JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

Practitioner's Section

Örjan Larsson* and Peter Wallin**

Digital Transformation in the Swedish Process Industries: Trends, Challenges, Actions

In the context of the fourth industrial revolution and digitalization as a driving force, a current approach in the Swedish industrial innovation system is the public-private partnership Strategic Innovation Programs (SIPs). The program Process-industrial IT and Automation (PiiA) has been founded to support the process industries' competitiveness through digitalization. This essay aims to briefly share seven years of empirical observations, analysis, and conclusions from the PiiA program. Digital transformation is a central theme in the article, underpinned by discussions about enabling digital technologies and managerial consequences, where industry firms can be found in three different positions of digital maturity.

1 Introduction

This section gives an overview of the Swedish process industries and the SIP system, particularly the PiiA program, as a model for industrial innovation. The process industries refer to a cluster of sectors (forest/pulp and paper, steel, chemical) (Lager, 2017) but also food, pharmaceuticals, and mining, approached in a cross-sectoral concept for the development of digitally supported production and business.

1.1 Process industries in Sweden

Sweden is very dependent on its raw materials and its process industry. The sector contributes to a significant part (SEK 135 bn) of the country's net export value (The Swedish Association of Industrial Employers, 2019). Competitiveness and position on the world market are crucial not only for the industry but for the Swedish economy as a whole. The forest industry, mining, steel, and chemical production, as well as pharmaceuticals, are worldleading industrial sectors. Production sites all over the country are essential hubs with high social and regional importance. The wide geographical spread also demands excellent logistics, and the industry accounts for a significant part of Sweden's transport volume.

The use of advanced technology adapted to continuously changing global conditions has ensured the Swedish industry's international success. The recipe has been to seek technology-intensive high-value niches and advanced production technologies. High productivity and dynamics through advanced facilities and world-leading automation are distinctive features. Collaborative technology development with firms like ABB, Ericsson, Sandvik, Atlas Copco, Epiroc, Volvo, and more has continuously and effectively changed the Swedish industry and also created a worldrenowned technology industry.

As the world now moves towards a new industrial paradigm, the raw materials and process indus-tries continue to be

* Örjan Larsson, Blue Institute, Box 160, SE 101 23 Stockholm, Sweden, orjan.larsson@blueinst.com
** Peter Wallin, RISE, Stora Gatan 36, SE 722 12 Västerås, Sweden, peter.wallin@ri.se

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

an essential focus for industrial transformation. Global sustainable development goals (SDG), strained natural resources, and emerging markets that devour capacity, requiring increased productivity and resource efficiency (Heck and Rogers, 2014), will be significant driving forces for change.

1.2 Strategic Innovation Programs (SIP)

The idea of a new industrial revolution (Marsh, 2012) (Rifkin, 2013) was identified by policymakers long before the industry commonly accepted it. In 2007, the Parliament of the EU attested a declaration of intent for an industrial shift with the means of renewable energy and digitalization (Larsson, 2013). A consequence of such movements has been a policydriven mobilization in national and regional innovation programs all over the world, often consisting of public-private collabora-tions directed towards digitally supported production. The aim is to safeguard domestic competitiveness, industry, and jobs in a new industry landscape.

Introduced in 2013, the model of Strategic Innovation Programs (SIPs) is a Swedish publicprivate partnership with a collective approach among industrial and academic stakeholders. From its inception, the SIP portfolio has been broadened to seventeen programs, with total funding of SEK 16 bn for 2013–2029 (VINNOVA, 2019). The program portfolio is funded and administrated jointly by the Swedish governmental agency for innovation systems, VINNOVA, the Swedish Energy Agency and Formas, a government research council for sustainable development. Formally, the SIPs have no legal structure but are virtual project organizations with home bases in universities, institutes, or industry federations. The Swedish research institute RISE is hosting PiiA. All the SIPs are required to have a board, most often with representatives from the industry.

The first tranche of programs established had a very natural connection to production value chains. These programs are best regarded as a continuation of earlier ‚branch' and collective research program traditions, though with significantly larger budgets (Arnold, 2020). Early programs seeking funding were:

- Swedish Mining Innovation - for the mining industry.
- Metallic Materials - addressing the Swedish steel and metal industry.
- LIGHTer - for industrial development and use of light materials.
- BioInnovation - for the development of the Swedish biobased sector.
- Production2030 - addressing the manufacturing industry.
- PiiA - Process-industrial IT and Automation (i.e., industrial digitalization), with a particular focus on continuous processes.

Up to now, the SIPs mentioned above, including industrial project partners, have invested some four billion SEK (50% in industry grants) in industrial innovation.

The SIPs' mission is to bring together stakeholders such as industry, academia, institutes, and pub-lic interests to collaborate. The common goal is to increase technological capability and the innova-tion climate to maintain or increase Swedish competitiveness. In this system, industry companies generally co-found projects in kind rather than in cash, typically by fifty percent.

The above-listed SIPs constitute a logic mirror of the real industrial value system, wherein digitalization is a generic enabling technology. The different SIPs mentioned constitute a system that combines in-depth domain knowledge with expertise and resources dedicated to digitalization. Their positions in the value chain are illustrated in Figure 1 below. The enabling digital technologies are in this context called IndTech, a concept discussed later in the article.

After five to seven years in operation, the programs have now found their modus operandi and places in the market. The next step foreseen is a broader approach wherein collaboration over program borders will take place. Digital transformation on a systemic level will then be a vital area to address; world-class in-depth domain/process knowledge combines with state-of-the-art capability in digitalization. We give an example of such cooperation in the project Digitala Stambanan later in this article.

1.3 PiiA

Founded in 2013, PiiA was an answer to the process industries' ambitions for increased competitiveness through digitalization. Of equal importance was a joint win-win logic for industry firms and technology vendors on the world market (the latter is an industry that exceeds both the

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

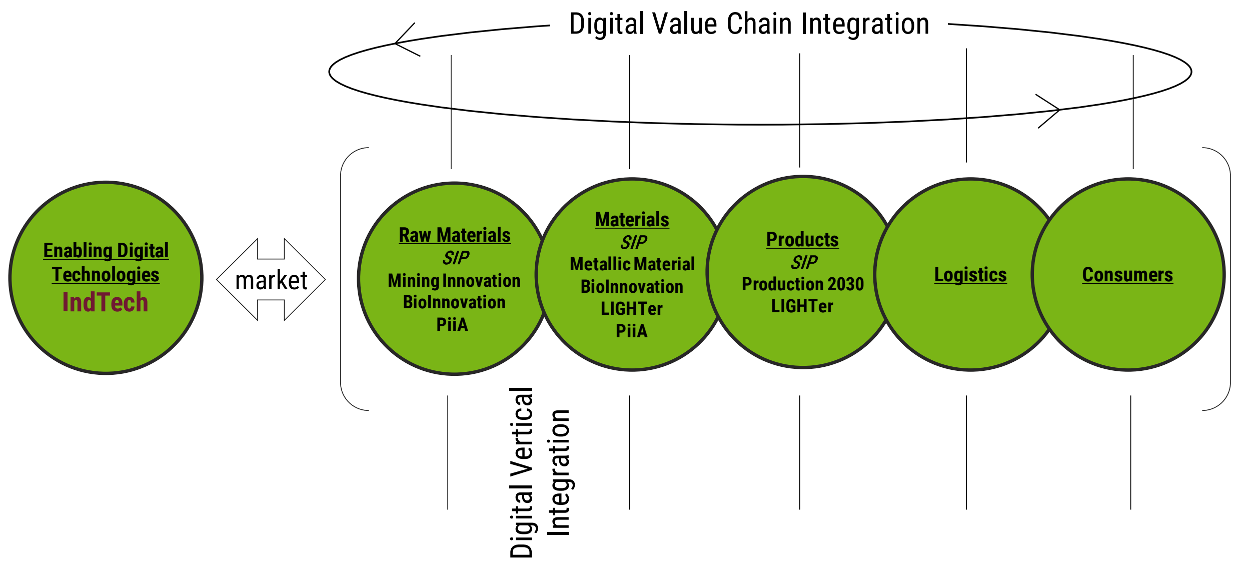

Figure 1 A value chain model with examples of different SIPs, constituting a knowledge system combining in-depth domain knowledge with expertise dedicated to digitalization. Enabling digital technologies are called IndTech, as discussed later in the article (source: PiiA/Blue Institute 2020).

Swedish mining and steel industry turnovers). Thus, PiiA's operational vantage point exists in the market between these interests, as shown in the value chain model above.

The program strategy rests on two pillars:

(i) Funding of innovation projects of higher Technology Readiness Level (TRL). PiiA is a funding body where consortia can apply for funding; thus, the overall delivery from PiiA comes from the joint deliveries of all funded projects.

At the beginning of 2020, PiiA had launched nearly 200 research and innovation projects and feasibility studies with 275 participating partners. About 25 percent of these were major process industries, 20 percent global technology suppliers, and 40 percent small and medium-sized enterprises. Academia, institutes, and other types of interest groups accounted for 15 percent. The projects have been financed by about SEK 800 million in VINNOVA grants and industry-in-kind.

(ii) Knowledge building through research and analysis in collaboration with the industry, tech vendors, and academia. Published so far are some thirty studies, reports, and papers, an essential portion of which is available for public reading on PiiA's website. Digital value chain and vertical integration, together with the concept of IndTech, are areas of particular interest.

In 2019, the first round of SIPs, including PiiA, went through individual and extensive six-year evaluations. In general, the SIPs showed excellent performance. The SIP strategies have served as focusing devices, directing activities towards a set of agreed-upon challenges, allowing each to update and strengthen capacity on a broad front. There are exciting project results already, and participants are optimistic that their work will generate more extensive benefits (Arnold, 2020).

1.4 Outline of the Paper

After this introduction of the Swedish process industry, the SIP concept, and PiiA, we will continue in section 2 with defining a framework for industrial digitalization. In sections 3 and 4, we will discuss the logic of digital transformation and illustrate the discourse with two projects from PiiA's empirical observations. Finally, in sections 5 and 6, we will share conclusions regarding managerial consequences and the future direction of PiiA.

2 The ontology of industrial digitalization

In this section, we share ideas central for the digital transformation of process industries as well as industries in general. Our seven-year experience of operating PiiA has encouraged us to work out several change models and a

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

concept called IndTech, now used widely in the country and increasingly internationally.

2.1 Computerization - Digitalization - Algorithmization

The computerization of industrial systems took off in the 1980s, when the microprocessor made automation possible in new efficient ways. The world is now entering the next paradigm. We call it digitalization when technologies that have changed the commerce, media and communications industries also reimagine industrial production. In parallel, artificial intelligence is emerging as the next significant phase of the digital concept. AI will have a high impact on society's resource efficiency and productivity (Larsson, 2019); consequently, demand for industrial AI is now increasing at the same rate as insights into the value it can provide.

What is occurring is a process of increasing algorithmization, which means that computers, through algorithms, take over value creation previously performed by humans. Algorithmization is thus a trend of both replacing humans with machines and providing support in daily work as illustrated in Figure 2. Simultaneously, concepts such as digital platforms, networks, and ecosystems become fundamental elements in a transformation process that will profoundly change the industry.

2.2 Data perspectives

From a real-world perspective, industrial value chains are always designed and physically built for production (of products) and to be maintained over time, as illustrated in the lower part of figure 3. From a digitalization perspective, the common denominator is data flowing through the real value systems and through time, as shown in the upper part in the figure. Thus allow value creation to spread and have effects elsewhere in time and space through two (schematic) streams: (i) support of production with a focus on operation, optimization, and maintenance and (ii) the digitalization of the products, including new services and efficient transactions. Increasingly, this is also achieved by the convergence between the two. The latter matters for the materials/process industry, where production data bundled as a service can raise the product value (e.g., in the pulp and steel industry) (PiiA Smart Steel, 2018). Although structured data already play a significant role in everyday operational excellence, through even more relevant data, better order, and new methods like AI, value creation will reach even more advanced levels.

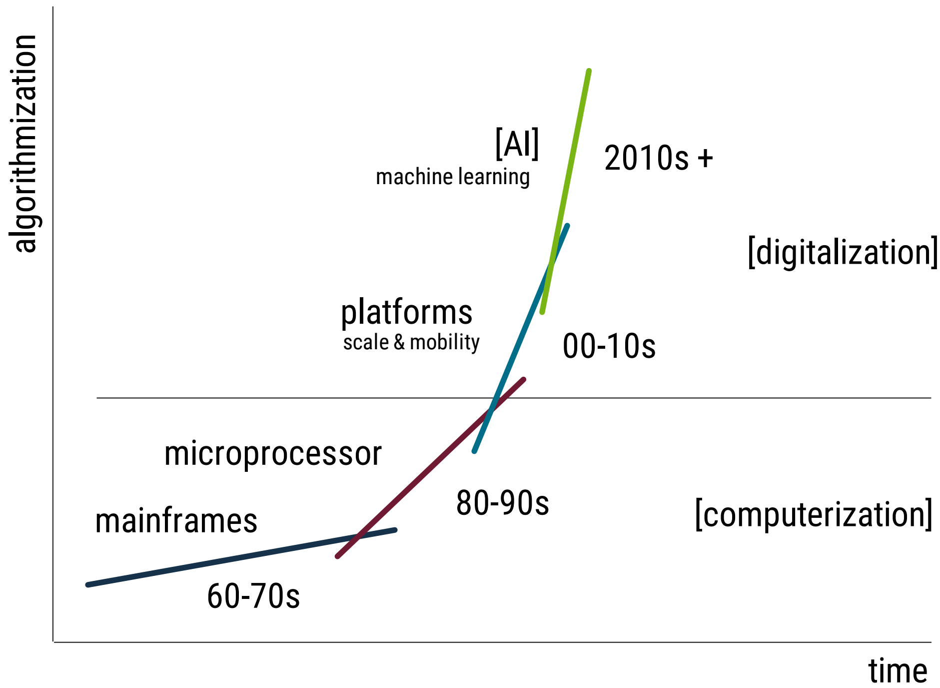

Figure 2 Algorithmization is a trend of both replacing humans with computers and providing support in daily work (source: AI & Digital Platforms 2019).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

With enough data and computational power, dynamic mathematical models of real operations, machines, vehicles, and products can be built. Live models that exist on digital platforms are often referred to as digital twins and can be used to develop new services based on predictive technologies. In future industrial structures, digital twins will be important planning, design, and collaboration instruments on several different levels.

In this concept, digital platforms (shown in the center part of figure 3) create value when collecting, storing, refining, and distributing data in structured ways. In practice, a digital platform is most often a complex of sub-platforms adapted for different tasks supplied by various firms and organizations.

In conclusion, data is the keyword for digitalization. The platforms ensure that relevant information is collected, computed, and distributed at the right time and place, then used in everyday reality for business support and automation, as well as to build models. Digital twins can predict what will happen and thus provide new business concepts. When all this occurs at the same time as organizations and business models adapt to new conditions and possibilities, digital transformation occurs, as we will discuss later in this article.

2.3 The concept of IndTech

The concept of industrial digitalization may also be called IndTech. This is an idea launched by PiiA and Blue Institute (Larsson, 2018) to reflect the changing market dynamics when traditional IT and automation merge with digital concepts such as AI, IoT, 5G, and the cloud. IndTech is consequently where the existing 80s-90s technology standard meets with modern digital innovations, as illustrated in figure 4. Potentially, this brings many possibilities but also challenges.

In understanding the market dynamics of IndTech, an essential characteristic is the installed base of earlier tech standards estimated to be worth some USD 5,000 bn globally, often with a substantial remaining lifetime. This installed base will effectively slow down the phase of industrial renewal, thus it is critical that the advantages of modern solutions can be proved by robust business cases (Larsson, 2018).

IndTech is a hidden yet giant industry and also a field of excellence for Swedish technology exports, with numerous renowned companies operating across the world. The yearly IndTech market worldwide is some USD 400 bn, and a new preliminary study points to a market share for Swedish vendors of about 3 percent (PiiA Swedish IndTech, 2018). IndTech does include renowned vendors such as ABB, Ericsson, Siemens, Schneider, SAP, IBM, AWS, Microsoft,

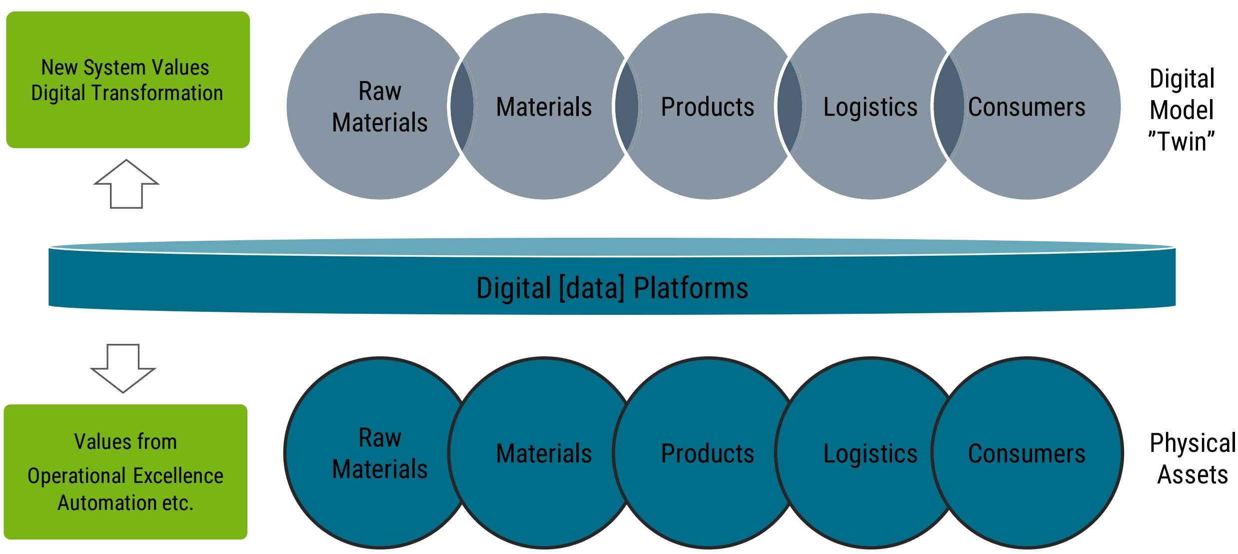

Figure 3 A holistic system perspective of an industrial system digitalization, with a physical layer of assets where efficiency is achieved using more refined automation methods such as AI. Digital twins will eventually mirror complete tangible value chains and approach the vision of the self-organizational value system. The real value chain, as well as the digital twin, is dependent on the data-carrying platform in the center of the illustration (source: PiiA/Blue Institute 2020).

JOURNAL OF
BUSINESS CHEMISTRY
Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

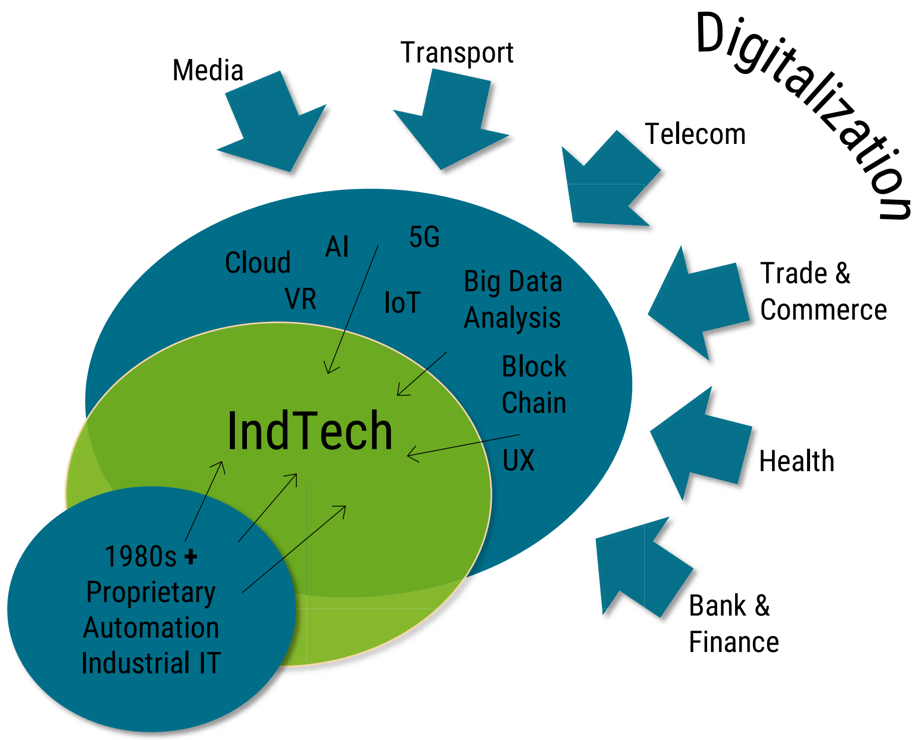

Figure 4 The model for IndTech: Traditional and new technologies come together and make 'smart industry' possible. Classic auto-mation and industrial IT meet digitalization and create new digital platforms and business ecosystems (source: PiiA Swedish IndTech 2018).

and more, together with small and medium-sized specialist firms, as well as machine and process suppliers when they digitize their offerings.

2.4 Time to tear down the pyramid

Traditional views of industrial automation have been pyramid-shaped hierarchies. This Automation Pyramid has, as is seen in the Figure 5, operational technology (OT) closest to production and IT for business processes located above it. The dissolution of such structures in the interest of more flexible arrangements has long been the subject of discussion. Incremental change scenarios, rather than disruptive ones, seem most likely given the industry's installed base. In the short term, the focus may thus be on removing silos through practical integration between computers and organizations, as well as between companies in the supply chains. In the long term, true interoperability is very likely, with full interchangeability of information without manual intervention, based on accepted industry standards.

The industry's business challenge going forward is to use digital platforms and information transparency to address coming market shifts, new organizational approaches and ways of doing business. Previous such changes in history has demonstrated the importance for firms of creating conceptual target pictures, as well as having clear objectives from the outset and working towards them incrementally, to adapt existing IT/OT capabilities to more modern approaches.

These objectives will, in most cases, include the possibilities of (i) having digital infrastructure deliv-ered through one, or several, more or less specialized cloud services; (ii) using advanced analysis, like machine learning, for automation, augmentation and a collaborative approach between people and machines; and (iii) using the Internet of Things as a comprehensive application platform to connect to existing structures and simplify hardware and software. Together, these three ‚verticals' may form a digital transfer platform with the potential to resolve information hierarchies over time. To this could be added the revolution occurring as a result of new methods and tools for data-centric engineering of products, systems, and plants, where systematic life cycle data management (LCDM) is a potential source of substantial efficiency enhancement and cost savings.

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

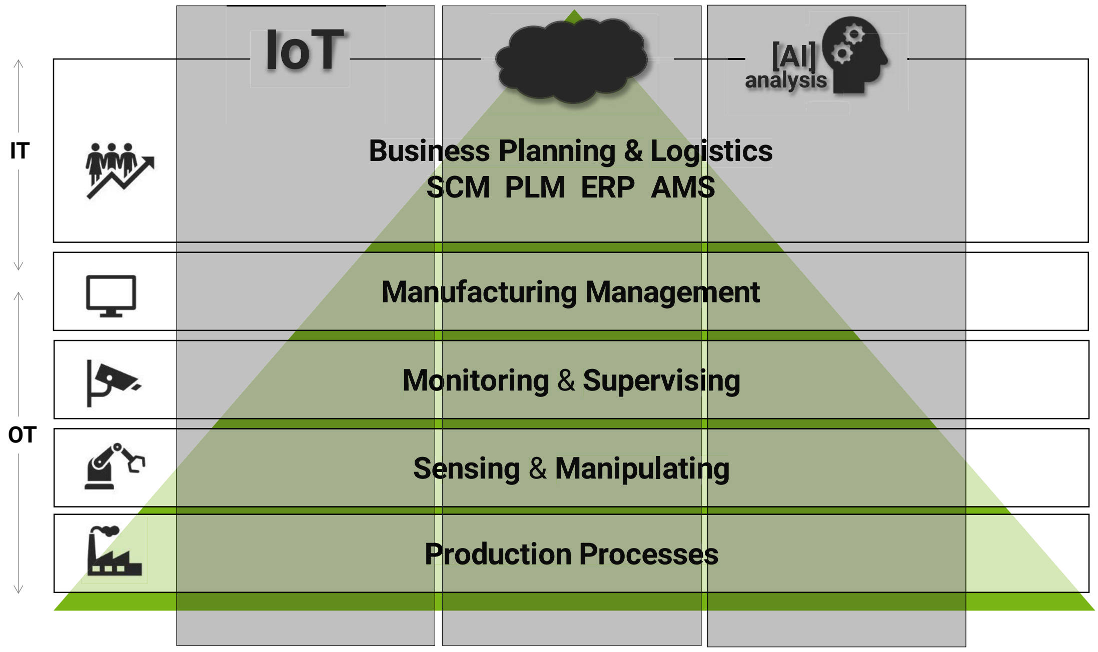

Figure 5 ISA 95 Automation Pyramid: Development is challenging traditional environments and hierarchies (source: AI & Digital Platforms 2019).

3 Digital transformation

PiiA has thoroughly followed the global development of industrial digitalization and has, by assessing global R&D efforts, endeavored to understand the strength of this development. Specific scope problems notwithstanding, our assessment shows that there have been initiatives amounting to USD 150 bn annually in recent years (Larsson, 2019) across three key stakeholder areas: (i) private-public national investments (e.g., SIP, PiiA and Industry 4.0); (ii) tech companies (e.g., Microsoft, IBM, and AWS) investments in cloud and AI; and (iii) the ICT and automation industry. These development projects are now leaving laboratories and site tests to emerge into the market.

A model used by PiiA to illustrate this development is a digitalization S-curve that connects to the idea of diffusion of innovations. In the concept of how innovation (through information) spreads over time among the members of a social system, where communication is a process of convergence and reduced uncertainty (Rogers, 1995), we notice some significant patterns.

Seen as three phases of convergence in Figure 6, the process of digitalization covers: (i) real technology test and demonstration; (ii) search for best (operational) practices; and (iii) fulfilled digital transformation. The first phase is part of a discontinuation, representing the end of an earlier S-curve and the entrance to a new one (Foster, 1986). The first phase has a negligible business impact, while the later stages contribute to new values and thus higher business impact.

As we will discuss further in the concluding section of this paper, change is eventually about management and people. Essential technology is already here; the challenge now is about making digital transformation happen. The principles for this are covered in the following pages and by two examples from PiiAs projects.

3.1 From Best Practices to Digital Transformation

Our analysis assumes that, following a rather long period of technology tests and demonstrations, we are now entering the search for best practices phase on the way to the vision of full digital transformation. This assessment is based on the fact that: (i) R&D investments need to yield returns; (ii) standardization work is well underway; and (iii) the world's industrial leaders have woken up to the transformative effect of digitalization on industry and are starting to act. Another force to be considered is that of the dynamics that arise as the three development foci start to propel each other, with developmental results reaching the market, which in turn leads to further increased momentum for the entire system.

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

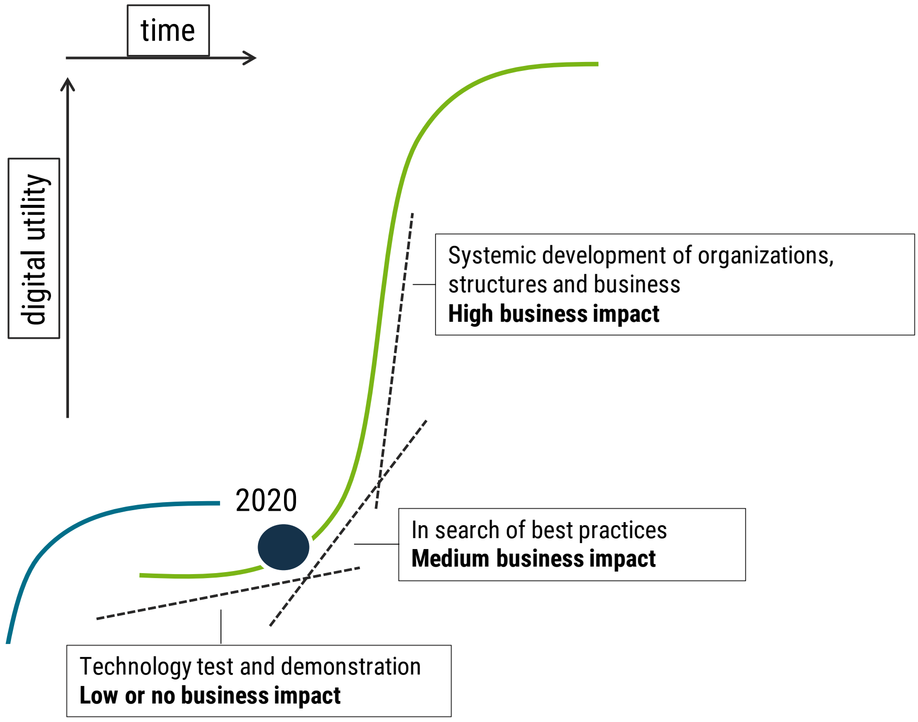

Figure 6 The S-curve is an often-used pedagogic tool in PiiA to illustrate the progress of digitalization. Starting with innovation tests and demonstrations, it continues with the search for best practices and eventually affects the industry community in digital transformation. Over the phases, the relative importance for business, of course, increases (source: Blue Institute (in allusion to Rogers 1995)).

Expecting that the most considerable value-creating impacts of digitalization are to come from changes at the industrial-system level (the value system-level), we foresee development in a form best described as the transformation of the industry towards becoming an information industry. Such a change is not intended to be interpreted as the demise of the production economy; rather, it suggests that business leaders will have to manage two logical frameworks.

This development has also been called the platform economy. Another idea in this vein is related to networks. The uniting factor in both network and platform logics is the need to match and facilitate connections between producers and buyers, regardless of the type of goods exchanged. Industry organization will change as a consequence of the competitive advantages that platforms can provide within meeting places. The connections between the concepts of networks and platforms also lend themselves to being described with metaphors from biological ecosystems. In this context, ecosystems refer to robust, scalable architectures that can automatically solve complex, dynamic problems, including self-organization, self-governance, sustainability, and scalability. Thus, the ecosystem approach can bring valuable contributions to the understanding of industrial dynamics. From an innovation perspective, the concept has its primary roots in the related concept of business ecosystems, as used by Moore and others (Moore, 1993). Granstrand and Holgersson (2020) define an innovation ecosystem as the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors.

In the business ecosystem, there is a network logic between the companies involved, which, in turn, is supported by a digital ecosystem characterized by a distributed peer-to-peer network model. The latter refers to a digital platform that makes relationships between companies and other organizations in the business network possible through transactions and technical support.

A vital business ecosystem reflects the balance between competition and collaboration in an open, dynamic, and free market. Harvard Business Review was the first publication to include a mention of the term business ecosystem in an article (Moore, 1993). The article presents the idea that companies not only belong to industries but also are part of

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

business ecosystems that extend across different industrial and knowledge sectors. With the word digital added to the business ecosystem concept as a reference to the socio-economic development made possible through information and communication technology, the term digital business ecosystem was introduced (Nachira, 2002).

The classic effects of network logic affect how the number of users in the network influences the value development for each user (i.e., the so-called positive-network effect). Adverse network effects, on the other hand, occur in poorly managed networks that reduce value development for each user. The positive network effect is, of course, the foremost and most sought-after competitive advantage within network logic. Consequently, the critical prerequisite for efficient networks is to use digital platforms and other features to increase size, thus increasing the value generated via network effects.

Digital platforms/ecosystems make it possible to bring new value for customers with low marginal costs to existing physical products – that is, to achieve scale without mass (Brynjolfsson et al., 2008) – and we are already getting an early indication of how the industry will separate physical production logic from virtual data-driven logic. The automotive industry is experiencing shrinking margins in vehicle manufacturing and is developing business models that address mobility on data platforms. The industrial technology vendors of tomorrow will not only sell hardware but will also extend into connected suppliers of efficiency and quality within production systems based on analysis, delivered in collaboration between human and artificial intelligence (Harvard Business Review, 2018). The process industry will sell not only materials but also data on these materials based on advanced analyses that increase the quality and efficiency of the manufacturing industry (PiiA Smart Steel, 2018).

Uncoupling physical assets from the value they create also means that certain products can be marketed as services for the best possible use and greatest value creation, rather than being limited to a specific owner. The result is an increase – in some cases a dramatic increase – in both efficiency and value.

Platforms also have the potential to change cost structures and pricing in physical production. Once someone launches a digital data platform that allows for trade and provides free marginal production capacity on a larger scale, purchasing prices for semi-manufactured products will theoretically fall at the same rate at which the released capacity fills up. Such a day is probably not too far away.

We conclude that while the business economics doctrine will undoubtedly continue to exist once the resources, process, and manufacturing industry develop towards an information industry, the way in which it is followed will be revolutionized.

3.2 The Future of the IndTech Industry

Finally, we would like to add a few comments on the future of the digital technology market that we consider to offer a case for fundamental structural changes as well. Traditional industrial IT and automation vendors now need strategies to deal with platform development as well as IoT structures.

As demand for digital platforms increases and the boundaries between industrial IT, automation, and other domains become blurred, more and more players are interested in industrial markets. Cloud and platform service providers like Microsoft and Amazon are building alliances with traditional automation providers. Ericsson, Cisco, Huawei, Nokia, Samsung, and other industry operators are looking for applications for 5G technology, and they consider the industry's Internet of Things to be an opportunity. Operators stand to increase revenues if the process industry and utility industry increase their use of wireless communication.

The substantial dominance of platform suppliers (like Microsoft and AWS) makes it impossible for automation companies to avoid dependency on their resources. The challenge will be to create strategies that develop the automation industry's strengths (domain and process knowledge and customer relationships) to avoid becoming marginalized in the platform war. The platform and ICT companies, on the other hand, can be expected to contribute by making automation solutions less complicated and more costeffective as well as by adding new value. Intelligent apps in intelligent ecosystems constitute a development trend that has the potential to make a significant impact.

Platforms also provide process and machine suppliers with automation capacity and the potential for advanced in-house analysis, making them less dependent on automation vendors. Machine suppliers and the automation industry also share an ambition to build connected competence centers for optimization and fault remediation in customer facilities.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

By extension, this strategy is also about competition for valuable data to be mined from industrial manufacturing.

In conclusion, a new image for the industry's suppliers is emerging, wherein we believe the ability to create real customer value will distinguish winners from losers. Suppliers succeeding in doing so will have a much more developed role in future industrial value systems as specialized vertical suppliers of efficiency and quality. If they do not, the outlook could be bleak, with diminishing margins when more effective cloud and IoT solutions successively supersede traditional automation technology, becoming commodities. For the industry investing in digital solutions, this outlook will still require substantial purchasing skills and know-how in system integration.

4 PiiA projects - empirical observations

The PiiA project portfolio includes some two hundred innovation projects and feasibility studies. Most of the projects are related to industrial applications. Participating project partners are typically major process industries, major technology suppliers, SMEs, and academia/institutes. Below are two samples of projects we consider to be on an interesting leading edge. Digitala Stambanan takes a holistic perspective when integrating real supply chains, while PIMM DMA marks a shift in creating on-site digital ecosystems based on 5G technology.

4.1 Digitala Stambanan ('The Digital Railway Trunk Line')

In the 19th century, the railway was a game-changer, connecting people and businesses and creating meetings and efficiency, and a fundamental factor in an industrial revolution. In the same way that trunk lines connected Sweden during the 1800s, digitalization now forms the foundation for the next industrial paradigm, this time through data.

The above is the metaphor and idea of the project Digitala Stambanan, initiated through the cooperation of the two Strategic Innovation Programs PiiA and Production2030, with expertise in raw materials and continuous processes and manufacturing, respectively. Digitala Stambanan (www.digitalastambanan.se) aims to connect existing companies in existing value chains, often while maintaining existing technology, at the next level of information exchange. The goal is to release hidden values and share knowledge and inspiration over the firm's borders and between industries. As discussed in this paper, an incremental change in systems and technology is more likely than disruptive movements, because the significant installed base of earlier generation IT and automation will not be replaced as long as it serves its purpose.

As illustrated in figure 7 below, the Digitala Stambanan set-up includes value chains in copper and precious metals, steel, packaging, and three different automotive supply chains. Engaging some thirty partners with different positions in the value system, the project's progression has gone through a thorough pre-project phase and is now in execution planned to end in December 2020. A third phase is under idea processing. Renowned firms involved in the project include ABB, AlfaLaval, Boliden, BillerudKorsnäs, Combitech, Hexagon, Kalmar, Siemens, Outokumpu, and Volvo. Academia is represented by Chalmers University of Technology, RISE Research Institute of Sweden, Blue Institute and MITC.

One of the project's cornerstones has the intention to create an inspirational movement. Experience tells us that one of the most potent means to achieve change is through the mutual inspiration of industry firms. Another cornerstone is related to collaboration. The model chosen as a common ground for such a diverse project (occurring in vastly different parts of the industrial systems) is based upon the idea of a digital twin of a conceptual value chain, wherein the different use cases all contribute with knowledge and findings. The latter also is a rich source of knowledge about organizational and people dimensions in digital transformation.

4.2 PIMM DMA

[A pilot for Industrial Mobile communication in Mining, Digitalized Mining Arena]

Productive site ecosystems, where connected operators, maintenance, equipment, and machines from different suppliers can share data for safety and productivity, will be in demand in the digital transition. For five years, leading Swedish firms have joined forces to demonstrate such a connected digital ecosystem. In a harsh industrial environment, the mining company Boliden has used the Kankberg mine as a testing site for a new industrial 5G

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

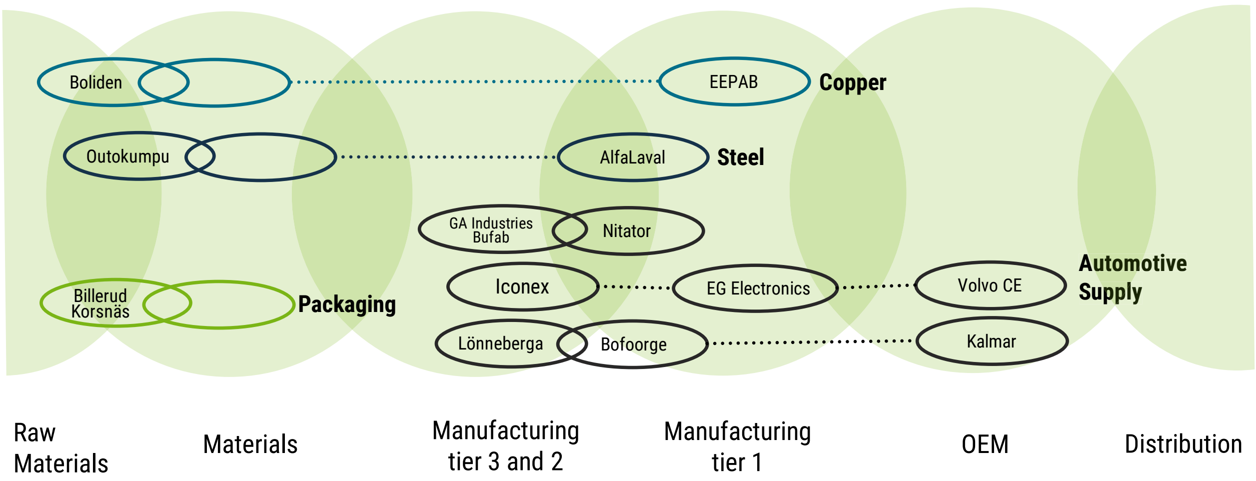

Figure 7 Project Digitala Stambanan is about the digitalization of six sub-value systems together, adding knowledge to a conceptual digital twin model (the greyed background area). The aim is related to cross-industrial learning for efficient large-scale supply chain integration (source: Digitala Stambanan).

communication infrastructure. The long-term effects of the project are expected to add competitive advantages for the mining business and industry in general, as well as for technology vendors.

Boliden Mining experienced the project's innovation-promoting collaboration to strengthen its position in digitalization and mine automation. The benefits of working with research and development, together with other technology companies, are vast and have given Boliden access to investment in state-of-the-art technology. Epiroc has developed a focus on interoperability and expanded the data and systems capacity of an ecosystem. A result of this is the greater use of data. As a result of the project, Boliden has the ability to subscribe to machine sensor data through the 5G network and services to share information with Epiroc.

Based on an increased understanding of the requirements, Ericsson has developed strategies and methods for the operation and maintenance of networks and systems for industrial end-users. Ericsson has also developed AI functionality for efficient troubleshooting in underground mobile systems. The telecommunications operator Telia has developed new digital services and has been given insights into requirements when communication services go from serving as business support to part of core industrial production. ABB has worked out concepts to link operations and maintenance staff in the mine in order to process data from their automation system over mobile communication. The development of smart solutions for automation and remote control of mining operations, which contributes to a more efficient and secure mining operation, has been an essential goal for ABB.

Volvo Construction Equipment has further developed remote-control technology to optimize driveability and give the machine operator a better overall experience. They have further deepened knowledge about how partnership and cooperation between strong players contribute to more excellent customer value and strengthen the mining industry. Volvo is developing a concept of digitalized solutions that could serve as a foundation for future business.

PIMM DMA was a continuation of the PIMM project addressing specific 5G challenges in underground environments. Partners in the project were ABB, Ericsson, Infovista, Volvo CE, Telia, Epiroc, and Boliden. RISE Research Institute of Sweden led the project.

5 Conclusions

When we look at the bigger picture of the industrial digital transformation, there may be little question concerning the way things are heading. However, on the corporate side, the path is not so obvious. Against this background, PiiA's role is to engage management and contribute to the Swedish industry's practical knowledge and preparedness for action, as well as to seek out best practices. Excellent achievements should then be made visible to inspire others.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

Experience from previous technological shifts has shown the power of good role models. Over just a few years in the 1980s, the Swedish pulp and paper industry became industry leaders in computerized automation. A significant explanation for this is to be found in company leaders inspired by sector colleagues, who shared their experiences. When industry leaders dare to take the lead in change, competitive advantages await as rewards. If they can get others to follow, large-scale industrial benefits will arise. The tradition of collaboration for technology development could be added as another success factor. In this case, ASEA (now ABB) and the forest firm SCA made groundbreaking efforts resulting in concepts that later constituted the foundation of ABB's position in process automation.

As mentioned before, the S-curve is a widely used model within PiiA. In the context of the digitally-driven industrial shift in which we currently find ourselves, we are preparing to leave the S-curve's initial innovation phase with its lab studies and industry pilots, to move into the next stage with early adopters leading the way in seeking best practices that deliver results; we call this the best practice phase. Best practice, in turn, lays the foundation for an accelerated transformation of the industry.

From aspirants to accelerators - experiences from the PiiA initiative

Examining the development of applied industrial digitalization and using the knowledge we have gained through, among other things, PiiA's project base, we can identify three types of companies in different stages of the S-curve (Larsson, 2019) as illustrated in Figure 8:

- The majority of companies – an estimated 70 percent (2019) – belong in 'the aspiring for insights' category. They realize that change is coming but still lack readiness and ability, which must, therefore, be developed. We call them Aspirants.
- We are now seeing the rise of the next category, the 'innovation pilots', to which an estimated 20 percent of businesses belong. They are engaged and have dared to take the first steps down the path toward a systematic digitalization approach. Typically, these are companies that have been active in innovation projects initiated by PiiA and other SIPs.
- The 'accelerators' category includes a small group of pioneers, estimated to be less than 10 percent of companies, who have found their own best practice solutions and are ready to scale up and transform their businesses using digital technology.

In our empirical observations, we return to the three prerequisites for succeeding with digitalization in industry, examining them from different perspectives:

- Leadership and adaptability involve creating appropriate change teams with the skills needed for the task ahead, but also taking into account new business models and the job changes that eventually will occur. This factor includes having the ability to collaborate between humans and machines (collaborative intelligence) and understanding the consequences of this ability on the organization and working models. To put the question of jobs into perspective, an estimated 14 percent of the global workforce will experience a change in their job duties as a consequence of AI (McKinsey, 2018)
- Also crucial is data, from both an ownership perspective and a quality perspective. Converted into money with the help of algorithms, data constitutes the raw material of digitalization. As discussed in this paper, data will have vast consequences on the industry when the production logic coexists with networked business approaches.
- The final essential prerequisite is related to security and risk management, an area which AI will put into a new and challenging light, togheter with legacy systems connected in ways they were not initially designed for

On the way to the top of the S-curve, it is crucial to address the challenges that arise. In our model, this starts with the company category "aspiring for insights", gaining the insights they need to understand the opportunities and to know the conditions within their own companies. Such companies may need to assess their technology base and analyze their data management, their organizational data strategy, and the value of their data. They need to think about their roadmap for digitalization. It may also be a good idea to lay the groundwork for rules and relevant policies for data security management within the company. The latter might include minimizing the risk of data breaches, as well as security measures for people and assets. It is increasingly common for policies for managing data, especially in connection with AI applications, to address ethics and the risks of skewed, biased data sets.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

Those in the innovation pilots category, meanwhile, have gained insights. Within PiiA's empirical data, we see companies at this stage that are trying out different methods and suppliers to gain knowledge and decisionmaking expertise to reach the next step, that of accelerators in this model.

The accelerator group now needs to increase the pace of implementation and transfer the responsibility for transformation to their line organizations, along with appropriate expert support. These development steps also come with growing demands on the ability of companies to manage job transformation, data as a strategic asset, and the security and ethical issues related to data usage.

6 PiiA - Future Directions

With the six-year program evaluation as a backdrop, the program management has spent essential time and effort to imagine the way ahead, now formalized in new strategic directions and actions. In summary, we find it will be crucial for PiiA to create collaborations, structures, and capabilities that:

- Guide the industry into the next stage (on the S-curve) and support industry firms in finding their best practises for sustainable competitiveness while, at the same time, spreading the successful examples to inspire others. The PiiA-body "IndTech Lab" will be developed and become a central function in this work, as well as a model for further increasing the industrial involvement in a strategy for future assurance.
- Develop and share knowledge of the logic and conditions for a Circular Industry with IndTech as enabling technology.
- Work to ensure that the phenomenon "Swedish IndTech" is well-developed and anchored in the industry and becomes a recognized international business success.
- Share PiiA's knowledge in the IndTech-area with more industries (outside the process industries) and continue to develop PiiA's knowledge position in general and especially about AI and Digital Platforms.

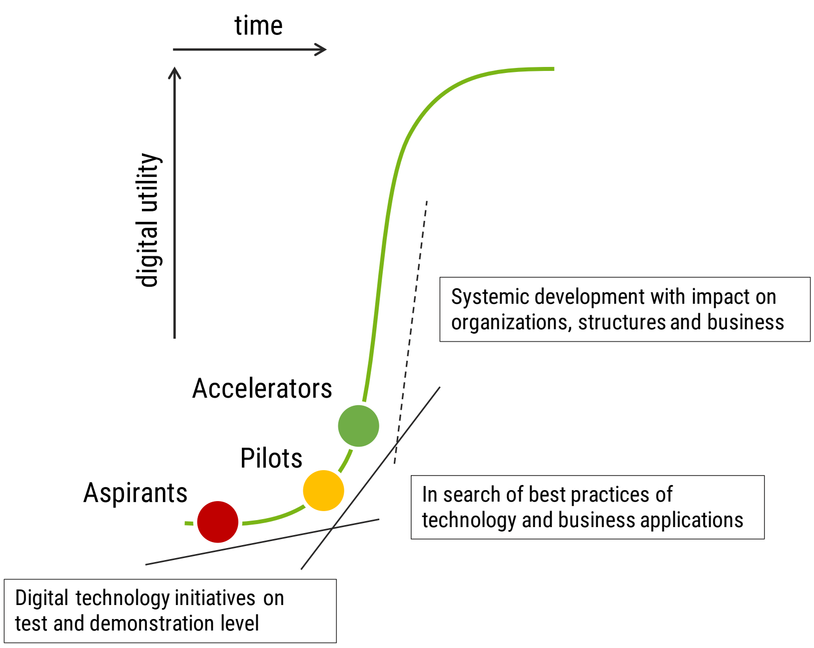

Figure 8 The S-curve with a schematic model of typical positions in the innovation movement. Aspirants are aspiring for insights, Innovation Pilots are trying to find their best practices, and a few Accelerators are prepared to take on more profound digital-ization (source: AI & Digital Platforms 2019 (in allusion to Rogers, 1995)).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

- Develop PiiA's methods, presence, and network for dialogue with the industry, academia, and authorities, to gather and disseminate knowledge and best practices.
- Focus on internationalization with enhanced conditions for several PiiA-relevant projects and constellations to receive funding from EU programs or other international organizations. PiiA will contribute to partners entering international contexts, where global insights in relevant areas are created and where Swedish actors can present themselves internationally. We will also build networks to PiiA-like relevant organizations that contribute to the above and actively participate in other actors' arenas and activities for the development of PiiA's internationalization strategy and increased international visibility.

Acknowledgements

We would like to express our sincere appreciation to the Swedish industry community for their curiosity and professional actions toward achieving progress in the vital area of industrial digitalization, for the future of the industry and a competitive economy. Our special thanks go to Vinnova and PiiA's program sponsors: ABB, Boliden, byBrick Interface, Kanthal, MineTec, Mobilaris, Modelon, Optimation, Oryx Simulation, Preem, Siemens, SSAB and Volvo Construction Equipment. Finally, we thank our reviewers for their valuable feedback, which has helped us greatly in improving the paper.

References

Arnold, E., (2020): Understanding the 2013 round of SIPs in a transitional perspective, Technopo-lis/Vinnova

Brynjolfsson et al. (2008): Scale without mass: Business process replication and industry dynamics, Harvard Business School

Eriksson, P., (2020): State of the art: Gruvindustri, PiiA and Blue Institute

Eriksson, P., (2020): State of the art: Livsmedelssindustri, PiiA and Blue Institute

Foster, R., (1986): Innovation, McKinsey & Co, pp. 90-94

Granstrand, O., Holgersson, M., (2020): Innovation ecosystems: A conceptual review and a new definition, Technovation

Heck, S., Rogers, M., Carroll, P., (2014): Resource revolution, Melcher Media

Lager, T., (2017): A conceptual analysis of conditions for innovation in the process industries and a guiding framework for industry collaboration and further research, Int. Journal Technological Learning, Innovation and Development

Larsson, Ö., (2013): Future Smart Industry, VINNOVA

Larsson, Ö., (2018): State of the art: Skogsindustri, PiiA and Blue Institute

Larsson, Ö., (2018): Swedish IndTech, PiiA and Blue Institute

Larsson, Ö., (2020): State of the art: Kemisk industri, PiiA and Blue Institute

Larsson, Ö., (2019): [AI] and digital platforms, PiiA and Blue Institute

Marsh, P., (2012): The new industrial revolution, Yale University Press

McAfee, A., Brynjolfsson E., (2014): The second machine age, WW Norton & Co

McKinsey Global Institute, (2018): Notes from the AI frontier: Modelling the impact of AI on the world economy, McKinsey & Co

Moore J.F., (1993): Predators and prey: a new ecology of competition, Harward Business Review

Nachira, F., (2002): Towards a network of digital business ecosystems, European Commission DG INFSO

Nguyen, H., et al., (2014): Remaking the industrial economy, McKinsey & Co

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119503634
DOI: 10.17879/60119503185

Nilsson, U., (2020): State of the art: Stål och Metallindustri, PiiA and Blue Institute

Parker, G. et al., (2016): Platform revolution, WW Norton Co

Rifkin, J., (2013): The third industrial revolution, Palgrave Macmillan

Rogers, E., (1995): Diffusion of innovations, The free press, New York, pp. 5-7

Wilson, J., Daugherty P., (2018): Collaborative intelligence: Humans and AI are joining forces, Harvard Business Review

www.digitalastambanan.se, accessed August 5, 2020

www.industriarbetsgivarna.se/in-english, accessed August 5, 2020

www.sip-piia.se, accessed August 5, 2020

www.sip-piia.se/2019/06/12/pimm-dma-uppkopplat-ekosystem-for-en-saker-och-effektiv-gruvindustri, accessed August 2020