Industry 4.0 Collaborative Research, Innovation and Development (RID) Projects[1]

Prof. Dr.Brane Semolic (Slovenia) and Prof. Dr.Pieter Steyn (South Africa)
LENS Living Lab & Cranefield College

Abstract

Post-globalisation industry, called "Industry 4.0" (there are some forecasts of Industry 5.0 already), characterised by digitalised high-technology and instability of business environments, demands continuous inflow of novelties, innovative improvements, and change. Modern technology products and solutions are geared by the mix of interrelated technologies, powered by different professions and industries. Digital and innovation literacy, supported by a collaboration culture on all levels and areas of business is becoming the critical enabling competencies of societies. ***"Open the boxes and collaborate with the partners in your value chain"***. Find new authentic business models for exchange of information and ideas. Establish collaboration with stakeholders (customers, end-users, suppliers, partners, technologies, developers, etc. These are the main challenges of contemporary organisations and their environments. Modern effective and efficient organisations are becoming more cross-functional, flexible, agile and virtual. Their boundaries are blurred and not closed as they were at the time of the early industrial eras. This paper discusses management and leadership complexity challenges of collaborative industry research, innovation and development projects, its innovation ecosystems, and related emerging competencies.

Keywords: projects, project management, collaboration, virtual organisation, research and innovation, open innovation environment, communities, complexity

1 Introduction

In recent years the world is witnessing simultaneous and profound changes in all areas of private and public corporate activities. Organisational and private lives are becoming highly volatile and value-driven, demanding continuous innovation and learning. These changes, caused by the inflow of new digital ***enabling technologies***[2] intertwining with our daily lives, influence the way we are performing our organisational activities and

[1] How to cite this paper: Semolic, B. & Steyn, P. (2018). Industry 4.0 Collaborative Research, Innovation and Development (RID) Projects, *PM World Journal*, Vol. VII, Issue VIII – August.

[2] Enabling Technologies - Equipment and/or methodology that, alone or in combination with associated technologies, provides the means to generate giant leaps in performance and capabilities of the user. For example, the coming together of telecommunication technologies, internet, and groupware has leveled the field so that even smaller firms are able to compete in areas where they otherwise could not (Business Dictionary, 2018)

daily chores (Semolic and Steyn, Sept. 2017). Moreover, this is only the first taste of dramatic changes in the years to come.

The key research findings in the *2016 Global Industry 4.0 Survey Report*, published by PWC (*Geissbauer, Vedso, Schrauf, 2016)*, reflect the following needs or situations:

- Industry 4.0 moved from theories and strategies to the real investments and actions.
- Companies that successfully implemented Industry 4.0 no longer need to choose between focusing on a better top or bottom line. They can improve both at the same time.
- Deepen digital relationships with more empowered customers. Customers will be at the centre of changes to value chains, products, and services.
- Focus on people and culture to drive transformation. This survey output shows that industry's most profound implementation challenge is not the right technology, but a lack of digital culture and skills in their organisations.
- Data analytics and digital trust are the foundation of Industry 4.0.
- Robust, enterprise-wide data analytics capabilities require significant change. Companies need to develop robust organisational structures to support data analytics as an enterprise-level capability.
- Industry 4.0 is accelerating globalism, but with a distinctly regional flavor.
- Significant investments with big impacts are required: It is time to commit. It is estimated that global industrial product companies will invest USD 907 billion per year through 2020. The primary focus will be on digital technologies like sensors or connectivity devices, as well as on software and applications like manufacturing execution systems (MES). Moreover, companies are investing in the education and training of employees, and driving organisational change.

The *Roundtable on Digitizing European industry – Work Group 1 Report*, avers that ***"digitalization is essentially an innovation issue"***, and organisations are approaching it with the usual wide variety of attitudes, methods and expectations encountered in managing innovation. These attitudes depend on the ***organisation's digital maturity***[3]. The urgent need for such innovation and change should rather be explained and motivated by the language of increasing profitability, competitiveness or customer satisfaction rather than hard technologies. Abstract terms such as "Industry 4.0" or "digital transformation" are likely to be unattractive in some business environments, like small and medium-sized enterprises (WG1 Report, 2017).

Global intensive digitalisation processes and technical complexity of industry products and services are generating ***the new landscape*** of Industry 4.0 markets. The global and regional markets are in ***the process of radical strategic change and***

[3] Digital Maturity – "Digital maturity is about adapting the organization to compete effectively in an increasingly digital environment. Maturity goes far beyond simply implementing new technology by aligning the company's strategy, workforce, culture, technology, and structure to meet the digital expectations of customers, employees, and partners. Digital maturity is, therefore, a continuous and ongoing process of adaptation to a changing digital landscape" (Kane et al, 2017)

transformation. Big companies will not solely dominate on these markets anymore. There is a place for innovative small and medium-sized companies that are becoming global leaders with their innovative products. Capacities to generate market attractive products and services by exploitation of the creative mix of own, regional and global technology resources formed in the innovative, flexible digitalised processes of agile, value and supporting supply chains, will be preconditions of business success. Allocation and sustainable exploitation of the regional innovation potential can generate benefits for all involved parties in such endeavors.

Industry 4.0 businesses are flourishing in regions and countries with adequate competencies, available resources, transformational leadership, sound corporate culture and sustainable regional support. Modern Industry 4.0 organisations in regions and countries are searching for new mechanisms to create favourable business conditions by providing adequate supporting services (Steyn and Semolic, March 2017).

It is evident that technology changes are not enough to achieve expected results, as was the case in the past. This problem was addressed in an article where the following was noted: *"Futurists often equate advances in technology with advances in civilization (Celente, 1998). To exploit innovative technologies for the benefit of all stakeholders requires a profound understanding of how these* ***novelties will affect*** *personal and business lives, organisations in developed and less-developed countries, and how they will reshape organisational landscapes, societies and culture. It is vitally important to gain a holistic understanding of the risks involved and to plan appropriate solutions for the timely mitigation of the risk and associated complexity*". The burning question is how organisations can successfully cope with such complex strategic transformation and change processes.

2 Industry 4.0 – the Age of "Smart Systems"

What are the critical success factors of business success in these dramatically changing business environments? Very often one hears or reads that there is a need to develop and utilise "Smart Systems" in organisations and all level of societies. What is the meaning of "Smart System" in this case? There is no unique definition of this phenomena. The use of this term can be found in different circumstances like smart machines, smart buildings, smart infrastructure, smart regions, smart cities, etc.

Common to all these cases is that all deal with the technologies, business models, and or competencies issues connected to the Fourth Industrial Revolution (Industry 4.0). It is concluded that the business environment is faced with a "techno-social" phenomenon. Smart digital technologies-based solutions deal with big data, analytics, feedbacks and adaptabilities of observed systems capabilities. The social part of "smart systems" deals with the recognition, development, and exploitation of personal, corporate, regional, and or national competencies with available resources, and the support of new business models.

All the technical and non-technical components of smart systems are intertwined and interrelated. One needs to address related innovation challenges and changes holistically as shown in Figure 1. Utilization of simultaneous bottom-up and top-down approaches is needed to achieve planned strategic transformation goals and generate value for all stakeholder involved. Figure 2 illustrates the complexity of interrelated areas of "Smart Systems" applications.

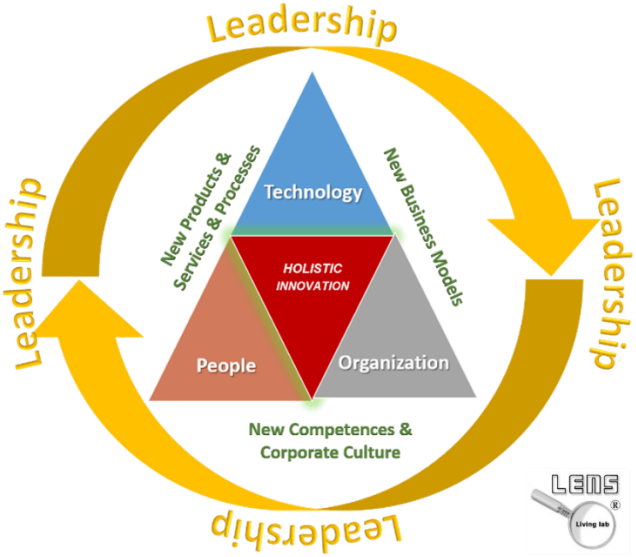

Figure 1: Holistic approach to innovation (Semolic, 2014)

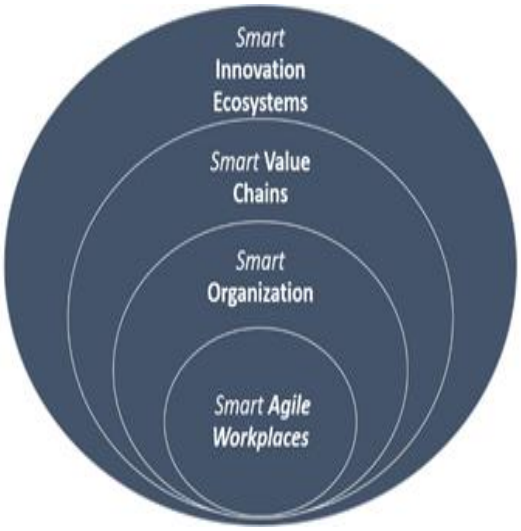

Figure 2: The complexity of interrelated areas of "Smart Systems" applications

"Smart Solutions" alone are not sufficient if not followed by sound collaborative: strategies, programmes and projects that generate benefits, as well as value creation for all collaborative partners and stakeholders (Semolic, 2016; Semolic and Steyn, Sept 2017). As shown in Figure 3 this needs to be orchestrated and synergised at all levels to exploit the total available innovation potential of participating value chains, research and innovation organisations, and regional, national and international business support agencies.

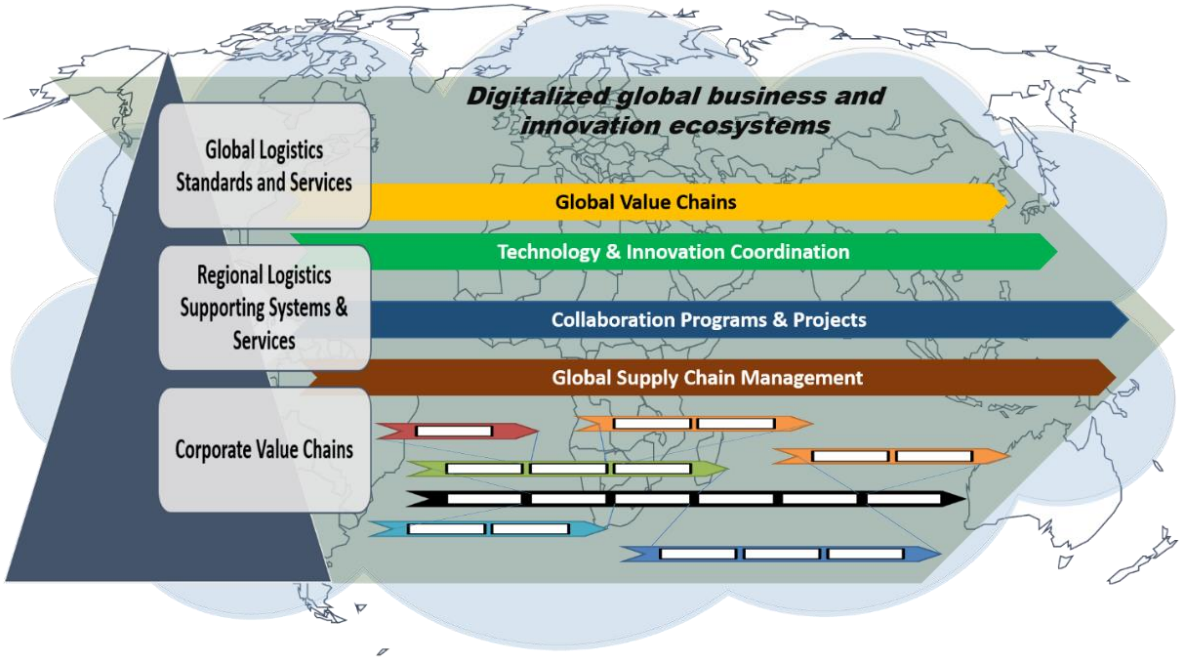

Figure 3: The Industry 4.0 innovation ecosystem
(Semolic, 2016, Semolic and Steyn, September 2017)

3 Industry 4.0 – Complexity Issues

What is "complexity"? The Oxford Advanced Learner's Dictionary explains the term "complex" as "having many parts connected in a particular pattern, a complex system or difficult to understand or explain because there are many different aspects or people involved". The same source defines it as "the state of being complex" (Oxford ALD, 1995).

The topic of "complexity" is a challenging issue for all Industry 4.0 driven technologies and organisations. Scientists encounter complexity a challenging issue as they probe the limits of the understanding of nature (Nam P. Suh, 2005). Cartwright (1991) explains complexity theory as the study of nonlinear systems promising to be a useful conceptual framework that reconciles the essential unpredictability of industries with the emergence of distinctive patterns. Levy, et al (2000) aver that this theory was originally developed in the context of physical and biological science, and note that social, ecological, and economic systems also tend to be characterised by nonlinear relationships and complex interactions that evolve dynamically over time.

The Industry 4.0 explosion of complexity is caused by rapid development of global markets and the continuous creation of new technologies and products. This stimulates the emergence of new forms of organisations and competences. Complexity is coupled with new products, services, technologies, emerging industries, new business models, organisation systems, projects, etc. Research aims to explain how the mix of these

technical and non-technical elements of complexity supports experts to cope with the chaordic Industry 4.0 economic environment.

Michael Simmons (2018) claims that he found studies independently conducted by four of the greatest thinkers of modern times that came to the surprising conclusion that many of the world's top entrepreneurs, like Bill Gates, Steve Jobs and Elon Musk, along with some Nobel Laureates, posess a rare skill called "***integrative complexity***." Integrative complexity is the ability to develop and hold opposing traits, values, and ideas and then integrate them into larger ones.

Knowledge and insight into every segment of Industry 4.0 technology and businesses complexity phenomenon are needed to understand and manage it successfully. The tools of formal modeling can be used to describe the complexity of observed phenomena and its different forms. Such codified knowledge can be useful for practitioners and further theoretical exploration.

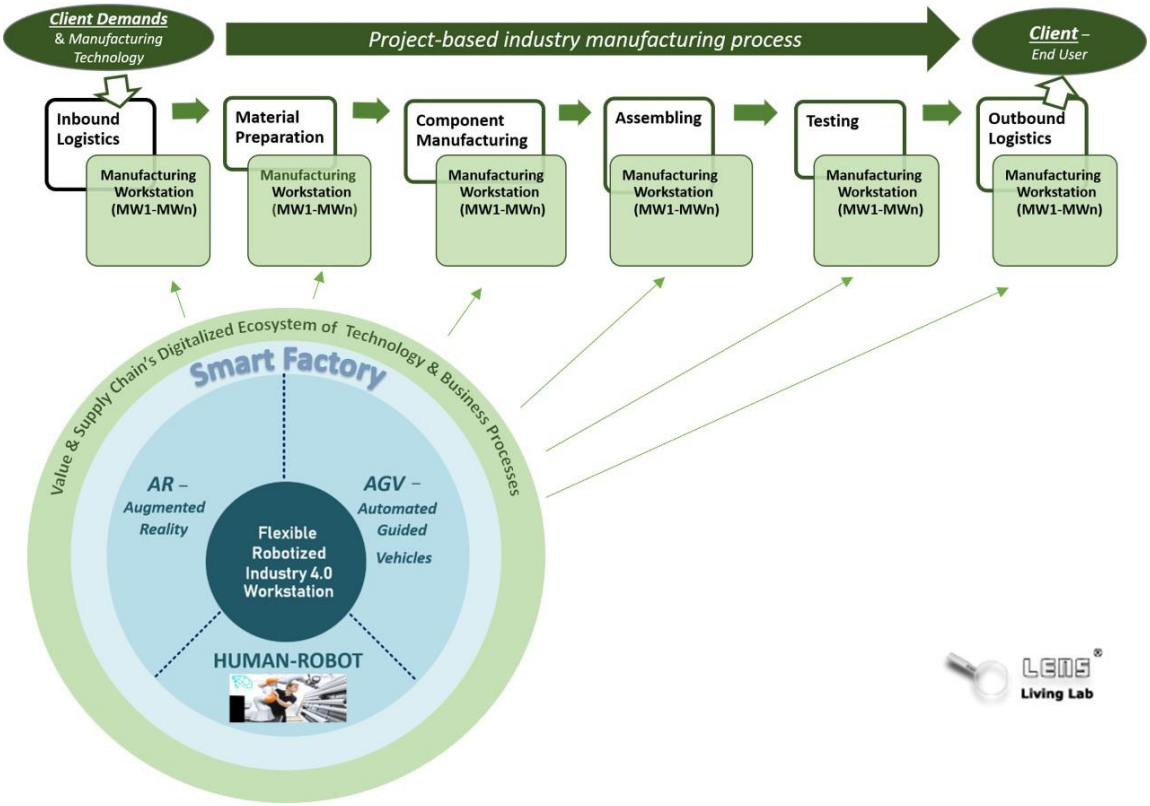

Figure 4: The complexity example illustration in the Industry 4.0 manufacturing process, innovation ROBOFLEX-1 project business case (Semolic, 2018)

Figure 4 (Semolic, 2018) is an example of complexity modeling. It is part of an actual industry manufacturing innovation project, where a company searches application opportunities for the use of cognitive, flexible and supporting digital technologies aimed at improving its competitiveness. In this case the company exploits its own innovation capacities and the potential of the pan-European innovation network of regional competence centres. These centres were established by the EU-funded partnering innovation project named "HORSE"[4].

In the above company's region, the network is presented by the technology innovation partner "*Competence Center ROBOFLEX."* This regional competence centre specialises in robotics and supporting digital technologies application development and integration for the needs of small and medium-sized manufacturing companies. It is a member of the regional digital innovation hub (DIH)[5]. The DIH's members provide a portfolio of technology development and innovation implementation services needed for efficient Industry 4.0 technology innovation project implementation as shown in Figure 5.

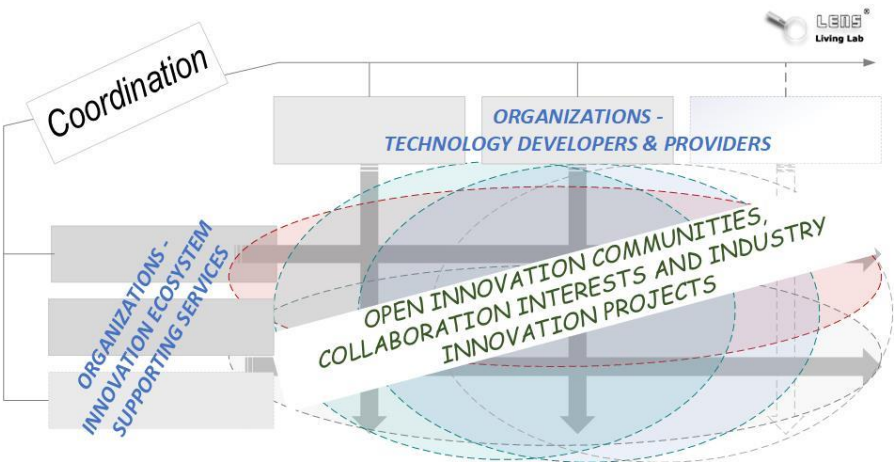

Figure 5: Illustration of the regional open innovation DIH architecture (Semolic,2018)

The purpose of this modeling and practical illustrations is to understand project business case complexity and support communication and better understanding between stakeholders.

[4] HORSE – Smart Integrated Robotics System for SMEs Controlled by Internet of Things on Dynamic Manufacturing Processes (This project has received funding from the European Union's HORIZON 2020 research and innovation program under grant agreement No 680734)

[5] Digital Innovation Hub (DIH) – is a support facility that helps companies to become more competitive by improving their business/production processes as well as products and services by means of digital technology (WG, 2017)

4 Industry 4.0 – Challenges

One of the most significant challenges is addressing the traditional gap between technology, organisation and behavioural development. An example of this situation is when new technologies are not entirely integrated and used beneficially to generate the value for all technology stakeholders. It is natural that technology development is faster, and enable both organisational and behavioural development. This gap can be closed by utilisation of new business models and adequate transformational leadership.

However, some traditional problems need to be resolved first. The following elements represent the issues driving the above gap (Semolic, 2018):

- Lack of adequate technology literacy.
- Lack of holistic and multidisciplinary approaches to the strategic transformation and change required when addressing technology, organisational and behavioral aspects simultaneously (at all levels and areas of society).
- Lack of equality perception and importance of all needed and involved professional disciplines (limited communication and understanding between different professional communities; different terminologies and different sub-cultures; all of which promote the well-known phenomena of “ivory towers”).
- Lack of collaboration culture between the value chain’s internal and external stakeholders.
- Lack of competencies, wrong beliefs, outdated industry and business values.
- Poor transformational leadership, management, coordination and governance.
- Lack of trust.

The above problems need to be addressed simultaneously by governments in their national, regional and international strategies, programmes, and projects, as well as by business actors at the level of national and international industry, knowledge and innovation markets. Industry 4.0 organisations are operating in the high-tech and highly competitive business environments. Industrial businesses have become increasingly high-tech, sophisticated, dynamic and globalised. New enabling technologies are providing endless opportunities for the introduction of new products, services, and business models, or improvement of those existing.

Talent and innovativeness empowered by a collaboration culture and profound transformational leadership are becoming primary prerequisite for business success in inter-personal and inter-organisational digitalised value chains (Semolic, 2018). Customer orientation, process thinking, acting with the exploitation of all available resources and innovation ecosystem potential, with maximizing benefits for all involved parties, is becoming the postulate of sustainable business success. These processes need to be strategically orchestrated on the base of the adequate business model, recognized and understood by all involved parties.

5 Industry 4.0 – Business Modelling (BM)

The Business Dictionary describes a business modelling (BM) as: *"a description of means and methods a firm employs to earn the revenue projected in its plans. It views the business as a system and answers the question, "How are we going to make money to survive and grow?" (Business Dictionary, 2018)*. BM reflects the organisation's tangible and intangible views, as well as its business reactions to the market opportunities and trends. Joann Magretta claims that business modeling is the managerial equivalent of the scientific method; one starts with a hypothesis, which is then tested in action and revise when necessary (Magretta, 2002).

BM charter includes a detail description of business motivators, the value proposition for observed business clients and funding organisations, a list of products and services, development strategies and supporting systems, resources, processes, organisation, costs-revenue forecasts, as well as a finance and risks mitigation plan. The executive summaries of the BMs are usually presented and communicated by the use of different graphics tools, like BM Canvas, BM Radars, etc.

6 Industry 4.0 – Processes

The partnering innovation capacities dealing with the complexity of intertwined inter-organisational technological and business processes are critical competencies of Industry 4.0 organisations and their value chains. Industry value and supply chains are forms of a harmonised mix of business and technology processes. ***Technology***[6] ***processes*** deal with the technology applications for different industry and non-industry needs. Moreover, they deal with the physical operations of the product manufacturing process or physical performance of services. Modern organisations use a mix of different technological processes, systems, products, and services.

Based on the Harrington (1992) definition of a business process, ***business processes*** can be defined as service processes and processes that support physical technology transformation processes. A business process consists of a group of logically related tasks that use the resources of the organisation to provide defined results in support of

[6] Technology presents the link between science and practical use of its knowledge. Galbraith offered one of the first generic definitions of the term "technology" in his book "*The new industrial state*," published in 1967. He said that technology is the systematic application of scientific or other organized knowledge to practical tasks (Monck, Porter, Quintas, Storey and Wynarczyk, 1988). Technology is universal phenomena which can result in any knowledge area as its application for the practical use. Technology presents the know-how of transformation of existing or new knowledge gained from research and practical experience, which is directed to producing new materials and products, to installing new processes, systems, and services, or to improving substantially those already built or installed. According to Mitchem the term "technology" comprises the entire system of people and organizations, knowledge, processes, and devices which are related to the process of creating and operating of technological artifacts, as well as the artifacts themselves (Pearson and Young, 2002).

the organisation's objectives. Business processes generally utilise and support several technological processes needed in the organisation's operation processes, and the "technological products and services" of the process deliverables. Organisations deal with a combination of different technologies with respect to products, services, and processes, which in the Industry 4.0 business environment are becoming increasingly digitised and interconnected (Steyn and Semolic, May 2018).

Jorgensen, et al (1989) argue that successful strategic management demands a balance between operations, adaptation, and development management dimensions to preserve the successful performance of an organisation. Semolic (1993) avers that this concept leads to the identification and definition of related business processes that are the subject of these management dimensions. The business processes are as follows (Figure 6):

- ***Operation business processes*** are found in production systems. They are enablers and supporters of the physical transformation processes from input sources into products/services, and deliver value for market clients and other stakeholders;

- ***Adaptation business processes*** are operating business process adaptation agents, triggered by the internal organisational or market changes. Their goal is to protect existing business success that may be jeopardised by the various internal and external changes caused by technology, market, political, social, environmental, legal, or any other change. Fast adaptation responsiveness to occurred changes means retaining or even increasing a company's competitive strength;

- ***Development business processes*** are supporters and enablers of existing operation business processes' innovations and the introduction of novelty products, services, processes, and systems. Economically speaking, these processes need to secure incoming value potential and growth.

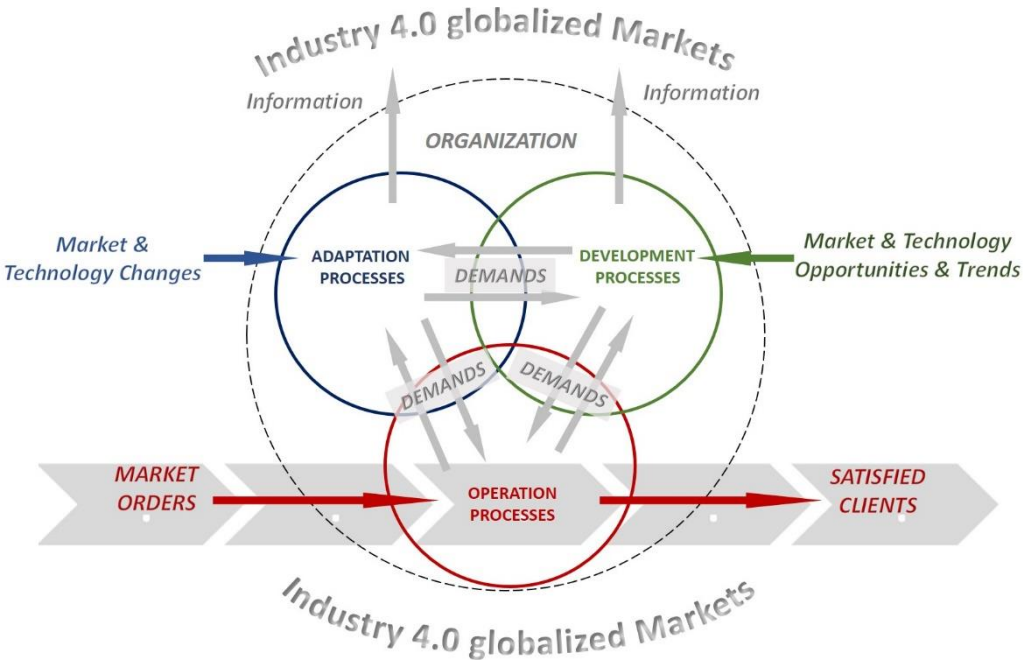

Figure 6: Application areas of business processes, with internal and external links (Semolic 1993, 1997, 2018)

The organisation is an artificial socio-technical formation that, due to influences of the environment in which it operates and to own entropy, is always under threat of failure. Hence, it is forced to continually adapt itself to change and develop its abilities and capabilities to survive and grow. It can achieve this by carrying out the above processes of adaptation and development.

Table 1 presents characteristics of the described processes with their typology.

Business Process Class	***Process Characteristics***	***Process Type***
Operation process	Mass process Batch process Unique process	Continuous process Continuous process Project
Adaptation process	Unique - process	Project
Development process	Unique – process	Project

Table 1: Characteristics of the described processes with their typology (Semolic, 1993)

Industry 4.0 operation processes deal with highly customised products and services. The trend is moving in the direction of entirely personalised products and services for client needs. It can be expected that project-based operation processes will become the dominant form of operational processes in the majority of industries (Steyn and Semolic, May 2018). Adaptation and development processes have characteristics of

unique business processes and are as such recognised as projects (see Figure 7). In industry business cases related to adaptation and development processes, organisational portfolios of various development, innovation, and industry research projects surface.

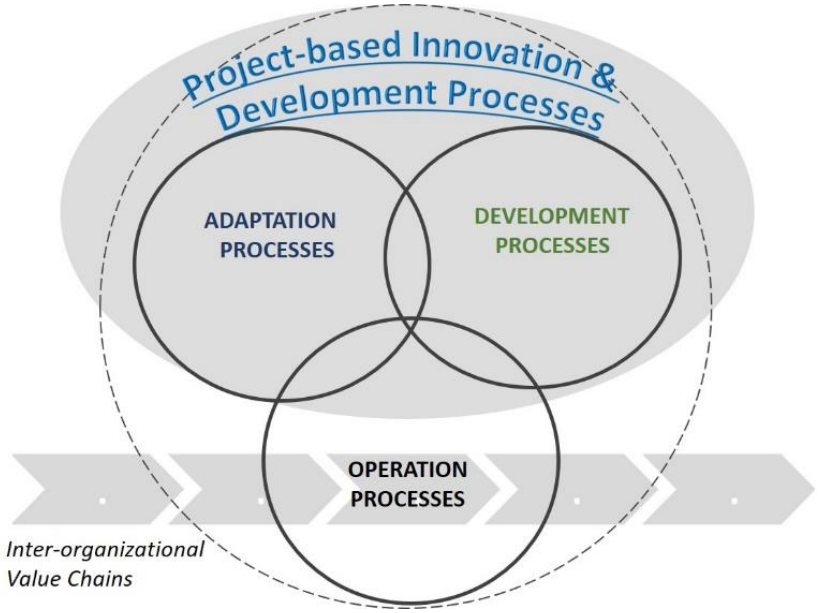

Figure 7: Adaptation and development processes identified as innovation and development projects (Semolic 1993, 1997, 2018)

The global Industry 4.0 high-technology markets and business environments are becoming profoundly dynamic and volatile. An adequate mix of optimised technology and business processes, harmonised with market needs and organisational strategic expectations are dominant requirements of modern businesses. Critical success factors of modern organisations are an ability to innovate continuously, being highly flexible and agile, and rapidly adapting to technology and market changes to meet specific customer needs while maximising value for all stakeholders. ***Authentic business models*** must be sought, innovated and developed continuously. Agile, digitalised and flexible processes are at the forefront of Industry 4.0. ***Project-based business processes*** are becoming the primary "***business and innovation vehicles***" of modern organisations and inter-organisational value chains.

7 Industry 4.0 – Management of Collaborative Research, Innovation and Development (RID) Projects

What is a collaboration project?

The terms "collaboratism" and "collaboratist economy", as also the decline of globalisation and rise of protectionism are comprehensively discussed in an article by the current authors (Steyn and Semolic, March 2017). Research, Innovative and Development projects are profound enablers of Industry 4.0 organisations and the degree of success they achieved. They provide a continuous stream of important business improvements, technical and non-technical novelties, and the agility required for survival in the high-tech, dynamic and chaordic global markets. Typical examples of collaborative projects and programmes are research-, innovative- and infra-structural development projects. Figure 8 is a matrix illustrating the technology and value chain complexities of Industry 4.0 research, innovation and development projects. The first dimension deals with the technical complexity of the project, demonstrated by the number of technologies involved in the project business case. The second dimension deals with the organisational complexity of the value chain business processes utilised.

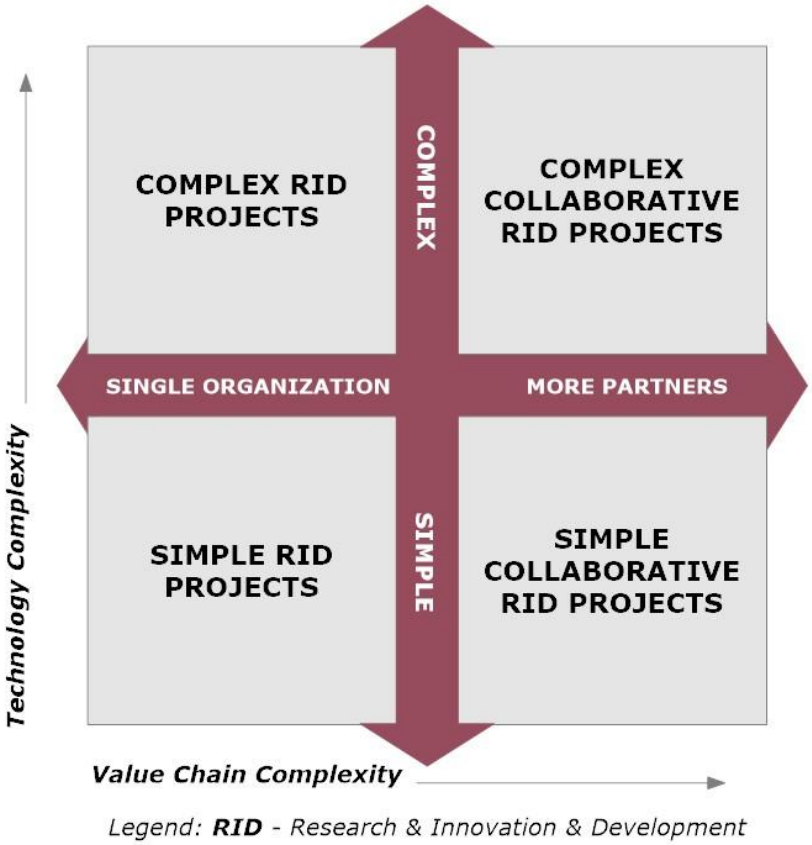

Figure 8: Complexity of the Industry 4.0 research, innovation and development projects

The above may pose a problem for small and medium-sized organisations with limited resources. They need to find other ways to solve the challenges. This may be to partner with the regional and global value chain partner-organisations and their stakeholders. Partners join projects on the basis of their interests and expectations. Such partnering arrangements form part of new emerging business models based on the organisational

concept of collaboration between legally and financially independent business entities seeking to realise their strategic intentions.

What is collaboration? The Oxford Dictionary (2018) defines "Collaborate"[7] as follows:

- Work jointly on an activity or project.
- Cooperate traitorously with an enemy.

The essence of the modern understanding of the term "collaboration" is reflected in the first bullet.

It is the difference between "cooperation" and "collaboration." Usually, one cooperates with project delivery organisations as suppliers of different products or services. Collaborating is partnering with two or more owner organisations in the various forms of project consortia.

Usually, collaborative projects in cases of various partnering RID projects are dealt with where two or more project owners are involved. In such projects, different, independent (not formally connected) organisations are collaborating on jointly identified and defined project business cases as partners with their own individual business motivations and expectations. The main business drivers for such partnering and collaboration efforts are:

- Limited capabilities (competencies, technology, specialisation, experience, etc.) and resources (human, equipment, financial) for planned applied research, innovation, and development efforts.
- Needs for sharing project costs and risks in pre-competitive industry research projects.
- Needs for the joint innovation ecosystem capacities development.
- Requirements of the external project-funding or co-funding organisations (different local, regional, national and international project funding agencies).

Collaborative RID projects are usually very complex and need the good understanding, orchestration and support of all project stakeholders in all project life cycle phases.

The complexity of collaborative RID projects

Basically RID projects and project management are integral parts of social sciences and at the same time complementary to other sciences like natural, engineering and technology, medical and health, agriculture, and humanities sciences. This dichotomy is inherent to all projects and depends on the application area of the specific project business case. Therefore, the complexity of projects and project management is related

[7] Late 19th century: from Latin collaborat - '*worked with'*, from the verb collaborare, from col - '*together*' + laborare '*to work'* (Oxford Dictionary, 2018)

to the study and explanation of observed non-linear dynamic systems and processes in an organisational environment relevant to the specific project business case.

There are six (6) levels of RID collaborative project and project management complexity as shown in Figure 9 (Semolic, 2013):

- **Level of physical processes and their outputs** – portfolio of physical processes of agreed incremental and final products or services;

- **Level of research, innovation and implementation technologies** – processes of practical application, and implementation of knowledge towards introduction of new knowledge bases, products or services by utilising a portfolio of different technologies;

- **Project level** – a unique collaborative enterprise to achieve specific collaborative business goals and objectives;

- **Project management level** – comprises management and leadership processes of the collaborative project;

- **Project governance level** – comprises collaborative controlling processes of project performance. Must provide resources, support and project visibility in all involved corporate environments. Responsibilities include an integration of project outcomes with individual corporate strategies;

- **Level of project stakeholders** – comprises the activities of internal and external project stakeholders' identification, assessment of their expectations and integration into project implementation and management processes.

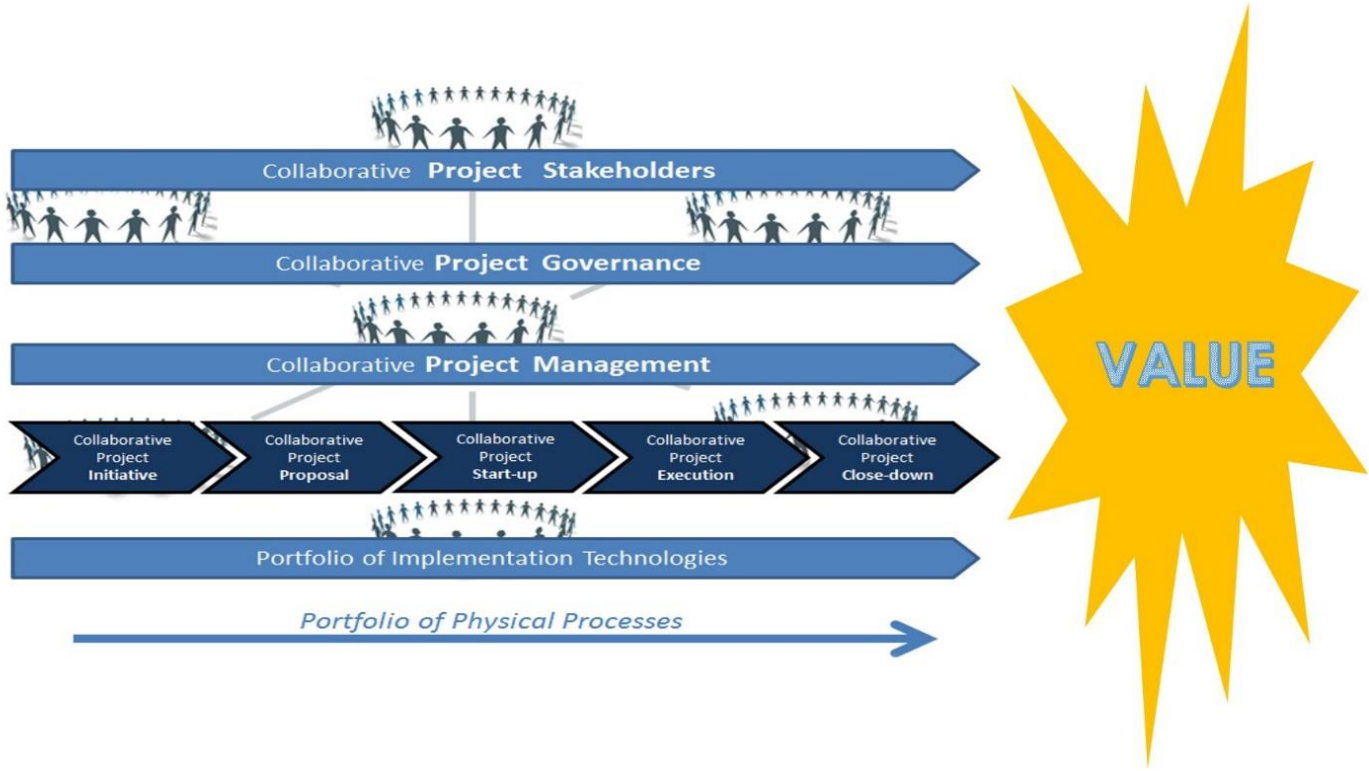

Figure 9: Collaborative projects – levels of complexity (Semolic, 2013)

Levels of complexity are present in all projects. However, in RID collaborative projects the complexity is much higher and needs careful assessment due to the profound project and business risks.

RID collaborative project open innovation communities

Effective placement of knowledge, information sources and their interaction to optimise the collective view of collaborative project stakeholders are of crucial importance. The impact of this can be seen in virtual associations that are mostly objective and based on knowledge resources (Duin 2008). Internal and external RID project talents garnered from different regional project stakeholder communities present the innovation potential needed in all phases of RID collaborative projects. According to Steyn and Semolic (2016) community is the condition of sharing, having things in common or being alike in some ways; a community of interests (Oxford Dictionary). Modern open innovation communities deal with a mix of business, professional and social communities, needing to be balanced, harmonized and well-coordinated. Semolic (2013) avers that the formal project organisation should be extended and virtualised by an organised portfolio of open innovation communities as illustrated in (Figure 10).

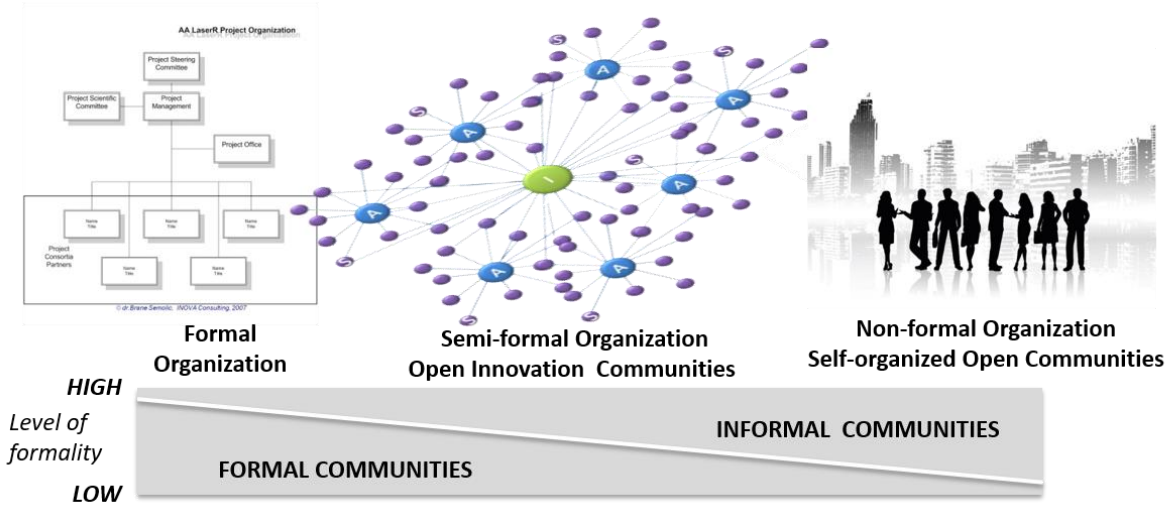

Figure 10: Pool of internal and external talents (Semolic, 2013)

Open innovation communities are critical components of the high performance virtual organization. Collaboration capacity is a precondition for successful collaboration in the virtual working environment. Semolic (2014) argues that it has technological, organisational and behavioral dimensions. The first dimension deals with the technology literacy of the project team members of open innovation communities. This literacy encompasses at least three distinct aspects: knowledge, the way of thinking and acting, and capabilities (Pearson and Young, 2002). The second dimension, organisational literacy, refers to a good understanding of the conceptual and regulatory framework of the project's open innovation business environment and acting accordingly. The third dimension relates to behavioural literacy, which ensures understanding and practicing the right collaboration culture and climate in daily activities inside innovation communities.

RID collaborative project management, strongly supported by the project owner, is responsible for the advancement and performance of project-based open innovation environments and related communities. Moreover, the efficiency of a collaborative system and its openness to others from the organisational environment are sensitive to regional cultures. More obstacles and problems can be expected in regions with a high uncertainty avoidance culture.

8 The Role of Projects and Project Management 4.0 Profession

In addition to new technologies, business models and systems Industry 4.0 demands new relationships, personal competencies, and a sound corporate culture. The critical integrators of new value chains and business processes are industry RID collaborative

programmes and projects acting as organisational vehicles and enablers of novelties, change, Industry 4.0 technologies, systems and businesses. Moreover, the characteristics of most organisational business processes (for example manufacturing) are moving towards project-based business processes which serve the specific needs of different value chain internal and external clients (Steyn and Semolic, May 2018).

Project management 4.0 (PM 4.0) is an integral part of the Industry 4.0 economy and engineering profession. Industrial engineering is concerned with the design, improvement, and installation of integrated systems of men, materials, equipment, and energy. It draws upon specialised knowledge and skills in the mathematical, physical and social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems (Zandin, 2001). Table 2 depicts PM 4.0 primary complexity challenges and critical success factors.

Primary Challenges	***Critical Success Factors***
Business complexity Technology complexity Business and technology literacy Organisational complexity Behavioral complexity Environmental complexity Legal complexity Risk complexity	Adequate attitude and leadership of multi-organisational and multidisciplinary project teams Adequate technology literacy of project stakeholders Project organisation as an open high-performing innovation ecosystem Continuous changes and improvements capabilities Support for the permanent transfer of knowledge and experiences Generate value for all project stakeholders

Table 2: PM 4.0 primary complexity challenges and critical success factors (Semolic,2017)

Managerial concepts on dealing with the challenges of Industry 4.0 are extensive. These are, *inter alia*, strategy management, value chain management, supply chain management (SCM), research management, innovation management, technology management, engineering management, production management, manufacturing management, construction management, process management, human resource management, project management and, importantly, programme management. Programme management plays a central role in the strategic governance of Industry 4.0 organisations (Steyn and Zovitsky, 2018). People often have a problem utilising the concepts and solution, and integrating them into a workable value-driven industry system.

Projects and project management (also programme management) are the proverbial "*blood vessels*" of Industry 4.0 organisational and inter-organisational value- and supply chain systems. Technology driven "chaordic" global businesses require a high level of technology literacy, skills in techno-entrepreneurship, and innovation. Moreover, transformational leadership with a penchant for continuous improvements and change

is needed. This calls for a good understanding of industry strategic value trends and related migration processes – regional and global.

Traditional industrial engineering with its embedded project management competencies and skills is insufficient to be recognised as a good candidate for the Industry 4.0 economic dispensation. More is needed. Figure 11 illustrates the conceptual framework of emerging Industry 4.0 competencies, indicating the relationship between synergetic competences of technology applications and project management.

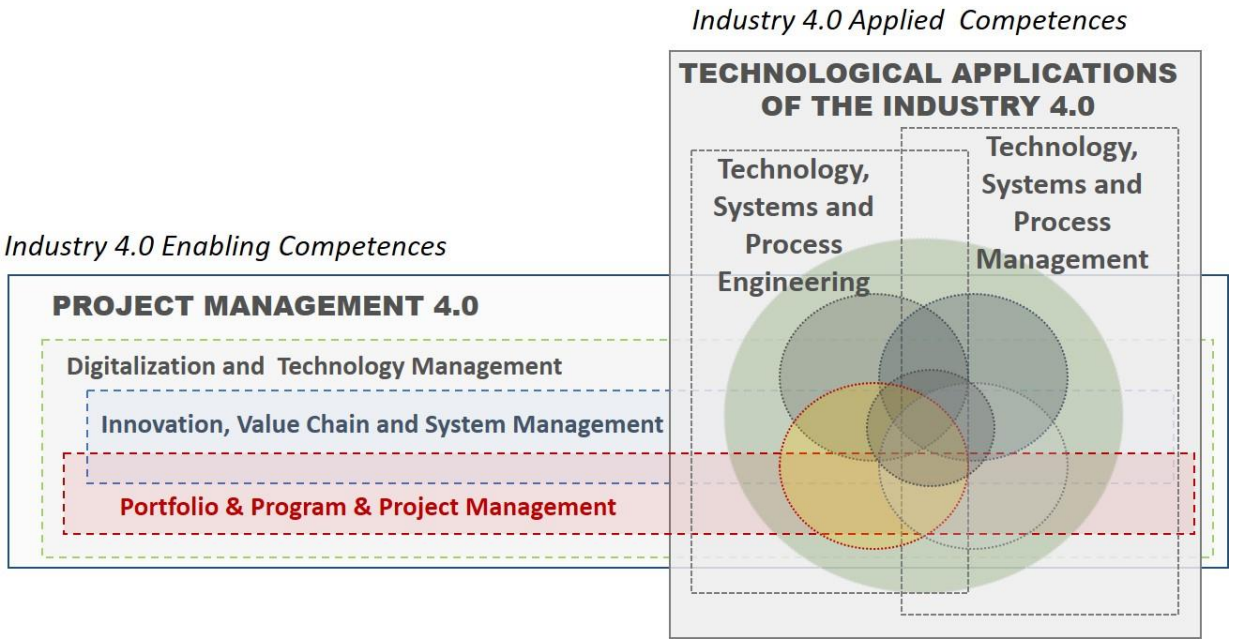

Figure 11: Conceptual framework of emerging Industry 4.0 competencies (Semolic, 2016)

9 Project Management 4.0 Transformational Leadership

The world is exiting the Industry 3.0 business environment where optimisation and automation of an organisation's resources were the main issues. The Industry 4.0 business ecosystem does not depend solely on innovation, optimisation, and competitiveness of resources, but inter-organisational value chain innovativeness, complementary partner technologies, products, digitisation and supporting services systems as a whole (Steyn and Semolic, March 2017). Together with partners innovative inter-organisational value- and supply chains are created operating in a global collaborative business ecosystem.

Primary drivers and causes of these changes lie in the rapid development, availability and affordability of modern key enabling technologies that are knowledge intensive and associated with high research and development intensity, rapid innovation cycles, high capital expenditure and highly skilled employment (Semolic and Steyn, Sept. 2017). The bottom line of key enabling technologies is overall digitisation with the internet of things (IoT) and services. In Industry 4.0 strategic transformation and change are driven by modern ICT artefacts that allow for the introduction and integration of new business models of vertical and horisontal supply- and value chains.

Moreover, to achieve success organisations are compelled to transform and change by abolishing bureaucratic practices and structures while adopting knowledge-based learning paradigms and designs. This demands exceptional governance, supported by ***transformational leadership excellence*** and knowledge of ***systemic programme management*** (Steyn and Zovitsky, 2018). Effective and efficient cross-functional and inter-organisational management of projects and programmes in virtual networks of partners emerged as a critical enabling competency for entities operating in the Industry 4.0 economy. This is centred on people, collaboration and building relationships.

The complexity of modern technologies, i.e., robotics, artificial intelligence, mass data, internet of things, integrating information technology and operations technology, etc., calls for specialisation and sustainable collaboration among partner organisations and demands exceptional talents and well-educated human resources. Consequently, organisational design, development and governance have entered a challenging new phase (Steyn and Semolic, 2016). In the Industry 4.0 economy organisations that experience an overall dearth of ***transformational leadership***, particularly in ***project management*** operations, will have difficulty in maintaining and improving their levels of operational productivity and strategic benefit realisation. Transformational leaders create a shift away from old motivations of bureaucratic powers, towards inspiring people to believe in a vision of economic and social progress. With transformational leadership people tend to abandon their own personal self-interests in favour of the organisation's interests.

Transformational leaders balance their attention between actions that create progress and the motivation of virtual team members. Transformational leaders possess unique qualities suited to the Industry 4.0 economic dispensation. They act as mentors and coaches to team members by listening to their concerns and needs. It encompasses the need to respect and celebrate the individual contribution that each member in a virtual network of partners makes to the team. Well-directed diversity of team members gives it true strength. Transformational leaders are visible and available to provide direction to virtual network of partner teams. They are master listeners, focus on identifying the needs of people instead of dictating to them, and empathise with others. This creates trust and support between the transformational leader and the virtual team members. Moreover, top transformational leaders have the capacity to inspire and keep people motivated despite the complexity and high risk associated with Industry 4.0.

Leaders and managers have a duty to ensure that design for customer needs delivers a competitive advantage. In the Industry 4.0 economy an effective and efficient design capability has emerged as an important competitive key success factor due to the advent of modern process technologies and virtual partner networks. Product, service and process design and development have become complex and highly important competative factors. When creation of the product or service is completed and a commercialisation strategy for its production and marketing been established, attention is turned to designing and developing the operational process for order fulfilment (Steyn and Semolic, May 2018). Product, service and process design and development are best achieved by utilising a supply chain-based cross-functional project and programme management approach.

Partnering has become profoundly important in the Industry 4.0 economy. Partner organisations come from small-, medium- and large-sized organisations. Great opportunities are emerging for the creation of new small and medium-sized entrepreneurial enterprises. This boosts much needed job creation opportunities and grow the economy in the right direction. Importantly, it dispels the notion that modern technology will lead to job losses (after all the steam engine led to massive job creation in the Industry 1.0 economy). Consequently, together with transformational leadership entrepreneurship has a pivotal and highly important role in the Fourth Industrial Revolution. Entrepreneurs use creative faculties to generate new products or services and exploit a new generation of opportunities in the developing collaborative market.

It is patently clear that modern technologies and its effect on product, service and process design have a significant influence on how the Industry 4.0 organisation is shaped, lead, managed and strategically governed (Van den Berg, Steyn and Semolic, 2018). Consequently organisations are compelled to abandon bureaucracy in favour of knowledge-based learning paradigms and structures, and employing ***transformational leadership*** to cope with the change. Human talent must be better educated and skilled to cope with the new situation. Processes are structured cross-functionally and programme-managed. Cross-functional processes incorporate collaborative virtual networks of partners to improve organisational effectiveness and efficiency, leading to much improved competitiveness. Moreover, partnering boosts small and medium sized enterprise creation and concomitant job creation. The resulting transformation and change hold profound benefits for society.

Conclusions

The continuous and simultaneous inflow of new technologies generates a need to accelerate innovation processes of products, services and processes, while searching for more innovative business models. Complexity is found in all areas and levels of businesses and societies. Challenges of emerging collaborative RID projects need to be focused on. Maintaining global competitiveness requires intensification of research and innovation efforts, as well as related investments from market players.

Organisations are beginning to partner on collaborative projects to decrease their related research and development costs and risk, while increasing their own innovation potential. Several levels of complexity are evident in collaborative projects (technical, organisational and behavioural complexity).

Knowledge and innovation are critical elements of knowledge-based projects. A main challenges is how to identify, organise and exploit knowledge and innovation potential inside and outside project-based organisations. How to deal with these challenges by organising different communities and collaboration platforms where internal and external knowledge potential can search for new ideas, solutions, support, and synergies were proposed. This requires partnering with project stakeholders and different corporate cultures.

The development and promotion of a vision for Industry 4.0 is critical in transformational leadership. The vision is key to the transformational leader being able to move human talent in a particular direction and must be developed with particular care. It must be a challenge that leaders and teams in virtual networks can fully believe in, and must excite and convert all members within a virtual network of inter-organisational partners towards higher performance. Transformational leaders must constantly sell the Industry 4.0 vision to partnering teams using every opportunity to persuade everyone about its benefits.

Programme management has evolved over the decades towards becoming the kingpin for leading, managing and governing Industry 4.0 entities. Moreover, cross-functional programme-managed structures and paradigms combined with effective and efficient transformational leadership, management and governance is the ideal vehicle for delivering the integration, coordination, collaboration and synergy required for mitigating complexity and risk, while achieving essential organisational performance, strategic benefits and value add in the Industry 4.0 environment

Literature

Business Dictionary (2018): http://www.businessdictionary.com/definition/business-model.html

Cartwright, T.J.(1991), Does strategy research need game theory? Strategic Management Journal, 12

Celente G. (1997), How to Prepare for and Profit from Changes of the 21st Century, Warner Books, New York, ISBN 0-446-67331-5

Crowther J. (1995), Oxford Advanced Learner's Dictionary, Oxford University Press

Duin, H.(2008). Systemic Strategic Management for VBEs in the Manufacturing Sector, In Camarinha-Matos, L. M. & Pickard, W. (Eds) Pervasive Collaborative Networks, IFIP TC 5WG

5.5. 9th Working Conference on Virtual Enterprises, Sept. 2008, Poznan, Poland, Springer, New York,

Eversheim W., Klocke F (1996).: Prozesorientierte Unternehmens-organisation, Springer Verlag, Aachen, 1996

Firestone, JM (2002). Enterprise information portals and knowledge management, , Butterworth-Heinemann, Amsterdam, ISBN 0-7506-7474-1

Geissbauer R., Vedso J., Schrauf S.(2016), Industry 4.0: Building the Digital Enterprise, PWC, Germany

Harrington H.J.(1991), Business Process Improvement, McGraw Hill, Inc, New York, ISBN 0-07-026768-5

Hornby, AS (1995), Oxford Advanced Learner's Dictionary, Oxford University Press, Cankarjeva založba Ljubljana,

Jasnoch U., Dohms R., Schenke F.B. (1998), Virtual Engineering in investment goods industry – Potentials and application concepts, The Globalization of Manufacturing in the Digital Communications Era of the 21st Century: Innovation, Agility and the Virtual Enterprise, Proceedings of the 10th International IFIP WG5.2/5.3 Conference, Prolamat

Jorgensen B. L. & Brask J. & Eriksen T.(1989), Corporate Development – from strategic planning to strategic management, Business Experience 14, Lisberg-CJ Management

Kane G.C., Palmer D., Phillips A.N., Kiron D., Buckley N. (2017), Achieving Digital Maturity, MIT Sloan Management Review & Deloitte Digital, MIT, USA, https://sloanreview.mit.edu/projects/achieving-digital-maturity/#chapter-10

Luczak H, Eversheim W. (1999), Telekooperation, Springer Berlin, Heidelberg

Levine, D.L. (2000), Application and Limitations of Complexity Theory in Organization Theory and Strategy, Handbook of Strategic Management, 2nd Edition, Edited by Rabin J., Miller G.J., Hildreth W.B., Marcel Dekker, Inc, New York, ISBN 0-8247-0339-1

Levy D. L. (2000), Applications and Limitations of Complexity Theory in Organization Theory and Strategy. Public Adm. Public Policy. 79. University of Massachusetts, Bosto, USA,

Magretta J.(2002), Why Business Models Matter, Harvard Business Review, from the May 2002 Issue, https://hbr.org/2002/05/why-business-models-matter

Merriam-Webster Learner's Dictionary (2018): http://www.learnersdictionary.com/

Mertins, K, Heisig, P, Vorbeck, E. (2003), Knowledge Management, Springer, Berlin, ISBN 3-540-67484-5,

Monck, Porter, Quiintas, Storey, and Wynarczyk (1988), Science Parks and Growth of High Technology Firms, Croom Helm, London, ISBN 0-7099-5441-7

Nam P. Suh (2005), Complexity- Theory and Applications, Oxford University Press, ISBN 0-19-517876-9

Parson G. & Young T. (2002), Technically Speaking, National Academy Press, Washington DC, ISBN 0-309-08262-5

Rheingold Howard (2000), The Virtual Community, MIT Press edition (Originally published in 1993 by Addison Wesley), ISBN 0 262-68121-8,

Semolic B. (1993), Integration of Project Information Systems into Corporate Information Systems, Research Work, EPF-UNI MB,

Semolic B. & Balic J.(1997), Strategic Information System – Integration of the Management and Engineering Activities, Flexible Automation and Intelligent Manufacturing, Proceedings of the 7th FIAM Conference, Begell House, New York

Semolic B.(2013), How to Organize Virtual Collaborative Working Space, KM FEST Cracow, Poland

Semolic B. (2015), Globalization and Innovation Ecosystems, 10th Annual MIBES International Conference, 15-17th October 2015, TEI of Thessaly, Larissa, Greece,

Semolic B. (2016), Logistics of Virtual Value Chains, Technology Collaboration Platform, LogDyn Platform Charter, LENS Living Lab – INTESO Group,

Semolic B. (2017), Open Research and Innovation Communities (RICs) – Virtual Project Office Services (Competence center ROBOFLEX business case), 16th PM-KM FEST, Odense, Denmark.

Semolic, Brane and Steyn, Pieter. 2017. "Industry 4.0 Virtual Value Chains and Collaborative Projects", PM World Journal, September Vol. VI, Issue IX, Dallas, USA.

Semolic B. (2018), Robotic Systems and Components – Factories of the Future, Collaborative RID Project ROBOTOOL-1, Project Charter, Competence center ROBOFLEX,

Semolic B. (2018), Innovation Ecosystem with Open Research and Innovation Communities, PTMI Journal, Volume 1,

Semolic B. (2018), Business Case of Digital Innovation Hub DIGITECH SI-EAST, Networking Among DIHs, Digital Innovation Hubs 3rd Wok Group Meeting, Brussels, Belgium

Simmons M. (2018), Studies Show That People Who Have High "Integrative Complexity" Are More Likely To Be Successful, https://medium.com/the-mission/studies-show-that-people-who-have-high-integrative-complexity-are-more-likely-to-be-successful-443480e8930c

Steyn, Pieter and Semolic, Brane. 2016. "The Critical Role of Chief Portfolio Officer in the Emerging 'Collaboratist' Economy", PM World Journal, Feb Vol V, Issue 2, Dallas, USA.

Steyn, Pieter and Semolic, Brane. 2017. "Collaboratism: A Solution to Declining Globalisation and Rising Protectionism", PM World Journal, March VI, Issue 3, Dallas, USA. (Award winning article).

Steyn, Pieter and Semolic, Brane. 2018. "Designing Industry 4.0 Virtual Networks of Partners Value Chains", PM World Journal, May, Vol Vll, Issue 5, Dallas, USA.

Steyn, Pieter and Zovitsky, Elzabe. 2018. "The Evolution of Programme Management Towards Governance of Industry 4.0 Organisations", PM World Journal, March, Vol Vll, Issue 3, Dallas, USA.

Van den Berg, J., Steyn, P., Semolic, B. 2018. "Chief Portfolio Officer: The Industry 4.0 Value Chain Change Agent", PM World Journal, Vol. VII, Issue VII – July.

Zadin B.B. (2001), Maynard's Industrial Engineering Handbook, 5th Edition, McGraw – Hill Standard Handbooks, ISBN 0-07-041102-06

WG-Work Group 1(2017), Roundtable on Digitising European Industry, Working Group 1, Digital Innovation Hubs: Mainstreaming Digital Innovations Across All Sectors, 3rd Report

Business Dictionary (2018), http://www.businessdictionary.com/definition/business-model.html & http://www.businessdictionary.com/definition/enabling-technology.html

About the Authors

Prof Dr Brane Semolic

Founder and Head of LENS Living Lab - International living laboratory

Celje, Slovenia

Brane Semolic studied mechanical engineering, engineering economics, and informatics; he holds a scientific master degree and doctorate in business informatics. His focus of professional interest is industrial and system engineering, innovation and technology management, virtual organizations and systems, project and knowledge management. He has 40 years of working experiences in different industries (industrial engineering, IT, chemicals, household appliances, government, and education), as an expert, researcher, manager, entrepreneur, counselor to the Slovenian government and professor. He operates as head of the open research and innovation organization LENS Living Lab. LENS Living Lab is an international industry-driven virtual living laboratory. He is acting as initiator and coordinator of various research and innovation collaboration platforms, programs and projects for the needs of different industries (ICT, robotics, laser additive manufacturing, logistics, education). He was co-founder and the first director of the TCS - Toolmakers Cluster of Slovenia (EU automotive industry suppliers). Since 2004 he is serving as the president of the TCS council of experts. Besides this, he is operating as a part-time professor at the Cranefield College.

He was head of project and information systems laboratory at the Faculty of Mechanical Engineering, Head of the Project & Technology Management Institute at the Faculty of Logistics, University of Maribor and professor of project and technology management at the graduate and postgraduate level. He acted as a trainer at the International »European Project Manager« post-graduated program, organized jointly by the University of Bremen.

He was the co-founder and president of the Project Management Association of Slovenia (ZPM), vice president of IPMA (International Project Management Association), chairman of the IPMA Research Management Board (2005-2012), and technical vice-chairman of ICEC (International Cost Engineering Council). Now he is serving as a director of the IPMA & ICEC strategic alliance. He actively participated in the development of the IPMA 4-level project managers' certification program. He introduced and was the first director of the IPMA certification program in Slovenia. He has been serving as the assessor in this certification program since 1997. He performed as assessor in the IPMA International PM Excellence Award Program in China, India, and Slovenia.

He is a registered assessor for the accreditation of education programs and education organizations by the EU-Slovenian Quality Assurance Agency for Higher Education.

He was a Member of Strategic Advisory Board of European Competitiveness and Innovation, as well as the president of the Slovenian Chamber of Business Services.

He got the award as ICEC Distinguished International Fellow in 2008. He received the »Silver Sign« for his achievements in research, education, and collaboration with the industry from the University of Maribor in 2015.

Professor Semolic is also an academic advisor for the ***PM World Journal***. He can be contacted at brane.semolic@3-lab.eu. Additional information about the LENS Living Lab can be found at http://www.3-lab.eu/ .

Prof Dr Pieter Steyn

Founder, Director, Principal
Cranefield College of Project and Programme Management
Pretoria & Western Cape, South Africa

Dr Pieter Steyn is Founder and Principal of Cranefield College of Project and Programme Management, a South African Council on Higher Education / Department of Education accredited and registered Private Higher Education Institution. The Institution offers an Advanced Certificate, Advanced Diploma, Postgraduate Diploma, Master's degree, and PhD in project and programme-based leadership and management. Professor Steyn holds the degrees BSc (Eng), MBA, and PhD in management, and is a registered Professional Engineer.

He was formerly professor in the Department of Management, University of South Africa and Pretoria University Business School. He founded the Production Management Institute of South Africa, and in 1979 pioneered Project Management as a university subject at the post-graduate level at the University of South Africa.

Dr Steyn founded consulting engineering firm Steyn & Van Rensburg (SVR). Projects by SVR include First National Bank Head Office (Bank City), Standard Bank Head Office, Mandela Square Shopping Centre (in Johannesburg) as also, Game City- and The Wheel Shopping Centres (in Durban). He, *inter alia,* chaired the Commission of Enquiry into the Swaziland Civil Service; and acted as Programme Manager for the Strategic Transformation of the Gauteng Government's Welfare Department and Corporate Core.

Pieter co-authored the "*International Handbook of Production and Operations Management*," (Cassell, London, 1989, ed. Ray Wild) and is the author of many articles and papers on leadership and management. He is a member of the Association of Business Leadership, Industrial Engineering Institute, Engineering Association of South Africa, and Project Management South Africa (PMSA); and a former member of the Research Management Board of IPMA. He serves on the Editorial Board of the PM World Journal. Pieter is also Director of the De Doornkraal Wine Estate in Riversdale, Western Cape.

Professor Steyn can be contacted at cranefield1@cranefield.ac.za. For information about Cranefield College, visit www.cranefield.ac.za.