The Triple-Helix sub-revolution and the hype of Industry 4.0

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Abstract

Society and operations managers are confronted with the hype of the FIR (fourth industrial revolution) in many ways. The magnitude of the next industrial revolution is a huge reality but it also needs to be seen for what it really is in terms of its progress, sub-revolutions, social dangers and unique cyber-physical systems (algorithms). The smart telematics, machine-to-machine (M2M) technology and connected devices through computer-based systems are not all new or disruptive. The notion that disruption is by default an inherent FIR value may be questioned especially when personal transformation is demanded or thriving in a time of endless innovation. An agile business in the digital age is not the only option for innovation improvement or for commendable transformation journeys. The FIR identity therefore needs to be clarified by means of an accepted model. An qualitative exploratory research approach was used to look deeper into the FIR movement and to address the research problem by providing perspectives about the hype, identifying Triple-Helix (TH) as a significant sub-revolution of the FIR and to make suggestions for further research to clarify its identity.

Keywords
Fouth industrial revolution (FIR); Triple-Helix (TH); entrepreneurial university; innovation eco-systems; social and customer intelligence (CI)

Introduction

The global economy is producing new type of leaders for exponential organisations. Bigger and better becomes a new norm with universities becoming businesses partnering with industry and government in terms of Triple-Helix (TH) configurations. These organisations perform in terms of the triple bottom line (3BL) known as \`people, planet and profit\`. Part of this movement is to upscale agility with leaders who think differently and leading others to a transformation journey. These leaders disrupt themselves first to model the way how to create agile businesses for the digital age. They need to master personal transformation to thrive in this age of endless innovation. Getting agile by deploying a wave of agile teams seems to be a sub-revolution on its own (not discussed in this paper) and an underlying force currently at work.

Previous revolutions (with technologies associated with electric power) and the recent digital technology remain fundamental for more revolutions to come. In the early seventies Braverman (1974) introduced the concept of a scientific-technical revolution that cannot be understood in terms of specific innovations. The FIR (fourth industrial revolution) is also inadequately characterized by a handful of key inventions that need to be understood holistically (in its totality) as a mode of production into which science and exhaustive engineering investigations have been integrated as part of ordinary functioning. This new big thing - the FIR movement – has many underlying social and behavioral dimensions and is not to be found in electronics, automatic machinery, aeronautics, chemistry or atomic physics but rather in the transformation of science itself into capital.

The magnitude of the modern economy and changes taking place cannot be ignored because we see social sub-revolutions (eg. social ergonomics) underlying the "smart factories" with machine-to-machine communication. We see how production organises itself by means of unique cyber-physical systems. We see a new kind of knowledge society and the changing ethos of universities to do business in a time of super-complexity. Entrepreneurial universities find new kinds of knowledge management becoming a natural phenomenon of our time regardless of those against this new university mission. This widened the scope of university research and interaction with a larger eco-system, especially for faculties of industrial engineering.

This paper examines perspectives of the FIR identity including a skeptic philosophical view of the FIR movement. The paper also identifies a massive sub-revolution in terms of entrepreneurial universities and the triple-helix (TH) of innovative eco-systems. Finally it makes suggestions for further research. The next sections provide a background to the problem and the problem statement.

Background to the problem

New developments in technology can artificially be associated with the FIR. Conventional technology, innovation and operations management were always creative. The sciences (eg. of industrial engineering) also transformed over decades providing multiple inventions. Old principles and techniques bring new developments to the fore. Different materials with unique chemical properties produce new composite (materials) when combined. Traditional money sees the lure of crypto and investors going into the cryptocurrency world. Computers become smaller and with creative companies like Virgin we should see more weird inventions and more odd jobs. Human creativity will see normal buildings become intelligent building systems and products and machines with no interfaces (or self-monitoring devices) will see more intelligent products and processes. Conventional machinery becomes intelligent machinery where `electrospindles` is manufactured for mechatronics. Early leak detection equipment is installed at power plants and the list goes on. These developments are not all for or from the FIR.

The new modern economy with sophisticated customer demands sees many changes such as customer intelligence (CI), upscaling agility, knowledge management and mass customisation. Dube and Mbohwa (2018) responded by creating a framework for evaluating and selecting technologies appropriate for mass customisation (MC). The selection criteria for MC will alert the stakeholders in the metal casting industry about importance of technology in the success of MC and to encourage objective investment in technology. This is necessary for many industries purely based on customer demand.

Another old age generic customer service challenge in terms of the queuing problem is a good example of an ongoing challenge. Aylak, Hendrikse, du Plessis (2018) improved on old simulation principles for cash registers of a giant retail company. They developed the capability to run different scenarios to solve the queuing problem based on the unique data of each shop. A discrete-event simulation model is constructed using SIEMENS Tecnomatix Plant Simulation software. The model is used in a way that it can dynamically use input data of every unique shop. The simulation model determine the number of cash registers which should be in the store as well as when they need to be manned.

Adams and Mpofu (2018) reviewed the implications of the FIR by using a meta-analytic approach to highlight contradictions, gaps, similarities and successful frameworks (such as “Aluminium Industry 4.0”) and game changing cases such as Exxon Mobil, Proctor and Gamble and Tata Motors. The work identifies gaps in knowledge and indicates the need for an optimal tool of assessment for companies to measure where they stand against the FIR movement. The question remains if the FIR is the norm and if companies must measure themselves?

There are many cases termed as super exponential or excellent, that is not related to the FIR. Safety excellence and predictive maintenance are inherent to all operations and also relevant to a leading aircraft tyre specialist. In terms of maintenance and the protection of equipment, metal oxide surge arresters play a major role in the protection of electrical devices or equipment from lightning and switching surges. Dlamini, Bokoro and Doorsamy (2018) reviewed commonly-applied techniques for condition monitoring of Metal Oxide Surge Arrester Models (MOSA) and the need to develop or improve suitable models for both online and remotely-applied monitoring application. In terms of wear degration, Phiri1, Oladijo and Akinlabi (2018) examined tribology and the advantages of the thin film deposition method because wear degradation is one of the most failure mode incurring realities in modern industries. Apart from lubricants, thin film deposition technologies are well established for the improvement of wear resistance in high friction operations. Solilo and Doorsamy (2018) studied power line inspection in terms of fault finding and regular maintenance. They came up with a design of a power line tracking unmanned arial vehicle which is commendable, but not related to the FIR.

Research problem

The FIR identity is weak (or unclear) with skepticism about its promises. Some even believe it's an artificial hype to improve conventional innovation. Automation, data, composites, smart factories, the internet and robotics are not new technology. In addition to these related questions is the reality of other significant sub-revolutions underpinning the movement. There is a need to clarify the FIR concept and to identify and elaborate on its causes, dimensions and objectives. Figure 1 illustrates the research problem simply as the FIR identity (that needs to be clarified).

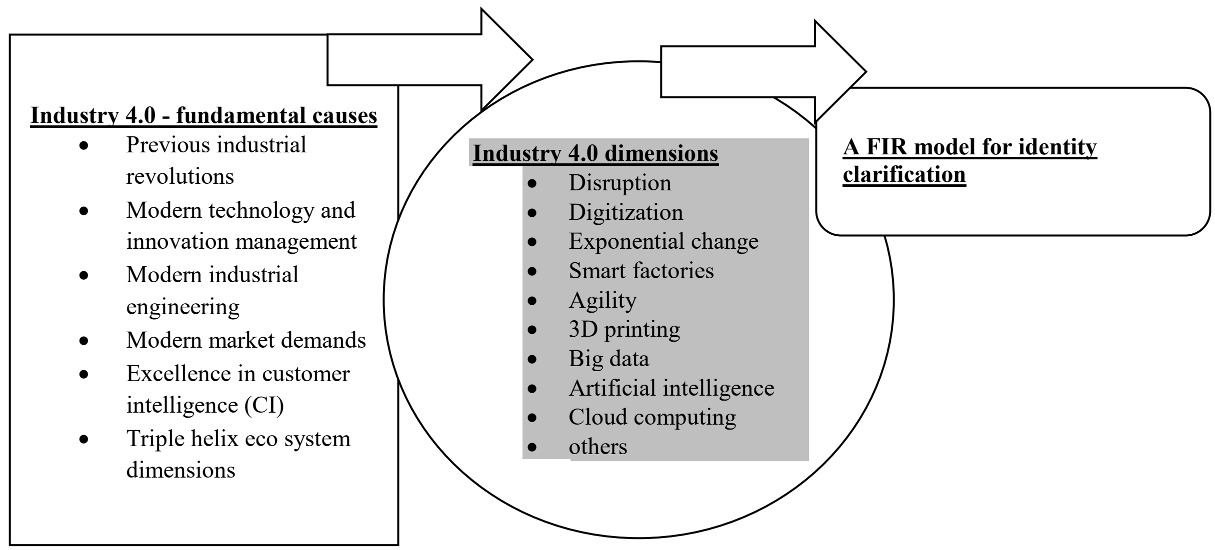

Figure 1: The FIR identity

Methods

The methods used to address the problem are discussed next. Plowright (2011) supports integrated research methodologies. Cooper and Endacott (2007) refer to generic qualitative research that may entail experiential knowledge of researchers and practitioners. Qualitative research provides for researchers to engage, observe and expose themselves to a particular phenomenon. The data used for this paper is narrative in terms of unique characteristics and specific accounts of experience and observations. This included secondary data in terms of multiple source publications (Saunders, Lewis and Thornhill, 2012: 307).

Data was also obtained in terms of institutional text documents, reports, non-text artefacts and exhibiting displays by means of personal observation during multiple university and institutional visits to Europe and the UK. Practical evidence of artefacts by observation provides physical perspectives of creative activities that were not naturally present. This included simple objects (human workmanship or modifications) as distinguished from natural objects), design evidences, photos and sculptures. Institutional artifacts includes entrepreneurial universities, innovation centres, science parks, innovation labs and technology transfer organisations (TTOs) strategically organised as partners within an innovation eco-system. The exploratory approach did not commit to a singular paradigmatic research practice, nor did it attempt to generalise results through external validity.

Research objectives

In general the paper contributes to the paucity of literature in terms of sub-revolutions of the FIR for a framework or model of the FIR. The primary aim of the exploratory study is to address the research problem and provide a comprehensive overview in terms of the following:

- To provide some perspectives against the hype of the FIR movement.
- To provide perspectives of a significant sub-revolution of the FIR in terms of TH concepts.
- To make suggestions for further research.

RESULTS

The results are presented in three sections namely perspectives of (A) the hype and weak identity of the FIR, (B) the entrepreneurial university and (C) triple-helix (TH) and innovative eco-systems.

(A) The hype of a weak FIR identity

General observation through conferencing, networking, university visits and literature does not indicate a very clear picture of the FIR. Besides its vague identity its morality, reality and progress needs to be re-visited due to the emotional hype of the movement. True business intelligence is to better understand the idea of real-time customer analytics by means of customer intelligence (CI). Detailed customer data provides everything about the customer and the best way to interact with each individual customer. This is simply common sense even if it encompasses the simulation of human intelligence and artificial intelligence.

The big, agile and better movement cannot be peremptory, but is it always good? The sometimes socially blind going with the flow can be a human weakness and it may be necessary to approach this tumult with the underlying promising rhapsodies with care and trapse. This aggressive propulsion may not be for a prodigious utopia with radiance and revelry, but driven by a remonstrative ravenous. This view may be abstruse (or a mere aversion for change) but benefaction do not have to be a disruptive fighting for an apex. The changes in industry may be normal or anomalous but with consistent barbiturate artifice and consummately.

The FIR originally encompassed machine-to-machine (M2M) technology, telematics and connected devices. The hype and different names for the FIR identity and reality seems to be tightly intertwined. Hyperbole and optimism have been combined and there is evidence of a new generation of case studies that elicit amazement. Smart factories performing near-miraculous feats because robots can think, machines communicate, cameras fly and inventory is available just-in-time.

On the other hand it quickly becomes clear that few have achieved a high level of maturity with an end-to-end FIR environment. Investment into these technologies has been strong, but most are largely focused on conventional manufacturing or solving a particular problem or weakness of the organisation. Evidence is sought of a holistic integrated enterprise strategy related to the FIR. The hypothesis is therefore the existence of a significant gap between executive ambition and transformative action. Most companies in the current uncertain world economy are considering whether they should invest in technology and how much integration is necessary.

Terms like digital disruption, quantum computing and artificial intelligence cause a variety of emotions including confusion and fear. Humankind went through many known and unknown revolutions and the FIR may not be what people think. Multiple previous and current sub-revolutions are at work and even the secret societies of the ``under-world`` may never be underestimated. The conservatives will remind communities that it's all about strategic shifts to remain competitive. The emotions, velocity and uncertainty of the impact of technological shifts predicting several ramifications for the way we will live can however not be ignored.

Operations management decisions were always dynamic and creative. The discipline will remain the same although strategic operations management will see a new focus on technology partners, digital transformation, business re-invention and operations excellence. Operations management will see the growing importance of the integration of business functions, ERP (enterprise resources planning) and lean synchronisation. Cyber-physical systems driven by the internet will bring the real and virtual worlds closer together. The most significant change in the production world may be in terms of data, where modern information and communication technologies merge with conventional processes. The internet of things will be central to new technological developments and the shifting of paradigms will result in all types of disruptions. Fresh technologies and innovation will bring new possibilities for doing new things faster, better and cost-effectively. The concepts are not all so new or different, and old ones not so old. These principles were always part of the core operations performance objectives and the FIR may be nothing else but a culmination of facets of the industrial engineering excellence.

Conventional principles of improvement (based on old techniques) can still be powerful. Although the principles from Hansen and Goelzer (1996), for example, are focused on noise reduction (with multiple win-win advantages), they are applicable to basic operations and technology management:

- Maintenance: replacement or adjustment of worn or loose parts, balancing of unbalanced equipment, lubrication of moving parts and use of proper cutting tools.
- Substitution of components (or less noisy materials) and substitution of processes. This may include the substitution of equipment such as stepped dies rather than single-operation dies, rotating shears rather than square shears and hydraulic rather than mechanical presses. Substitution of parts of equipment such as modification of gear teeth by replacing spur gears with helical gears have economic advantages and also generally resulting in 10 dB noise reduction.
- New benchmarks for work methods are always welcome. In the context of noise reduction, moulding holes in concrete rather than cutting after production of concrete component must be considered. Select slowest machine speed appropriate for a job and minimise width of tools may have also have multiple advantages.

A new kind of knowledge management (KM) caused a new wave of innovations (inventions) over the past decade. The Triple-Helix (TH) concept (discussed in section C) is powerful and can be regarded as the foundation of this sub-revolution. Leydesdorff (2018) notes that the FIR introduced new metaphors replacing and perhaps encompassing older models such as the National Systems of Innovation (NSI), the Knowledge-Based Economy" (KBE) and the Triple-Helix (University–Industry–Government relations). The author argues that the innovations during the FIR remained to be programmatic while "industrial revolutions" can be associated with the development of capitalism driven by technological innovations. The emotional hype of "Big Data" may not need to be so big because the knowledge is not in the data, but in the quality of the utilisation of the data using models. If the metaphors of KBE and TH is used the data is not "given" in nature but constructed in previous cycles. The FIR may therefore not be this radical new change on earth because TH and other sub-revolutions may be more significant.

The advantages of innovation and new technology must be measured holistically and not only financially. It may be good to be neutral or frivolous to any movement to prevent a helter-skelter going with the ebullient flows of life. To be in the front-line demands bold and unique esoteric decisions to gain the benefits of an encroached niche market, but it may also debilitate human resources due to its extraneous unfamiliarity. Some touting leaders can manipulate the organisation in a credulous and syllogism manner that should rather have been a divulsive or elucidated decision to deny the opportunity.

Reischauer (2018) question the claim that the FIR represents a revolution that will reshape manufacturing industries akin to previous industrial revolutions. The author states that despite the popularity of this claim, it provides no real help to clarify the identity of the FIR. Such a clarification is much needed given the emotional excitement and the worldwide proliferation of digital technologies in manufacturing. Reischauer addresses this gap by arguing that the FIR is a policy-driven innovation discourse in manufacturing industries that aims to institutionalize innovation eco-systems encompassing a major sub-revolution such as the Triple-Helix (TH) of business, academia, and politics (discussed in the next sections).

The FIR identity also seems to be a fusion of technologies that is blurring the lines between the physical, the digital and biological spheres. One thing is sure - the speed of technological breakthroughs has no historical precedent, but the threat for humans to be ``robotized`` must be managed with creativity and stewardship. All the dimensions of artificial intelligence of this revolution are improving the quality of life for all. Larger amounts of data increase the hope for more in terms of ``big data``. It is not the FIR that is causing the swelling data deluge, but there is no doubt that with big data sets we can do things that were previously impossible. The amount of zettabytes of data produced in the world may even grow to 40 zettabytes during the next few years. The functionalities for data storage and information exchange will increase. Products will have passive data storage and also storage for autonomous information exchange. This however, does not fully clarify the FIR identity.

The FIR `toolbox` may bring more clarity. As mentioned, many technologies such as robotics, automation, the internet and smart factories are not new – but the applications are. Sensors are nothing new but the integration of sensors is. Sensor readings are now processed by the product. Products will send and receive signals. The product will have types of connectivity such as industrial Ethernet interfaces. So besides data storage and exchange, the toolbox will dramatically improve regarding monitoring (detection of failures) and additional possibilities (models) around the product. The Helsinki Institute of Information Technology founded a company for all touch tracking software. The technology can pick up and track an unlimited number of fingers, hands and objects.

Factories will remain to be noisy places while the Industrial Internet of Things (IIoT) leads to more electronics in factories and electromagnetic noise replace audible noise (that may cause new health risks). As the need for process efficiency increased, factories will be filled with sensors for process monitoring, to reduce costs and pre-emptively predict failures. Each sensor produces a magnitude of data (so called "big data") which travels through wires and across the airwaves, creating electromagnetic noise. With the addition of hundreds (or even thousands) of sensors, along with computer and other communication networks, there are more devices than ever. Although modern electronics is a long way from the heavy equipment originally found in factories, modern devices may run on low voltages (even a few millivolts) of noise, but a signal line can wreak havoc with high-speed data feeds (https://www.eeworldonline.com/modern-factories-electromagnetic-noise-is-replacing-audible-noise/).

It is certain however that smart factories and other manufacturers alike will obviously need to remain relevant in the market place. They cannot ignore change and need to begin the process of digitalization (and designing cyber-physical systems) by defining the vision, developing the strategy, setting goals, and starting with small pilot projects.

(B) Entrepreneurial universities

Entrepreneurial universities became more open for engagement and involved in partnerships, networks and other relationships to generate an umbrella for interaction, collaboration and co-operation. Although conventional traditions must be retained and carefully treasured, the implication is that universities will not remain the same since natural evolution, economic pressure and formal changes to university structures are transforming internal cultures, social relations and functional integration in new ways not yet foreseen.

What started to be a method to elaborate contract research, sell patents or offer short courses for an additional stream of income, developed into institutions becoming central to innovation eco-systems. The modern university (and the top universities in the world such as MIT, Stanford and the University College of London) adopts a new kind of knowledge management (KM) with established industry–science links and technology transfer organisations (TTOs) actively engaging in different configurations of UBC (university business cooperation).

A compelling case as to why businesses should partner with universities is about smart collaborations. Data from the Australian Bureau of Statistics indicates as much as 16 000 Australian companies have formal ties with higher education institutions. That is an average of 410 industry partners for every university in Australia. Another unique collaboration is by Telecom Italia (TIM) who redefines knowledge and technology transfer through open labs (Woolley & Diriba, 2018). The collaboration between TIM and Italian universities represents an ideal UBC environment. TIM has filed close to 30 applications for patents and more than 60 PhD's have been completed as part of the collaboration.

Sam and Van der Sijde (2014) reviewed the taxonomy of the three European higher education models, namely the Humboldtian, Napoleonic, and Anglo-Saxon models, followed by a discussion on the emergence of the Anglo-American model of higher education. The Anglo-Saxon model focuses on personality development through liberal education. Soft skills are emphasized in modern higher education to enable students to act flexibly and intelligently in a changing and challenging environment. It is characterised by professionalism, institutional autonomy or self-governance. It seems the risk is too high for those against the entrepreneurial university when the overwhelming progress and advantages gained from the Anglo-American model of HE is considered.

Although complex, the phenomenon confronts the core tuition mission of the university. Loi and Chiara Di Guardo (2015) refer to the third mission of universities in their investigation of the espoused values as "an invisible revolution". They note different orientation patterns such as the need for coherence, exploitation, readiness to participate in external change and to satisfy external needs, and focusing on entrepreneurial activities as a source of funding. It shows a complex phenomenon for the institutionalization of the third mission with respect to a simple binary public–private opposition.

Audretsch (2014) refers to the entrepreneurial university for the entrepreneurial economy and examines how and why the role of the university in society has evolved over time. Van Looy, Ranga, Callaert, Debackere and Zimmerman (2004) report on a study indicating how scientific performance and entrepreneurial activity among academia promote research outputs. The exposure to more creative opportunities and the types of industry–science links complements the areas of research and outputs. Van Looy et al. (2004: 438–439) state that as resources increase, this interaction becomes more significant, pointing towards a Matthew effect. The entrepreneurial universities of Holland are well-known and Hofste-Kuipers (2016) from the University of Twente (UT) indicated how UT became number one in the valorisation ranking of Dutch universities. The next section continues with the entrepreneurial university in the context of TH and eco-sytems.

(C) Triple-helix (TH) and innovative eco-systems

The Triple-Helix (TH) concept is a body of thought referring to knowledge spaces brought about by inter-related roles of engagement by government, academia and business as TH actors. The underlying philosophy is to find synergy though cooperation. The Triple-Helix Association (www.triplehelixassociation.org) originated at Stanford University under the leadership of Professor Henry Etzkowitz. The highly rated Massachusetts Institute of Technology (MIT) is a benchmark for TH consultation. They provide a body of knowledge to help universities to cooperate with industry and government, to develop innovative markets, to promote more innovation-friendly financial institutions and to make universities interactive entrepreneurial partners in the broad national innovation systems. The TH mode of innovation highlights the multidisciplinary foundation of innovation as a model for analyzing innovation in a knowledge-based economy. The TH mode of innovation challenges traditional ways of how business, politics, and academia innovate as actors. It urges them to cross the borders of the sphere of society they mainly operate in and orientate towards (Etzkowitz and Viale, 2010).

Etzkowitz, however, described the development of MIT into an entrepreneurial university since the 1930s. This make the entrepreneurial university not so new although the interaction with industry and government was not so prominent. Recently all the TH leaders gather during the annual university-industry-interaction (UII) conference. The TH concept showed tremendous growth and has tremendous interest and power. Many public universities are moving out of a comfort zone defined by some as a traditional ethos of slowness and complacency. This social revolution cannot be mistaken and the vision of Etzkowitz (1994) can be seen in his work titled "Academic-Industry Relations: A Sociological Paradigm for Economic Development".

Although many are against TH in terms of traditional education ethos, it is made more acceptable as a voluntary opportunity for academia to combine the interest in university–industry relations with the dynamics of science and technology. This became the TH model but richer models could be developed by using the Quadruple Helix approach (with a fourth dimension such as social-ergonomics or upscaling agility as sub-revolutions on its own) or an evolutionary model firmly anchored in both Etzkowitz's interest in the institutional dynamics of relations and the operationalization of an evolutionary model of the knowledge-based economy in terms of a few dimensions of social dynamics.

Leydesdorff (2018:7) provides a perspective and summary of the differences between institutional TH and evolutionary TH. The author acknowledges the known TH overlay model (with government, university and industry) of government interacting with universities and industry, industry interacting with government and universities and universities interacting with industry and government. The evolutionary TH model similarly describes the same triangle (the triple helix) with a focus on innovation by means of policies (replacing government), markets (replacing industry) and sciences (replacing university). Innovative ecosystems usually consist of institutional partners for the sake of innovation. Dondofema and Grobbelaar (2018) used case study research to analyse innovation platforms in South African healthcare sector. The authors provided an innovation ecosystem perspective and a value chain perspective on innovation platforms. Their study included concrete observations, predictions and the evolution of theoretical frameworks. There are many international examples of ecosystems designed for innovation not for (or because of) the FIR.

Visits to top entrepreneurial and innovative universities provided multiple observational and informational artefacts of industrial engineering, technological developments, triple-helix (TH) and the upscaling of agility as sub-revolutions of the next industrial revolution. The perspectives obtained share intuitions that technical artifacts are objects that exist by human intervention and technical artifacts (contrasted to natural entities). Perspectives obtained indicates that the FIR is not the cause of changing the rules of business through digital disruption for a hyper-connected world but rather the result of multiple sub-revolutions (movements) of normal culture shifts and sound strategic management. The following section briefly describes ten examples of institutional artefacts of TH strategically positioned within a specific eco-system for innovation observed during research visits:

- Maastricht University Brightlands ecosystem - their `core` philosophy stands for collaborative open research education. They create TH hotspots on the Brightlands campuses. This is a continuation of the Knowledge Axis investment programme. The focus is on future challenges such as safety of food, affordable care and cybersecurity.
- Leuven eco-system, Belgium - KU Leuven is a research-intensive international university, known for the world's leading anti-HIV drug and central to the innovation eco-system. Research volarisation constitutes an important form of societal return. Their institutes support high-tech entrepreneurship with a long tradition of technology transfer, collaboration with industry and creating spin-off companies. The eco-system consists of several incubators, science parks such as the renberg Science Park and Haasrode Science Park and business centres in the Leuven region.
- Kennispark Twente - this innovation campus is in the midst of high-tech SME's. The innovative ecosystem has innovation centres such as for advanced materials, road safety, thermoplastic composites, micro and nano technology, medical imaging and technologies for recycling, wireless sensors, cloud computing and re-using textile. Apollo Global R&D centre in Enschede, Cottonwood Technology Fund and Foseco R&D center are located in this region due to the vibrant eco-system. Medimate Twente is another production location for healthcare solutions and nano-products
- Innovation exchange Amsterdam (IXA), University of Amsterdam, provides support in the entire valorisation process helping inventors (from the region and outside) into partnerships with organisations.
- The Technology Centre (TC), University of Amsterdam, develops scientific instruments in the fields of glass, construction, electronics and software.
- Innovation network Science Park, Amsterdam, hosts innovative companies and research organisations at the Science Park. Most of these companies seek partners, valorisation and new ventures.
- TU Innovation lab, Eindhoven University of Technology - the university's activities related to knowledge transfer and research is coordinated in this lab. Scientific knowledge is translated to small businesses.
- Aalto University, Finland - the university is known for more than 3000 doctoral students and its brain simulation technology. The MIT study of 200 top universities ranks Aalto very high. Design thinking for business innovation is a program presented by the ESADE business school. The centres of excellence include computational nanoscience, Inference research, Generic Intelligent machines, Samert Radios and Wireless Research.
- Strathclyde, Glasgow, University of the year (2013/2014) – this leading technology university has centres for innovation and for applied photonics. They support enterprise research and is known for its high spin-off company success.
- ASML, Veldhoven, Netherlands, produce integrated circuits (or chips) populating the modern world. Lithography machines produce microchips and this implies the integration of transistors. They can create structures as small as 20 nanometers.

Conclusions

The paper indicates a weak FIR identity that may be improved (clarified in a model) by acknowledging the unnecessary hype and other sub-revolutions. The FIR is not the cause of changing the rules of business through digital disruption for a hyper-connected world but rather the result of multiple sub-revolutions (movements) of normal culture shifts. A sceptical perspective was discussed and it also highlighted some potential dangers of the FIR (and its hype). The paper identified and discussed other dimensions of the FIR and especially highlighted the massive sub-revolution of TH and its eco systems. Other sub-revolutions (eg. agility and social ergonomics) are identified for further research.

In terms of further research, a Quadruple-Helix model could be developed for the FIR. The quadruple helix model adds a fourth component to the framework of interactions between university, industry and government, namely civil society and the media. It was first suggested by Carayannis and Campbell (2009) as the `Quadruple-Helix' model towards a 21st century fractal innovation ecosystem`. The aim is to bridge the gaps between innovation and civil society (the social sciences). Indeed, this framework claims that under the TH model, the emerging technologies do not always match the demands and needs of society, thus limiting their potential impact. This framework emphasizes a societal responsibility of universities, in addition to their role of educating and conduction research. This is the approach that the European Union has intended to take for the development of a competitive knowledge-based society. In terms of this paper (and the sub-revolutions mentioned) a quadriple helix model of the FIR can be considered.

Civil society, CSR (corporate social responsibility) and social ergonomics are only a few terms associated with a new social revolution. Since we can't digitize human talent, dreams, humour, creativity, morality, ethics, life, experience and so forth, successful organisations will be those that are able to fuse the digital world with the social sciences. Social ergonomics may fit the model because the increased respect for human well-being makes ergonomics a social-technical science. The overwhelming focus on aesthetics of things at the cost of the well–being and quality of work–life (QWL) of people has led to this concept (social ergonomics) utilising a combination of engineering, design, and social science to assist companies to change how people interact with technology (MacLeod, 2008). This is especially powerful when individuals are educated to improve their own ergonomics in terms of their own work environment to work smarter, safer and healthier. This sub-revolution focuses on personal empowerment, job enrichment, community ergonomics, new work paradigms, participatory design and virtual organisations. The social ergonomics philosophy promotes the best technology that fits people by challenging the status quo (www.socialergonomics.com).

The spiritual leaders of today will advocate the human element and to improve organisations will have more open conversations, understand end users, be exceptional in the eyes of the internal and external customers, consider new kinds of skills to be future-fit, learn to listen to alternate voices and nurture human talent.

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Biography

Rigard Johan Steenkamp is fulltime professor in Operations Management at the University of South Africa. He holds Bachelor of Commerce (BCom) in Marketing Management, MBA and DCom degrees from the University of Pretoria. As an academic and practitioner he received multiple researcher of the year awards, two teaching awards and the AHI Business of the Year award. He has taught several courses related to operations, project and quality management and published widely on related OM topics including TQM, service quality, corporate entrepreneurship (Triple-Helix) and leadership. Professor Steenkamp participated in several international conferences (IBC, EDSI, EOQ, IEOM, Euroma, etc) and he is also the leader of the UNISA TQM 12-month short learning program (SLP) and author of several books. His CSR community engagement program is Moves for Life (www.movesforlife.co.za) to support the sport Chess at schools. He is a sport lover, entrepreneur and also publish on life from a Biblical perspective.