created. To get a better understanding of the latter, it is useful to distinguish between closed and open innovation.

Table 1 summarizes the different conceptualisations of the innovation process as captured under the labels open and closed (Chesbrough, 2003), based on the argument that our world is becoming increasingly complex; with advances in knowledge increasing rapidly, and knowledge becoming increasingly distributed globally. As a consequence, the traditional closed approach to innovation is no longer fit for purpose as the costs of research and innovation projects grow exponentially; the generation of new knowledge occurs through cross-fertilization across disciplines; the life cycles of new technologies are increasingly shorter; and knowledge leaks happen more and more frequently (Frattini, 2017).

Table 1. Open and closed innovation principles.

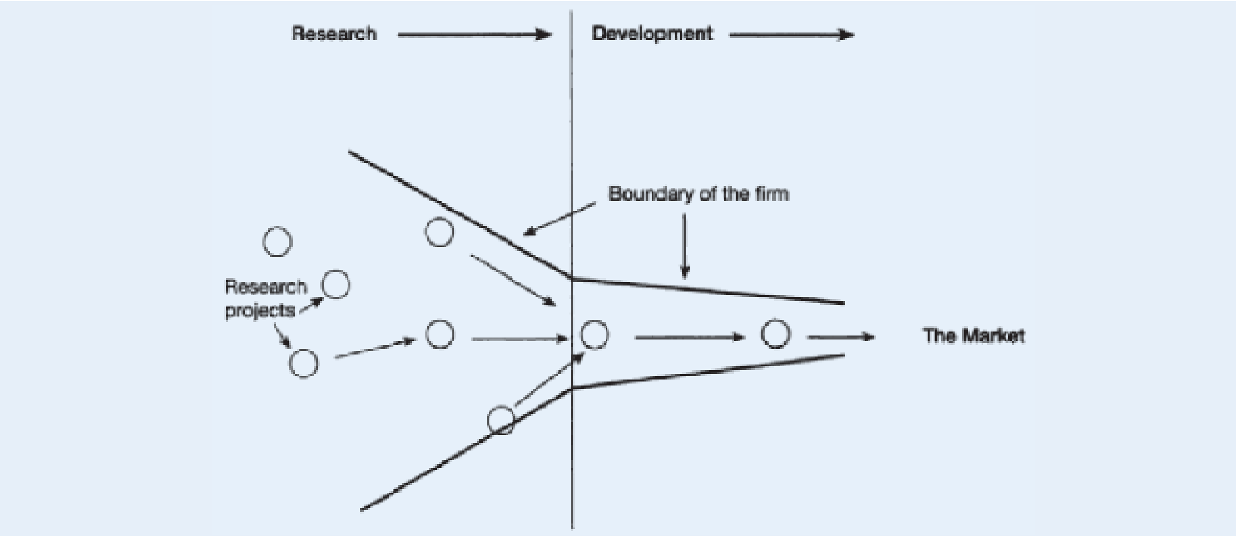
CLOSED INNOVATION PRINCIPLES	OPEN INNOVATION PRINCIPLES
The smart people in our field work for us.	Not all of the smart people work for us* so we must find and tap into the knowledge and expertise of bright individuals outside our company.
To profit from R&D, we must discover, develop and ship it ourselves.	External R&D can create significant value: internal R&D is needed to claim some portion of that value.
If we discover it ourselves. we will get it to market first.	We don't have to originate the research in order to profit from it.
If we are the first to commercialise an innovation, we will win.	Building a better business model is better than getting to market first.
If we create the most and best ideas in the industry. we will win.	If we make the best use of internal and external ideas, we will win.
We should control our intellectual property (IP) so that our competitors don't profit from our ideas.	We should profit from others' use of our IP, and we should buy others' IP whenever it advances our own business model.

* This maxim first came to my attention in a talk by Bill Joy of Sun Microsystems over a decade ago. See, for example, A. Lash. The Joy of Sun: The Standard, June 21. 1999. http:Jfthestaooard.net.

(Source: Chesbrough, 2003).

Graphically, the traditional approach to innovation is commonly portrayed as follows.

Figure 1. The traditional approach to research and innovation in firms.

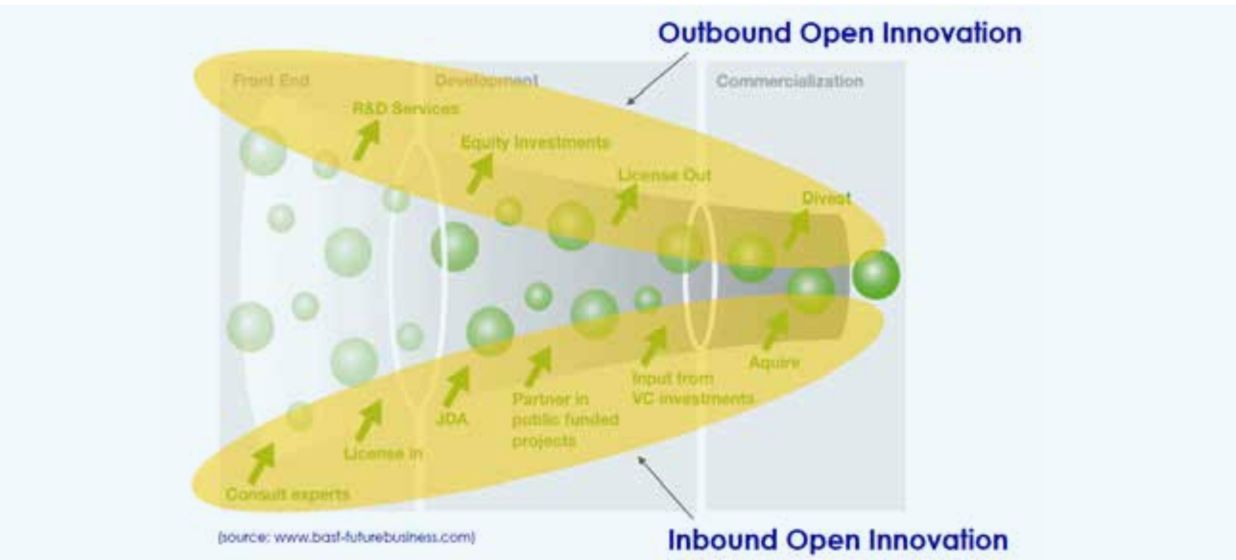


(Source: Frattini, 2017).

As global trends outlined above make "control" over the innovation process increasingly unproductive and unmanageable, a more open and connected approach to innovation has emerged, based on co-operation, complementarity and sharing of knowledge and resources. The principles underpinning this approach are that learning and knowledge rest in the productive diversity of opinion; that learning is a process of connecting specialised nodes or information sources and that the capacity to know more is more critical than relying on what is currently known. In this process connections need to be nurtured and maintained to facilitate continuous learning. Consequently, the ability to see connections between fields, ideas and concepts becomes a core skill; and that currency (accurate, up to date knowledge) is at the core of all connected learning activities (Frattini, 2017).

This is symbolized in figure 2. In this evolved conceptualisation of innovation, the classic *know-how* increasingly is being replaced by *know-where*. This is clearly articulated in the notion of innovation as *ecosystems.*

Figure 2. The new "open" approach to research and innovation in firms.



(Source: Frattini, 2017).

Innovation Ecosystems: Complementing, Collaborating and Sharing

The notion of an ecosystem obviously finds its roots in biology and evolutionary theory where it refers to a community of interacting organisms and their physical environment. In a more general sense it refers to a complex network or interconnected system. In the context of innovation, such ecosystems consist of a core set of building blocks (Van Agtmael & Bakker, 2016). First, there needs to be a connector to bring all the interdependent actors together. In other words, collaboration needs to be orchestrated and facilitated. Second, it needs to have a diverse but complementary set of actors to maximize the fruits of collaboration, this always includes research universities, other post-secondary education institutions, governments (local and provincial and sometimes national), and companies, start-ups as well as matured with a strong focus on advanced technology. In other words, this is the classic operationalisation of the so-called *triple helix* (Etzkowitz & Leydesdorff, 1995).

Third, there needs to be a focus on a certain set of disciplines or activities. It is not enough to *just* bring these groups together; they need to be collectively focussed around a certain theme or discipline, such as advanced manufacturing. Fourth, there need to be physical spaces where these actors can interact in close proximity. The benefits of co-location are maximized and the *"energy"* that flows from this in turn attracts other actors.

In this way, high tech activities can be complemented with socio-cultural activities as is demonstrated by all effective innovation ecosystems across the globe, from Silicon Valley to Medellin, from Milan to Eindhoven. Finally, no innovation ecosystem can exist without the availability of significant capital on which the actors can draw. As with any biological ecosystem, unless there is a fertile and rich environment, the system will either remain struggling or will collapse. The availability of capital is an essential condition for any innovation ecosystem.

Transforming regional economies is something of great importance to Australia given our long-term dependence on natural resources, the fact that coal-fired power stations from an ecological perspective are no longer sustainable, and the growing realization that our traditional manufacturing base is no longer competitive in a globalized world. In this context, effective innovation ecosystems and open innovation become more than just academic concepts. They become the vehicles necessary to drive socio-economic transformation. But we also need to realize the nature of our economy. As evidenced in the most recent Australian Innovation System Report (Department of Industry, Innovation and Science, 2016), Australia does not have a strong foundation of large-scale, multi-national industries, but is primarily a country of small and medium sized enterprises (SMEs), with a strong concentration in the services sector. According to ABS 2016 data, 68% of employment in Australia is in the SME sector, and 85% of this is in the services industries (everything excluding agriculture, forestry, fishing, mining and manufacturing), which also is responsible for 77% of industry value add.

This has a major impact on the nature of innovation in Australia, being driven by SMEs and predominantly of a process-type nature rather than a *new product* to market. This strongly suggests that widely-heralded innovations such as Wi-Fi, the Cochlear ear-implant and the cervical cancer vaccine are exceptions rather than the rule. According to the Australian Innovation System Report, part of the problem is in a weakly networked innovation system: “Australia ranks poorly against OECD comparators in most business to research and business to business indicators” (ibid, p.2). This problem of a weakly networked system also was at the heart of the Australian Academy of Technological Sciences and Engineering (ATSE) 2013 position paper “Translating research into economic benefits for Australia; rethinking linkages”, which points to the cultural differences between SMEs and academia as one of the factors inhibiting stronger collaboration.

Yet, Australia also is home to successful regional innovation ecosystems. Two clear examples of these are Geelong and the Newcastle Hunter region. Geelong in effectively dealing with the demise of car manufacturing through a concerted change agenda involving Deakin University, the Gordon TAFE, local and State governments and a series of companies, including Ford. In similar vein, the Newcastle Hunter region has transitioned from a resources economy to an advanced manufacturing economy, with the city itself emerging from the process as the proverbial "smart city". Again, the recipe has included a strong research university (the University of Newcastle), other post-secondary education providers (Hunter TAFE), local and State governments, including Regional Development Australia (RDA) Hunter, and industry. So, whilst collaboration may not be Australia's strongest trait, these examples clearly demonstrate that it certainly is possible.

Equally, we may have a rather unique industry make-up, but again there are examples of other countries tackling this effectively. A case in point is the Netherlands, which has a services based economy like Australia. Taking an open innovation approach as its starting point, this spurred the Dutch Scientific Council for Governmental Policy (WRR) to argue the case for a move away from the traditional R&D model to one based more on the principle of *knowledge circulation* rather than solely on *knowledge generation* (WRR, 2013: 22):

> ***"The focus cannot be on knowledge generation alone; it will be just as important to see that that knowledge is properly absorbed and circulated. The question, then, is whether a country (especially a small one like the Netherlands) should seek to remain in the lead by investing only in knowledge generation. In many cases, it is not necessary for a country to top the world science rankings, as long as it understands developments in science well enough and is connected to networks in which new knowledge circulates. On the other hand, knowledge will become more important as a basic attitude. People have to be able to absorb new knowledge quickly and make it productive"***
> **(WRR, 2013: 22).**

This line of argument seems appealing from the compelling case of open innovation. The logical consequence of such an approach would be a much more prominent role for vocational education (VE) given its close proximity to the SME sector. This would require the capacity of VE to effectively engage in the process of knowledge circulation, which would in turn require a greater ability to absorb research and translate it to professional practice. This position is recognised in the recent *Performance Review of the Australian Innovation, Science and Research System 2016* (Australian Government 2016). The review clearly articulates that Australia's VE sector is "an underused resource in the IRS System" (p. 76). In line with the principle of knowledge circulation outlined above, the Review emphasizes that "people with VET occupations are amongst businesses' principle sources of ideas for technological innovation" and that people with VET qualifications "are well placed to diffuse, share and implement innovation" (ibid.). Albeit somewhat implicitly, the absence of an applied research function with a dedicated budget is seen as an obstacle to maximising the sector's role in innovation. We return to the role of applied research in the next sections, when further elaborating the developments in the Netherlands and Canada.

The Netherlands: Universities of Applied Sciences and the Evolution of an Applied Research Function

The Dutch Universities of Applied Science (UAS) have their origins in a large-scale merger process initiated in 1983 to transform what was at that time a totally fragmented sector that technically was part of secondary education, into a professionally oriented higher education sector complementary to the Dutch research universities. Consisting of some 400+ small, mono disciplinary institutes and colleges at the start of the amalgamation process, the sector now (in 2017) consists of 37 large to very large multi-disciplinary institutions. They are characterised by strong institutional autonomy, professional leadership and management, and strong links to industry and the labour market. The sector caters for the majority of Dutch higher education students (some 450,000 compared to 265,000 in the university sector), with a very strong emphasis on bachelor degree programs: 96% of students are enrolled in a bachelor, 2.5% in masters and 1.5% in associate degree programs. In comparison, 62% of university students follow a bachelor, with 38% enrolled in masters programs.

Although the UAS started as *teaching only* institutions, around the turn of the century momentum gained for strengthening the sector through building its research capacity. This was driven by the need to better align graduates with the needs of industry, producing so-called *reflective practitioners* or *modern professionals*, as well as the need to upgrade staff to make 'modern' professional education a reality.

The Dutch Ministry of Education and Science endorsed this process and explicitly stated that the UAS should be embedded more strongly in *regional* knowledge networks, their *applied* research should be directly linked to the *improvement* of the *quality of teaching*, acknowledging that 21st century graduates needed an enhanced skills set that included *analytical thinking* and *critical analysis*, and, importantly, that UAS staff should be aligned with, and knowledgeable about, the latest developments in their vocational fields. These objectives were to be achieved through a stronger research orientation of the UAS.

Following this government position the UAS peak body published a visions paper *Higher Education ten years forward* in which it launched the idea of Lectorates. This was a new category of staff aimed to professionalize existing staff, and change the culture from teaching-only to a stronger research orientation, as well as to develop a stronger teaching-research nexus, and to improve knowledge exchange between the UAS and industry/professions. This paper resulted in a four-year agreement between the Ministry and the sector to implement the concept, and a budget was made available for this.

A process was developed whereby institutions could submit proposals to establish *Lectorates*. The proposals were assessed by an independent body, which then allocated funding and monitored the implementation followed by a formal evaluation. This temporary grant scheme became part of the UAS regular lump sum funding in 2007, following positive evaluations. The research enhancement process in the UAS was further stimulated in 2005 by the implementation of the RAAK program: **R**egional **A**ction and **A**ttention for **K**nowledge innovation. It was an additional funding program for the UAS sector to stimulate knowledge exchange and circulation with (small) business with a particular focus to improve innovation of regional industry. An independent foundation was established to coordinate the program (the Innovation Alliance Foundation), and proposals could be submitted by consortia of public and private partners. Projects could be for a maximum of 2 years, with a maximum of €300,000, and a minimum of 30% co-financing by the consortium. As with the *Lectorates*, this temporary program was subsequently incorporated in the lump sum funding of the UAS and incorporated as a UAS-dedicated program of the Dutch National Research Council.

The last element in the evolution of applied research in the UAS was the establishment of *Centres of Excellence* in 2010, of which there are currently 16 in operation across the sector. They are public-private partnerships, focussing on national research priority areas, and operate as network organisations bringing together Lectors, industry, researchers from public and private institutions, teachers and students.

Since its inception in 2002, about 600 *Lectorates* have been established at the UAS, with the Dutch government in 2016 arguing for a significant expansion of this number. Despite initial scepticism at the initiative from many actors, there is little doubt that the UAS sector has been transformed over the last decade through the incorporation and growth of an applied research function. A number of factors appear to have contributed to this. A number of ambitious institutions served as role models for the sector, with additional funding and independent organisations/foundations administering the programs. Initially, the research universities essentially ignored the process or were dismissive of it. However, today the UAS sector is widely regarded as being an important component of the national innovation system. The continuous structured evaluation of the programs further aligned and fine-tuned the programs from their original objectives, resulting in a ‘virtuous circle’ of innovation in the professions and the SMEs, combined with an upgrading of the teaching programs at the UAS through the participation of (final year) students in the applied research projects.

The Use of Technical Readiness Levels (TRLs) to Explain the Innovation Process

Agencies and institutions across Europe speak a common innovation language based on the concept of technical readiness levels (TRLs). This concept helps to explain the innovation process, and the different roles that partners have in the innovation process. A phrase that struck us during the study mission was “the bridge to opportunity”. In the context of the TRLs, TRL 4-6 is often considered to be the “valley of death” as much innovation fails to span the gap to commercialisation. However, in an open and inclusive network of institutions this can instead equally be “the bridge to opportunity” driven by applied research.

In essence, a technology readiness assessment (TRA) is a systematic, evidence-based process that evaluates the maturity of a product or system at a specific point in time. It allows for consideration of the risks and benefits of moving forward to progress the technology or system, and what other critical steps and support may be necessary to achieve level TRL9. It also highlights the different and differentiated activities and actors that together constitute the innovation ecosystem; a system to which each partner contributes in its own unique ways (see Figure 3).

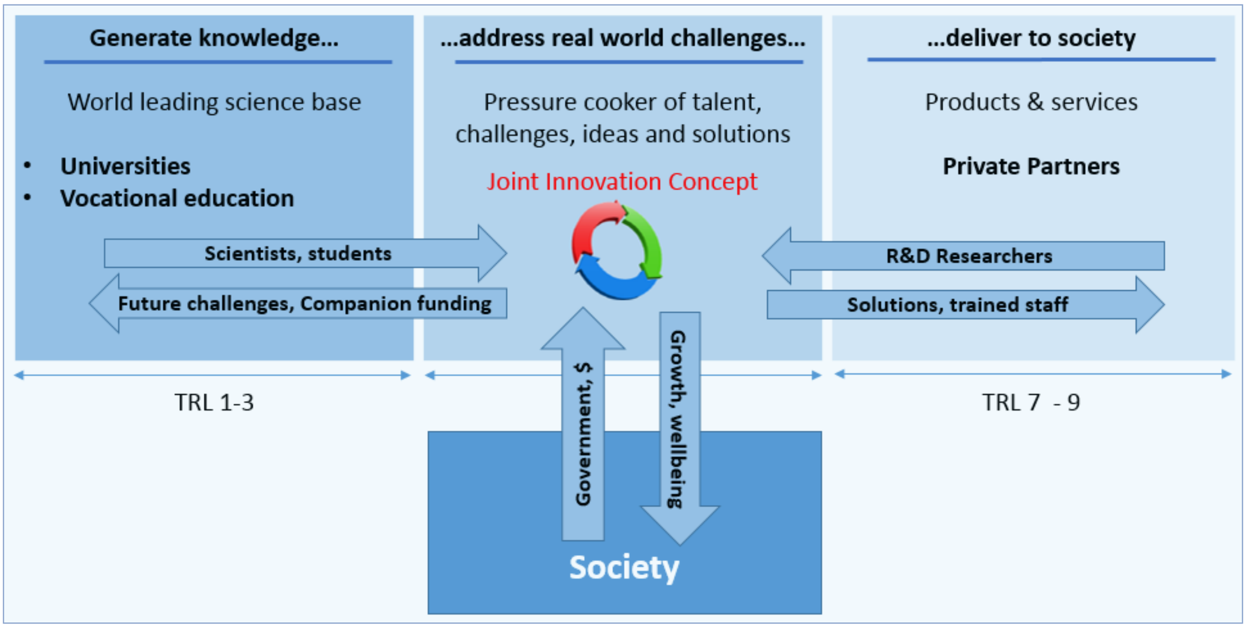
Figure 3. Technology Readiness Scale, Research and Application Focus.

TRL Level	1	2	3	4	5	6	7	8	9
European Commission	Basic principles observed	Technology concept formulated	Experimental proof of concept	Technology validated in lab	Technology validated in relevant environment	Technology demonstrated in relevant environment	System prototype demonstration in operational environment	System complete and qualified	Actual system proven in operational environment
Type	Idea	Concept		Technology			System		
Activity	Discovery	Invention			Development				Deployment
Research	Basic Research			Applied Research		Demonstration			Application
Deliverable	Proof of principle		Proof of concept		Prototype			Product	
Situation	Laboratory				Real World/Living Labs			Design lab	Market
Example		Technological research			Demonstration & Pilot Line		Operation		
Focus	• Research focus & profile • Academic cooperation & partnerships • Strategic academic partnerships			• Public-private cooperation • Ecosystem development • Business development • Strategic private partnerships			• Cooperation with societal partners • Solutions for societal challenges • Strategic societal partnerships		

(Source: Eindhoven University of Technology; presentation for LH Martin Institute study mission, April 2017).

From the University of Eindhoven, the Netherlands, figure 3 illustrates the technology readiness level range against the concepts underlying each stage and research and application focus.

Figure 4. The Innovation Ecosystem and the Technology Readiness Scale.



(Source: Eindhoven, University of Technology presentation for LH Martin Institute study mission, April 2017). Figure 4 illustrates the innovation ecosystem overlaid on the technology readiness scale).

Figure 4 shows that effective innovation ecosystems are not just about technological advancements, but are about inclusive, transformative system change. In line with the recent report on transitioning regional economies by the Productivity Commission in Australia, this emphasises the incorporation of community-based activities and the realisation that place-based innovation is context dependent and is a *network* not a linear process. Central to the joint innovation concept is the awareness that effective innovation ecosystems are built around a wide set of institutions and networks that include firms, user groups, scientific communities, policy makers, social movements and special interest groups (Coenen, Hansen & Rekers, 2015).

The Netherlands: Enschede and Eindhoven

The Netherlands is known for its high quality higher education and has the largest number of English language programs and courses in continental Europe. English is also a compulsory subject for all students at high school.

There are two main kinds of universities in the Netherlands: 13 research universities and 37 universities of applied sciences (Hogeschool or HBO in Dutch). Universities of Applied Sciences and HBO are still used interchangeably in the Netherlands. Research universities offer more academically rigorous education that focuses on specific disciplines, while Universities of Applied Sciences offer profession-oriented programs that are designed for students who are looking to enter a particular career upon graduation. The relationships between the two types of universities has in the past have been one of contestation and academic and professional drift. However, over the last 15 years this has changed significantly, with each sector finding its own niche in a non-competitive and non-threatening manner. There is clear program differentiation between the two sectors, drawing significantly on different types of students, and engaging in very different forms of research. Previously status and resource competition was the name of the game, today the two sectors collaborate in place-based innovation networks.

University of Twente (UT)

Enschede is a modest regional city in the eastern part of the Netherlands close to the German border, with a relatively sparse population base in European terms. The city had a population of 158,000 in 2015 with close to 600,000 in the overall region of Twente. The region had a long history in textile production however, by the mid 1950s this industry was suffering from major competition from international manufacturing and the region suffered a significant decline.

The University of Twente (UT), named after the region, was announced in 1961 and opened in 1964, as a result of active lobbying of the national government from the region. The University is located between Enschede and Hengelo, two of the major towns of the region. The establishment of UT as the third technical university of the Netherlands was always closely connected to the economic growth and well-being of the region.

Early in the history of the University, in a region considered "remote" and less important than the western seaboard and the cities of Amsterdam, Rotterdam, Utrecht and The Hague, the University focussed on building a unique business orientation. This was formalised in 1983 by the Rector Magnificus Harry van den Kroonenberg, who saw entrepreneurship as both an essential survival strategy for the University and a career option for its students. This has been subsequently built into the DNA of the institution and resulted in the University of Twente becoming an Entrepreneurial University.

This spirit of entrepreneurial action at UT is epitomized in the response to the refusal to add medicine to the university offerings. Medicine was and still is considered internationally one of the elite fields of study, so when in the 80's the request to start a medical faculty was declined, in the 90's the UT answered with an engineering approach to medicine, namely Biomedical Technology and Technical Medicine. This has resulted in BIG registration (translated from Dutch meaning individual health care professions Act) from around 2010, when the first engineers were allowed to be present in operation theatres and perform on patients up to a certain level of complexity.

In 2015 UT achieved the following rankings:

- 126 on Leiden ranking
- 149 on Times Higher
- 188 on QS World University Rankings
- 301 on ARWU - Shanghai world top 500

The university is a small-scale institution with 20 Bachelor of Science and 33 Master of Science programs. Most of these programs are technical, with traditional programs such as mechanical engineering and electrical engineering being offered.

UT is structured into five broad faculties and five multi-disciplinary research institutes:

FACULTIES	RESEARCH INSTITUTES
Behavioural Management and Social Sciences	Institute for Innovation and Governance Studies
Electrical Engineering, Mathematics, and Computer Sciences	ICT Research in Context
Engineering Technology	Biomedical Technology and Technical Medicine
Science and Technology	MESA+ Institute for NanoTechnology
Geo-Information Science and Earth Observations	Geo-Information Science and Earth Observations

Recently UT has started cross-domain programs such as advanced technology, where students learn to invent the technology of the future, even creating new materials which address the needs of society. UT also offers a limited range of social science programs built on the engineering problem solving approach. Combined, these approaches constitute what UT calls High tech, with a human touch.

Figure 5. University of Twente – High tech human touch.

(Source: Presentation by T. Palstra - Rector Magnificus @ University of Twente, LH Martin Institute study mission, April 2017).

Two unique examples of the High Tech approach at UT include the MESA+ Institute for Nanotechnology and the Professional Doctorate in Engineering (PDEng).

Figure 6 a&b. European grant success of MESA+ researchers, and LH Martin Institute study mission delegates at the Nanolab.

(Source: R. Schubert – LH Martin Institute study mission, April 2017).

MESA+ is a leading centre in nanotechnology and nanomaterials, systems, and devices. As a multi-disciplinary institute, MESA+ is able to undertake leading edge research supported by high tech innovation infrastructure such as the NanoLab (which is a state of the art cleanroom) and the High Tech Factory. Research staff and students as well as enterprises are able to collaborate, undertake research and stimulate entrepreneurship. MESA+ has an annual turnover of about €50M, and 60% of that is from external funds.

From 2010-2015, MESA+ produced:

- >2000 publications
- 10 new companies
- 35 patents
- 295 PhD theses

Figure 7 a&b. Clean Room Technology, and the external users of the Nanolab.

(Source: Presentation by J. Hoedemaekers – MESA+ Institute of NanoTechnology, LH Martin Institute study mission, April 2017).

The strategic research areas for MESA+ include: soft matter science and technology; advanced materials science and technology; applied nanophotonics; micro & nanofluidics. Developing sensors and actuators is one of the original core strengths of MESA+. This work includes, for example, medical experts and scientists joining forces to shape ways of preventing or diagnosing diseases at an earlier stage. At MESA+ they are working closely with medical experts to identify so called *bio markers* for selected diseases, to develop devices and ever smaller bio-sensors for analysing those markers.

The Professional Doctorate in Engineering (PDEng) is an example of a program that successfully blends complex enterprise needs and academic achievement. The program is offered as a two-year post master qualification, with the closest equivalent being a PhD, which is typically a four-year pure research program in the Netherlands. The PDEng is a national program offered at the three technical universities with an applied focus. Five program themes are offered at the University of Twente including: Civil Engineering, Energy and Process Technology, Health Care Logistics, Maintenance and Robotics. The heart of the program is a complex technological design project, which requires the student to participate in an educational program at UT and work on the design project at a company. The student is jointly employed and supervised by UT and the sponsoring company.

The program is clearly focused on developing work skills for future, with graduate competencies including:

- Analytical mind-set
- Creativity
- Technological design skills
- Goal-driven
- Professional skills

Figure 8 PDEng Design Project: Automatic feeding robot for farms based on GPS and vision sensors.

(Source: Presentation by Dr. Ir. T. Vaneker - Implementation of the PDEng program @ University of Twente, LH Martin Institute study mission, April 2017).

Saxion (University of Applied Science)

Saxion is a University of Applied Sciences, also known as a Hogeschool or HBO in Dutch. Saxion is focused on higher vocational/professional education and has over 26,000 students and 2,700 staff, with a turnover in 2015 of €222M. The mission of Saxion is to provide education and research for the benefit of society, and to be a problem solver by co-creation between students, teachers/researchers and partners.

As a University of Applied Sciences, the applied research priorities at Saxion focus on the improvement of quality of living through the application of innovative technology with the aim of making life easier, more affordable and more sustainable. Co-creation and collaboration between the disciplines are important guiding principles.

In the language of the Technical Readiness Levels, Saxion contributes to valorisation (commercialisation) by bridging the gap between research and practice, and thereby contributing to the economic activity of the region by strengthening existing companies and institutions, and the creation of new business activities and job opportunities.

Saxion has three areas of strategic priority under the umbrella of "Living Technology":

- Areas & Living (Smart cities)
- Smart Industry (HTSM)
- Health & Wellbeing (Smart health)

Figure 9. Research Agenda – Living Technology 2016- 2020.

(Source: Presentation by Ger Brinks - About Saxion, LH Martin Institute study mission, April 2017).

Saxion has approximately 50 active research groups, each headed by a Lector in an applied field and with each Lector having research and professional experience in the domain. Each Lector leads and is supported by a group of professionals, typically teacher/researchers who have academic qualifications at the Masters/PhD level, with students integrally involved in the research process.

The area of smart functional textiles currently has 14 applied research projects, with another 16 in development. The focus on textiles is reflective of the economic legacy of the region in the Netherlands and its position within the EU.

Sustainable textiles	Responsive smart textiles	Surface modification
SaXcell® - upscaling of cotton	OOG II - optical fibres in defensive clothing	Nano - Textile in healthcare
RECURF - recycle urban textile waste into composites	TEXENERGY - energy harvesting in textiles	Funcy - smart surfaces
Going Eco Going Dutch - local production	XOSOFT – soft exoskeleton	Family dairy tech
Closing The Loop - circular economy	Project cooling garment	Cleaning doormat

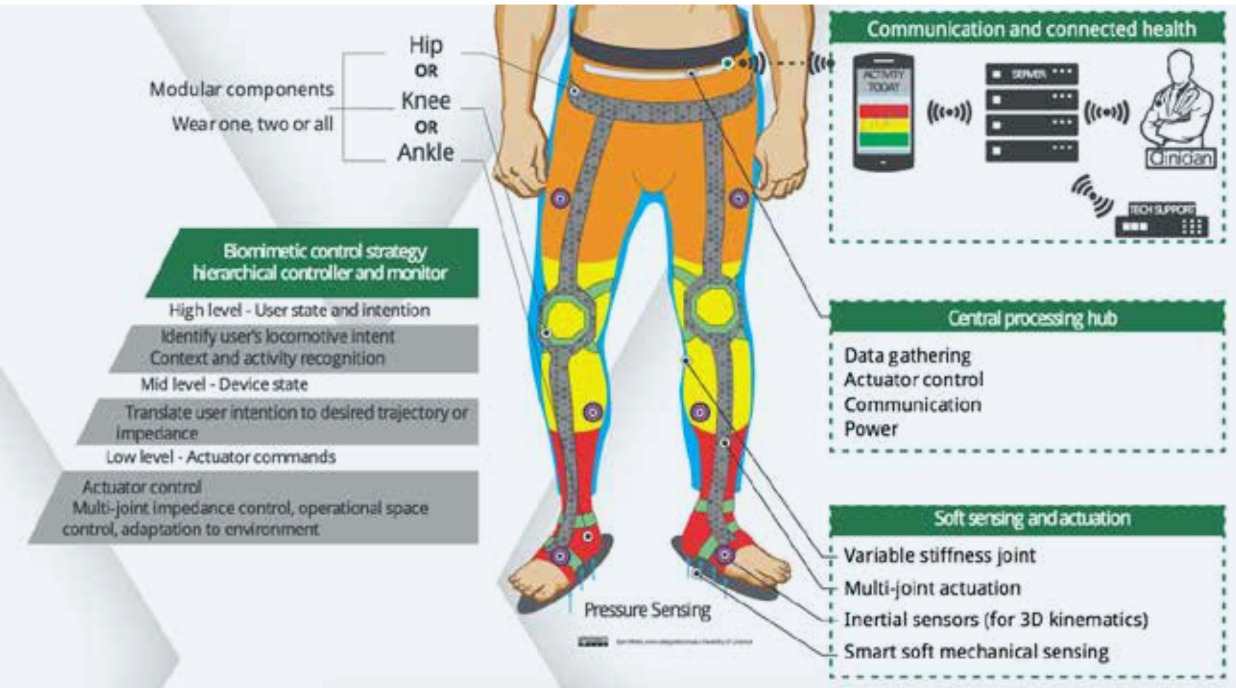
Figure 10 a&b. LH Martin Institute study mission delegates in Saxion Research Lab on Textiles and the Saxion FabLab.

(Source: R. Schubert – LH Martin Institute study mission, April 2017).

An integral part of the applied research process at Saxion is the number of industry networks and companies (greater than 50) involved including:

- ETP - European Technology Platform for the future of textiles
- NETFAS - Network of European Textile and Fashion Universities of Applied Sciences
- H2020 – European Union projects and new initiatives
- MODINT - Industrial innovation roadmap projects
- SMARTEX – Smart Textiles Germany/Netherlands
- OICAM – Open Innovation Center Advanced Materials

Figure 11. Saxion Research Project – XOSOFT, Soft Exoskeleton.



(Source: Presentation by Ger Brinks – About Saxion, LH Martin Institute study mission, April 2017).

Novel-T

In line with the entrepreneurial thinking of the University of Twente (UT) Kennispark Twente was established in 2005 (within 5 minutes of UT). The province, city, region, and universities (Twente and Saxion) are founding partners of the Kennispark Twente foundation. Kennispark has recently been renamed Novel-T. The aim of Novel-T is to be an Innovation Campus of national significance, and part of the complete innovation ecosystem.

Figure 12. Founding partners of Kennispark Twente, now Novel-T.

(Source: Presentation by H. Brouwers – Novel-T, innovate and accelerate, LH Martin Institute study mission, April 2017).

Novel-T has a focus on the student population as one of central drivers of innovation. This is evident in the UT curriculum and extracurricular activities such as innovation bootcamps/events and student societies such as Hardstart (society for entrepreneurial students). The extra currciular activities are offered together with Saxion (University of Applied Science), and include activities such as:

- Creathons (pressure cooker solution-focused team events – current themes include smart urban biking)
- Create Tomorrow: the world's biggest think tank
- PreU (science on tour, science for primary and secondary school)
- Room and support to entrepreneurs (Novel-T and Financial opportunities, Funds)
- Space in the Gallery and facilities like the High Tech Fund

Novel-T connects and activates talent, knowledge, capital, networks and infrastructure. They support both start-ups and established entrepreneurs. The services and support are many and varied, ranging from mass student-led events, to formal networking, business mentoring, and attracting capital. The figures for Novel-T to date include more than 1,000 spin-off companies, 10% of the Benelux Technology Fast 50, more than 400 companies and 6,300 commercial jobs on site. Novel-T provides the bridge from pure and applied research into the technical readiness levels of commercialisation.

Twente has moved from being a declining region to one with a dedicated high tech knowledge base, having an entrepreneurial university (UT was ranked the most entrepreneurial university in the Netherlands in 2015) and a University of Applied Sciences that enabled it to become an entrepreneurial high tech region, through an explicit partnering with local and regional governments and industry in the classic triple helix format.

Take aways from the Twente case:

- Never waste a good crisis
- Create a clear profile through strategic choices
- The power of collaboration and external engagement
- Incorporation of students in (applied) research and entrepreneurship
- Individual leadership matters
- Create physical spaces for collaboration
- Innovation requires investments (facilities, equipment, human capital)
- Change does not happen overnight

Eindhoven

Eindhoven is famous for being the home of Philips, an entrepreneurial manufacturing company founded in Eindhoven in 1891. It grew to become the major employer for the region and over the 20th Century developed into a major multinational with factories across the world. It is this DNA legacy that continues to provide the technology-focused drive for the region.

Figure 13. Companies in the Eindhoven region grown from the Philips legacy

(Source: Presentation by R. Westenbrink - Eindhoven University of Technology, LH Martin Institute study mission, April 2017).

University of Technology Eindhoven (Technische Universiteit Eindhoven- TU/e)

TU/e is a research university that specialises in engineering science and technology, and through education, research and knowledge valorisation, focuses on:

- Science for society: solving the major societal challenges and increasing prosperity and wellbeing, with a focus on the strategic areas of Energy, Health and Smart Mobility.
- Science for industry: developing technological innovations in collaboration with industry, with a focus on High Tech Systems and Data Science.
- Science for science: promoting progress in engineering sciences through excellence, with a focus on Complex Molecular Systems and Integrated Photonics.

TU/E DEPARTMENTS AND DISCIPLINES COVER THE FOLLOWING AREAS:		
Mathematics, Computer Science	Industrial Engineering, Innovation Science	Built Environment
Electrical EngineeringComputer Sciences	Mechanical Engineering	Applied Physics
Chemical Engineering	Industrial Design	Biomedical Engineering

In 2015 TU/e had 10,000 students; by 2020 the expected number of students is 14,000, with current turnover of €300 million, of which €80-100 million is from external research funding.

TU/e ranks in:

- European top 25 in Leiden Ranking Physical Sciences & Engineering
- World top 25 & European top 10 in Shanghai Ranking Engineering
- World top 10 Academia-Industry collaboration Leiden Ranking and THE

TU/e as part of the Brainport innovation ecosystem (see further) is addressing a critical issue in innovation, namely that the timescale for a product lifecycle has significantly shortened; therefore the innovation cycle must also be shorted. Disruptive technologies have provided opportunities but also threaten long-term investment and private R&D investment. Therefore, there exists a greater need for universities and industry to bridge the gap and accelerate innovation.

Innovation is increasingly complex, with processes and technologies that cross traditional lines of expertise, disciplines, materials and information. This is increasingly expensive and requires greater collaboration across regions, institutions, enterprises, and researchers, and also requires state of the art research facilities that are shared between tertiary providers and industry. Specialised ecosystems are able to address these challenges with innovative companies and industries that are co-located with tertiary education providers and researchers, to share highly educated talent, knowledge, and facilities. In addition to these, the close integration of supply chains, and development of new products point to the importance of proximity (Westenbrink, 2017). Recent research in the Netherlands has pointed to the significant drop off in effectiveness of ecosystems when partners are more than 25km apart.

As part of Brainport, TU/e is part of a series of networks including:

- Research Centre for Functional Molecular Systems (TU/e, Radboud, RUG, M€26), brought together to extend the frontiers of chemical self-assembly.
- Netherlands Centre for Multiscale Energy Conversion (TU/e, UU, UT, M€32) focuses on the fundamental questions of the nanoscopic, mesoscopic and macroscopic worlds of a catalytic process.
- Networks (TU/e, UvA, Leiden, CWI, M€23) focuses on new techniques to model, understand, control and optimise broad range of networks that are intrinsically complex and highly volatile.
- Research Centre for Integrated Nano-Photonics (TU/e, M€20) aimed at the development of the optical technology needed to connect the world's population with data centres.

Figure 14. Brainport network members.

(Source: Presentation by R. Westenbrink - Eindhoven University of Technology, LH Martin Institute study mission, April 2017).

TU/e actively supports student-led innovation by providing a dedicated research facility and staff who mentor cross-disciplinary student teams. These teams have developed fully functioning prototypes of domestic drones, a solar powered family car, electric touring motorcycle, competitive race car, driverless car, and vehicle fabrication material from biological sources. Student teams compete in international events such as the World Solar Challenge from Darwin to Adelaide (winning the cruiser class in 2015), and the Formula Student competition where a student design team develops and races a small formula-style racecar. The electric bike team staged a round the world event completing the journey in 80 days.

Figure 15 a&b. TU/e student teams – Formula student race vehicle and fully rechargeable electric road bike.

(Source: R. Schubert – LH Martin Institute study mission, April 2017).

Figure 16 a&b. TU/e student teams – Solar powered family car and driverless car.

(Source: R. Schubert – LH Martin Institute study mission, April 2017).

Fontys (University of Applied Sciences)

Figure 17 a&b. Fontys University of Applied Sciences.

(Source: R.Schubert of LH Martin Institute study mission, April 2017 of N. Meijers, Chair Executive Board - Fontys – University of Applied Sciences).

Fontys University of Applied Sciences is the second largest higher education institution in the Netherlands, it has 45,000 students and 4,300 staff members. The institution has:

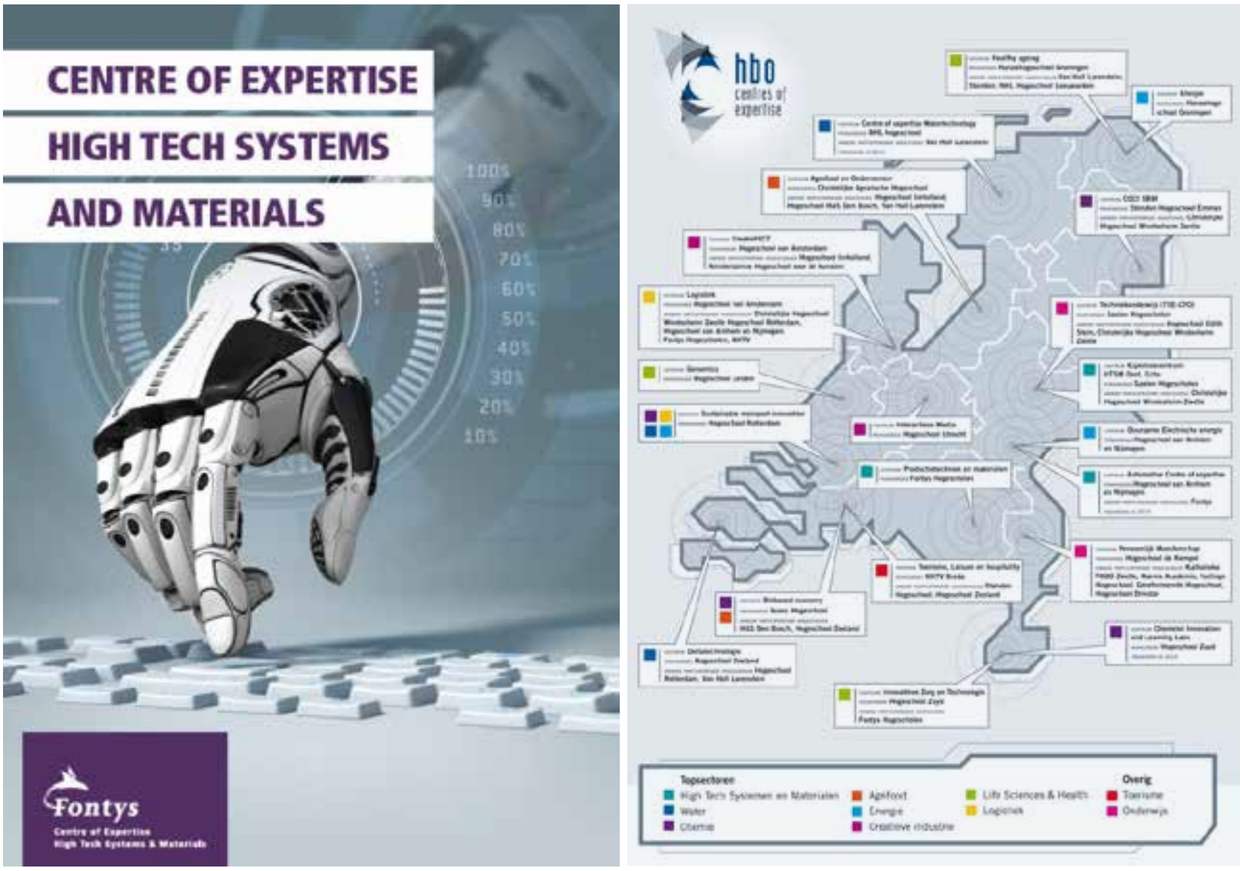
- 28 schools/faculties
- 58 Bachelor programs
- 40 Master programs
- 6 Associate Degree programs

The vision of Fontys is to build *reflective practitioners* and to that end applied research is embedded in all schools. Fontys has 39 Lectors, who lead the applied research agenda and who have close connections with their professional field. The research focus is on societal impact and the integration of work-based learning and research. Workbased learning and research provides *innovation in the curricula, innovation in teaching*, and also *innovation in professional practice*.

Fontys has two nationally recognised *Centres of Expertise*:

- Centre of Expertise Health and Technology (EGT)
- Centre of Expertise High Tech Systems & Materials (HTSM)

Figure 18 a&b. Fontys centres and locations.



(Source: Presentation by K. Adriaanse - Centre of Expertise High Tech Systems & Materials for LH Martin Institute study mission, April 2017).

Figure 19 a&b. Fontys research labs with the Robot Baxter and LH Martin Institute study mission delegates.

(Source: R. Schubert - LH Martin Institute study mission, April 2017).

In the *Centre of Expertise on High Tech Systems and Materials, Lectors* are working in the following areas:

- Production technologies
- Mechatronics/Robotics (Baxter at https://www.youtube.com/watch?v=xCKKgdTJy1o)
- Thin films and functional materials
- Business entrepreneurship
- Embedded systems
- Big Data
- Interaction Design
- Serious Gaming
- Virtual Reality
- Future Power Trains

Lectors are supported in their teaching and research with access to *Living and Open Labs* with specialist facilities in the following areas:

- Lab youthcare
- Expert centre Health and Technology
- Automotive Expert centre (Helmond)
- Creative Labs FACI
- Centre for Entrepreneurship
- Lab FSH: Move to be
- ICT/Education lab
- Lab WMO/reflection FHSS
- Objexlab – 3D printing/Robotica
- Green Tech Lab (Venlo)

Fontys is centrally located, and an integral partner in three fundamental networks, Brainport, Midpoint (Centre of Social Innovation), and Greenport (top region for entrepreneurs).

Brainport

In the 1990s, the bankruptcy of DAF (Dutch truck builder) and the re-organization of Philips was to cost the region 36,000 jobs and brought Eindhoven to the verge of disaster. Local government leader, Mayor Rein Welschen, together with Henk de Wilt, Executive Chairman of TU/e, and Theo Hurks, Chairman of the Chamber of Commerce, "initiated a close Triple Helix collaboration between government, industry, and research and educational institutions". Together, they attracted investment and brought organizations like TNO (Netherlands organisation for applied scientific research) to Eindhoven (http://www.brainport.nl/en/about-brainport/co-creating-the-future, 2107). This collaboration also gave rise to the Brainport Foundation in 2005, a public-private partnership, and earned the city of Eindhoven the International Eurocities Award in 2010.

Today the Brainport region has a population of 750,000 and a workforce of 400,000 people. The economic success of Brainport can be attributed to the culture of trust and understanding that the future lies in co-creation, expressed in the Triple Helix: the cooperation between industry, knowledge institutions and public authorities. Brainport is considered crucial to the international competitiveness of the Netherlands, as one of the three pillars of the Dutch economy, along with Amsterdam (Airport) and Rotterdam (Seaport).

High Tech Campus Eindhoven

Central to Brainport is the High Tech Campus (HTC) Eindhoven. Set up by Philips in 1998 in an attempt to concentrate its R&D activities formerly scattered around Eindhoven and elsewhere, it became highly successful in bringing researchers from very diverse backgrounds and disciplines together in a setting characterised by collaboration and exchange of knowledge and ideas. In 2003 Philips opened up the campus to other high tech companies, transforming it to one of the innovation hotspots in Europe.

The HTC currently is home to 150 companies, including about 40 start-ups clustered together in two dedicated buildings. In total 10,000 researchers from 85 countries are employed by these 150 companies, this has generated 50,000 jobs and about **4 patents a day**.

Fondly known as "the smartest km2 in Europe" it houses a range of R&D facilities open to the Campus residents. Characteristic of the adoption of an *Open Innovation* approach, all IP is shared trough the Campus Cloud and accessible in return for a nominal membership fee. A range of services is provided to the companies present on the campus, such as child care, logistical services, on-site car rental and drop off, and, of course, a bicycle repair shop.

In order to stimulate interaction, so-called "Strip" houses ten restaurants and eateries and a bar, and this area is the central hub for the more than 500 events hosted on campus yearly. In addition, campus sports allow the residents to further meet in informal settings, again stimulating interaction.

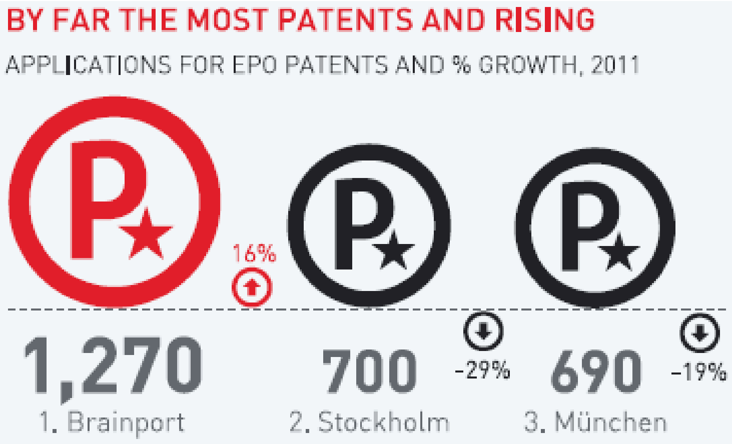
As with the original Philips vision, concentration still is a feature of HTC. Its focal areas are Energy, Health and Smart Environments. More detailed information can be found at: https://www.hightechcampus.com/uploads/documents/Media-Toolkit/HTC-006514_HTC-Brochure-inside_V05_WEB.pdf and https://www.hightechcampus.com/who-we-are/downloads.

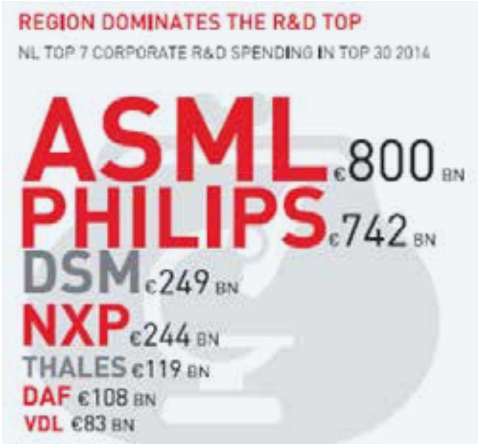
Figure 20. High Tech Campus Eindhoven.

(Source: High Tech Campus website).

The region now dominates private R&D expenditure in the Netherlands, with 5 out of the top 7 enterprises, accounting over €2.5 billion annually. The Brainport Eindhoven Region also registers the most patents in Europe by far, almost doubling runners-up Stockholm and Munich.

Figure 21. Patents and R&D spend in the Eindhoven Region.





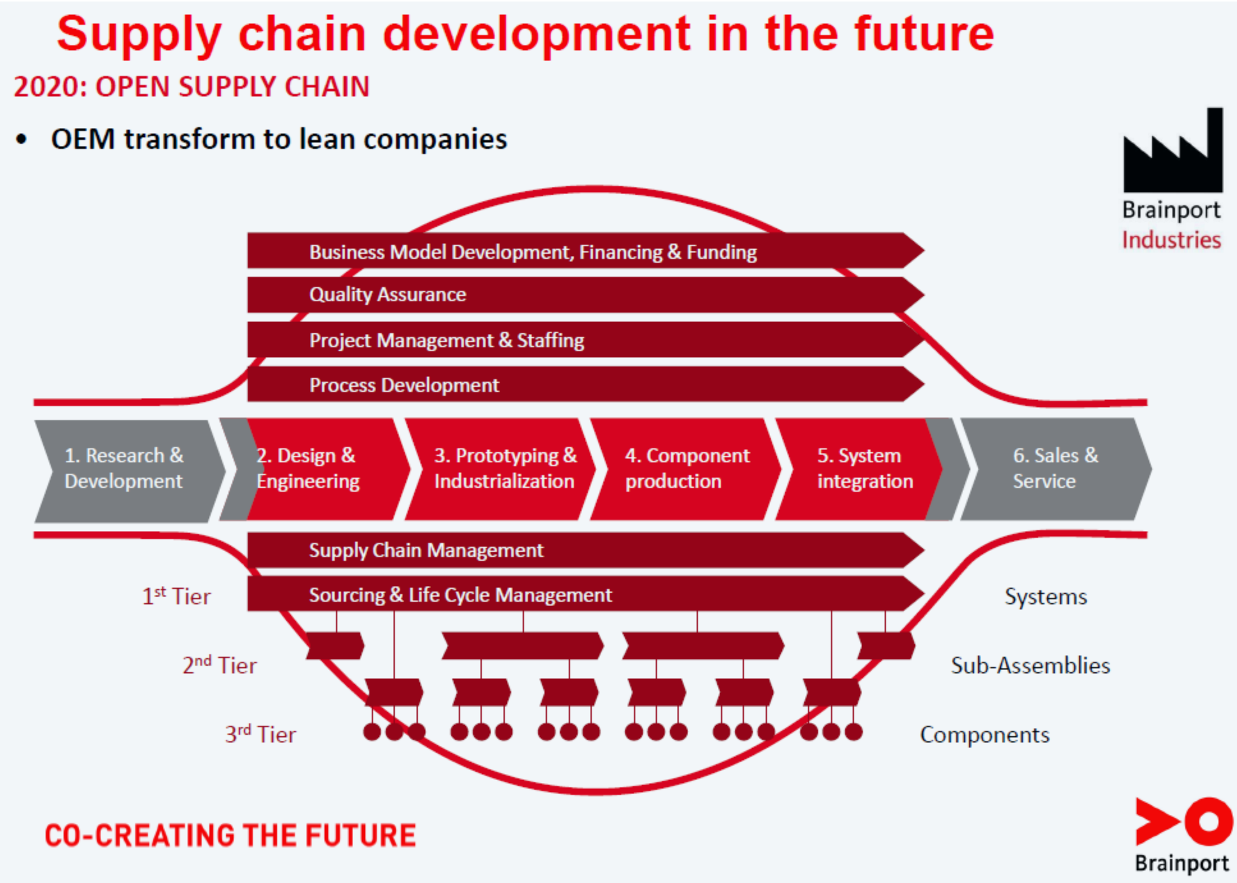
(Source: Presentation by R. Westenbrink - Eindhoven University of Technology, LH Martin Institute study mission, April 2017).

Brainport has identified ten key characteristics that make its ecosystem unique:

- Top companies
- Innovative SME sector
- Strong supply chains
- Well-educated labour force
- Open innovation
- Innovation campuses with international allure
- Strategic location in Northwest Europe
- Strong European player
- The multi-helix collaboration
- A great place to live

A key message from both Brainport and Novel-T in regards to open innovation systems is the importance of co-located supply chains, and the interaction with knowledge workers from education providers on R&D across the supply chain.

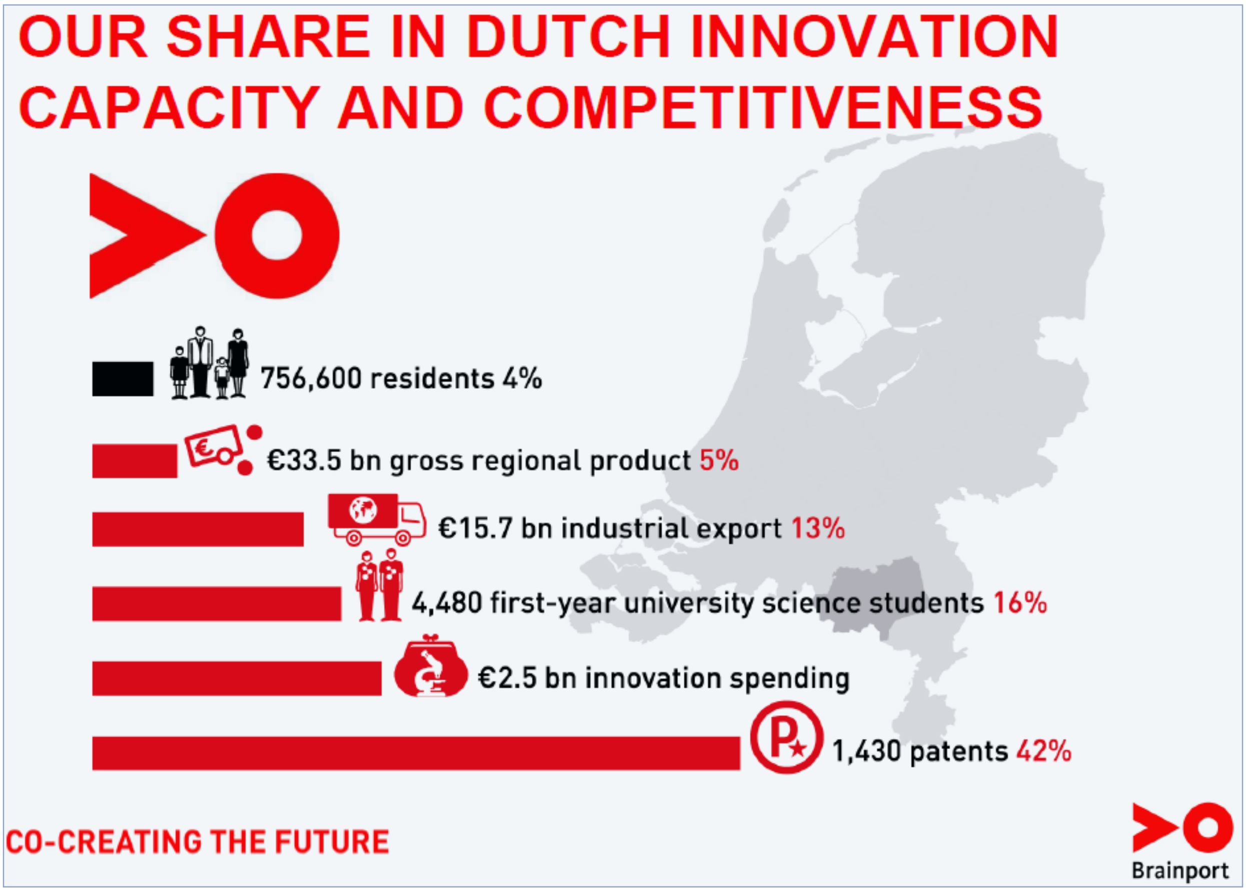
Figure 22. The Open Supply Chain of the future as proposed by Brainport.



(Source: Presentation by E. Van Leest – LH Martin Institute study mission, April 2017)

The Eindhoven story is of a region rich in technological innovation and the Brainport infographic below demonstrates the region's economic strength and impact on the Dutch economy.

Figure 23. The Eindhoven economic contribution to Dutch Innovation and Competitiveness.



(Source: Presentation by E. Van Leest – The Power of Cooperation, LH Martin Institute study mission, April 2017).

Take aways from the Eindhoven case:

- Never waste a good crisis
- Create a clear profile through strategic choices
- The power of collaboration and external engagement
- Incorporation of students in (applied) research and entrepreneurship
- Individual leadership matters
- Create physical spaces for collaboration
- Innovation requires investments (facilities, equipment, human capital)
- Talent attracts talent
- A successful innovation ecosystem has great cultural and social spill-overs
- Change does not happen overnight

Italy: Milan

Figure 24 a&b. Architectural design masterpieces in Milan - Galleria Vittorio Emanuele II and Duomo di Milano.

(Source: R. Schubert - LH Martin Institute study mission, April 2017).

Milan is located in Lombardy, the leading region in Italy. In 2015, Lombardy accounted for 22% of the Italian GDP. 250 medium-sized enterprises are located in Milan, with 1,000 located in Lombardy, complemented by 123 large enterprises in Milan.

Milan is the industrial and financial centre of Italy, but is also a global city known for its arts, fashion, design, healthcare, education and research. Milan is noted for its entrepreneurial and collaborative spirit, where companies, universities, non-profit and governmental institutions have been able to work together to create their own innovation ecosystem.

Lombardy has many human capital/knowledge based institutions including:

- 13 Universities
- 1 Institute for Advanced Study
- 12 CNR (National Research Council) Institutes and 18 territorial sections of CNR Institutes
- 3 sections of Italian National Institute for Nuclear Physics and one European Joint Research Centre
- 19 Institutes for Treatment and Research

The Lombardy region has 270,000 university students and just fewer than 13,000 international university students of which almost 10,000 are in Milan (Assolombarda, 2017). Between 2007 and 2013, almost 1,500 knowledge-intensive start-ups were born in the arts, culture and creative industry sectors. Lombardy also tops the ranking of Italian regions regarding the workforce employed in creative industries including:

- 19% of Italian cultural businesses
- 26% of Italian value added cultural businesses
- 300,000 jobs provided by the sector of culture

Figure 25. Number of medium-sized manufacturing companies, with a workforce comprised between 50 and 499 employees.

(Source: Tableau de bord Assolombarda Confindustria Milano Monza e Brianza on Mediobanca – Unioncamere data. Assolombarda Booklet Italy, Lombardy and Milan, No.3 January 2017).

Polytechnic University of Milan (Politecnico di Milano)

Politecnico di Milano is the leading university in Italy for Architecture, Design and Engineering. The Politecnico was founded in 1863, and has 40,000 students and 1,400 professors and lecturers. Graduates from the Politecnico make up a significant proportion of current professionals employed in Italy and account for:

- 22% of Architects
- 16% of Engineers
- 45% of Designers graduated

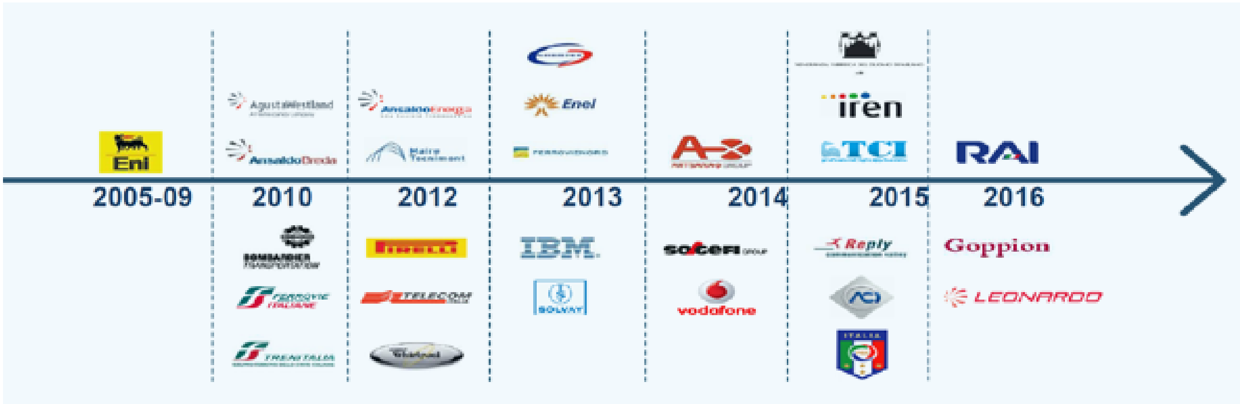
The international QS World University Rankings 2017 rank the Politecnico di Milano as:

- 24th best university in Engineering and Technology **(1st in Italy)**
- 18th best university in Mechanical, Aeronautical and manufacturing engineering **(6th in EU)**
- 14th best university in the field of Architecture / Built Environment **(1st in Italy)**
- 7th best university in the field of art and design **(1st in Italy)**

POLITECNICO DI MILANO HAS THE FOLLOWING DEPARTMENTS:		
Aerospace Science and Technology	Civil and Environmental Engineering	Management, Economics and Industrial Engineering
Architecture and Urban Studies	Design	Mathematics
Architecture, Built Environment and Construction Engineering	Electronics, Information a nd Bioengineering	Mechanics
Chemistry, Materials and Chemical Engineering "Giulio Natta"	Energy	Mechanics

The Politecnico is highly attuned to changes in European strategic research priorities, and changes in societal challenges, company needs and increasing complexity. The Politecnico has a well-developed and well-resourced research culture, with all departments having research labs, in total 239. The Politecnico has also stimulated inter-department cooperation on interdisciplinary topics through the establishment of 25 inter-department research labs. In addition, the Politecnico created new interdisciplinary PhD fellowships on specific application research areas, with supervisors from at least two departments, with 20 fellowships due to start in November 2017.

Figure 26. Politecnico di Milano active joint research centres.



(Source: Presentation by D. Sciuto - Politecnico di Milano, LH Martin Institute study mission, April 2017).

An important difference in the Italian education system compared to the Netherlands and Australia is in regard to vocational education, which is considered part of the high school system as opposed to the Tertiary/University level.

There are two types of high schools in Italy, the *Liceo* which is a more traditional academic school and the *Istituto*, which has a vocational orientation. The first two years provide a broad-based education and then the specialised courses begin in the third year. Italian high schools fall into one of 6 categories and it is the *Istituti Tecnici* (Technical Institutes) that prepare students to work in a technical or administrative capacity (Wikipedia, 2017). High school is a five-year commitment and provides students with a pathway into university or a vocational outcome. A vocational education is called the *Formazione Professionale*, with two levels of formal outcome; a *Qualifica Professionale* after three years, and after two more years, the *Licenza Professionale*.

Table 2. Education and certificates awarded at Italian high schools.

LEVEL	NAME	DURATION	CERTIFICATE AWARDED
LOWER SECONDARY EDUCATION	Scuola secondaria di primo grado (first grade secondary school; “middle school”)	3 years (age: 11 to 14)	Diploma di scuola secondaria di primo grado (was “licenza media”)
UPPER SECONDARY EDUCATION	Scuola secondaria di secondo grado (second grade secondary school; “high school”)	5 years (age: 14 to 19)	Diploma di liceo Diploma di istituto tecnico Diploma di istituto professionale
	Formazione professionale (vocational education)	3 or 5 years (age 14 to 17 or 14 to 19)	Qualifica professionale (3 years), Licenza Professionale (5 years)

(Source: https://en.wikipedia.org/wiki/Secondary_education_in_Italy).

What is consistent with the Netherlands is the active participation of regional and local government agencies and associations. Given the difference in the education system, particularly in relation to vocational education, this is then reflected in the way small and medium-sized enterprises engage in innovation. *Assolombarda* is the main association in Milan for companies, and in the past three years, Assolombarda started a strategic project with the universities to increase the level of research and innovation in SMEs. In this process, the Politecnico found that many SMEs were looking for innovation of products or processes at low cost i.e., high TRL levels, which had not been the main focus of the Politecnico, and that the more innovative SMEs were already in the ecosystem of the Politecnico. This however means that it is the University sector in Italy that must be more active across a greater breadth of the TRL levels, and develop other institutional structures to facilitate the network and activity compared to the situation found in the Netherlands.

The Lombardy region has also been active in defining the *Smart Specialization Strategies for 2014-2020*, including priorities for research and innovation, with the region accessing funds from the EU (€350 M) in the areas of:

- Aerospace
- Agri-foods
- Eco industry
- Creative and cultural industry
- health
- Advanced manufacturing
- Sustainable mobility

In establishing the collaborative research projects, the Region has strict requirements in terms of participation and administrative rules for co-funding. This includes creation of formal associations among companies, universities and research centres in the region related to the specific topics. Politecnico di Milano has also been active in participating in the Horizon 2020 funding, the results from 2014 to the first quarter of 2017 being 158 Projects totalling more than €75 M, with the active participation of 117 partners.

Politecnico di Milano initiatives to bridge the commercialisation divide include a relatively new campus at *Polo territoriale di Lecco* with a dedicated suite of co-located research labs, and the Polihub which focuses on mentoring and supporting start-ups.

Campus of Lecco (Polo territoriale di Lecco)

Figure 27 a&b. Study mission delegates at the Lecco Campus main entrance and research labs.

(Source: R. Schubert, LH Martin Institute study mission, April 2017).

Polo di Lecco offers a selection of degree programs in engineering and architecture, and like the Netherlands, most courses are taught in English. Polo di Lecco has a higher proportion of international students and 93% of graduates are employed within a year. The Lecco province has approximately 30,500 enterprises, with a higher proportion of SMEs at 34% of the total number. The campus has a unique suite of 16 high tech research labs that are centrally located in the campus. This allows for a high level of interaction between the research groups and local enterprises. The following are just two examples of this lab precinct.

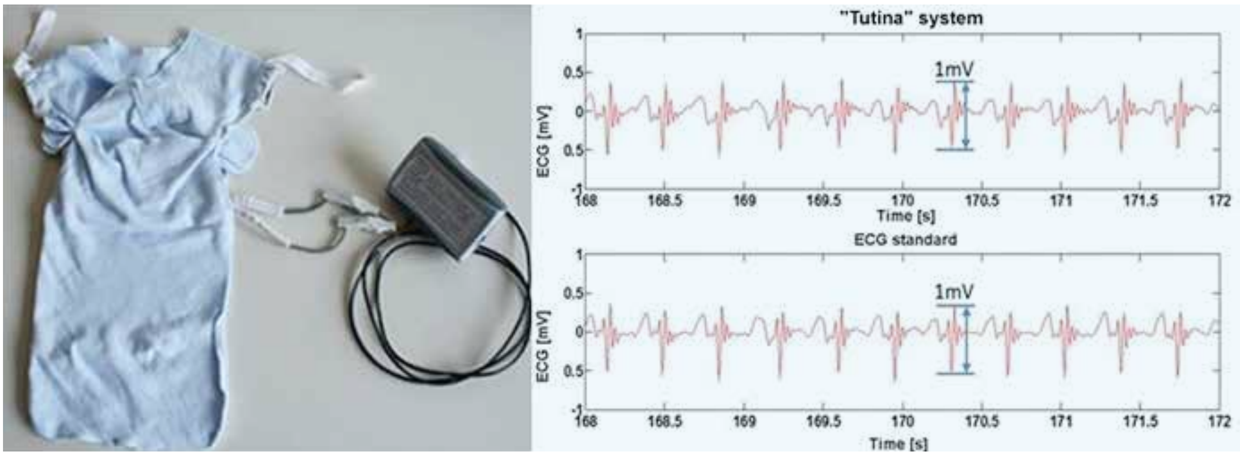
Figure 28 a&b. Study mission delegates, researchers and staff at two research labs.

(Source: R. Schubert, LH Martin Institute study mission, April 2017).

SensibiLab-Biomedical Sensors and Systems

This lab develops solutions and models of systems and sensors usable in the remote monitoring of clinical research, in telemedicine, sports and aids for the disabled. The research activity is concentrated on the design of wearable solutions to measure biological signals, and communication aids to support the handicapped.

Figure 29. Sensilab products.



(Source: Presentation for LH Martin Institute study mission, 2017).

SMaRTLab-Sustainable Marine Research and Technology

Given the location of Lecco (on Lake Como), this lab is highly responsive to the local environment and conducts experiments relevant to the manufacture and optimization of production processes in the nautical field. Research is conducted with enterprises in relation to composite materials, workplace safety, development of monitoring systems and computation models in support of yacht design. It also focuses on design for waterfront structures, water sports, disability and physical and social rehabilitation.

Figure 30 a&b. Examples of SMaRTLab marine research and technology outcomes.

(Source: Presentation for LH Martin Institute study mission, April 2017).

Polihub

Figure 31. Polihub founding partners.

(Source: http://www.polihub.it/en/partners/).

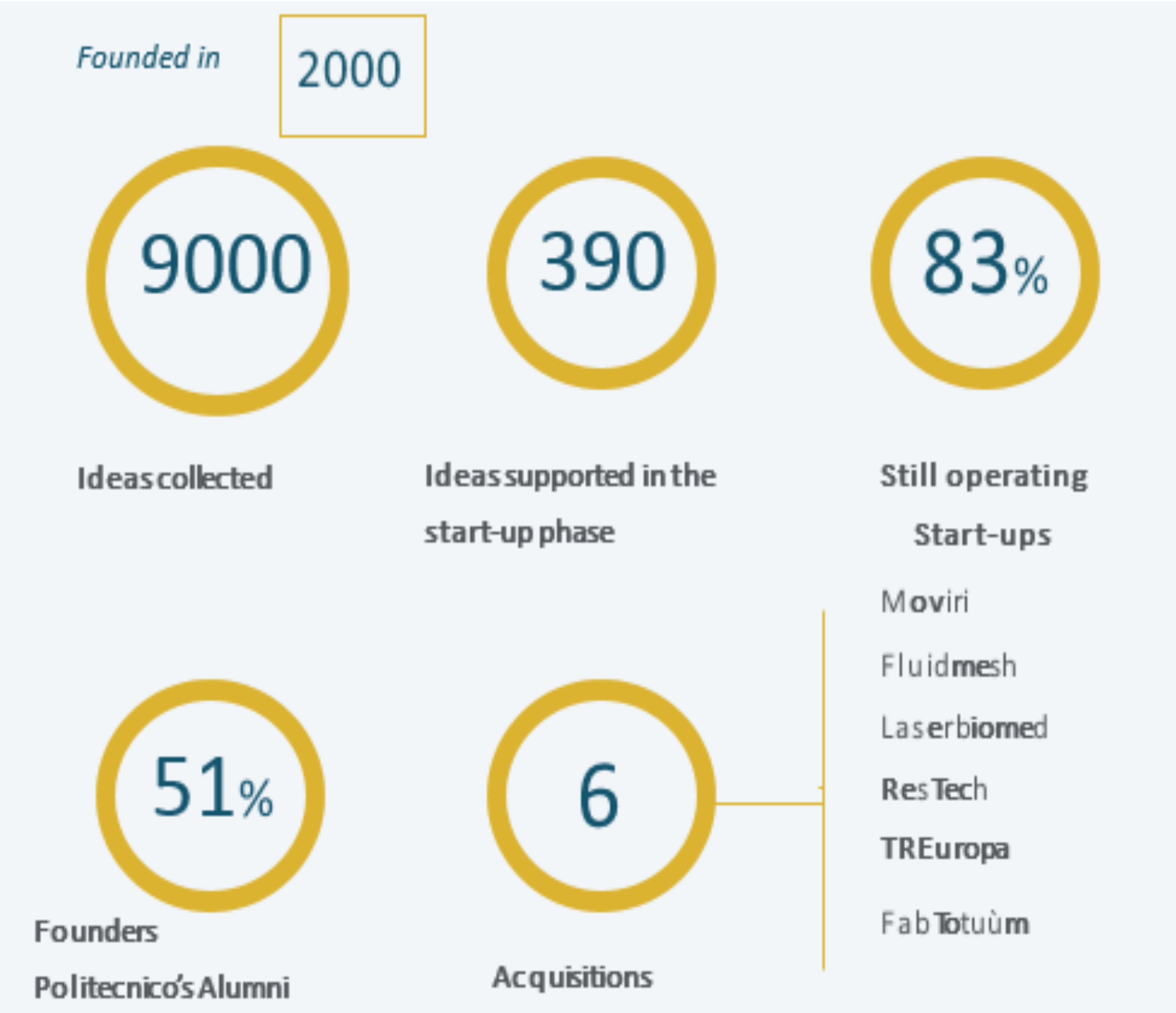
Polihub is both a start-up district and incubator, with the objective to keep successful start-ups co-located as the enterprise grows. Polihub is an initiatve of three founding partners, Polytechnic University of Milan, the City of Milan and the Foundation of the Polytechnic University. Consistent with the Netherlands, Polihub is an example of a regional government being a key partner in the establishment of innovation places. The key services provided by Polihub include access to funding, accleration, mentorships, and ongoing adhoc advice.

Polihub is ranked by UBI World Ranking Business Incubators in 2015 as:

- 2 placed University Incubator in Europe
- 5 placed University Incubator in the World

Polihub has over 4000m2 of floor space, with 45 incubated start-ups and €17.5Min start-up turnover. A critical part of the service to start-ups is a *tough love* mentoring service by experienced entrepreneurs. Entrepreneurs are matched with start-ups and give carefully structured advice to potential entrepreneurs. Polihub formally facilitates networks of accelerated and start-ups and continues to build a connected district of businesses.

Figure 32. Polihub key data since commencement.



(Source: Presentation by M. Croce for LH Martin Institute study mission, April 2017).

Take aways from the Milan case:

- Create a clear profile through strategic choices
- The power of collaboration and external engagement
- Incorporation of students in (applied) research and entrepreneurship
- Individual leadership matters
- Create physical spaces for collaboration
- Innovation requires investments (facilities, equipment, human capital)
- Create an active intermediary structure to facilitate access of SMEs to knowledge hubs
- Change does not happen overnight
- Existing regulation is not a barrier to innovation and entrepreneurship

Applied Research as Part of the Innovation System in Canada

In 2015, the LH Martin study mission to Canada led a senior delegation from the Australian and UK Vocational Education sectors and examined in detail the Applied Research system in Canada. The delegation found that the Canadian experience in mobilising the head, heart and hands of students and staff at institutions across Canada provided enterprises with a powerful and cost-effective means of driving their own product, process and service innovation. Students in Canada form a vital part of the innovation workforce as they, in effect, become the R&D department for enterprises that sign up to the country's applied research model. This problem-solving approach involves teams in the classroom, lab, workshop or workplace that address enterprise challenges and issues. Some projects take a matter of months; some are longer term, over several years.

An important principle distinguishing the applied research model in Canada from Australia is that in almost all cases the resulting intellectual property remains with the enterprise that invests in the project by either paying to employ the students, or for materials, or both. This model has grown in strength across Canada in the last 12 years, largely due to the support of the federal government, which provides the majority of the funding, and most importantly, the private sector continues to provide significant co-funding. Yet the federal funding is still modest compared with the funds given annually to the Canadian higher education sector for research.

Colleges and Institutes Canada (CICan) is the peak body for publicly supported colleges and institutes across Canada. CICan reported in 2015, that more than 6300 Canadian companies, mostly small or medium-sized enterprises had partnered with colleges and institutes to undertake activities through the applied research model. With 32,000 students engaged in research, this represented a 52 per cent increase in the number of students engaged in entrepreneurial activity since 2012–13. The applied research model continues to grow in strength with the most recent report in May 2017 noting that:

> ***"Colleges and institutes together with government, the private sector and other sources invested a total of $246 million in applied research in 2015-16, an increase of 76% over 2010-11, and for every $1 of federal investment; an additional $0.87 is invested by private sector and not for profit."***
>
> ***(CICAN, 2107. p.6)***

In the province of Ontario, all Colleges and Institutes are involved in fostering innovation through the applied research model. Centennial College has focused on energy, health and aerospace, with projects ranging from designing new landing gear for planes and wearable interactive clothing for healthcare workers, to hybrid street lamps. It is not all small business, as Centennial is also a partner in the Downsview Park Aerospace Campus, which is federally owned land with Bombardier facilities and an innovation centre.

> ***"The new campus will house an innovation and research working group that brings together industry leaders and academic partners, including University of Toronto Institute for Aerospace Studies, Ryerson University, York University, Bombardier and others. The campus will anchor the Downsview Aerospace Innovation and Research (DAIR) Cluster, which will work to maintain Canada's fifth-place ranking as an aerospace supplier to the world."***
>
> ***(Centennial College, 2016.)***

Niagara College, which has expertise in wine making and boutique brewing, developed an alcohol-free beer. The project had funding support of CAD$2.3 million over five years from *Mothers against Drunk Driving (MADD)*. The alcohol-free beer is now a commercial success across Northern America. This was one of the few projects from which some royalties went back to the college. Algonquin College reported that for every 100 projects, 24 jobs are created and for every $1 invested, the return on investment was $1.80.

Figure 33. Researcher Becky Scott with MADD funded Virgin Craft Brewed no-alcohol lager.

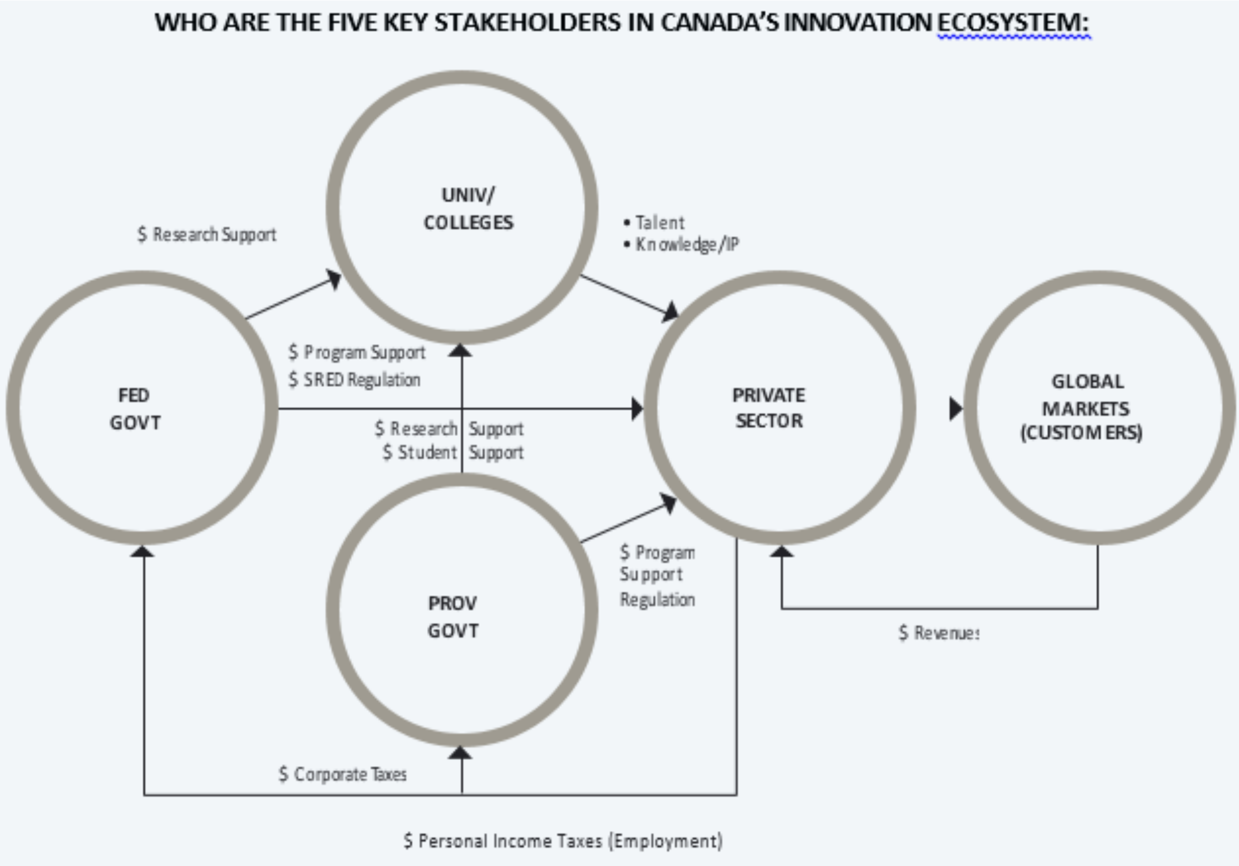
(Source: https://www.niagarathisweek.com/news-story/4619484-a-lot-of-buzz-around-the-no-buzz-beer/).

Figure 34. The opening of Centennial College's aerospace campus at Downsview Park.

(Source: D. Rider - https://www.thestar.com/news/canada/2016/11/21/centennial-college-to-create-aerospace-campus-at-downsview-park.html).

Canada, like Australia, has recognised that it is slipping down the innovation rankings and, like Australia, is a predominately services based economy at around 75% of GDP. A recent report, Towards an inclusive innovative Canada, confirmed the need for an innovation ecosystem involving the key partners as identified in Europe.

Figure 35. Key stakeholders in the Canadian innovation ecosystem.



(Source: http://innovationproject.ca/wp-content/uploads/2017/02/towards_an_inclusive_innovative_canada.pdf).

The Canadian and European models show that small and medium-sized enterprises benefit from targeted interaction to support innovation and development, especially when part of a wider innovation ecosystem.

The National Innovation and Science Agenda

According to the Australian Government's website "Extraordinary technological change is transforming how we live, work, communicate and pursue good ideas". We need to embrace new ideas in innovation and science, and harness new sources of growth to deliver the next age of economic prosperity in Australia. The National Innovation and Science Agenda is an important step in the right direction." (https://www.innovation.gov.au/).

The NISA focuses on four areas: Culture and Capital, Collaboration, Talent and Skills, and Government as an Exemplar. A schematic overview is presented in Figure 38 below.

Figure 36. Summary overview of the National Innovation and Science Agenda.

CULTURE AND CAPITAL	COLLABORATION
Tax incentives for angel investors	Critical research infrastructure
New arrangements for venture capital investment	Sharper incentives for engagement
Access to company losses	Global Innovation Strategy
Intangible asset depreciation	Cyver Security Growth Centre
CSIRO Innovation Fund	Innovation Connection Programme
Bomedical Translation Fund	Advancing quantum computing technology
Incubator Support Programme	Measuing impact and engagement of univerity research
Improve bankruptcy and insolvency laws	ARC Linkage Projects Scheme
Employee Share Schemes	
TALENT AND SKILLS	**GOVERNMENT AS AN EXEMPLAR**
Inspiring all Australians in digital literacy and STEM	Data61
Supporting innovation through visas	Business Research amd Innovation Initiative
	Digital marketplace
	Innovation and Science Australia
	Public data strategy

(Source: Innovation and Science Australia, 2016).

Culture and Capital essentially is code for the continuation of the industry tax break policy, formally known as the R&D Tax Incentive. A recent evaluation found that the program is not achieving its stated objectives (Ferris, Finkel & Fraser, 2016). The report argues that '(t)he objectives, as stated in the program's [sic] legislation, are to "encourage industry to conduct research and development activities that might otherwise not be conducted…to benefit the wider Australian economy."

In other words, the incentive seeks to encourage additional R&D (additionality) that benefits others (spillovers)' (Ibid, p.2). The report concludes that this AU$2.95 billion program 'falls short of meeting its stated objectives of additionality and spillovers. There are a number of areas where improvements could be sought in order to improve the effectiveness and integrity of the program and achieve a stronger focus on additionality' (Ibid, p.2).

The area of Collaboration focusses on a perceived shortcoming of the Australian innovation system, namely the lack of engagement between industry and universities. Australia traditionally comes last in the OECD's annual assessment of university-industry collaboration, and for many, this is the obvious missing link in our national innovation settings. Whilst there is no denying that this is an issue, one should also consider the impact, not merely the scope of collaboration. An analysis of the Scopus database through SciVal shows that Australia is a top performing country when the impact dimension of collaboration is included. So, while we may not collaborate enough, when we do the results are very good. This, of course, is particularly true in the (bio) medical sciences where much of this collaboration occurs.

The category of **Talent and Skills** essentially embraces the digital age and reconfigures the current visa policies for attracting overseas talent to Australia. Whilst both are obvious elements of a national innovation strategy, the absence of a focus on our own tertiary institutions significantly contributing to upgrading and improving both the talent and skills components is remarkable, to say the least.

Finally, while it may be surprising that an **exemplar** role is defined for **government** in relation to innovation; this does reflect the reality that the public sector is better at innovation than the private sector, contrary to popular belief and dogma (Arundel et al, 2016). This reality has been reconfirmed in the latest Study on Australian Leadership (SAL, 2016). The study reveals a pattern of mediocre leadership in many organisations likely to impair their capacity to shift to a knowledge economy and impede efforts to raise productivity. As stated on the project website: "Innovation drives growth and productivity. Yet most organisations struggle to turn knowledge and ideas into successful innovations. Too few (18%) private sector organisations report high levels of radical innovation. Surprisingly, public sector organisations were more likely than private sector organisations to have reported high levels on both types of innovation, and findings show those organisations that do innovate successfully achieve superior performance outcomes." (SAL, 2016; http://sal.workplaceleadership.com.au/about-sal).

This sentiment is reflected in the *Performance Review of the Australian Innovation, Science and Research System 2016*. Ongoing business, management and leadership skills gaps are identified as one of the key weaknesses of the system. Although the NISA acknowledges the world-class nature of our universities and their potential to assist in transitioning Australia's economy, this is primarily operationalised through the commercialisation dimension of its research activities, and little attention is paid to the main *product* of universities i.e., graduates. No attention is paid to VE's contribution to a highly skilled workforce, although this in part is redressed in the previously mentioned *Performance Review* report.

It can likewise be argued that the importance of a high quality and integrated education and training system is presented as one of the key challenges in the *2030 Strategic Plan Issues Paper* (ISA, 2017), yet except for posing the questions of how we can create a cohesive education and training system that is integrated into the innovation and research system, and how we can increase people and idea exchanges between industry and the education and training system, little is brought forward as to the government's or ISA's own views on what steps ought to be taken. Given the comprehensive analysis contained in the performance review report, this is at best disappointing.

Conclusion

Europe and Canada are shining examples of how to develop collaborative open innovation ecosystems. Their national and provincial government policies have supported the role of diverse tertiary education institutions and regional governmental agencies, so that together they play a fundamental role as foundation partners in establishing innovation ecosystems; systems that are firmly linked to places and regions.

It is the dynamic combination of tertiary education providers, Research Universities, Universities of Applied Sciences, Colleges and Institutes that provide successful conduits for enterprises of all sizes into the innovation ecosystem. Small and medium enterprises are especially at risk of being excluded from innovation networks because of the difficulty they traditionally face in accessing advanced knowledge. Yet in these innovation ecosystems they become an integral part of a collaborative and cohesive structure without these traditional barriers. They become an important part of the research chain by providing real-life cases for applied research involving staff and students alike. This generates a knowledge flow from the tertiary institutions into local industry as well as from industry back into the institutions as a result of the project outcomes being fed back into the education and training programs. In this way, these (applied) research projects can cover the full spectrum of the nine technical readiness levels. Institutional structures such as supported and funded pure and applied research groups, large and smaller scale student projects, incubators, including student incubators, and mentored start-up hubs work to cross the commercialisation "valley of death".

The LH Martin study mission in 2017 focussed on three regions in Europe. Enschede, Eindhoven and Milan are all recognised as regions that have experienced significant economic downturns, and have turned their economic futures around by responding to these challenges in a strategic and collaborative way. Crucially important in these regions has been the incorporation of the SME sector into the innovation ecosystem, through very targeted approaches by both tertiary institutions and the various government actors. Combined with the active involvement of larger enterprises, this has resulted in the true realisation of the Triple Helix: co-dependency and co-creation through collaboration, partnership and the explicit sharing of knowledge and experiences. Essential in this is the complementarity of knowledge and experience that the partners in the ecosystem bring to the table, coupled with a strong culture of trust. The latter clearly needs to be nurtured over time, as it does not come as by magic. Our three case studies demonstrate very clearly not only that the creation of such innovation ecosystems indeed is possible, they further highlight the fact that open innovation is the way for the future, with very specific roles and responsibilities for the different partners.

TAFE Institutes and TAFE divisions of dual sector universities in Australia are best placed to perform the role of Universities of Applied Sciences as in the Netherlands, or the Colleges of Canada, by developing an applied research capacity. This will further enable them to be an integral partner in regional innovation networks and facilitating the link between pure research and commercialisation. As has been demonstrated in our case studies, dynamic innovation ecosystems are not created overnight. They require vision, planning, careful implementation and upscaling, and the availability of targeted resources – human, as well as financial capital. They also require key actors, including the different levels of government, to actually collaborate and be engaged. Our case studies show this is hard work, but the results speak for themselves.

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