JOURNAL OF
BUSINESS CHEMISTRY

NEW DESIGN

ISSUE

Vol. 17 - Iss. 3

Published on Behalf of the Institute
of Business Administration at the
Department of Chemistry and Pharmacy,
University of Münster, Germany

Special Issue on Innovation & Production Management in the Process Industries
Guest Editors: Thomas Lager and Koteshwar Chirumalla

The 4th International workshop on „Innovation and Production Management in the Process Industries" will be convened at Provadis School of International Management and Technology in collaboration with the University of Münster 14 - 15 October 2021 in Frankfurt, Germany. Further information will be announced beginning of 2021 in this journal.

ISSN 1613-9623

JOURNAL OF
BUSINESS CHEMISTRY

Aim and Scope

The Journal of Business Chemistry (JoBC) focuses on current developments and insights at the intersection of management and chemistry, biotechnology or pharmacy.

The JoBC provides an international forum for researchers and practitioners in companies, research institutes, public authorities, consultancies or NGOs to present and discuss current challenges as well as potential solutions in an interdisciplinary manner. Thus, the JoBC aims to foster the dialog between science and business, to support management practice in the chemical and pharmaceutical industry and to indicate where further research from academia is needed. The JoBC offers high quality publications with academic standards, a fast publishing process and global reach. With this multidisciplinary and boundary-spanning approach, the JoBC intends to become the leading journal for decision makers in the chemical and pharmaceutical industry.

Publisher

The Journal of Business Chemistry (ISSN 1613-9623) is jointly published by the Institute of Business Administration at the Department of Chemistry and Pharmacy (University of Münster) and the Center for Industry and Sustainability (Provadis School of International Management and Technology). It is published every four months as an open access journal.

Subscription

Online-Subscription is possible at:
subscription@businesschemistry.org
or LinkedIn: www.linkedin.com/company/jobc/
The articles are available for download free of charge at:
www.business-chemistry.org.

Abstracting and Indexing

The Journal of Business Chemistry is covered by the following abstracting and indexing services:
- EBSCO Publishing
- Hamburg Institute of International Economics
- German National Library of Economics
- Chemical Business NewsBase (CBNB) by Elsevier Engineering Information, Inc.

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020

Contents

ISSN 1613-9623

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

Extended Editorial

Thomas Lager * and Koteshwar Chirumalla **

Innovation and production management in the process industries—An extended editorial viewpoint and a way forward for future research

1 Introduction

The third International Workshop on Innovation and Production Management in the Process Industries (IPM2019) was convened at Mälardalen University in Sweden in October 2019. The overall theme is related to bridging academy–industry interfaces, innovation–production management interfaces, and the interactions among different industrial sectors of the process industries. The workshop aimed to explore the possibility of developing a platform for a research agenda for the cluster of process industries as well as develop special issues (SI) in the journal Technovation and the Journal of Business Chemistry. This article, as an extended editorial viewpoint, serves three purposes:

- Contextualizing the significance of the workshop in the area of innovation and production management in the process industries
- Presenting the results from the workshop inquiry and round-table discussions as a platform and directions for future research
- Introducing the articles in this special issue and their contributions to the area of innovation and production management in the process industries

1.1 Process industries as one part of all manufacturing industries

The family of industries generally called "the process industries" spans multiple industrial sectors, constitutes a substantial part of the entire manufacturing industry, and is generally considered to include petrochemicals and chemicals, food and beverages, mining and metals, mineral and materials, pharmaceuticals, pulp and paper, steel, and utilities. In this context, the following definition is used (Lager, 2017a, p. 203):

The process industries are a part of all manufacturing industries, using raw materials (ingredients) to manufacture non-assembled products in an indirect transformational production process often dependent on time. The material flow in production plants is often of a divergent v-type, and the unit processes are connected in a more or less continuous flow pattern.

One of the principal differences between companies in the process industries and those in other manufacturing industries is that the products supplied to and often delivered from the process industries are materials or ingredients rather than components or assembled products (Flapper et al., 2002, Frishammar et al., 2012). Furthermore, whilst product innovation in assembly-based industries begins in the design office, the development of non-assembled products in the process industries generally starts with experimental work in the laboratory or pilot plant (Frishammar et al., 2014). This inherent condition for product and process innovation among sectors within the process industries thus requires unique experimental facilities and development approaches different from those that are common in other manufacturing industries. Moreover, the importance of an integrative perspective on raw materials, process technology, and products in innovation is another significant contextual condition of the process industries (Lager, 2017), a fact that most likely favors a more amalgamated process

* Mälardalen University, School of Innovation, Design and Engineering, P.O. Box 325, SE-63105 Eskilstuna, Sweden, thomas.lager@mdh.se
**Mälardalen University, School of Innovation, Design and Engineering, P.O. Box 325, SE-63105 Eskilstuna, Sweden, koteshwar.chirumalla@mdh.se

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

and product innovation approach (Hullova et al., 2016).

1.2 Innovation and production management research in the process industries—A road less travelled

In a special issue of the journal R&D Management on the topical area of management of research and development (R&D) and innovation in the process industries (Lager et al., 2013, p. 194), the lack of innovation management research in a process-industrial context was described as follows: "It could be that the industry environment in the process industries is not as 'glamorous' compared to other industries like IT, design, and service. Additionally, the production process of process firms could appear complicated and hard to understand for scholars lacking an appropriate technical background".

In a special issue on operations management research in the process industries, Van Donk and Fransoo (2006, p. 211) remarked that: "Much of the work proposing models lacks specific knowledge of the process industry domain, enforcing that many of the characteristics are either assumed too general or not addressed specifically". This lack of process-industrial operations management research was also confirmed in a recent literature review (Samuelsson et al., 2016).

An early study found that about 30% of the top 2,000 worldwide investors in R&D belonged to the process-industrial cluster (Lager, 2010). However, despite the importance of this cluster of industries within the disciplines of innovation management and production management, as well as for industrial production and innovation in general and for the world economy at large, the family of process industries is surprisingly under-researched.

This article is organized as follows: Section 2 sets the stage for the third international workshop and provides summaries of three round-table discussions. Section 3 introduces the five articles in this special issue and provides a preliminary synthesis. Section 4 presents the results from the workshop inquiry as well as the top 10 listed topical areas for future research in the process industries. Finally, Section 5 gives concluding remarks and details a way forward.

2 IPM2019: The third International Workshop on Innovation & Production Management in the Process Industries at Mälardalen University (MDH)

The Product and Production Development research group within the Innovation and Product Realization (IPR) research environment at MDH hosted the workshop, whose objectives were to bridge the industry–academy interface and stimulate cross-sectorial and cross-disciplinary research for the future on innovation and production management in the process industries. IPM2019 was the third edition of an international workshop focusing on the process industry, and previously the workshop had been hosted in France and Australia. At this time, it included 40 representatives from various universities and companies in the pharmaceutical, steel, mineral, food and drink, and forest industries from the UK, Scotland, Denmark, Germany, the Netherlands, Switzerland, and Brazil. The organizational and scientific committee included Professor Thomas Lager (chair), Professor Glenn Johansson, Professor Jessica Bruch, and Dr. Koteshwar Chirumalla (program coordinator) from Mälardalen University as well as Professor Jens Leker from the University of Muenster and Mr. Jeff Butler (Technovation).

The workshop offered 6 plenary and key-note academic and industry-related presentations, covering different sectors of process industries, including those by Dr. Thomas Friedli (professor at the University of St. Gallen), Dr. Stephan von Delft (Glasgow University), Dr. Paulo Figueiredo (professor at the Brazilian School of Public and Business Administration), Dr. Rachid Gamal (Nestlé), Magnus Edin (SunPine AB), and Dr. Peter Wallin (Process Industrial IT and Automation, PiiA). Day 1 of the workshop included 14 academic and industrial presentations and a visit to Bolinder Munktell Museum. Day 2 included five round-table discussions on selected topics for identifying a platform for future research directions for the innovation and production management in the process industries. Day 3 included a visit to Outokumpu Stainless AB, Nyby mill in Torshälla.

The following sections present the topical areas and summaries from three selected round tables.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

2.1 Bridging the Industry—Academy interface

The state of affairs was rather provocatively described by Rynes et al. (2001, p. 346) as "academic research [falling] behind, rather than [jumping] ahead of organizational practice". A number of studies support the view that the problem with the "growing gulf between managers and research" ought to be addressed (Ghobadian, 2010). Academic scholars should thus seek industrial input regarding the industrial need for improved management tools and methodologies and to promote the reverse flow of ideas in the form of improved mechanisms for the transfer of research results from academia to industry (Barrett and Osborn, 2018). Because of the important idiosyncrasies of the contextual and inherent conditions for innovation in the process industries, particularly in the unique experimental environment, one can presume that close contact and strong collaboration between academics and industry professionals is of interest to those seeking to stimulate and bridge the gap between industry and academia (Lager, 2017a). In Figure 1 summary notes are presented from the round-table discussion on bridging the industry – academy interface.

2.2 Cross-disciplinary innovation and production management—In search of facilitating mechanisms for a conjoint approach

Brown et al. (2005, p. 15) stated that "there is a need to view operations management as part of a fluid, interactive, mutually beneficial series of relationships between raw materials and the end customer". Although the early integrative development of product and production technology is desirable in other manufacturing industries (Bruch and Bellgran, 2014), the integrative perspective on raw materials, process technology, and products needs to be given much stronger consideration in process-industrial product and process innovation (Hullova et al., 2019, Hullova et al., 2016). A company's ability to respond to change is often limited in the short term, and Hill (1994, p. 128) articulated this state of affairs distinctively for all manufacturing industries:

In all instances, the mismatch results from the fact that while manufacturing investments are inherently large and fixed (once a company has purchased them, it will have to live with them for better or for worse for many years), markets are inherently dynamic [...] The inherently changing

Figure 1 Summary notes from the round-table discussion (own representation).

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

nature of markets and companies' ability to alter marketing perspectives to allow for changes and repositioning are in opposition to manufacturing decisions that bind business for years ahead.

However, despite the overwhelming scientific evidence that product innovation and production innovation must go hand in hand, especially in a process-industrial context, this fact is unfortunately often still disregarded in both academia and industrial practice.

Indeed, scholars from the disciplines of innovation management and production (operations) management rarely interact during international conferences, seldom publish in the same journals, and infrequently share ideas in "coffee table" conversations. Likewise, and notwithstanding a desire to bridge the manufacturing–R&D interface (Lager and Rennard, 2014), similar barriers are often found in many manufacturing companies. Thus, one objective for this round-table discussion was to address this unfortunate condition, discuss how to stimulate company cross-functional attitudes and behavior, and search for a cross-disciplinary research agenda for innovation and production management in the process industries. In Figure 2 summary notes are presented from the round-table discussion on cross disciplinary innovation and production management.

2.3 Cross-sectoral learning in innovation and production management in the process industries—In search of common denominators and sectoral idiosyncrasies

Pavitt (1984, p. 343) argued that it is important to study sectoral patterns of technology change because it has implications for our "understanding of the sources and directions of technical change, firms' diversification behavior, the dynamic relationship between technology and industry structure, and the formation of technological skills and advantages at the level of the firm, the region and the country".

However, Hirsch-Kreinsen's (2008, Hirsch-Kreinsen et al., 2005, p. 39) findings also suggest that the concept of sectoral boundaries has to be conceived more broadly as well as more systematically in order to make it possible to understand the relevant aspects of the courses of technological innovation:

[A] comparison between high and medium tech industries shows that recurring principles and similarities with respect to innovation patterns can have a cross-sectoral character. These contexts are only insufficiently grasped by well-established approaches of the systems of innovation.

General problem	Barriers	Possibilities	No Good examples but Important conclusions
▪ The cluster of process industries has years of experience with the collection of process (traceability) and customer data; but what to do with the data? ▪ There is a lack of understanding and predictability of how raw material properties affect the production process and final product properties. ▪ How do individual process parameters influence product properties and satisfaction of customer demands?	▪ Production and product innovation involve (or should involve) different personal traits and capabilities. ▪ Often 90% of product innovation is related to "product renovation" when there is really a strong need for good knowledge about the production processes. The other 10% of more radical product innovation (green field) does on the other hand need deep production knowledge. ▪ Few production individuals are able to give feed-back on product design.	▪ Present organizational design in the process industries should be challenged. Well integrated product and process innovation is an important opportunity. ▪ There is a need for a more end-to-end thinking and collaboration between the production function and product innovation. ▪ Bridging mechanisms are people with a T-shaped profile, methodologies like QFD, and Digital production and simulation models.	▪ This workshop topical area is of vital importance to be addressed in the future. It is unfortunately seldom discussed and highlighted in company forums. ▪ The general academy structure and organization does not generally facilitate cross-disciplinary research and scientific journals are usually not truly cross-disciplinary

Figure 2 Summary notes from the round-table discussion (own representation).

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020

URN: urn:nbn:de:hbz:6-60119505997

DOI: 10.17879/60119504644

Although different sectors of the process industries share a large number of characteristics related to their production systems, those characteristics significantly differ from the production system characteristics in other manufacturing industries (Lager, 2017a). Consequently, sectoral experiences from process-industrial innovation and production management can be shared within the process-industrial cluster but are of less interest for other manufacturing industries. The "family" of process industries is thus similar within itself, but dissimilar to other manufacturing industries. In Figure 3 summary notes are presented from the round-table discussion on cross-sectoral learning in innovation and production management in the process industries.

3 Innovation and technology management in the process industries - In search of common denominators and sectoral idiosyncrasies

Out of the 14 academic and industrial presentations at the workshop, six were selected for potential publication in a special issue of the Journal of Business Chemistry. Two additional articles were submitted in late spring. After the workshop, all potential articles got early feedback from the guest editors and, after resubmission, five articles were ultimately selected and sent out for the double-blind review process.

The following introduction of the individual articles is to be regarded as a collection of "extended abstracts", however, composed by the Guest Editors, and in use of the original text from each article; an aspiration to capture and advertise the most important messages within each article to academics and industry professionals. Because of that, they contain an unusual large number of citations and parts from the authors' original articles; well formulated sentences and arguments which the Guest Editors did not wanted to reduce or even impair.

3.1 Contents of this special issue

The first article, entitled "Digital Transformation in the Swedish Process Industries: Trends, Challenges, Actions" (2020) by Örjan Larsson and Peter Wallin from Process Industrial IT and Automation (PiiA) Sweden, addresses a pressing topical area for all manufacturing industries and, in particular, the process industries. In the context of the fourth industrial revolution and digitalization as a driving force, the current approach in the Swedish industrial innovation system is the public–private partnership Strategic Innovation Programs (SIPs), (Larsson and Wallin, 2020). The program portfolio is funded and administrated jointly by the Swedish governmental agency for innovation systems, VINNOVA, and the Swedish Energy Agency and Formas, a government research council for sustainable

General problem	Barriers	Possibilities	Good examples
▪ Differences between industry sectors also between process industry sub-sectors ▪ Different challenges and drivers between sectors ▪ Cross-sectorial experience sharing is seldom done ▪ Differences drives between functions in companies ▪ Internal budget processes and standard KPIs limits innovations	▪ Different communities ▪ Management does not encourage cross-sectorial learning ▪ Cultural changes ▪ Common believe that their operation is unique limits interests for exchange ▪ Productivity and efficiency drive	▪ Consultants and other suppliers with cross-sectorial business are important in this aspect ▪ Local cross-sectorial exchange to learn ▪ People changing jobs bring in new experiences ▪ Networking	▪ Experience transfer of water treatment from pulp & paper to mining and pharma ▪ Cross-sectorial team visits (pulp & paper to mining) ▪ Change terminology from "project" to "experiment/initiative" for radical developments to change expectation and demands

Figure 3 Summary notes from the round-table discussion (own representation).

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

development. “Within the SIPs, and founded in 2013, PiiA was an answer to the process industries’ ambitions for increased competitiveness through digitalization”. By the beginning of 2020, PiiA had launched nearly 200 research and innovation projects and feasibility studies with 275 participating partners. This article presents seven years of empirical observations, analyses, and conclusions from the execution of the PiiA program.

Experience from previous technological shifts has shown the power of good role models and, using the knowledge gained through the PiiA’s project base, three types of companies in different stages of the S-curve were identified in the PiiA model presented in Figure 4.

The majority of companies—an estimated 70 percent (2019)—belong in the aspiring for insights category, meaning they realize that change is coming, but still lack readiness and ability, which must be developed. Such companies may need to assess their technological base and analyze their data management, their organizational data strategy, and the value of their data (Larsson and Wallin, 2020). They need to think about their roadmap for digitalization. They are called aspirants. The rise of the next category has been identified as the pilots, to which an estimated 20 percent of businesses belong. They are engaged in and have dared to take the first steps down the path toward a systematic digitalization approach. The accelerators include 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. It is advocated that: “The accelerator group now needs to shift the responsibility for transformation to their line organizations, along with appropriate expert support, as well as improve their ability to manage job transformation, data as a strategic asset, and the security and ethical issues related to data usage”, (Larsson and Wallin, 2020).

The second article by Richard Tuin (2020), entitled “Flawless Start-up of Production Plants in Process Industries: The Link between Successful Project Performance and Optimal

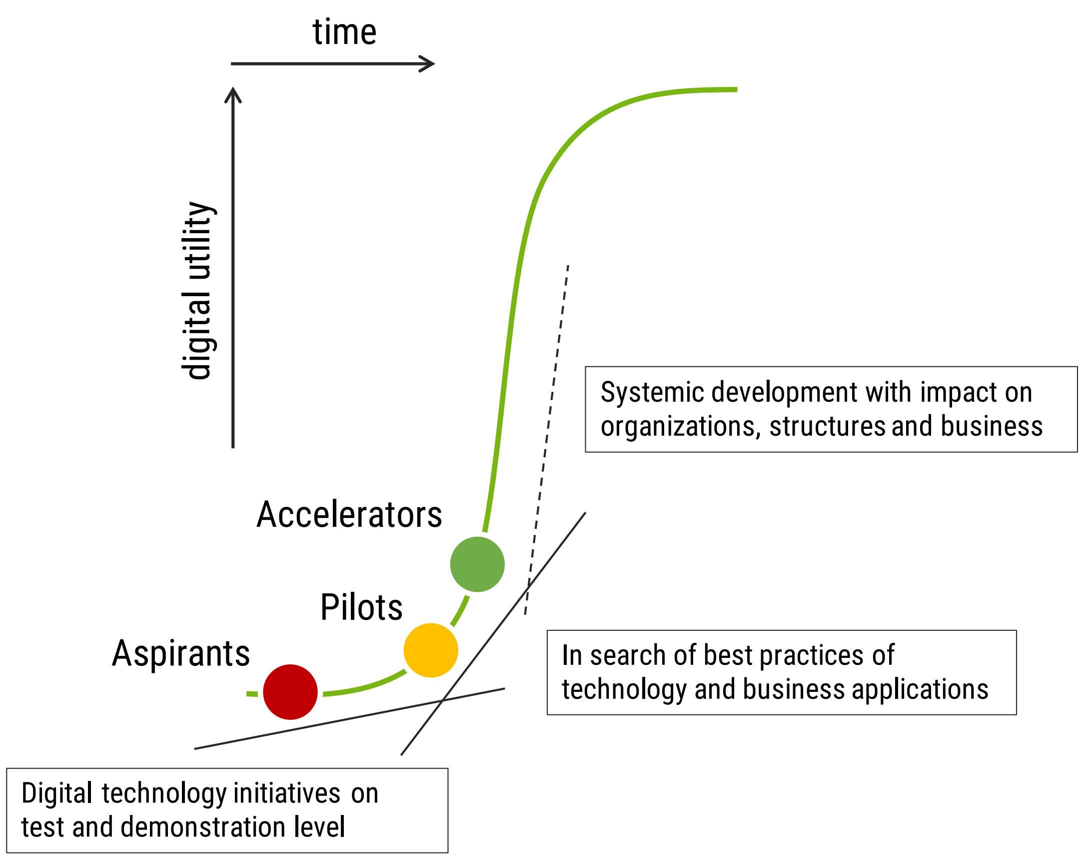

Figure 4 The PiiA model for digital transformation in the process industries (Larsson and Wallin, 2020).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

Future Operations", discusses the last phase in technology transfer—namely, the start-up phase. The article illustrates that projects in the process industries often lack intentional goals for process plant start-up and initial operations, which frequently result in prolonged periods of underperformance. "Apart from underperformance - namely, the failure to reach on-specification (nameplate) operations—there is also the increased risk of harm to both humans and the environment when projects are not executed and delivered properly", (Tuin, 2020). This study describes and analyzes why commissioning and start-up are often underestimated and undervalued, and fundamental measures and approaches are identified that can facilitate the success of commissioning and start-up in process-industrial projects. An improved plant start-up work process is presented, including the following areas (Tuin, 2020):

- Acknowledgments and insights among stakeholders and management on the importance of proper start-up and commissioning
- Determination of start-up strategies and selection of a start-up management team
- Definition of contractual terms with a strong attention to start-up
- Project cohesion and intra- and inter-organizational integration
- Proper planning, budgeting, and organization

Although the scope of start-up activities and resources depends on project size and business organization, this article argues that one of the core issues for success at start-up is the commencement of the front-end phase. Thus, of vital importance is the early involvement of a commissioning and start-up representative; in addition, in the conceptual phase of a project, there must be plans for transforming the project flawlessly into an on-specification operating plant (Tuin, 2020). Ultimately, the authors conclude that cross-sectoral cooperation and knowledge sharing within the process industries are rare, possibly because of an attitude that whatever a particular company is processing is unique rather than viewing the commonalities of technical and business processes for improvement, innovation, and learning opportunities.

Similar to the previous article, the contribution by Haitem Hassan-Beck and Thomas Lager (2020), entitled "Success factors for intra-firm process technology transfer, and a petrochemical outlook", noted that the introduction of existing, improved, or radically new process technology in the process industries is not finished until the technology is implemented and operating well within the company's organization and premises. Moreover, as the company's digital transformation also depends on the successful inter- and intra-firm transfer of technology, excellence in technology transfer is of increased industrial importance. However, the necessary reciprocal information sharing (organizational transmitting and receiving capabilities) highlights the misleading nature of the technology transfer concept, as it seems to indicate a one-way communication process (Hassan-Beck and Lager, 2020).

Based on the authors' previous industrial experiences and their literature review, they developed and operationalized 25 candidate success factors for intra-firm technology transfer. Using the success factors in an exploratory survey of professionals in the petrochemical industry, an illustrative case was further developed. The general high importance ratings of nearly all candidate success factors suggest that they could be deployed in a checklist format for a company's intra-firm process technology transfer (Hassan-Beck and Lager, 2020). The findings further indicate that process companies would benefit from the use of an internal guide for carrying out process technology transfer projects. The success factors from this study could be useful components in the development of such a manual. Moreover, the authors argued that the results can serve as guidelines for both new company technology transfer projects and a company improvement program for technology transfer.

The subsequent article, entitled "Supporting start-ups in the process industries with accelerator programs: types, design elements and success measurement", was written by Thorsten Bergmann and Timo Rothausen (2020) and discusses a different kind of start-up. A wide range of support forms for nascent ventures like start-ups exists, such as incubators, venture studios, start-up competitions, and business angel investors, and one such support form is an accelerator program, which is a novel phenomenon to foster entrepreneurship (Bergmann and Rothausen, 2020). The authors initially conclude that most research on accelerators has previously focused on start-ups dealing with digital media and that little is known about accelerator types, which support start-ups in areas like advanced materials and biotechnology. Currently, no research exists on accelerator types and their design in the context of process industries. To get an in-depth understanding of accelerator types and

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

their design in the context of the process industries, semi-structured interviews were conducted with ten accelerator managers using the topical areas of strategic focus, selection process, alumni relations, program package, and success measurement.

The results from this study show that starting an accelerator requires clear strategic goals and focuses, deciding whether to take a horizontal (i.e., including a variety of industries) or vertical (i.e., focusing on a specific industry) approach. Moreover, accelerators must establish a strong network to scout and identify suitable start-ups, and they must provide tangible benefits for start-ups (Bergmann and Rothausen, 2020). It is further recommended that accelerators provide tailored trainings according to the start-up's development stage, needs, and industry background. In the context of process industries, technical expertise and industry experience are very important. Bergmann and Rothausen (2020) further conclude that success stories from alumni start-ups can leverage the accelerator's reputation, improving its visibility, network, and access to high-profile mentors and investors. Furthermore, that accelerators must continuously assess their offers and services with carefully chosen success metrics (such as KPIs). In the context of the process industries, start-ups that offer digital solutions may be particularly interesting for participation in an accelerator, as they require fewer financial resources and are less asset-intensive (Bergmann and Rothausen, 2020).

The fifth article, "Start-ups as an Indicator of Early Market Convergence" by Magdalena Kohut, Jens Leker, Stefanie Bröring, and Nathalie Sick (2020), also discusses start-ups, but from a rather different angle. As the call for this special issue indicated a "search of common denominators and sectoral idiosyncrasies," this topical area is of particular interest. During industry convergence, defined as "the blurring of boundaries between formerly distinct industries," dominant industry logic is subject to significant changes, and established firms need to position themselves adequately in the market and acquire new competences (Kohut et al., 2020). When industries converge, previously vertically integrated value chains begin to disintegrate competition increases, and a new ecosystem starts to emerge, where established firms have to position themselves in new roles. To investigate the role of start-ups in convergence processes, this study examines the field of probiotics, a product family present in several cross-industry sectors that have emerged at the intersections of the chemicals, food and beverages, and pharmaceuticals industries and includes hybrid products like nutraceuticals, cosmeceuticals, and nutricosmetics.

In a new framework, a stepwise convergence process is presented as science convergence, technology convergence, early market convergence, and market convergence, together with the related indicators scientific publications, patents, start-up companies, and reported product launches. The study asked the following research questions: Is start-up formation present when two or more sectors converge, and can start-up formation act as an indicator of early market convergence? In this study, the data sources were scientific publications, patents, and press releases. The empirical results positively answered both research questions, and the authors concluded that (Kohut et al., 2020): "the start-up indicator offered insights into the critical transition from technology convergence to market convergence, where product launches may not yet be observable, thereby allowing the identification of early transfer opportunities along the convergence process". The authors explain that practitioners in the field of industry forecasting can benefit from having the formation of start-ups as an additional data source for the analysis of industry lifecycles. Moreover, further managerial implications arise from the strategic importance of converging industries for innovation, enabling firms to identify these processes early and prepare for changes in demand, technology, and competition (Kohut et al., 2020). As a result, they further concluded that firms can better analyze the competitive environment as well as depict newly forming, cross-industry relationships.

3.2 A preliminary synthesis of the articles in the JoBC special issue

The circles in the matrix in Figure 5 indicate the industry sectors covered in each article. Although some sectors are missing and other sectors are only represented in a single study, the impression is that the empirical evidence covers the family of process industries fairly well. Another impression is that most articles, even when a single sector is used to collect empirical data, have clear relevance for other sectors of the process industries and could be applied elsewhere in a cross-sectoral approach. The experiences from digital transformation in the Swedish process industries (Larsson and Wallin, 2020) certainly further validate such a cross-sectoral approach. The emerging sectoral convergences presented by Kohut et al. (2020) also

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

emphasize the importance of crossing sectoral borders in the future.

A noteworthy finding is that three articles take a cross-disciplinary innovation and production management perspective in digital transformation, technology transfer, and flawless start-up of production plants. Part of the content in some articles gives particular insights into a specific industry sector, but may nevertheless contribute to advancing the general understanding of innovation and production management in the process industries.

4 In search of a coherent research agenda for innovation and production management in the process industries—A workshop inquiry

4.1 The inquiry

The workshop delegates were a mixture of academic scholars, industry professionals, and representatives from related organizational bodies, all with a profound knowledge of different aspects related to innovation and production management in the process industries. Thus, the following presentation of the results from workshop delegates can be regarded as “top-of-the-mind” viewpoints from a number of “informants” (Barrett and Oborn, 2018; Kumar et al., 1993). Workshop delegates were introduced to the questionnaire on the morning of the second day, and they received ample time to respond to the questionnaire before participating in the subsequent round-table discussions.

The workshop inquiry presented in the Appendix includes 33 questions covering different aspects of innovation and production management in the process industries. The questions are categorized into the following areas: strategy, digital transformation, product and process innovation, manufacturing, and general. The participants were asked to rate the importance of all areas using a Likert scale, where 1 equals “not important” and 5 equals “very important.” In total, 23 workshop delegates responded to the questionnaire.

4.2 Results from the workshop inquiry

The Appendix presents all areas included in the questionnaire together with the mean and standard deviation figures of the delegates’ importance ratings. The ten highest rated topical areas are presented in order as a top-ten list:

Industry sector / *Topical area*	Petro-chemical	Chemical	Food and Drink	Steel	Forest	Mineral and metal	Pharma - ceutical
Digital Transformation in the Swedish Process Industries: Trends, Challenges, Actions				●	●	●	
Flawless Start-up of Production Plants in Process Industries	●			●			
Success factors for intra-firm process technology transfer and a petrochemical outlook	●	●					
Supporting start-ups in the process industries with accelerator programs		●					
Start-ups as an Indicator of Early Market Convergence		●	●				●

Figure 5 Abbreviated titles of the five papers included in this special issue are listed in the left column (the practitioner’s section uses a green shaded background). The industry sectors from which their empirical information is derived are indicated with the green circles. The upper green shaded part of the industry sector area shows the sectors to which workshop industry delegates belonged.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

1. Managing company digital transformation in the process-industries (industry 4.0)
2. Product and production innovation work processes in a process-industrial end-to-end perspective—from raw materials to end-user applications
3. Production capabilities and product lifecycle management in the perspective of a circular economy
4. Developing and fostering sustainable innovation cultures in production-oriented industrial operational environments
5. Cross-sectoral process-industrial innovation and technology management learning—in search of and fostering adapted and improved management best practices
6. Strategies for fossil-free production technologies
7. Digitalization as a supportive instrument for improved supplier and customer interaction—new innovation and production management tools and best practices
8. Process automation and digitalization for improved product quality and production flexibility
9. Innovative new perspectives on business model development adapted to process-industrial concepts
10. New process-industrial project management perspectives and best practices (e.g., managing long-term innovation projects in times of changing organizational company environments)

A detailed list of the top three rated topical areas in each category in ranking order as well as their respective rank in the top ten list is presented in Table 1.

4.3 Preliminary analysis and discussion

The results reflect some ongoing major shifts in the process-industrial sectors. Digital transformation, circular economy, value chains, and business models are a few of the shifts covered by the top ten ranked topical areas. The following subsections briefly present the top ten areas with respect to their categories.

4.3.1 Digital Transformation

The highest ranked topical area is from the digital transformation category, which is about managing company digital transformation in the process industries, including industry 4.0 technologies. In fact, of the ten topical areas, three belong to digital transformation, which shows the criticality of this area for the companies in the process industries. More specifically, experts acknowledged the importance of studying the role of digitalization and its technologies in improving customer–supplier relations (ranked seventh in the list), product quality, production flexibility, and process automation (ranked eighth).

4.3.2 Product and process innovation

The second highest ranked topical area, product and production innovation work processes in a process-industrial end-to-end perspective—from raw materials to end-user applications, is from the product and process innovation category. Previous research has stressed that more detailed investigations on process-industrial work processes are needed when it comes to product and process innovations. The workshop enquiry extends this view, pinpointing the need for further investigations of work processes from the value chain and ecosystems perspective (i.e., from raw materials to end-user applications). Process industries can benefit by having a broader understanding of work processes, which means enabling value chain collaboration and value co-creation. Moreover, delineating and extending the work processes in detail while especially considering all value-chain actors in the ecosystem (i.e., work process configurations and design) could enhance the process of digitalization and digital transformation in process industries. Thus, a detailed understanding of work processes is a prerequisite for the highest ranked topical area: managing company digital transformation in the process industries.

4.3.3 Strategy

The third topical area from the top ten list is from the category of strategy: production capabilities and product lifecycle management in the perspective of circular economy. This topical area reflects the ongoing initiatives and efforts by the European Union, which announced that a circular economy (CE) is top in its agenda. Indeed, the EU and many European countries announced a CE action plan for a cleaner and more competitive Europe. Of course, there are more issues to be resolved in this context. The experts in our workshop inquiry emphasized that both practitioners and academic scholars need to rethink the existing production capabilities and the product lifecycle management to make a successful transformation toward CE. Moreover, from the category

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

Table 1 Top three rated topical areas in each category (own representation).

Category	Description of the category	Rank in the category	Rank in the top ten list
Strategy	Production capabilities and product lifecycle management in the perspective of a circular economy	1	3
	Strategies for fossil-free production technologies	2	6
	Innovative new perspectives on business model development adapted to process-industrial concepts	3	9
Digital transformation	Managing company digital transformation in the process-industries (industry 4.0)	1	1
	Digitalization as a supportive instrument for improved supplier and customer interaction—new innovation and production management tools and best practices	2	7
	Process automation and digitalization for improved product quality and production flexibility	3	8
Product and process innovation	Product and production innovation work processes in a process-industrial end-to-end perspective—from raw materials to end-user applications	1	2
	Customer-centric product innovation frameworks, methodologies, and best practice	2	-
	Managing the "fuzzy front end" in both product and process innovation	3	-
Manufacturing	Developing and fostering sustainable innovation cultures in production-oriented industrial operational environments.	1	4
	Managing process equipment and plant start-up in the perspective of product and process innovation	2	-
	Product introduction work processes in the perspective of management of industrialization	3	-
Organisation	Cross-sectoral process-industrial innovation and technology management learning—in search of and fostering adapted and improved management best practices	1	5
	New process-industrial project management perspectives and best practices (e.g., managing long-term innovation projects in times of changing organizational company environments)	2	10
	Effective orchestration, coordination mechanisms, and collaborative models for supplier, customer, and end-user interactions in complex process-industrial supply/value chains	3	-

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

of strategy, two additional topical areas ranked in the top ten list: strategies for fossil-free production technologies (ranked sixth) and innovative new perspectives on business model development adapted to process-industrial concepts (ranked ninth). In addition, also from the strategy category, platform-based production and design of non-assembled products is considered a key topical area (ranked 11th), where the configuration modelling and integration of company raw materials, production technology, and products are anticipated to be significant.

4.3.4 Manufacturing

The fourth topical area in the top ten list is from the manufacturing category: developing and fostering sustainable innovation cultures in production-oriented industrial operational environments. This topical area acknowledges the fact that sustainable innovation culture plays an important role in process industries, which is similar to other manufacturing industries, where the topic has been significantly addressed both in practice and academia compared to the process industries. This topical area might be even more important for the process industries due to the rigid engineering and production culture.

4.3.5 General

The fifth topical area from the top ten list is from the general category: cross-sectoral process-industrial innovation and technology management learning—in search of and fostering adapted and improved management best practices. All participants agreed that process industries have great opportunities to learn from each other. Although process-industrial sectors are sharing many similarities and characteristics at the general level, each sector is also implementing unique and novel initiatives and efforts to cope with the emerging challenges (e.g., digitalization, circular economy, business models, and ecosystems). Process industries could leverage their competitive advantage by cross-sectorally sharing their lessons learned and best practices. One additional topical area from the general category is ranked in the top ten: new process-industrial project management perspectives and best practices (ranked tenth). Process industries will deal with more novelty or long-term innovation projects in the future due to all emerging transformations happening in the business environment.

5 A way forward for future research and industry collaboration

The five highest-rated topical areas from the workshop inquiry are presented in Figure 6. These areas capture a select number of areas in innovation and production management that ought to be addressed in future management research and in the development of industry best practice in the context of the “family” of the process industries.

The digital transformation and circular economy areas most likely depend on properly delineated work processes; in company implementation, they certainly rely on open and trustful organizational cultures. The fifth area is recognizing the most interesting cross-sectoral learning opportunities within the process-industrial cluster. This is further underscored in the synthesis of the articles in this special issue and supported by the interesting notes from the round-table discussions.

The need for cross-disciplinary innovation and production management research was one area discussed during the round-table discussions, and it was concluded that this issue is not only important for management research, but also vital for better company performance in the process industries: the process embodies the product. Two articles in this special issue (“Technology transfer”; “Start-up”) emphasized the importance of production management as well as how to manage industrial projects in the early phases, commissioning phases, or plant start-up phase when there are geographically dispersed multiple actors involved from the value chain or extended ecosystem.

Regarding the interesting round-table discussion results on bridging the academy–industry interface and the promising overall outcomes from this third International workshop on Innovation and Production Management in the Process Industries, one can conclude that a continuation of this initiative would be a worthwhile activity for both academics and companies in the process industries. Scholars researching innovation and production management in the process industries and industry professionals are invited to further reflect on and discuss the outcomes from this workshop presented in this article in order to further develop this platform into a more coherent research agenda.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

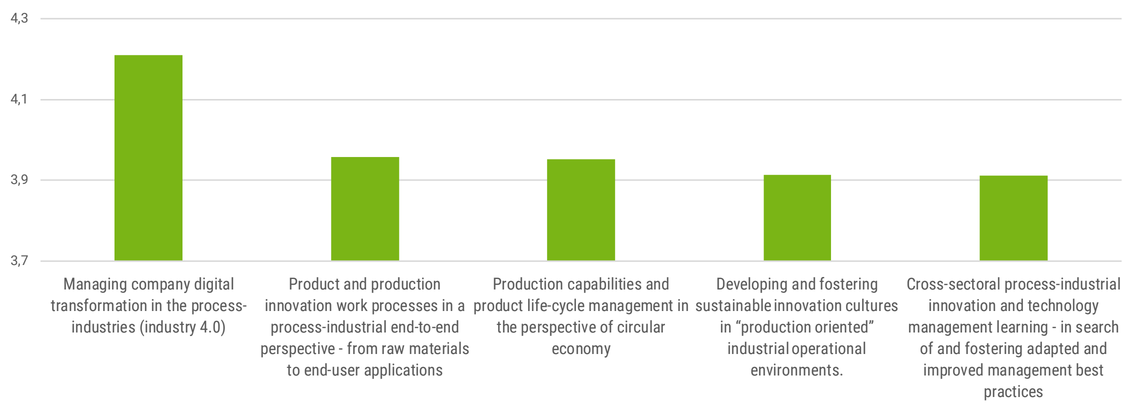

Figure 6 The five highest-ranked topical areas in the workshop inquiry (own represenation).

Acknowledgements

The academic partners for this workshop were Mälardalen University, the University of Muenster, and Provadis Hochschule. The support from the sponsoring organizations—Excellence in Production Research (XPRES), Mälardalen Industrial Technology Center (MITC), and eit/RawMaterials—is gratefully acknowledged. Many thanks go to Outokumpu Stainless AB for arranging the visit to Nyby mill in Torshälla. the authors sincerely acknowledge valuable ideas and suggestions from anonymous referees.

References

Barrett, M. and Oborn, E. (2018): Bridging the research-practice divide: Harnessing expertise collaboration in making wider set of contributions. Information and Organization, **28**, pp. 44-51.

Bergmann, T. and Rothausen, T. (2020): Supporting start-ups in the process industries with accelerator programs: types, design elements, and success measurement. Journal of Business Chemistry, **17**.

Brown, S. Lamming, R. and Jones, P. (2005): Strategic Operations Management, New York, Elsevier.

Bruch, J. and Bellgran, M. (2014): Integrated portfolio planning of products and production systems. Manufacturing Technology Management, **25**, pp. 155-174.

Flapper, S. D. P., Fransoo, J. C., Broekmeulen, R. A. C. M and Inderfurth, K. (2002): Planning and control of rework in the process industries: a review. Production Planning & Control, **13**, pp. 26-34.

Frishammar, J., Lichtenthaler, U. and Kurkkio, M. (2012): The front end in non-assembled product development: a multiple case study of mineral- and metal firms. Journal of Engineering and Technology Management (JET-M), **29**, pp. 468-488.

Frishammar, J., Söderholm, P., Bäckström, K., Hellsmark, H. and Ylinepää, H. (2014): The role of pilot and demonstration plants in technological development: synthesis and directions for future research. Technology Analysis & Strategic Management, **27.**

Ghobadian, A. (2010): Growing gulf between managers and research. Financial Times, 31st of May.

Hassan-Beck, H. and Lager, T. (2020): Success factors for intra-firm process technology transfer, and a petrochemical outlook. Journal of Business Chemistry, **17**.

Hill, T. (1994): Manufacturing Strategy: text and cases, Boston Massachusetts, IRWIN.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

Hirsch-Kreinsen, H. (2008): „Low-Technology": a forgotten sector in innovation policy. Journal of Technology Management & Innovation, **3**, pp. 11-20.

Hirsch-Kreinsen, H., Jacobson, D. and Laestadius, S. (2005): Low-Tech Innovation in the Knowledge Economy, Frankfurt-am-Main, Peter Lang.

Hullova, D., Simms, C. D., Trott, P. and Laczko, P. (2019): Critical capabilities for effective management of complementarity between product and process innovation: Cases from the food and drink industry. Research Policy, **48**, pp. 339-354.

Hullova, D., Trott, P. and Simms, C. D. (2016): Uncovering the reciprocal complementarity between product and process innovation. Research Policy, **45**, pp. 929-940.

Kohut, M., Leker, J., Bröring, S. and Sick, N. (2020): Start-ups as an Indicator of Early Market Convergence. Journal of Business Chemistry, **17**.

Kumar, N., Stern, L. W. and Anderson, J. (1993): Conducting Interorganizational Research Using Key Informants. Academy of Management Journal, **36**, pp. 1633-1651.

Lager, T. (2010): Managing Process Innovation - From idea generation to implementation, London, Imperial College Press.

Lager, T. (2017): A conceptual framework for platform-based design of non-assembled products. Technovation, 68, pp. 20-34.

Lager, T. (2017a): A conceptual analysis of conditions for innovation in the process industries and a guiding framework for industry collaboration and further research. International Journal of Technological Learning, Innovation and Development, **9**, pp. 189-219.

Lager, T., Blanco, S. and Frishammar, J. (2013): Managing R&D and Innovation in the process industries. R&D Management, **43**, pp. 189-195.

Lager, T. and Rennard, J. (2014): Managing the manufacturing - R&D interface: an extended editorial viewpoint. Journal of Manufacturing Technology Management, **25**, pp. 146-154.

Larsson, Ö. and Wallin, P. (2020): Digital transformation in the Swedish Process Industries: Trends, Challenges, Actions. Journal of Business Chemistry, **17**.

Pavitt, K. (1984): Sectoral patterns of technical change: Towards a taxonomy and a theory. Research Policy, **13**, pp. 343-373.

Rymes, S. L., Bartunek, J. M. and Daft, R. L. (2001): Across the great divide: knowledge creation and transfer between practitioners and academics. Academy of Management Journal, **44**, pp. 340-355.

Samuelsson, P., Storm, P. and Lager, T. (2016): Profiling company-generic production capabilities in the process industries and strategic implications. Journal of Manufacturing Technology Management, **27**, pp. 662-691.

Tuin, R. (2020): Flawless Start-up of Production Plants in the Process Industries: The Link between Successful Project Performance and Optimal Future Operations. Journal of Business Chemistry, **17**.

Van Donk, D. P. and Fransoo, J. C. (2006): Operations management research in process industries. Journal of Operations Management, **24**, pp. 211-214.

Appendix

A workshop inquiry on innovation and production management in the process industries

Please give your "top of mind" perspective on the following tentative topical areas for the development of a coherent agenda for future process-industrial research.

(1 = Not important   5 = Very important)

(In this slightly simplified design of the questionnaire, mean values from the study are introduced in advance of all areas in a bold font. The overall mean and standard deviation of each category is also mentioned in parenthesis.)

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

Strategy (Mean = 3.5; Standard deviation = 0.3)

(4.0) 1. Production capabilities and product life-cycle management in the perspective of circular economy.

(3.0) 2. Capturing business opportunities in the emerging process-industrial landscape - transcending sectoral demarcations and traditional technology system configurations.

(3.4) 3. Integrated portfolio planning of company products and production systems – lessons to be learned from other manufacturing industries.

(3.8) 4. Innovative new perspectives on business model development adapted to process- industrial contexts.

(3.4) 5. Strategic management of global manufacturing networks.

(3.3) 6. Industrial manufacturing and investment strategies in the perspective of dynamic market environments.

(3.6) 7. Platform-based production and design of non-assembled products – configuration modelling and integration of company raw material, production technology and products.

(3.9) 8. Strategies for fossile free production technologies.

Digital transformation (Mean = 4.0; Standard deviation=0.2)

(4.2) 9. Managing company digital transformation in the process-industries (industry 4.0).

(3.9) 10. Digitalization as a supportive instrument for improved supplier- and customer interaction – new innovation and production management tools and best practices.

(3.9) 11. Process automation and digitalization for improved product quality and production flexibility.

Product and process innovation (Mean= 3.2; Standard deviation=0.3)

(3.0) 12. Open innovation in a process-industrial context – new opportunities for consumer interaction.

(3.2) 13. Capturing value from commodity products, through expanded supplementary product service offerings or application development.

(4.0) 14. Product and production innovation work processes in a process-industrial end-to-end perspective - from raw materials to end-user applications.

(3.3) 15. New perspectives on company strategic raw materials supplies – e.g. interactive raw material and process technology innovation.

(3.2) 16. Product and process innovation strategies in the perspective of product position on the commodity/functional product scale and technology position on the S-curve.

(3.3) 17. Frugal and inclusive innovation in a process-industrial context – integrating low cost production systems, simplified product architectures and new business models for emerging and mature markets.

(3.5) 18. Customer-centric product innovation frameworks, methodologies and best practice.

(3.4) 19. Managing the "fuzzy front end" in both product and process innovation.

(3.2) 20. Pilot planting and demonstration plants in the perspective of product and process innovation total work processes.

(2.6) 21. Strategies for process-industrial Immaterial Property Rights (IPR) in the perspective of integrated product and process innovation.

Manufacturing (Mean = 3.3; Standard deviation = 0.3)

(3.3) 22. Operational excellence and management of lean production.

(3.0) 23. Open production ("wall-to-wall") company production models by the integration of raw material

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119505997
DOI: 10.17879/60119504644

(packaging) suppliers or equipment suppliers in company production systems.

(3.9) 24. Developing and fostering sustainable innovation cultures in "production oriented" industrial operational environments.

(3.4) 25. Product introduction work processes in the perspective of "management of industrialization".
(3.5) 26. Managing process equipment and plant start-up in the perspective of product and process innovation.

(3.2) 27. Maintenance management in process-industrial production environments.

General (Mean = 3.5; Standard deviation = 0.2)

(3.6) 28. Strategic process-industrial sustainability challenges in the perspective of necessary new or improved innovation management capabilities and adapted organizational frameworks.

(3.3) 29. Company "internal start-ups" (autonomous hubs within company R&D demarcations) as new organizational solutions.

(3.7) 30. New process-industrial project management perspectives and best practce (e.g. managing long-term innovation projects in times of changing organizational company environments).

(3.5) 31. Intra- and inter-firm collaboration and technology transfer models and best practices.

(3.6) 32. Effective orchestration, coordination mechanisms and collaborative models for supplier, customer and end-user interactions in complex process-industrial supply/value chains.

(3.9) 33. Cross-sectoral process-industrial innovation and technology management learning - in search of and fostering adapted and improved management best practices.

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

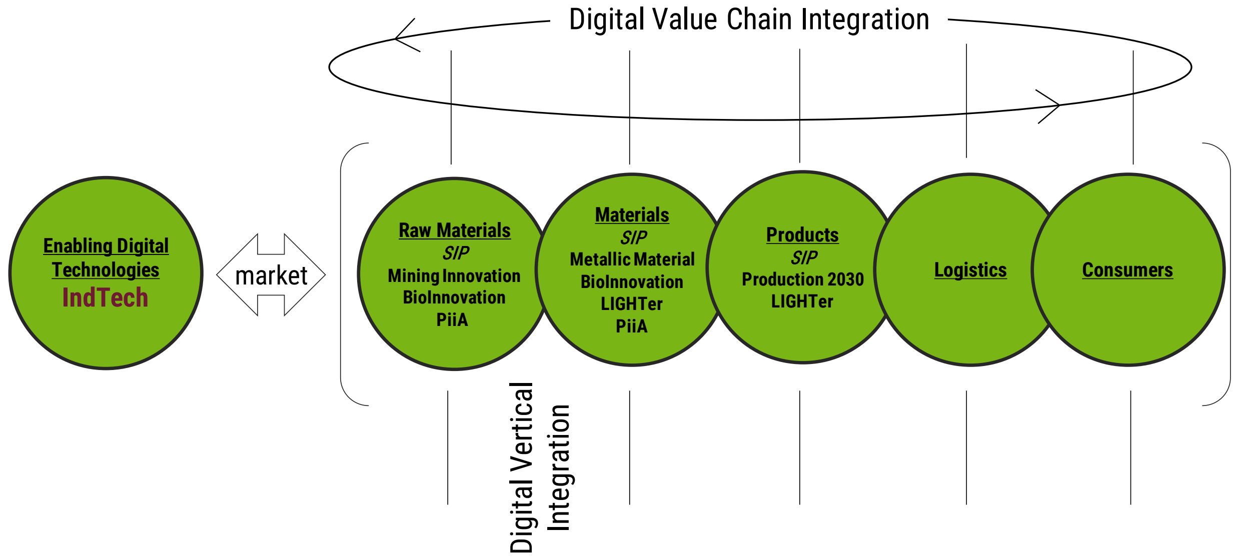

Figure 1 A value chain model with examples of different SIPs, constituting a knowledge system combining in-depth domain knowledge with expertise dedicated to digitalization. Enabling digital technologies are called IndTech, as discussed later in the article (source: PiiA/Blue Institute 2020).

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.

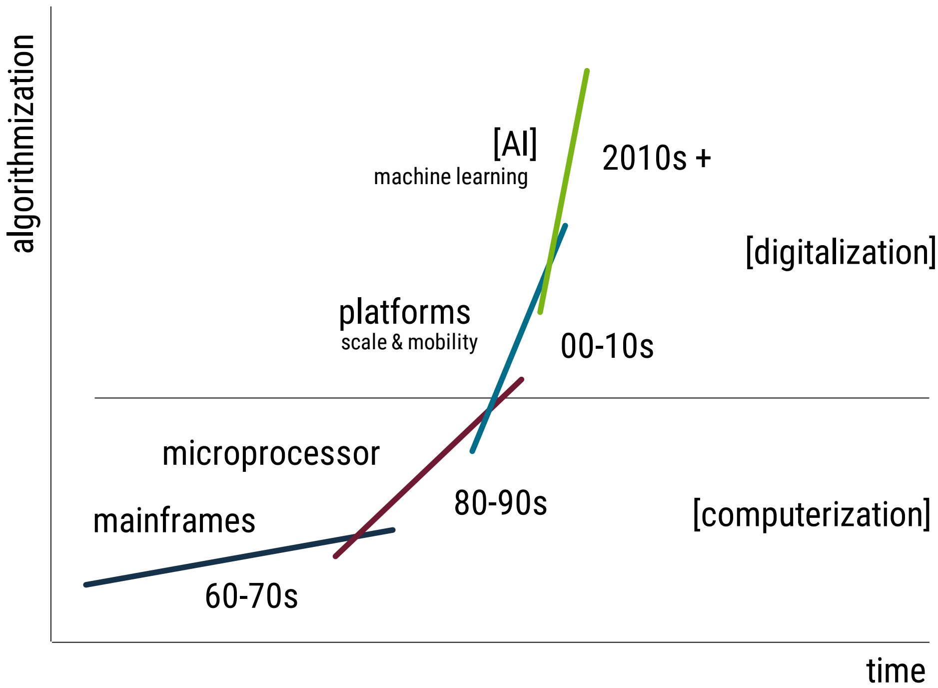

Figure 2 Algorithmization is a trend of both replacing humans with computers and providing support in daily work (source: AI & Digital Platforms 2019).

JOURNAL OF
BUSINESS CHEMISTRY

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,

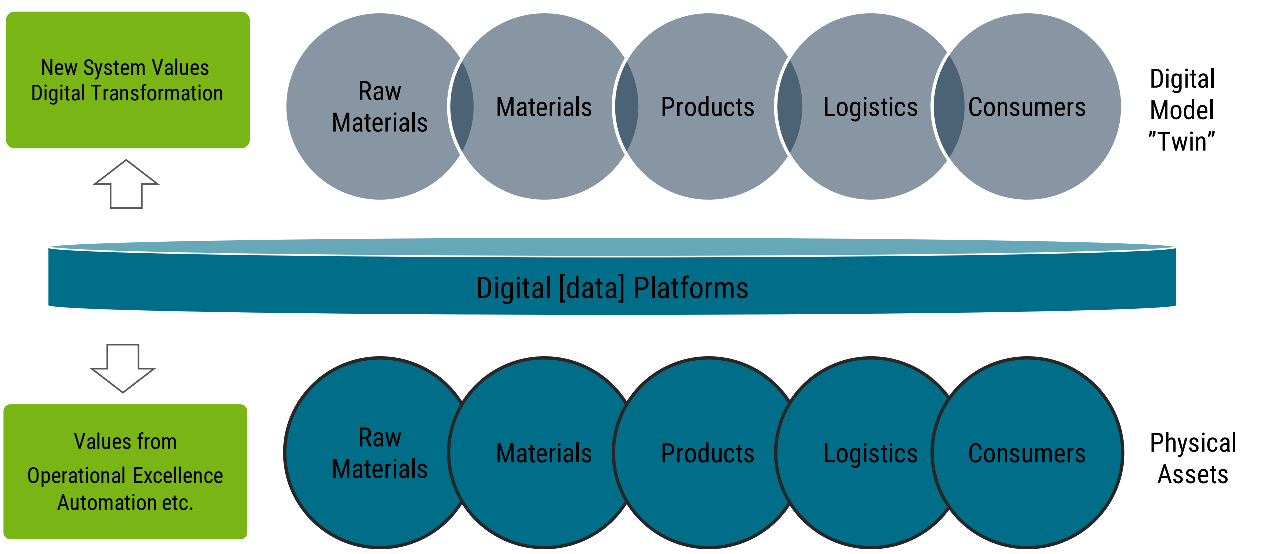

Figure 3 A holistic system perspective of an industrial system digitalization, with a physical layer of assets where efficiency is achieved using more refined automation methods such as AI. Digital twins will eventually mirror complete tangible value chains and approach the vision of the self-organizational 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).

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

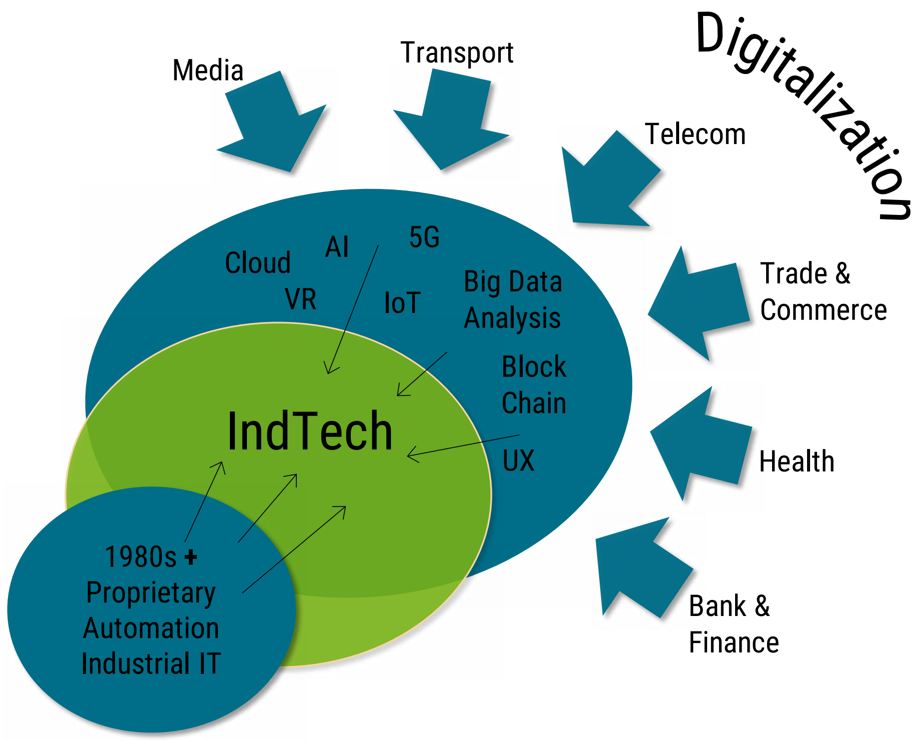

Figure 4 The model for IndTech: Traditional and new technologies come together and make 'smart industry' possible. Classic auto-mation and industrial IT meet digitalization and create new digital platforms and business ecosystems (source: PiiA Swedish IndTech 2018).

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

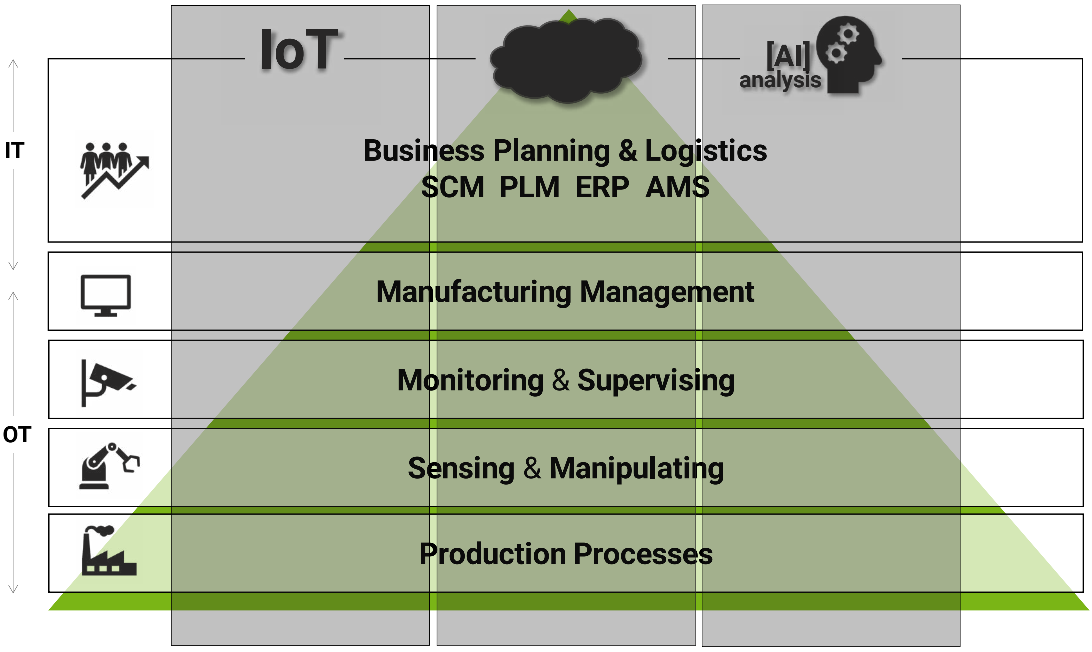

Figure 5 ISA 95 Automation Pyramid: Development is challenging traditional environments and hierarchies (source: AI & Digital Platforms 2019).

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.

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

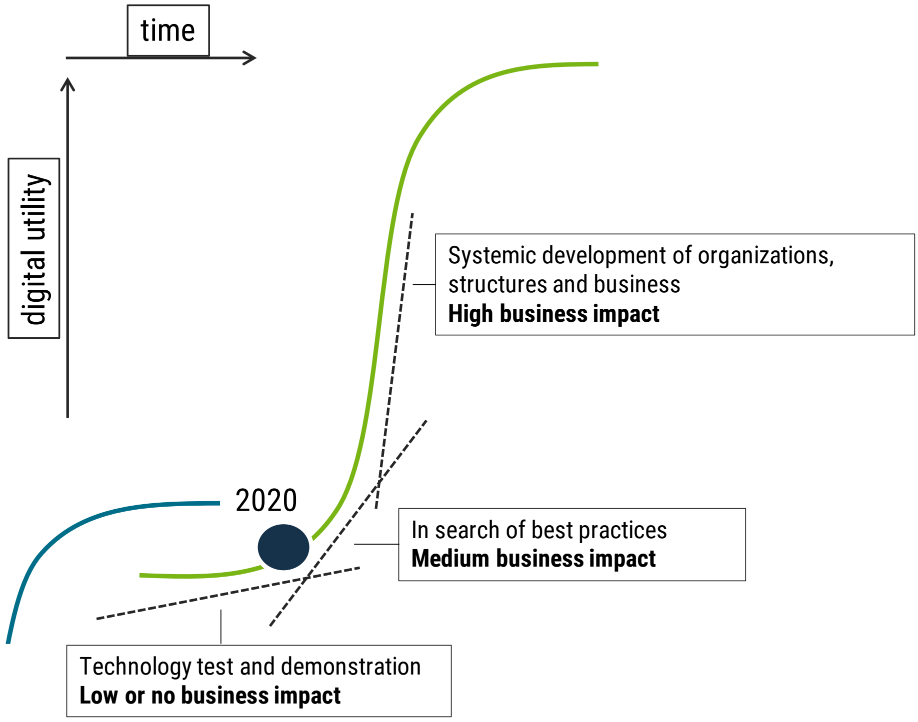

Figure 6 The S-curve is an often-used pedagogic tool in PiiA to illustrate the progress of digitalization. Starting with innovation tests and demonstrations, it continues with the search for best practices and eventually affects the industry community in digital transformation. Over the phases, the relative 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

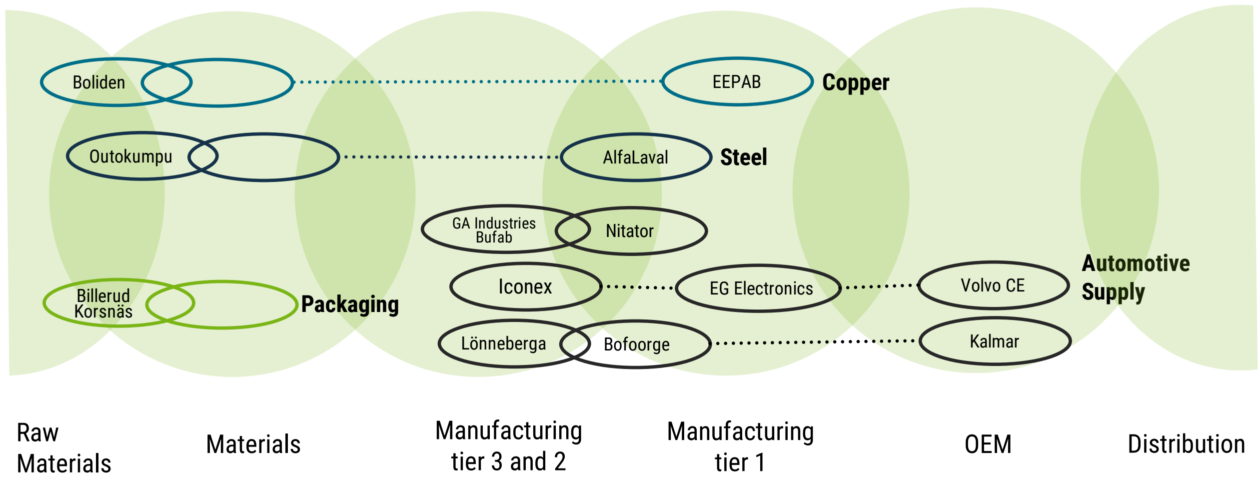

Figure 7 Project Digitala Stambanan is about the digitalization of six sub-value systems together, adding knowledge to a conceptual digital twin model (the greyed background area). The aim is related to cross-industrial learning for efficient large-scale supply chain integration (source: Digitala Stambanan).

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.

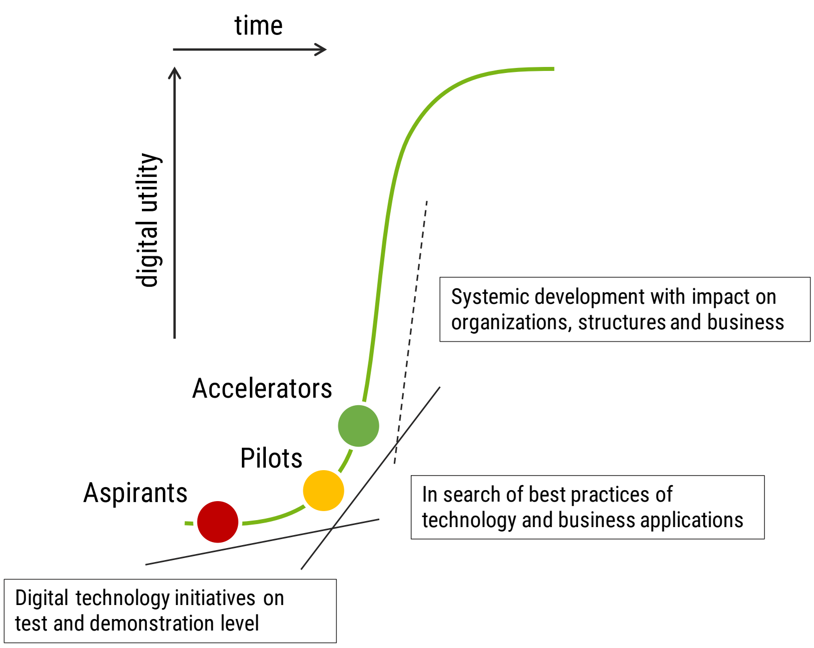

Figure 8 The S-curve with a schematic model of typical positions in the innovation movement. Aspirants are aspiring for insights, Innovation Pilots are trying to find their best practices, and a few Accelerators are prepared to take on more profound digital-ization (source: AI & Digital Platforms 2019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

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Practitioner's Section

Richard Tuin*

Flawless Start-up of Production Plants in Process Industries: The Link between Successful Project Performance and Optimal Future Operations

Process plant start-up is a key element in the transition from the project phase to business operation. A proper start-up phase ensures safe and reliable process plant operations. When project start-up tasks are not properly considered, they can become activities performed at the end of a project with no clear acknowledgement of ownership. Failure to take start-up considerations into account in all project phases can have serious negative effects on net present value for a prolonged period of time over the total asset life cycle. To ensure project success, the start-up phase must be supported by those participating in both the project and business teams, and this starts with confirmation by top management that plant start-up is a fully-fledged project phase. This study presents the challenges that are most common within the process industry and can be solved or mitigated with adding proper actions and implementations into project management and execution processes. Providing a valuable contribution to the knowledge around start-up of new process plants, the study is based on experience based empirical observations and a comprehensive literature review.

1 Introduction

There are many examples in which the projects of process plants and assets lack intentional goals for start-up and initial operations. Often the main performance indicators in projects include their scope, time, and budget, as established in policies and contracts. These performance indicators are focused solely on the project execution (Leitch, 2004). The most important goal of a project is its intended result. Owners, operators, and/or shareholders want revenues, as agreed, once the project has been delivered. To look beyond the project and examine the relative success of the operations or production phase after start-up, research (EY, 2014; Bagsarian, 2001; Lager, 2011) reveals unnecessarily long periods of underperformance or compromises in safety (Davies et al., 2009). Underperforming efficiency in the operational phase due to improperly executed projects requires innovative measures that promote improvements. Apart from underperformance, i.e., failure to reach on-specification (nameplate) operations, there is also the increased risk of harm to both humans and the environment when projects are not executed and delivered properly (Wallsgrove, 2015). Shortfalls with respect to process-plant start-up frequently result in prolonged periods of

* Tata Steel, Wenckebachstraat 1, 1951 JZ Velsen-Noord, The Netherlands, richard.tuin@tatasteeleurope.com.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

underperformance. In contrast, there are also examples of industries and companies that have given proper attention to start-up during all project phases.

This study describes and analyzes why commissioning and start-up are often underestimated and undervalued. Then, the fundamental measures and approaches are identified that will facilitate the success of commissioning and start-up in process-industry projects. Process industries are found in a wide range of industrial sectors, including petrochemicals and chemicals, food and beverages, mining and metals, mineral and materials, pharmaceuticals, paper, and steel (Lager, 2017). Although the oil and gas industry is often categorized as separate industries, in this study, the oil and gas industry is ranked as one sector of process industries. There are many differences among process industries, including distinct differences among production and operation processes with respect to production volumes, complexity, business model strategies, and low and high technologies. There are also commonalties among process industries, in that the production processes are often complex, capital intensive, hazardous, and under continuous production. These commonalities are factors that make a successful start-up important. For example, unplanned shutdowns in a continuous production process can be extremely costly and difficult to rectify.

Planning and execution of a plant start-up as an integrated project activity do not always occur. Often, only some level of commissioning activities are executed and start-up is left to the operations department with no substantive preparation. This study focuses on process-plant start-up as a project phase that must be fully developed and integrated.

The authors of multiple studies have specified the difficulties associated with project delivery, budget, and planning. Often these studies have focused on mega projects and suggest ways to address problems or improve project methods and approaches (O'Connor et al., 2016; Davies et al., 2009, Burke and Kirkham, 1993, Bush et al., 2000, EY, 2014). The transition from project to operating status, with start-up as a key element, requires that technical and business objectives be addressed during early phases of the project. As early as the project definition phase, planning and development of strategy and contractual requirements for transition to operations should be established.

Start-up is often carried out by the operations team with support from the commissioning team in accordance with a jointly prepared start-up plan. The start-up proceeds by ramping up and realizing the product qualities and production rates outlined in design documents and specifications. Commissioning is the heart of the start-up phase (Lewton, 2006). Failure to include or including only minimal commissioning and start-up activities in a project can have serious safety or environmental consequences. During the start-up and production period, flaws can emerge that can cause long periods of lost revenue or worse (Lawry and Pons, 2012; Killcross, 2012). Flawless production-plant start-up contributes to a smooth transition from the project organization to business operation. If commissioning and start-up are successful and production output is as anticipated, the project as a whole will be a success.

The objective of this study is twofold. First, it is important that process industries create a thorough understanding and awareness regarding the start-up phase of a project. Adequate acknowledgement by and the provision of knowledge about this phase within top management will ensure that the project start-up phase will be accepted by all stakeholders as a genuine project phase with its own related processes. Often, what has been lacking is a distribution of knowledge regarding the benefits of giving adequate consideration to project start-up among stakeholders. Apart from addressing the lack of necessary insights for improving the start-up experience in projects, acknowledgement and support by senior management must be promoted. The second objective of this study is to promote more research and data gathering to build reference models to facilitate the appropriate incorporation of start-up in projects. Examples include collecting reference data from executed projects and establishing models that support the provision of resources, budgets, and scheduling requirements for commissioning and start-up within process-industry projects. This can be an explicit task for researchers because companies themselves often do not carry out enough projects to collect enough data and insight.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

2 Research Methodology

This study addresses a knowledge gap within projects regarding commissioning and start-up. The research for this study was conducted through a mix of literature review and empirical observations by the author, who has been active for many decades in the commissioning and start-up of industrial plants. Interviews with informants were also conducted. The interviews involved commissioning and start-up management issues sustaining the empirical data. Several illustrative examples are presented to support various issues and topics. The illustrative examples are all drawn from the author's project experience. No detail references have been added on purpose. Because no permission has been requested and the author's intention is not to discredit the involved projects.

Start-up in process industries is a project area wherein many improvements can be made and a knowledge base established. Collaboration between those in academia and industry can facilitate these improvements.

3 Overview of Barriers and Difficulties in Plant Start-ups

Process plants often face many problems during initial start-up and initial operations. Studies show that it can take much more time to reach on-specification operations or production levels than anticipated, disregarding the risks related to safety and the environment. (YE, 2014; Bagsarian, 2001).

In process industries, there is a wide variety in how project commissioning and start-up is organized. Some organizations have such a substantial project portfolio that they are justified in having permanent project staff in-house, some of whom are responsible for commissioning and start-up. In contrast and more often, many organizations have no project staff or only a small core project team, whose members have no or only basic in-house commissioning and start-up knowledge (Lager, 2011). Although project magnitude influences the scope of a start-up, this does not imply that the start-up of a relatively small project is less important. Small projects can have a large impact on company performance.

There are a wide variety of reasons why problems occur at plant start-up such that on-specification operations are not realized. This paper presents the challenges that are most commonly experienced by process industries (Bagsarian, 2001; Killcross, 2012; Wallsgrove, 2015; Merrow, 2011), which can be solved or mitigated by the implementation of proper actions in project management and project execution tools. The proposed improvements and solutions are presented in section 2. These problem areas are presented in the following subsections under the headings:

1. Lack of knowledge among project stakeholders regarding commissioning and start-up
2. Contract deficiencies that affect start-up success
3. Late commencement of commissioning and start-up
4. Lack of recognition of the start-up phase and supportive actions
5. Understaffing during the start-up phase
6. Uniqueness of projects and technologies

3.1 Lack of knowledge among project stakeholders regarding commissioning and start-up

Lack of knowledge and insights regarding project commissioning, start-up, and operational readiness processes are often the reasons why plant start-ups are not properly prepared for and executed (Bagsarian, 2001). When insight is lacking, it is not easy to assess, with sufficient justification, the value of considering commissioning and start-up factors early in a project. The causes and likelihood of problems during commissioning and start-up are then misjudged (Lawry and Pons, 2012). The following barriers and difficulties regarding plant start-up presented here can be considered to result from a lack of knowledge about effective commissioning and start-up.

Commissioning and start-up are no easy tasks within a project. This phase commences in a relatively short period of time toward the end of a project. In a multi-disciplinary environment, equipment is put into service for the first time and budgeting the start-up activities correctly is key. Planning must be meticulous and equipment experts must be present at the right time. Personnel with sufficient knowledge and experience must have been recruited. During project execution, unexpected problems and difficulties can occur along with an increase in the level of uncertainty.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

3.2 Contract deficiencies that affect start-up success

The usual project terminology regarding completion, testing, verification, and start-up can be ambiguous and a source of confusion that can result in improperly executed activities. A lack of knowledge regarding definitions and terms leads to misinterpretation and failure to meet contractual agreements. This lack of knowledge and likelihood of misinterpretation can be found in standard contracts or contract configurations that have been copied from previous projects that do not correspond with the actual project. Appendix I provides a glossary of terms. Besides the project milestones related terminology there are contractual and legal term used to define completion milestones. For example contractual complete, primary acceptance and final acceptance. The contractual and legal terms can lead to confusion if they are not matching the project completion terminology.

Illustrative example 1: Lack of commissioning and start-up knowledge

In a large project organization established to deliver an onshore natural gas plant, with a budget of approximately €800 million, the need for a commissioning manager was acknowledged. The company that initiated the project had no in-house project knowledge or resources for a large project. A project team was fully established with the exception of a commissioning start-up manager. Several interviews were conducted but no suitable candidate was identified by the project manager and his deputy. Only when a candidate himself argued that he could perform this task did the interviewers accept that this person was the right candidate. This example illustrates that there is often a lack of substantive knowledge regarding commissioning and start-up within a project team. This lack of understanding increases the number of project risks and related consequences.

Illustrative example 2: Contract misalignment

A mega-cross-country project for a natural gas pipeline in Turkey was executed using an engineering, procurement, construction and commissioning (EPCM) contract set-up. The EPCM contract and related subcontracts were in place prior to recruiting the project commissioning manager. When the commissioning manager came onboard and reviewed the project contracts, he found four different contract definitions of Mechanical Completion. This meant that the related contract holders all had to be dealt with according to different definitions. This type of inconsistency can lead to mistakes and misunderstandings. This illustrates the need for the participation of a commissioning start-up specialist very early in the project to ensure the provision of proper contractual input regarding commissioning and start-up.

The project scopes outlined in contracts are often solely focused on the schedule and budget. With attention being given only to these internal project deliverables (Leitch, 2004), the time and cost associated with commissioning and start-up are inevitably underestimated.

In many cases, project-related contracts are already in place when the commissioning start-up manager comes on board. To be able to make the right decisions regarding the establishment of appropriate commissioning and start-up procedures, it is essential that the commissioning start-up manager read contracts as one of the first activities when joining a project.

Often, process-plant project contracts lack focus with respect to agreements about the connection between the project and operations. This lack of focus makes it unclear who is responsible for the transition between project, start-up and initial operations phase. Frequently, the project team will deem a project to be finished after testing and inspection and the operations department expects a fully functional installation. At first glance, this seems acceptable, but if the operational expenditure during the project stage has not been taken into account, this can have significant negative

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

effects on production efficiency (Powell, 2012).

Since the term process industry covers a large group of industrial sectors, the variety of contract models is correspondingly large. Each sector has its own preferences regarding the preparation, presentation, and standards of contracts. Even within one sector of a process industry, there can be a variety of preferences regarding contract types. For example, the same sector in different geographical locations can have different preferences regarding contractual formats and types.

Typical project-related contracts are fixed-price contracts (Barnes, 1988), which are also referred to as lump-sum contracts. To avoid costly changes, a lump sum (fixed price) approach requires careful definitions of scope when setting up the contract. There are several lump-sum contract arrangements, a popular one being engineering procurement and construction (EPC) contracts. Unfortunately, many projects executed based on a lump-sum contract experience significant cost overruns (Merrow, 2011).

In EPC contracts, risk and control aspects are substantially the responsibility of the contractor, including the risk of any cost overruns, and the contractor must usually provide a performance guarantee. EPC contractors are necessarily focused on avoiding risk and safeguarding their profits from a project. This set-up creates a lack of integration and contributes to disagreements among stakeholders (Davies et al., 2009). To avoid negative contractual or legal consequences, EPC contractors will determine which tests in the contract are most relevant to them and which are related to applicable rules and regulations (McNair, 2004). This can lead to situations in which the EPC contractor or its sub-contractors avoid certain commissioning activities, which makes the start-up phase a more separate and uncertain project activity (O'Connor et al., 2016; Leight, 2004; Davies et al., 2009). An EPC contractor receives the largest contract price payment, approximately 85%, at construction completion. Within this large contractual payment is the contractor's profit for the project. The retainer for the portion of commissioning and start-up activities in the contract price payment are only in the range of 5 to 8 percent, which is not much of an incentive for the contractor to expend a lot of effort.

As the name suggests with turnkey contracts, the operational team must only turn the key and the plant is expected to operate as specified. This implies that turnkey contracts include commissioning, start-up, and initial operations. When implementing a turnkey contract, it is recommended that the turnkey contractor be an experienced and licensed operator of similar facilities with extensive experience in start-up. The reasons for selecting turnkey contracts include the following: when a company is on a tight schedule, when the project is considered to involve low-risk technology, when a company has no experience with the selected technology, and when the company has insufficient resources to execute start-up activities. The possibility of encountering problems is often overlooked when selecting a turnkey contract in relation to start-up and on-specification operations (Bagsarian, 2001).

Nowadays, other contract forms are being developed. For example, contract owners tend to use reimbursable contracts, which also apply effective definitions of commissioning and start-up activities.

Examples of how deficiencies in contractual agreements affect commissioning and start-up are as follows. When commissioning and start-up activities are not well defined and not properly communicated, the construction department may not be fully aware of upcoming activities. When construction is completed, temporary construction facilities, such as accommodation and office equipment, are dismantled and taken away, without taking into account that the commissioning and start-up personnel must make use of these facilities.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Illustrative example 3: Contract responsibilities

A natural gas plant project in the Netherlands had established construction contracts with prior involvement of the commissioning and start-up manager or subject matter expert. The electrical and instrumentation subcontractor of the EPC contractor succeeded in establishing a contractual agreement whereby the contract scope ended at construction completion. This implied that no test activities had been performed upon delivery of the construction work. As a consequence, the pre-commissioning inspection and checks were not included in the responsibilities of the electrical and instrumentation subcontractor, and had to be executed by the company project department. Since deficiencies identified at pre-commissioning can often be traced back to poor construction activities, they should be the contractual responsibility of the contractor. The establishment of a better contractual strategy and set-up regarding roles and responsibilities in the delivery and scope of a project will enhance project efficiency.

3.3 Late commencement of commissioning and start-up

There are a wide variety of times in which a project's commissioning activities may commence, including, for example, during engineering, construction or when construction is complete. Starting the commissioning process when construction kicks off is typical. To be successful, the importance of establishing the correction project construction sequence has been recognized (Mukherjee, 2005). If commissioning and start-up preparation commences at construction project phase, there is no commissioning and start-up influence in the engineering project phase, with all its negatives consequences. For example, better commissioning and start-up can be achieved by taking into account the application of an extra process connection or an extra valve during the engineering phase. During engineering of the control system, it is very useful to ensure that test and start-up scenarios are programmed, for example, such that one process system is ready for commissioning and start-up and another process system is separate from and safe with respect to construction activities.

Apart from failure to incorporate design interference with respect to commissioning and start-up input, commencing too late also has consequences for the budget allotted for commissioning and start-up. Often, the allocated budget is not sufficient (Wallsgrove, 2015) when commissioning and start-up activities are scheduled to begin too late in the project.

The literature regarding the plant commissioning and start-up costs of process industries indicates that these costs range from 5 to 20 percent (Leitch, 2004; Mukherjee, 2005; Sheridan, 2015) of the overall capital cost of a project, when properly and thoroughly budgeted. This is a substantial amount of the overall capital expenditure, and this percentage depends on a wide variety of factors, such as the type and size of the project.

3.4 Lack of recognition of the start-up phase and supportive actions

Senior managers, directors, business leaders, and stakeholders all need to understand, recognize, and support project methods that ensure flawless project delivery and operations (O'Conner et al., 2016; Merrow, 2011). Lack of support regarding start-up and related project methods can occur during the construction phase if there have been no agreements made with respect to the preparation of commissioning and start-up. *Taking into account the early commissioning and start-up of utilities is often considered by the external construction contractor to be a barrier to completing the construction.* Given that construction management has more influence on resource and budgetary decisions, it can be difficult to persuade related contractors to adapt to commissioning and start-up methods if these have not been or were poorly incorporated into the contractual agreements (Killcross, 2012). A singular focus on project performance means that budget and schedule concerns can provoke nearsighted behavior. Many of the problems that occur during start-up can be related to earlier project phases and activities such as contract negotiations, engineering contractor performance, procurement specifications and pricing, construction workmanship, financial restraints, and operating group performance (Wallsgrove, 2015).

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

3.5 Understaffing during the start-up phase

When a project's start-up preparation and execution is not properly acknowledged, there will be inefficiency in the use of human resources during both the commissioning and start-up phases, with negative consequences (Lawry and Pons, 2012). Both the correct amount of resources and the right personnel (Bagsarian, 2001) are important. Without a sufficient number of people involved in start-up, the workload of those involved becomes too severe, which can lead to fatigue, reduced effectiveness, and the increased probability of errors (Wallsgrove, 2015). The right people for the job implies personnel with commissioning and start-up experience.

Depending on the geographical location, one current issue is the difficulty in finding a technically skilled workforce (EY, 2014). Inexperience of the operational staff is one of the reasons that achieving an effective start-up and reaching specified production rates is difficult. An important aspect of the commissioning and start-up activities is the provision of training for operational personnel. The integration of operational staff and of staff from other departments in the business organization within a project team can also be difficult (Sparks, 2018). This is because, to a large extent, company departments work independently of each other. And those working in business organizations are typically already fully occupied.

During a project and in particular at start-up, staff from the operations department are often necessarily put into the position of doing tasks that they are not and cannot be fully qualified to perform and have seldom or never performed in the past. Their inexperience adversely affects start-up. As such, operations staff should have important input during the design process and planning for start-up (Wallsgrove, 2015).

3.6 Uniqueness of projects and technologies

The uniqueness of projects (Davies et al., 2009) means that often project execution cannot be managed using standardized methods for commissioning and start-up. To address this issue, there must be a good evaluation of a wide range of variables when developing a strategy and plan. Variables that influence the project approach include, for example, geographical location, company experience, organizational culture, and the use of new technology. Even if a project is a virtual copy of an existing plant or facility, there are variations to be taken into account. These include the likelihood that the project will be executed by different people and that companies may fall into the trap of copying previous project mistakes (Wallsgrove, 2015).

The characteristics of a project can have a large impact on the start-up duration and time taken to reach nameplate capacity (Bagsarian, 2001). Examples include when a project is a copy of previous projects or involves new technology (Bush et al., 2000).

The use of new technology in a project contributes significantly to the time needed to start up a process plant (Davies et al., 2009). If the impact of a new technology is disregarded in a project, the commissioning and start-up effort will become tedious (Lager, 2011). Besides the burden experienced during start-up, new technology can also be problematic in remote areas and harsh climates that make operation and maintenance more difficult (Powell, 2012). In addition to new technology, poorly selected or inadequately designed technology will further contribute to a problematic start-up that will then require an extended period of time to reach on-specification operations. Frequently, senior management is unaware of the impact of new technology (Wallsgrove, 2015) on the start-up, ramp-up, and operational performance.

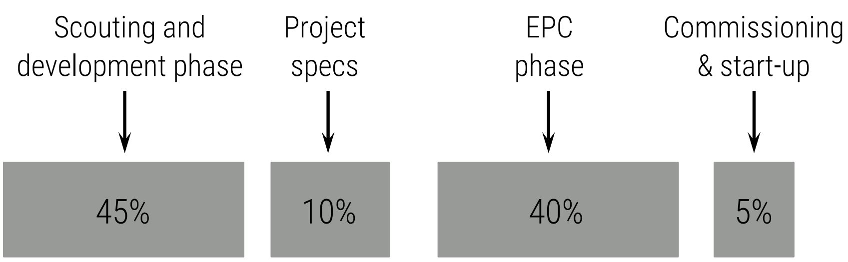

Figure 1 Flaws introduction in project phases (source: Sasol Ltd., 2008).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Illustrative example 4: Underestimating the influence of new technology

In a greenfield natural gas plant project in the Netherlands, the incorporated equipment included a substantial amount of new technology. The public relations department proudly announced that the development of the plant involved state-of-the-art technology, since the use of new technology by a project is viewed as positive. However, project stakeholders were unaware of the implications of introducing new technology in the project and faced multiple start-up problems, and it took a long time to reach on-specification operations. Introducing a new technology into a project means that more time is needed to obtain stable and on-specification operations. When this influence is recognized early in the project preparations, the related difficulties can be mitigated by adequate budgeting and the development of a realistic schedule. Alternatively, in the definition and selection phase of a project, the choice can be made to implement more proven technology if the economic advantages of the new technology are drastically reduced by costly start-up.

4 Proposed Improved Plant Start-up Work Process: The Right Way

Having assessed the main reasons for lack of adherence to a properly established start-up as a project phase, in the following sections, we present factors that improve the success of the start-up phase. Through better understanding and preparation, the problems that often occur during start-up and operational underperformance can be mitigated. Innovations in the project start-up phase and initial operations can enhance the financial returns of the operations phase (O'Conner et al., 2016; Powell, 2012; Burke and Kirkham, 1993). In addition to focusing on the organizational and technical aspects of commissioning and start-up, attention must also be paid to the preparations of the operations phase, including reviews of the project operability, maintainability, and availability (Powell, 2012). Issues related to the business organization should also be in place prior to start-up. The business-related scope to be addressed and implemented includes, among other things, operational and environmental permits, health safety and environmental procedures, infrastructure, finance, human resources, and information technology.

Start-up execution can be successful by understanding, preparing for, and acknowledging that this phase will involve time and money (Bendiksen and Young, 2015). When start-up and commissioning are considered throughout the project life-cycle, this helps to prevent or mitigate flaws that will only emerge during the execution of start-up and commissioning. More than 50% of flaws are introduced in the development and specification phases of a project (see Figure 1). If these flaws are not recognized and solved during the early stages in which the flaws first occur, the project will suffer delays and cost overruns (Sasol Ltd, 2008).

The challenges in achieving a flawless start-up and on-specification operations are multiple and ambiguous. To achieve success in planning start-up, safety, and expected revenues, the preparation and execution of start-up should encompass the key concepts presented in the following sections.

4.1 Acknowledgement by project stakeholders

First and most importantly, prior to implementing strategic project plans, insights regarding the realization of a sound commissioning and start-up phase must be shared with the company top management for their acknowledgement, support, and understanding (O'Conner et al., 2016; Bush et al., 2000). Implementing better strategies and methods with respect to start-up must be recognized as providing added value and must be supported by the top management (Busch et al., 2000, Leitch, 2004, Merrow, 2011). If start-up interventions and efforts throughout all project phases are not recognized or understood, they may be considered by top management to represent extra and unnecessary effort and investment. As such, it is important to obtain expert input on this topic in the early stages of a project. In organizations where process plant start-ups often occur, it is recommended that references be gathered of successful and unsuccessful projects to convey the importance of an adequate focus on start-up. In addition to acknowledgement from senior management, it is important that all other

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

stakeholders be informed and trained accordingly.

4.2 Determine start-up strategies and select the start-up management team

Continuity and attention to commissioning and start-up throughout the project are paramount for keeping the determined project philosophies and goals clear and alive (Burke and Kirkham, 1993). The main focus of start-up is on the successful end result. Paying attention to start-up and taking into account the efficiency of a project start-up is not a new concept—Baloff (1966) presented a study of this subject more than fifty years ago.

All stakeholder and project disciplines involved should have one common project goal in mind across all project phases, i.e., start-up and operational readiness. Operational readiness, a project process common in the oil and gas industry, relates to the readiness process and includes technical operations and operational business that ensures proper preparation of the process plant business organization for on-specification operations (Powell, 2012).

In the project definition and feasibility phase, it is important that commissioning and start-up strategies be presented, discussed, and selected. In this early phase, decisions are made regarding the scope of contracts and the related budget and preliminary duration period. Budgets and duration periods in the early project phase can be determined in various ways. In early project phases, acceptable margins are often used for the budget and schedule. When sufficient attention is given to start-up, the chance of meeting the business goals within the anticipated period becomes more realistic (Leicht, 2004).

An innovative approach to achieving a flawless start-up requires that project start-up be given strong attention not only at the last minute but throughout the project life cycle (see Figure 2).

If the focus of a project is start-up and operations driven and the work processes are driven by the commissioning and start-up manager, much responsibility lies with the person who executes this role. Therefore, the necessary knowledge, experience, and qualifications must be carefully defined. A commissioning start-up manager must have a multitude of skills; he or she must be a leader, communicator, decision maker, and problem solver. This person must have multi-disciplinary technical knowledge and experience. Sound business and project insight and experience are also required. To indicate the versatility required and the amount of work involved, Appendix II presents a comprehensive summary of the activities associated with ensuring commissioning, start-up, and operational readiness for each project phase with regard to large projects and mega-projects (Horsely, 1997; Bendiksen and Yong, 2015; Killcross, 2012; Tuin, 2019). From the activities listed in Appendix II, it is clear that preparation is crucial to ensure that the start-up of a process plant occurs without any flaws or problems.

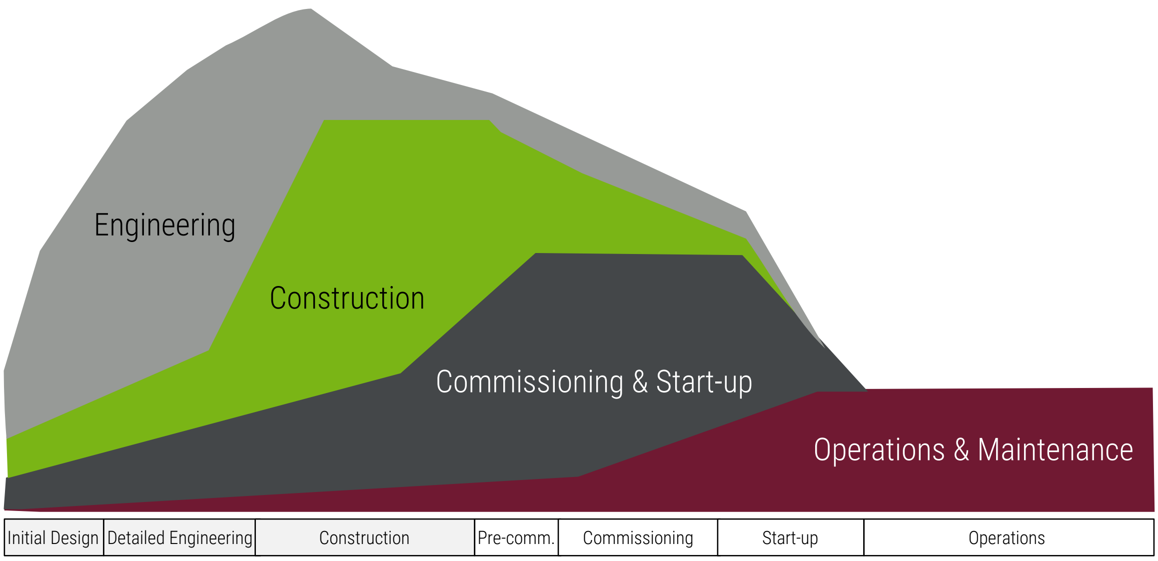

Figure 2 Start-up involvement throughout all project stages (source: Sasol Ltd., 2008).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Illustrative example 5: Conflicting interests amongst project stakeholders

In a new oil and gas production facility offshore in Qatar, a vendor representative was asked to perform commissioning activities. The vendor delivered process equipment to a construction company, who built the production facility in the Middle East. The construction company was responsible for delivering the offshore oil and gas facility to the operator within a specified period, which was fast approaching. The vendor representative performed the inspections, found that the installation was not ready for commissioning, and proposed necessary measures to reach readiness for commissioning. The vendor representative was then persuaded by the construction company to establish lenient acceptance criteria for the current state and to proceed with commissioning test activities. This case illustrates the underestimation of the requirements related to thorough testing. The primary focus of the construction contractor was the completion of the main scope of the construction and not on project commissioning. A different contractual approach would involve and ensure the interest of contractors in cooperating to achieve a flawless start-up.

Companies who include start-up and operational readiness as part of their project execution, according to the list in Appendix II, will have a good likelihood of success in process-plant start-up and reaching on-specification operations in the shortest possible time (Tuin, 2019). Ownership of the start-up and readiness factors that affect operational activities depends on the parameters of various project and business teams. Examples include project size, scope, and related in-house knowledge of the business organization. Large organizations can more easily assemble project teams that can work continuously on a project. Operational organizations must have flexibility to adapt to the changes that come with a new plant or installation (Biery, 2015).

4.3 Define the contractual terms with a strong attention to start-up

Contractual set-up and execution are significant factors in achieving a successful plant start-up and reaching on-specifications operations. Different types of projects demand different contract approaches to commissioning and start-up (Lawry and Pons, 2012).

To devote more attention to successful project delivery and its subsequent flawless start-up and on-specification operations, there must be full cooperation and integration among contractors and other project stakeholders (Davies et al., 2009). Rather than trying to predict and establish all risks in the contractual agreements, it is recommended that risks be shared with the contractors and their genuine cooperation be obtained. The approach involving cooperation, integration, and risk-sharing calls for a matching contract strategy (Davies et al., 2009; Leitch, 2004). This type of contract set-up could be a mix of fixed-price and reimbursable or cost-plus incentives agreements that reflect the performance and innovations established by the contractors. The contract and outsourcing strategies and plans must be established in the early project phases (Powell, 2012). To secure safe and efficient preparation and execution, clear terms and definitions must also be used in contractual documents regarding the requirements for checkout, handover and acceptance, commissioning, and start-up (Lawry and Pons, 2012). An even better contract strategy might be for the plant owner or operator to take responsibility for start-up, with assistance from the contractors.

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Illustrative example 6: Contract innovation

In an EPCM contract for a natural gas mega-project in Turkey, commissioning, start-up, and operational readiness were incorporated under the term "operations assurance." This contractual set-up could suggest that the operations assurance team was not fully independent with regard to inspections and testing, which could result in potential problems during start-up and initial operations. A better solution was implemented by transferring the operations assurance team to the owner's operational organization. Although extensive meetings and negotiations were needed to establish this adaptation, this is an example of good cooperation and innovation within a contractual set-up.

4.4 Project cohesion and intra- and inter-organizational integration

A truly integrated project team (Lawry and Pons, 2012), led by, for example, an interface coordinator, can contribute significantly to a successful project start-up. True integration and cooperation can ensure that vital knowledge is conveyed to the project stakeholders (Burke and Kirkham, 1993). In addition to integrating all the stakeholders in a project, the commissioning, start-up, and operational readiness must be integrated and consistent in every project phase (Annandale, 1990). An inventory of different interfaces should be established and consolidated to ensure the efficient execution of activities. Important interfaces include those between the operator/owner, engineering team, procurement and construction, vendors and specialists, and regulators and statutory bodies. Equally important within a project are the interfaces between various disciplines. A mechanism that establishes a holistic project goal can facilitate the realization of this envisioned integration.

Commissioning, start-up, and operational readiness activities must be planned, scheduled, and budgeted in close cooperation with all stakeholders and with due consideration to the recognized interfaces to ensure the efficient execution of activities (Tuin, 2015). In addition to the integration of start-up considerations throughout all project stages, commissioning and start-up leadership of a project will help to keep the attention focused on achieving a flawless start-up (O'Connor et al., 2016). Establishing a common goal between the client and contractors is important for a successful integration (Leitch, 2004). Early involvement of construction contractors in the detailed design phase adds value by the contractors' experience and knowledge of specific subjects relevant to the project (Davies et al., 2009).

In addition to integrating commissioning and start-up into every phase of a project, the involvement of the production team during all stages of the project adds value to the design due to their operational experience and knowledge (Kirsilå et al., 20007). Involving operations personnel in the design phase can lead to better commissioning and start-up plans and procedures. During the construction phase, operational personnel can contribute to construction quality by performing regular inspections. In addition to providing formal training, the involvement of operational personnel in all stages of a project ensures the provision of a level of confidence, insight, and knowledge that cannot be obtained during any other period of the plant life cycle (Horsley, 1997; Wallsgrove, 2015; Bush et al., 2000; Killcross, 2012). Training and participation of the production team during project stages can yield valuable insights for start-up and during plant operations. On-the-job training of operational staff consists of performing inspections, participating in testing, preparing operational procedures, participating in safety studies, and reviewing designs.

Many publications relating to plant start-up report integration aspects as a success factor, while acknowledging that implementing and benefitting from this success factor can be challenging. Project organizations are set up in different ways than company organizations, and this topic is addressed in section 2.5.

Typically, when a project phase is completed, the corresponding contract is terminated and the people involved leave the project, taking their relevant knowledge with them. This means that information is being lost or can be misinterpreted in other project phases. Problems related to a lack of personnel continuity become perfectly clear when commissioning and start-up activities are introduced too late in the project.

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

To contribute to a highly successful start-up, integration, as a success factor (Burke and Kirkham, 1993; Bush et al., 2000), requires effort from the project leaders and a focus on common project goals (Sparks, 2018).

4.5 Planning and budgeting

Having a sound organization alone does not ensure successful commissioning and start-up. To be fruitful, substantial and meticulous planning is also required (Accenture, 2012). Project progress must be checked frequently, as problems arise and are solved, to keep the actual status matched with the planned schedule. If schedule flexibility is taken into account, encountered problems can be accommodated and addressed. A key element in achieving efficient plant start-up is commencing plans for plant start-up at the project's front end (Sheridan, 2015). Prior to plant start-up, it is recommended that as much of the equipment as possible is run to identify any problems early so that they can be adequately solved (Burke and Kirkham, 1993). This requires innovative thinking by the commissioning start-up manager. For example, natural gas equipment could be run with nitrogen or chemical systems could be tested with water.

Commissioning and start-up can be commenced when all construction activities are complete and all necessary documentation is in place. This method is referred to as the ***traditional commissioning*** method (Burke and Kirkham, 1993), which can be used with a small or uncomplicated project, or when no contractual agreements are made regarding staggered construction delivery at the system level. When no contractual arrangements are made regarding the method of systems commissioning but these arrangements are attempted, confusion may arise and even dangerous situations. The systems commissioning method or systemization is based on the concept that to efficiently complete a project; the installation must be divided into practical commissionable portions that are addressed in the correct sequence (Tuin, 2015). Systemization of the installation or plant is an important consideration during planning. With systemization, the sequencing of delivery and completion is determined most efficiently. Therefore, it is important to change from area planning to system planning when the construction process is 60 % to 70 % complete (Burke and Kirkham, 1993). This approach allows for the early start-up of plant utilities that must be live prior to the start-up of other process systems. Another advantage of the system commissioning approach is that the construction teams are still active on-site during the commissioning activities and can be deployed to rectify problems as they occur.

In terms of efficiency, it is recommended that multiple points be established in the schedule for inspecting the construction quality for flaws, defects, and omissions by each discipline. Rather than a punch list action, scheduled milestones can be used to determine whether the construction contractors should be paid at construction completion. A second effect of early and frequent inspections during construction is that the commissioning and operations teams are frequently present on site and the contractors get the message that the client is serious about error-free delivery.

The "ready for start-up" (RFSU) milestone is a critical stage in a project, when the facility is checked and all testing and inspections are confirmed as having been completed. This means that all necessary safety precautions are in place, all start-up requirements have been met, and the operator and start-up team are prepared and ready; technical, statutory, regulatory, and compliance requirements are in place and it is considered safe to commence the first-time start-up process.

Estimating the duration of the commissioning and start-up phase involves consideration of all components and details, which require time and resources. All these components and details must be properly identified and reflected in the schedule. The systemization of commissioning activities contributes significantly to project efficiency. It is important to determine and include vendor assistance in the schedule. To create a manageable schedule, the commissioning activities must be broken down into logical steps and systems, and the planned schedule must be compared with the actual progress on a regular basis to identify and solve any problems to prevent delays.

Table 1 presents a method for predicting the time needed for commissioning and start-up, for which the duration must be aligned with the resources available (Tuin, 2015). This formula is based on data gathered from previous projects. Time prediction models can be an excellent tool in early project phases for determining the impact of commissioning and start-up on project duration and resources. In this formula, it is estimated that in a basic case, the time allotted for commissioning and start-up is 15 % of the total

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Table 1 Formula: prediction of commissioning and start-up duration (source: Sasol Ltd., 2008).

TIME= A x (0.15+B+C+D+N x E)
A = Construction time
B = Process factor
0.15 for radically new process
0.05 for relative new process
-0.01 for familiar process
C = Equipment factor
0.15 for radically new
0.08 for very new
0.05 for relatively new
-0.01 for familiar equipment
D = Workforce factor
0.15 for workforce in short supply
0.05 for workforce scarce
-0.01 for surplus workforce
N = Number of dependent process units (e.g. utilities considered as unit)
E = Dependency factor
0.25 for interdependent process units
0.10 for moderately dependent
-0.02 for independent plants

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Table 2 Formula: prediction of commissioning and start-up cost (source: Sasol Ltd., 2008).

COST= A x (0.10+B+C+D+NxE)
A = Total indicated cost of project
B = Process factor
0.05 for radically new process
0.02 for relative new process
-0.02 for familiar process
C = Equipment factor
0.07 for radically new
0.04 for very new
0.02 for relatively new
-0.03 for familiar equipment
D = Workforce factor
0.04 for workforce in short supply
0.02 for workforce scarce
-0.01 for surplus workforce
N = Number of dependent process units (e.g. utilities considered as unit)
E = Dependency factor
0.04 for interdependent units
0.02 for moderately dependent
-0.02 for independent plants

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

construction time. The application of new technology, i.e., radically new equipment or a new process, will have a huge influence on the project duration. Merrow (2011) reported that the influence of new technology on the duration of a project start-up will vary with the type of project. A small project can be managed and changes incorporated relatively easily, which means that the impact of a new technology on the start-up period is manageable. When a new technology is heavily applied in large projects, the start-up time can be five times that when proven technology is used (Merrow, 2011).

When organizations undergo frequent process start-ups, and to a large extent the project members are staff of the business organization, it is recommended that process-related parameters from previously executed projects be identified to enable the development of specific models and thereby obtain a tailor-made commissioning and start-up duration model for a particular organization. The process of gathering the required data and building the model requires a significant amount of time and professional dedication.

Budgeting accuracy heavily depends on how well the project has been defined during the preparation and planning phase. Effective estimations of the commissioning and start-up costs is a task that requires great insight and experience. An average of 5 % to 20 % (Killcross, 2012; Bendiksen and Young, 2015; Leitch, 2004; Wallsgrove, 2015) of the overall capital cost of large to mega-projects is allocated to commissioning and start-up. The most significant cost items in this total comprise feedstock during start-up and related off-specification production, manpower, managing the impact of a new technology, equipment, and chemical and utility consumption (Wallsgrove, 2015).

Start-up budgets for process plants can be estimated based on calculations of a percentage of the total indicated cost of a project, with the addition of weight factors for various project parameters. Table 2 presents a commissioning and start-up cost model, the formula for which is based on data gathered from previous projects. The start-up cost model predicts the associated budget at an early project stage. The model assumes that the basic cost for commissioning and start-up is 10 % of the total project cost. The weight factors presented do not include margins for mistakes, problems, or other issues that would increase costs. New technology and new process, in the formula, has a substantial impact in the commissioning and start-up cost. The prediction can be used in the early project stages to support, for example, feasibility studies. As the project progresses, the budget estimates should be refined by entering the actual costs. For example, the rates for commissioning and start-up personnel can be determined and obtained.

In each project phase, operation and maintenance (O&M) requirements must be assessed to ensure that they have been implemented (Dvir, 2005). These requirements should take into account project cost as well as life-cycle operating costs (OPEX) to ensure the financial sustainability during operations (Biery, 2015).

4.6 Organization for a flawless start-up

Early involvement and preparation by the commissioning start-up manager is imperative to ensure that fundamental decisions and related budget and planning for start-up and operations are taken into account. Good definition and preparation improves the performance and increases the ultimate value of a project.

Establishing appropriate personnel plans for the commissioning and start-up team is a task that must be started early in the project (Burke and Kirkham, 1993). If not planned early, difficulties will arise regarding budget and availability of the resources needed when it is time to execute start-up (Lager, 2011). Vendor resources must be booked far in advance (Mukkerjee, 2005) to ensure the availability of the field engineer or specialist when needed. Also important is establishing agreement about the availability of construction personnel during testing for tasks such as removing or installing mechanical process isolations. The level of experience of commissioning and start-up team members is also a key factor that can determine the success of plant start-up (Burke and Kirkham, 1993). Recruiting experienced and qualified people is a lengthy process that must be planned carefully well in advance. A measure that also ensures continuity within the project is the engagement of engineers from the design phase during commissioning.

Lager (2012) described different start-up organizations with different levels of interference from the operator or owner, with the start-up organizations varying with respect to the size and type of project. Start-up is often led by the operations team since operational licenses are provided to the operations department.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

An O&M team must be established or involved early enough in the project to be able to participate in design reviews and receive necessary training (Lager, 2011). The involvement and training of O&M personnel during a project adds great value to the plant operation (Kirsilå et al., 2007).

In organizations that have a permanent commissioning and start-up manager, there is the opportunity to develop tailor-made models that can help to determine project resources, budgets, and duration with respect to start-up and operational readiness.

5 Management Implications and Suggested Further Research

5.1 Management implications

High operational costs due to troublesome operations and unscheduled maintenance activities can be prevented if the importance of the commissioning and start-up phase is acknowledged and proper preparations are made. Flawless project delivery and project start-up can only be achieved via a structured work process to establish the required policies, standards, business processes, and procedures.

One of the most important aspects is to secure support from top management. Serious attention to the start-up phase and operational readiness must be given and supported by top management, followed by communicating this project approach to all project stakeholders. In addition, it is recommended that in the initiation phase of a project, a decision step should be incorporated regarding the strategy to be selected for start-up and how its execution and delivery will occur. Awareness of the importance of start-up among top management and project stakeholders as one of the measures for increasing start-up success sounds very plausible, but is more difficult to establish than introducing methods for project start-up.

Although the scope and magnitude of start-up activities and resources depend on the project size and the business organization, the fixed core issues that apply to success at start-up are commencement at the front-end loading phase, integration and focus on start-up throughout all project phases, intensive active involvement of the business organization in the project, and use of the appropriate type of contract with the additional focus on flawless start-up and operational readiness. Controlling the commissioning and start-up progress of a project from one phase to the next, as presented in appendix II, can be managed by gate reviews and audits (powell, 2012).

5.2 Conclusions and suggested further research

Members of the process industries face increasing pressure regarding project cost control and increasingly onerous environmental rules and regulations. Therefore, a project approach that envisions a flawless start-up and on-specification operations is paramount. In this light, it is surprising to learn that the importance of plant start-up and the transition from project to operations are often underestimated. These factors require more attention, understanding, promotion, and implementation. In general, project stakeholders understand and acknowledge that preparations are important and essential to project success. The deficiencies related to plant start-up and the transition from project to operations is so underexposed that it is actually a shame. Of vital importance is early involvement of a commissioning and start-up representative. In the conceptual phase of a project, there must be funded plans for determining how to transform a project flawlessly into an on-specification operating plant. Ownership of the commissioning and start-up within a project is correspondingly important. Is this responsibility left to a contractor with only minor interest and little incentive regarding commissioning and start-up? For the plant owner, the whole operation's business is at stake!

Cross sectional cooperation and knowledge sharing within process industries is rare (Lager, 2017). One of the reasons for this failure to share knowledge and lack of cooperation is the attitude of those in process industries that whatever a particular company is processing is unique and difficult rather than viewing the commonalities of technical and business processes for their improvement, innovation, and learning opportunities. The positive aspect of two very different process-industry sectors cooperating is that there is no competition aspect to restrain the parties in sharing valuable information to improve their business performance.

Better and more intensive cooperation among practitioners and researchers regarding process-industry plant start-ups can establish a platform from which innovation and knowledge can be shared, complex problems solved,

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

and knowledge and insight gained toward improved management tools and methodologies (lager 2017).

Further research may consist of data gathering and analysis regarding the efficiency of project start-ups in process industries with respect to budget, duration, resources, and preparation. This will contribute to improved insights, greater understanding, and better project performance. Large organizations with substantial project portfolios could build their own knowledge bases to better understand and improve their own plant start-ups. Organizations that are unable to perform independent data gathering could benefit by obtaining support from and collaborating with scientific institutions that can provide industry-specific data, research, and tools for supporting better process-plant start-ups.

Acknowledgements

I sincerely thank all persons involved in interviews and discussions for the development of this paper. In particular Dirk Bosch and Bill Leyshon. The support from Tata Steel to publish this article is also recognized and appreciated. Last but not least, the author sincerely acknowledges valuable ideas and suggestions from three anonymous referees.

References

Accenture (2012): Capital Project Delays and Budget Overruns Could Cost Oil and Gas Utility Industries Trillions of Dollars, Available at http://newsroom.accenture.com/news/capital-project-delays-and-budget-overruns-could-cost-oil-and-gas-and-utility-industries-trillions-of-dollars-accenture-research-shows.htm (Accessed: 24-4-15).

Annandale, G. (1990): Planning for Successful Commissioning, The Ten Commandments of commissioning, SAIChE seminar. South African, 27-4-1990. South African: Institution of Chemical Engineers.

Bagsarian, T. (2001): Avoiding startup stumbles, new Steel, February, pp.16-19.

Baloff, N. (1966): Start-ups in Machine-Intensive Systems, Journal of Industrial Engineering, January, pp. 25-32.

Barnes, M (1988): Construction project management, London: Butterworth & Co (Publishers) Ltd.

Bendiksen, T, Young, G (2015): Commissioning of offshore oil and gas projects: the manager's handbook: a strategic and tactical guide to the successful planning and execution of the commissioning of large complex offshore facilities. 2nd ed. Bloomington: AuthorHouse.

Biery, F. (2015): Getting Ready to Operate for Minerals Projects Starts in FEL, Available at: http://www.ipaglobal.com/getting-ready-to-operate-for-minerals-projects-starts-in-fel (Accessed: 19-7-15).

Burke, J. and Kirkham, R. (1993): Successful Start-up of a 1.5 Billion Pound per Year Ethylene Plant, AIChE 1993 Spring National Meeting, Fifth Annual Ethylene Producer's Conference, Houston Texas, March 1993.

Bush K, Duarte G, Pohlmann A, and Zaparoli a D, (2000): Improve Start-up of an Olefins Complex, Hydrocarbon Processing issue **79**(6), pp. 37-44.

Davies, A., Gann, D. and Douglas, T. (2009): Innovation in Megaprojects: systems integration at London Heathrow terminal 5, California Management Review, **51**, pp.101-25.

Dvir, D. (2005): Transferring projects to their final users: The effect of planning and preparations for commissioning on project success, London: Elsevier Ltd.

EY Global Ltd. (2014): Spotlight on oil and gas mega projects, Available at www.ey.com/oilandgas/captialprojects (Accessed: 22-7-15).

Horsley, D. (1997): Process Plant Commissioning –A user's guide, Rugby: IChemE.

Killcross, M. (2012): Chemical and Process Plant Commissioning Handbook: A Practical Guide to Plant System and Equipment Installation and Commissioning, Oxford: Butterworth-Heinemann.

Kirsilå, J., HellstrÖm, M, and Wikstrom, K. (2007): Integration as a project management concept: A study of the

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

commissioning process in the industry deliveries, London: Elsevier Ltd.

Lager, T. (2011): Managing Process Innovation, London: Imperial College Press.

Lager, T. (2012): Startup of new plants and process technology in the process industries: organizing for an extreme event, Available at: http://www.businesschemisrty.org/article/?article=148 (Accessed: 27-8-15).

Lager, T. (2017): A conceptual analysis of contextual and inherent conditions for innovation in the process industries, International Journal of Technological Learning, Innovation and Development, Vol. **9**, Iss. 3.

Lawry, K., Pons, D. (2012): Integrative Approach to the Plant Commissioning Process, Journal of Industrial Engineering, Available at: https://www.hindawi.com/journals/jie/2013/572072/ (accessed: 27-8-15)

Leitch, J. (2004): Effective new plant startup increases asset's net present value, Hydrocarbon Processing, July, pp. 95-98.

Lewton, K. (2005): Planning a Start-up, available at www.metdemand.com/planning_a_start-up.html. (Accessed 27-8-2015).

McNair, D., Delkousis, J., March, D. (2004): EPC Contracts – Oil & Gas Sector, Mallesons Stephen Jaques.

Merrow, E., (2011): Industrial Megaprojects, Concepts, Strategies, and Practices for success, New Jersey, John Wiley & Sons, Inc.

Mukherjee, S., (2005): Preparations for Initial Startup of a Process Unit, Chemical Engineering, **1**, P. 36-42.

O'Conner, J., Choi, J., Winkler, M. (2016): RR321-11 – Identification and Implementation of Critical Success Factors in the Commissioning and Stratup of Capital Projects, The University of Texas Austin.

Powell, D. (2012): Operations Readiness & Assurance, Operations Readiness & Assurance Ltd., Stockton-On-Tees.

Sasol Ltd. (2008): Plant Start-Up & Commissioning – Feedback on World Engineering Congress Thailand, Internal document (Sasol), Unpublished.

Sheridan, M. (2015): Managing Large Chemical Plant Startups: Prudent planning and scheduling during a project's front end can lead to more expedient commissioning and startup activities, Chemical Engineering, May 2015.

Sparks, A., (2018): Improving the Effectiveness of Capital Project Organizations, IPA global.

Tuin, R. (2019): peer review with Dirk Bosch Commissioning manager London and Bill Leyshon Operations readiness specialist.

Tuin, R., (2015): Oil and gas commissioning strategy: Insight towards ownership, M.B.A. Thesis, unpublished.

Wallsgrove, C. (2015), Process Plant Start-up, East Brunswick: The Center for Professional Advancement.

Wilkie, V. (2010) Achieving World-Class Start-up –in the Philippines, Reading: Foster Wheeler Review.

Appendix I – Brief Glossary of Terms Commonly Used In Commissioning and Start-up of Process Plants

When dealing with the issues involved in project definition and execution a major source of difficulty is the lack of a common language and a set of widely accepted definitions of the key concepts. Therefor it is important to define the terms being used in this study.

Area (construction) planning: Construction activities in logical order per area per discipline.

Business readiness: Process of managing change within the enterprise, for example after a project a company has a new system, or process that has an effect on the organization. Business readiness is used to proactively plan and manage the steps that need to occur to ensure the business impacted by the upcoming changes will be ready (Powel, 2012).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Commissioning: Actual plant commissioning demonstrates that systems operate correctly and in accordance with operational characteristics that comply with the vendor purchase orders, engineering, procurement and construction contracts, and other contracts. This demonstration includes all functions, including test runs of individual units and their associated auxiliary and safety systems, and ensures that the systems are safe and operable (Tuin, 2015).

Commissioning start-up manager: Specialist with knowledge in managing the development of all project commissioning and start-up standards and practices and related business aspects to ensure successful commercialization and implementation of a project. The commissioning start-up manager is held accountable for ensuring the provision of sufficient commissioning and start-up resources for all projects to effectively mobilize project operations and ensures that teams work towards the timely completion and handover of safe, and operable and maintainable plants.

Construction: Project phase starts with the receipt of the first purchased component on site and ends with the last functional system having achieved the mechanical complete status.

Completion: Status of a project (phase) at which all relevant criteria have been reached and can move into a next stage. For example, construction complete is reached when the following conditions are simultaneously met: all components of the systems are erected, installed, assembled, hooked up, flushed, cleaned, preserved and aligned according to construction drawings and specifications.

Emergency shutdown test: Test verifying emergency shut down functions of a plant. Testing the shutdown function by triggering a process value that stops process operations and isolating from incoming connections or currents to reduce the possibility of an unwanted event quickly.

EPC: A contracting arrangement by an engineering and construction contractor that will carry out the detailed engineering design of the project, procure all the equipment and materials necessary, and then construct to deliver a functioning facility or asset to the clients. The main EPC contractor can sub-contract specific disciplines.

EPCM: Engineering, Procurement, Construction Management is a type of contract different from an EPC contract in that the contractor is not directly involved in the construction but is responsible for administering the construction contracts.

Flawless commissioning and start-up: Focused and systematic approach to influence successful commissioning, start-up and first cycle operation. Its objective is to achieve trouble-free start-up and sustained operational performance for the total project (Powel, 2012)

Flawless project delivery: Promoting and ensuring that good methods are in place to stop the occurring of flaws and the concept of doing activities right first time within a project. It is the adoption of processes and actions by which risks to this objective will be identified, assessed and addressed during engineering, procurement and site implementation in a proactive manner (Powel, 2012).

Handover: Transfer of responsibility regarding the care, custody, and control for the project. An example is handover to owner at the final stage of project after the plant is constructed, inspected and tested. The handover activity includes all relative constructed facilities as well as project documentation as specified in the contract. The plant handed over should be in safe condition. There can be several handover moments within a project, from engineering to construction, form construction to commissioning and form commissioning to plant operational team (depending on project set-up). At Lump-sum Turnkey Type (LSTK) Contracts where there is only one handover - a single handover to Operations, namely Handover of running Plant after successful completion and acceptance of Performance Test Runs.

Lump sum contract: Contract under which a customer agrees to pay a contractor a specified amount that will cover entire project phases as specified in the contract. This contract does not allow for changes in the contract. Any additions require a change order.

Mechanical completion: Widely used term with various definitions. Often it is a contractual milestone related to construction complete, but also used as a project term to mark completion of systems. It would be better to avoid the term mechanical completion and use for example the phrase Construction Completions, since this presents more accurate the actual moment and its importance.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Nameplate operations: Operations level of a process plant with production targets output as per specified in the design. Also referred to as the plant is at full production or as on-specifications operations.

Operations assurance: Process used in the performance of projects to measure progress towards achieving the state of "readiness to operate". The process also includes an assurance component that gives an ongoing, real-time indication of the likelihood that the project will achieve that state by the time of handover to the owner/operator.

Operational readiness: Process of preparing the operational staff of an asset under construction and their supporting organizations to be fully ready to assume ownership of the asset at the point of delivery/handover, and to be able to take responsibility for performing the safe and efficient operation of that asset (Powel, 2012).

Pre-commissioning: Test activities carried out on a single discipline basis (such as electrical, instrumentation and piping) and requires materials, equipment or systems to be energized, but does not require the introduction of process fluids.

Process plant start-up: Project phase that starts with the receipt of the first feedstock and ends with the plant having achieved fully operational status; regarding capacity and design specifications. The objective of start-up is to verify that the facility operation is in accordance with the design requirements as defined in the project specifications. Typical start-up activities include the basic tuning of control systems and verification of start-up and shutdown sequences.

Ramp-up: After start-up, the process is brought to its design parameters and sustained operation. Flawless project delivery is characterized by a smooth start-up and steady ramp-up. Ramp-up in the process industries must not be confused with ramp-up in the manufacturing industries.

Ready for start-up: Status in the project that all the compiled functional systems have reached the condition of commissioned, documents are as-built, agreed spare parts are handed over to client including preservation records, and the operations organisation is able to operate and take care, custody and control of the unit for processing feed stocks, diligently complying with all relevant codes, regulations, guidelines, licence prescriptions, and applicable operating procedures and standards.

Reimbursable contracts: Contract under which allowable and reasonable costs incurred by a contractor in the performance of a contract are reimbursed in accordance with the terms of the contract.

Shutdown: A stoppage of a production process. Shutdowns are not always planned. A planned shutdown is also referred to as turnaround.

System Planning: Planning approach based on the completion of systems in a logical order.

Systems commissioning (Systemization): A system is a composite assembly of equipment, instruments, electrical supplies, etc., which can be defined as having a singular purpose. It is a section of the assets for which a clear function can be identified, and to a significant extent can be commissioned and brought into operation either in isolation or with primary support e.g. power from adjacent systems. Advantage of a system commissioning approach is it can already commence when simultaneously construction activities are still executed. This has a time saving effect within large multi discipline projects.

Staggered construction delivery: Deliver construction completion on a system level that goes together with systems commissioning.

Traditional commissioning: The opposite of systems commissioning. Testing and inspection that commences after construction is totally completed (Burke and Kirkham, 1993). This could be a good approach towards commissioning and start-up in small project, in projects where there are no contractual agreements on systemization or where the risks are too high when implementing systems commissioning.

Turnkey contract: A contract in which a contractor is given full responsibility to plan, build, test and start-up the industrial plant. In the process industries this often difficult since the contractor must have operational knowledge and often license to be able to operate the plant.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Appendix II - Overview of Activities Related To Commissioning and Start-up of Process Plants

Once a project strategy adopts integrated commissioning and start-up in all project phases, the strategy must be translated into methods and tools. Per project phase commissioning and start-up processes, tasks, actions, and involvement are presented. This comprehensive list is to demonstrate the amount of activities when process plant commissioning and start-up is thoroughly managed and executed. The presented activities are executed, managed or inspected by the commissioning start-up manager or the commissioning start-up team. Implementing all activities throughout the project phases could be a substantial transformation towards project execution method and therefore could take considerable amount of time. Depending on projects characteristics, presented activities could be clustered or altered as required. The presented project phases progress and readiness can be controlled though assessments or audits referred to as project gate review.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Table A1 1. Concept, Feasibility and Basic Engineering Phase (own representation).

1. Concept, Feasibility and Basic Engineering Phase
■ Recruit or appoint commissioning start-up manager in this early phase.
■ Determine and formulate commissioning start-up in project strategy.
■ Clarify and communicate the contracting strategy including key contractual requirements
■ Develop the philosophy regarding commissioning and start-up, containing commissioning and start-up approach and organisation.
■ Set up commissioning and start-up preliminary budgeting and schedule, including pre-production budget.
■ Provide basic engineering input and review including:
■ *Defining the sequence of Commissioning & start-up of systems in the process plant.*
■ *Listing early need requirements regarding utilities, resources, and spare parts.*
■ *Determining long lead items.*
■ Provide input in operations and maintenance philosophy and strategy from which the needed requirements are determined.
■ Contribute to basis for design and invitation to tender, regarding commissioning and start-up scope and deliverables.
■ Develop the training philosophy and strategy regarding commissioning and start-up and operations and maintenance.
■ Review equipment arrangement in respective to commissioning requirements. Providing the need for temporary jump-overs, bypasses, etc.
■ Conduct interviews and appoint lead commissioning engineers for detail engineering phase.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Table A2 2. Detailed Design Phase (own representation).

2. Detailed Design Phase
■ Improve commissioning and start-up budget and schedule based on project detailing.
■ Build commissioning and start-up organisation and implement roles and responsibilities.
■ Set up commissioning and start-up plans regarding preparation and execution and set-up commissioning and start-up schedules.
■ Commissioning start-up management documents includes:
■ *Commissioning start-up execution plan (Commissioning Manual).*
■ *Pre-commissioning, commissioning and plant start-up sequence.*
■ *Defining the transfer of care, custody & control (legal responsibility) at predetermined level of Completion in the project. Such as ready for commissioning and ready for start-up in the handover management plan.*
■ Developing procedures for pre-commissioning and commissioning, including:
■ *Pre-commissioning specific documents, such as test and inspection procedures.*
■ *Commissioning specific documents, such as test and inspection procedures.*
■ *List spare parts, special tools and consumables to be ordered for commissioning activities.*
■ *What systems or equipment need preservation until start-up and how.*
■ *Flange management, assuring flange connections are leak tight.*
■ *Interface management, stating what interfaces need to me managed by who and how.*
■ *Roles and responsibilities subdivision between commissioning and engineering, construction and operations.*
■ Set-up the framework and communicate handover management within the project and to operations. Describing what is handed over to whom.
■ Safety and risk reviews and management.
■ *Contribute to the project risk reviews.*
■ *Develop mitigation plans related to commissioning and start-up risks.*
■ *Develop HSE commissioning and start-up plan.*
■ *Develop and communicate list with necessary Inhibit and overrides.*
■ *Contribute to set-up Permit to work system in test and start-up phase.*
■ *Develop and communicate list with process isolation.*
■ *Build test plan and procedures for emergency shutdown, and Emergency Response plans.*
■ *Procedure for dealing with management of change during commissioning and start-up.*

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Continuation Table A2 2. Detailed Design Phase (own representation).

2. Detailed Design Phase
■ Provide design input and contribute to design reviews.
■ Develop completion management system.
■ Implement training plan and execution.
■ Continue to conduct interviews and appoint commissioning team members, including operations & maintenance personnel who form part of integrated team.
■ Develop pre-start-up safety review and readiness review.
■ Develop and agree procedures for simulations operations.
■ Develop process tie-in strategy, to establish safe commissioning and sequential start-up.
■ Develop and communicate the plant ramp-up plan.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Table A3 3. Construction Phase (own representation).

3. Construction Phase
■ Populate the remainder of commissioning start-up organization structure.
■ Finalise detailed commissioning plans and schedules.
■ Commissioning start-up team attending risk reviews, giving operational and commissioning input.
■ Implement handover meetings with stakeholders.
■ Finalise mass balances (steam, utilities, power, etc.), to be used during plant tests and solving problems during commissioning and start-up.
■ Implementation completions management system, containing the following items:
■ *Tracking of progress of completion, tests and inspections.*
■ *Check-out of plant is built in accordance to specifications (Punching workflow).*
■ *Handover control.*
■ *Handover/completion audits.*
■ *Implementing various reporting documents and levels.*
■ Implement systems planning approach at ±70% construction completion.
■ Conduct pre-commissioning activities.
■ *Perform check-outs/walk downs.*
■ *Manage and check Flushing/cleaning.*
■ *Manage and check tightness testing.*
■ Construction verification and acceptance of systems handover.
■ Determine an implement reporting requirements for management regarding completion.
■ Executing training for operations and maintenance staff.
■ Handover or turnover (depending how defined in project) from construction to commissioning.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Table A4 4. Commissioning and Start-up Phase (own representation).

4. Commissioning and Start-up Phase
■ Mobilizing Vendor support.
■ Execute inspections, for example; opening up Towers, Distillation Columns, Boilers and, Pumps.
■ Conduct commissioning and start-up risk reviews.
■ Conduct commissioning activities per system, area, unit, etc. depending on requirements.
■ Test runs and functional testing without feedstock (Dry runs) - cold and hot water runs.
■ Conduct final leak testing. Can be prior to process medium during function tests. Pressurise facilities on air, water, nitrogen and conduct simulated operating runs.
■ Simultaneous operations (SIMOPS) construction, pre-commissioning, commissioning and start-up in progress.
■ Acceptance and handover from commissioning to start-up.
■ Execute pre-start-up safety review and readiness review.
■ Transfer end-of-job (EOJ) documentation including all statutory documentation.
■ Conduct business readiness review.
■ Close-out all outstanding punch items.
■ Acceptance of clearance for operations.
■ Demobilisation of commissioning team.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119502627
DOI: 10.17879/60119502196

Table A5 5. Ramp-up and Operations (own representation).

5. Ramp-up and Operations
■ Reaching and executing plant and business start-up.
■ Implement plant insurances for operations.
■ Terminate construction all risks (CAR) insurance policies.
■ Provide operations & maintenance support.
■ Plant optimisation and problem solving.
■ Verify alarm management system. Number of active alarms can be excessive during start-up and needs to be minimised within acceptable and manageable levels to allow Console Operator to control without distraction of unnecessary and nuisance alarms
■ Implement any start-up modifications For example; temporary jump-overs, strainers etc. Will require a separate budget and each modification treated as a mini project with related HSE precautions.
■ Verify operations competency declarations.
■ Conduct performance testing.
■ *Hydraulic efficiency – major equipment test runs.*
■ *Process guarantees.*
■ Verify environmental performance.
■ Obtain steady state operations.
■ Handover
■ Collect, and discuss lessons learned to be turned into improvements.
■ Close-out of the project.

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

Research Paper

Haitem Hassan-Beck* and Thomas Lager**

Success factors for intra-firm process technology transfer, and a petrochemical outlook

The introduction of existing, improved or radically new process technology in the process industries is not finished until the technology is implemented and operating well within the company's organization and premises; a fact of growing importance in the perspective of digital transformation. In a literature review of technology transfer models, studies of intra-firm process technology transfer were found to be scarce, and this article, aims to close this gap. Relying on the author's industrial experiences and a literature review, 25 success factors for intra-firm process technology transfer were developed and operationalized for company use. To serve as an illustrative case in order to facilitate company implementation of the results, the success factors were afterwards included in a questionnaire in an exploratory survey to professionals in the petrochemical industry. The findings indicate that companies would benefit from the development and use of an internal guide for inter-firm process technology transfer. The holistic hierarchic structure of the success factors could not only be used as components in such a manual but also serve as a "checklist" for companies' internal improvement programs for process technology transfer.

1 Introduction

The cluster of industries generally denoted as "the process industries" spans multiple industrial sectors, constitutes a substantial part of the entire manufacturing industry (Lager, 2017); in Appendix 1 the concept process industries is defined in detail. One of the principal differences between companies in the process industries and those in other manufacturing industries is that the products supplied to them and often delivered from them are materials or ingredients rather than components or assembled products (Frishammar et al., 2012). The final step in process development is the transfer of the results to production; a point when efforts shift from the R&D organization to the production function. This phase will generally involve modifications of existing production equipment, new process installations or even the erection of a complete new production plant. However, bringing new plants, production processes, minor unit operations or single equipment items on stream is not only a production and financial risk, but an activity that is always also a safety-critical endeavor (Bagsarian, 2001).

One should thus not overlook the installation and startup of even minor process equipment integrated in big plants

* ADNOC Refining Research Centre, Abu Dhabi, United Arab Emirates, hbeck@adnoc.ae.
** Mälardalen University, School of Innovation, Design and Engineering, Campus, Eskilstuna, Sweden, thomas.lager@mdh.se.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

since, regardless of size, there is always a potential of a major process and production disturbance (Lager, 2012). In conclusion, this phase is not just handing new technology over to production (Bagsarian, 2001, Gans et al., 1983, Leitch, 2004), since this phase can represent the part of the total development process that can make the difference between project success and failure. It thus argued that more attention should be paid to this final part of process innovation; the intra-firm technology transfer process. Moreover, since the company's digital transformation and digitalization also will depend on successful inter- and intra-firm transfer of technology and systems, excellence in technology transfer is of increased industrial importance. While management of the technology transfer process is generally an issue of concern in all manufacturing industries (Burnett and Williams, 2014, Distanont et al., 2018, Lavoie et al., 2017), it is of particular interest for process technology transfer in the process industries because of high fixed asset costs and a need for high operational availability during process technology transfer.

In spite of its importance for theory building and for industrial production and innovation, process-industrial innovation is unfortunately still under-researched, and in a literature review of technology transfer and technology transfer models, studies of intra-firm process technology transfer were found to be scarce; this article aims to close this gap. Success factors for intra-firm transfer of process technology are defined in this study as: "specific working methods and best practices that lead to successful outcomes of technology transfer" (Lager and Hörte, 2005b), which is related to the construct of effectiveness in technology transfer. Furthermore, previously presented barriers for technology transfer are converted into success factors by identifying how they could be overcome.

The point of departure for this study was the development of a conceptual framework for intra-firm transfer of process technology in the process industries. Afterwards, based on the authors' previous industrial experiences in technology transfer and a review of extant literature on technology transfer, 25 candidate success factors for intra-firm process technology transfer were iteratively developed. These success factors were afterwards used in the development of a questionnaire for an exploratory survey to professionals in the petrochemical industry in order to serve as an illustrative case to facilitate company implementation and use.

Apart from companies' general management of the technology transfer process and the use of a number of success factors for excellence in management of process technology transfer, the complexity of the technology to be transferred is generally one out of several contextual determinants for successful technology transfer. The matrix in Figure 1 thus illustrates the influence of *the newness of the process technology to the company's production system* and *the newness of the process technology to the world* on the technology transfer process complexity (Lager, 2002). In this study, the importance ratings of individual success factors were consequently differentiated in the inquiry for both "well-proven technology" and "new technology".

Success factors for improving a process company's R&D organization's desorptive (transmitting) capabilities (Lichtenthaler, 2006) were categorized in this study as technology-related, work-process-related, and knowledge- and culture-related. Success factors for improving a process company's production organization's absorptive (receiving) capabilities (Cohen and Levinthal, 1990), however, were more knowledge- and culture-related.

The remainder of this article is organized as follows. In the next section, technology transfer in general and intra-firm technology transfer in particular are reviewed. Afterwards, the development of a conceptual framework, research design and the methodological development of success factors for process technology transfer are presented. The empirical findings from a survey of companies in the petrochemical industries are then introduced, including individual success factors and their related supportive references. The results are then discussed, followed by managerial implications and conclusions.

2 A literature review and the development of a conceptual framework for process technology transfer

In this article, the distinction proposed by Stewart (1987) is followed, and the term of "technology diffusion" is thus used to refer to the spontaneous flow or meandering of information and knowledge about a technology, whereas the term "technology transfer" is used to refer to a company's intentional transfer of technology and knowhow. This article focuses on "technology transfer"; for a recent comprehensive

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

treatment of the topical area, see, for example, Tidd (2010).

2.1 Introducing the concept of technology transfer

The importance of technology transfer is today generally considered unquestionable; however, John Mason Mings (1999) presented two contrasting perspectives:

Technology transfer is sometimes suggested as an El Nino in business, government, industry and even education decision-making, and for some it has meant disruption, dislocation, and danger. For others, technology transfer has been the vanguard of progress and an inexhaustible fountain for productivity, empowerment, and convenience.

While technology transfer is important, it certainly may have both advantages and disadvantages; thus, excellence in the management of the technology transfer process is consequently of industrial importance from an organizational perspective on innovation management. Defining technology as comprising the physical object (artifact), the process of making this object and the necessary knowledge to operate the object (Levin, 1993), this study views the transfer of technology as not only the physical movement of equipment and the transfer of the necessary skills to operate the equipment but also an understanding of necessary embedded knowledge and cultural skills; these elements are not generally distinctive and separable but rather form a seamless web.

In a taxonomy for technology transfer, the following categories of transfers were identified by Reisman (1989): "Scientific disciplines, Professions, Industries, Economic sectors, Geographic regions and Societies/Countries". Reisman and Zhao (1991) further suggested the inclusion of the dimensions "duration, cost, nature and modality (organizational forms for collaboration)". The lesson to be learned here is that, in modelling technology transfer or in the development of new conceptual frameworks, it should be specified for what type of technology transfer and what kind of transfer environment the results are supposed to be relevant for, as well as which kinds of transfer mechanisms, success factors, or determinants that is referred to. Khabiri et al. (2012), in search of a technology transfer model for SMEs, propose a slightly modified version of the model proposed by Malik (2002), and for a recent review of technology transfer models, see Kundu and Bhar (2015).

2.2 Technology transfer at a company-to-company level

The process of introducing existing, improved, or newly developed technology in a company is not finished until the technology is implemented and operating well within the company's organization and premises. By analogy, just as the final phase of product development is the

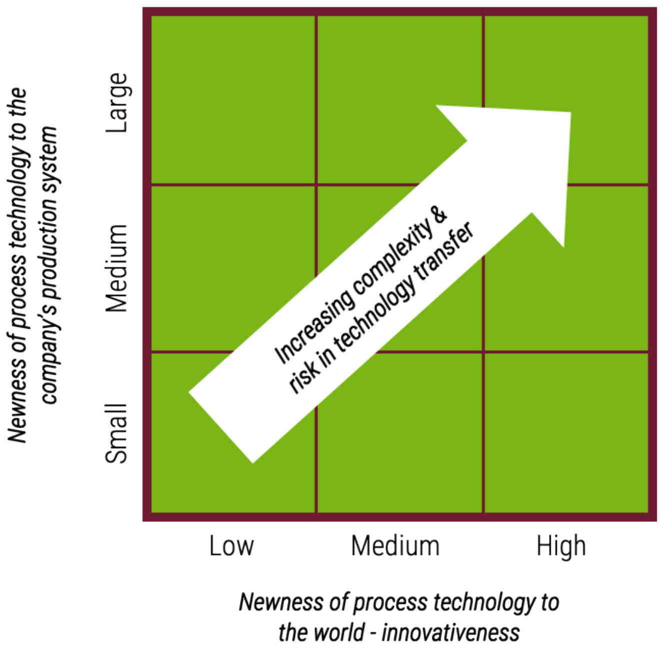

Figure 1 The contextual dependency of the transfer of process technology in the process industries (in allusion to Lager 2002).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

launch of a new product on the market, the final phase of process development is the implementation and start-up of a new technology — that is, technology transfer. In a study of barriers to technology transfer, at a personal level of analysis, Jung (1980) concludes that an organization that wants to minimize barriers must observe a number of factors, including looking for personalities that facilitate technology transfer, rewarding good technology transfer behavior, building and maintaining trust, and improving documentation. Trott et al. (1995) likewise recognize the importance of non-routine activities and effective communication between credible boundary-spanning individuals. This area is further discussed by Leonard-Barton and Deschamps in their study of managerial influence in the implementation of new technology (Leonard-Barton and Deschamps, 1988, Leonard-Barton and Kraus, 1985).

In a study of internal technology transfer and the determinants for success, Leonard-Barton and Sinha (1993) observed that important success factors include not only the cost, quality and compatibility of the technology but also user involvement in the development and adoption by the developers and users of both the technical system itself and the workplace. They further observed that a technical system transferred from a development site to a user site always encounters differences in context, equipment, operators' skills, and so on. Moreover, even if developers successfully meet their original technical objectives, new technology often requires fine-tuning in the operating environment. Malik (2002) concluded that barriers to technology transfer could be overcome by a personnel approach (temporary or permanent transfer of the knowledge owner to the user group), an observation that is supported by Langrish (1971). He further recognize that barriers or likely-to-inhibit factors include lack of interest in the project, the "not invented here" syndrome, lack of people transfer, lack of perceived market benefit, lack of trust, lack of training, lack of incentives, language barriers, and perception of new technology as a threat (Malik, 2002).

A study of critical success factors for technology transfer in the petrochemical industry (Badruzzaman, 2003) acknowledges the importance of securing recipient "buy-in", providing an early demonstration of expected benefits, and ensuring the transferee's prior knowledge of the technology. Chai et al. (2004), in a study of process innovation, identified the effort required for the "adoption of the technology for local use" and the "degree of technology embeddedness in the original organizational setting" as critical factors. In an organizational learning perspective, Daghfous (2004) identifies a number of factors for an improved inter-firm transfer of technology, such as the inclusion of a transferee representative in the technology development, the importance of prior knowledge of the technology at the transferee company, and a need to identify necessary organizational implications.

In a study of internal technology transfer in complex product development (Magnusson and Johansson, 2008), the importance of the "system aspects" is stressed. This fact, highlights the corresponding "system aspect" in the transfer of process technology into complex process-industrial production systems. In two articles (Part 1 and Part 2), Lager and Hörte (2005a, Lager and Hörte, 2005b) studied success factors for the development of process technology in the process industries, and a number of success factors that relate well to technology transfer are noted in the presentation of these success factors in the empirical findings. In the book ***Managing Process Innovation: From idea generation to implementation***, Lager (Lager, 2010) also presents success factors related to process technology transfer; for example, "strong mutual trust exists between the development organization and the production organization".

In a review of critical success factors in manufacturing industries, Mamat and Roslan (2012) concluded that the most important overall factor was good communication, but they noted that the transfer of key personnel, selection of a proper transfer mode, and compatibility in partnership were also important. Modelling the technology transfer process in the petroleum industry, Mohamed et al. (2012) point out the importance of the transferee having good prior knowledge in the area of technology, as well as the importance of mutual trust between the transferor and the transferee. In a study of knowledge transfer in the oil and gas industry, Burnett and Williams (2014) recognized that successful development of technology is in large part due to personal interactions and, in many cases, informal sharing of both tacit and explicit knowledge. Searching for "catalysts" of intra-firm technology transfer, Petronia et al. (2015) recognized the importance of the transfer of tacit knowledge, risk estimation and the link to previous testing of the technology. Moreover, Chuan (2018) identified a number of challenges to intra-firm technology transfer, such as:

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

- *Managing tacit information*
- *Avoidance of "not invented here"*
- *Lack of people transfer and "face-to-face" communication*
- *Culture and trust*

In the development of a technology transfer framework for the energy sector, Lavoie et al. (2017) considered the following capabilities to be important: "training at the donor's site, assigning experienced staff, overcoming language barriers, early interaction with transferor, future revenue estimates, and risk analysis". In a review of critical success factors for university–company technology transfer, de Souza Andrade et al. (2017) identified the importance of technology training and communication abilities. The latter factor was also highlighted in a study by Behrane and Grobbelar (2018). Distanont et al. (2018) identified the following factors affecting technology transfer in the petrochemical industry: "strong knowledge of the technology by the transferor, crossing language barriers, classroom training, face-to-face learning, and on-the-job training".

2.3 A conceptual framework for intra-firm transfer of process technology

In an early seminal paper titled "Innovation and learning: the two faces of R&D," Cohen and Levinthal (1990), introduced the concept of "absorptive capacity":

We argue that while R&D obviously generates innovations, it also develops the firm's ability to identify, assimilate and exploit knowledge from the environment – what we call a firm's "learning" or "absorptive" capacity.

In a later review and reconceptualization, Zahra and George (2002) distinguished between potential and realized absorptive capacity. The antonymous concept is "desorptive capacity", defined by Lichtenthaler (2006) as "a firm's ability to identify technology transfer opportunities and to transfer technology to the recipient". The ability of an R&D organization to excel in intra-firm technology transfer is to a large extent dependent on its ***transmitting*** capabilities for knowledge and technology, which in today's vocabulary are often called its "desorptive capabilities". In a similar vein, the process company's production organization's ***receiving*** capabilities for new or improved internal technology can be called its "absorptive capabilities". In Figure 2, a conceptual framework for intra-firm process technology transfer has been outlined. However, please note that success factors related to the areas marked with dashed borders were not targeted in this study.

2.3.1 Success factors for intra-firm transfer of process technology

In the perspective of intra-firm transfer of process technology, Figure 2 illustrates that the process company's research and development (R&D) department both internally develops "core technology" in-house (Dussauge et al., 1987) and also often serves as an intermediary in the transfer of external technology into its own company's production department. In both cases, the company's R&D department must have good desorptive capability in its transfer of technology to production. In a review of critical success factors for university–company technology transfer, de Souza Andrade et al. (2017) identified the importance of technology training and communication abilities. The latter factor was also highlighted in a study by Behrane and Grobbelar (2018). In this study, success factors for improving the desorptive capabilities of the process company's R&D department were categorized as:

- *Technology-related success factors*
- *Work-process-related success factors*
- *Cultural and organizational climate-related success factors*

However, the production department must also have a strong absorptive capability in order to successfully learn, master and implement new technology into the production system. Success factors for improving the absorptive capabilities of the process company's production department have been identified and categorized in a similar manner as for the R&D department. While a production department's desorptive capacity giving feedback to the company's R&D department is generally also desirable, this capability was not included in this study, nor were the two complementary activities of "Internal Start-ups" and "Technology transfer to other business units". While Giroud and Mirza (2006) studied the latter activity from a company–country transfer perspective, Holden and Konishi (1996), in a study of Japanese and US organizations, identified the following factors as central to successful inter-firm management of technology transfer:

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

- *Excellent project management skills (tact, flexibility and diplomacy in interactions between organizations with different practices, structures and cultures).*
- *Strong and effective communication paths.*
- *Selection of partners based on complementary technology and business interest (long-term partnership).*

"Internal start-ups" are the opposite of "external spin-outs" but are related to "external spin-ins" in an inter-firm process technology transfer perspective. In a study by Festel (2013), such internal start-ups were identified as a new approach for companies' internal technology transfer from research departments to business units focused on commercial operations to overcome innovation barriers within companies (i.e., "into-firm" diffusion).

2.4 Research questions for intra-firm technology transfer

The following research questions have been identified:

RQ1 *What are the success factors for a process company's R&D organization's transmitting (desorptive) capabilities for process technology to the company's production organization?*

RQ2 *What are the success factors for process companies' production organization's receiving (absorptive) capabilities for process technology?*

In this article, only success factors for intra-firm technology transfer and the related survey results are presented.

3 Research design and methodological considerations

Lacking a suitable framework for process technology transfer, and based on the results from the literature review, a conceptual framework for intra-firm process technology transfer in the process industries was thus initially developed, as shown in Figure 2 in the previous section. The overall research strategy and design adopted to answer the research questions for this study is presented in Figure 3. Because of the large number of candidate success factors, the research findings are presented in two separate articles; this article presents the results on intra-firm process technology transfer.

In this study, both authors acted not only as management researchers but also in their capacity as industry practitioners, since both have more than 20 years of general or management experience operating in the process

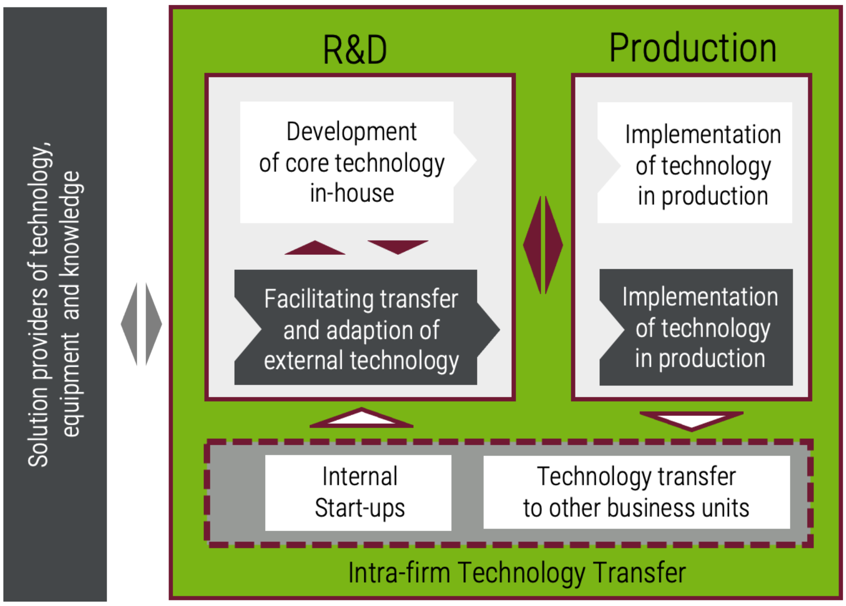

Figure 2 A conceptual framework for intra-firm transfer of process technology in the process industries. The bi-directional arrows illustrate the desired reciprocal information sharing and collaboration perspectives. The importance of the role of the R&D organization as an intermediary in the inter-firm transfer process is also illustrated. Areas marked with dashed borders are not investigated in this study (own representation).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

industries (Mineral Industries and Petroleum Refining/ Petrochemical Industries). Thus, in a grounded theory perspective (Glaser and Strauss, 1967), both authors were able to contribute first-hand knowledge in the topical area in the development of the candidate success factors, thus "letting the practitioners speak", in the words of Binder and Edwards (2010). Such prior understanding can have many advantages for a study of this kind, as expressed by Markus (1977):

The problem is how to get beyond the superficial or the merely salient, becoming empirically literate. You can understand little more than your own evolving mental map allows. A naive, indifferent mental map will translate into global, superficial data and interpretations – and usually into self-induced bias as well. You have to be knowledgeable to collect good information.

It is argued that the authors' familiarity with the process industrial context and the subject area has not only improved the construct validity of the selected candidate success factors but also secured the identification of knowledgeable informants - a fact which will be discussed in the following sub-section.

3.1 The methodological development of a hierarchy of candidate success factors

After the development of the conceptual framework, a number of ***potential success factors*** were initially developed based on the authors' previous industrial experiences with technology transfer in two different sectors of the process industries and an in-depth literature review of technology transfer in general and inter-firm technology transfer in particular. In this context, the construct of "success factor" was defined and later presented to the respondents as: "Specific working methods and best practices that lead to successful outcomes of technology transfer". (For a more extensive presentation and discussion of success factors in the management of process innovation, see, e.g., (Lager and Hörte, 2005a, Lager and Hörte, 2005b). A number of ***potential success factors*** relevant for the process technology transfer processes were thus initially developed. Additionally, previously identified barriers to process technology transfer were developed into success factors by considering how they could be overcome.

Afterwards, the ***potential success factors*** were iteratively revised, further refined, and reformulated into more understandable ***candidate success factors*** for process

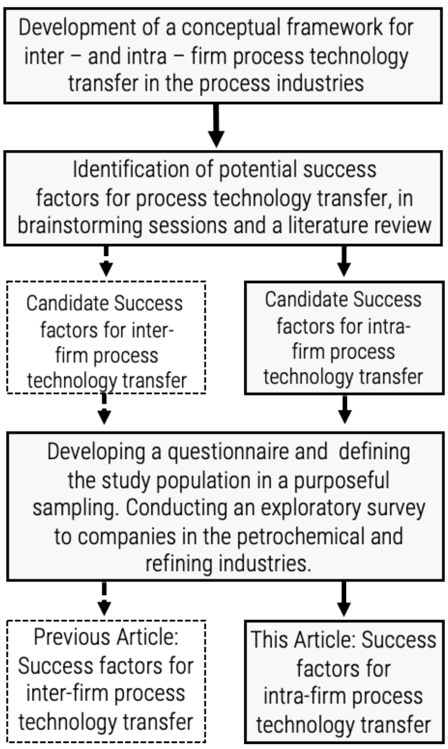

Figure 3 The overall research design. Because of the large number of candidate success factors, the research findings are presented in two separate articles, as illustrated by the dotted lines. Previous article (own representation).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

industry professionals. All ***candidate success factors*** were initially separated into inter-firm and intra-firm success factors; thereafter, in a clustering exercise, they were finally arranged in hierarchical structures. The success factors for R&D organization's transmitting capabilities were in a bottom-up clustering exercise categorized as "technology-related", "work-process-related" and "knowledge- and culture-related", while the production organization's absorptive capabilities related mainly to cultural and organizational climate-related factors . All ***candidate success factors*** for intra-firm process technology transfer are integrated in the presentation of the research findings in the following section. Associated supportive literature references, if any, for the individual success factors are presented together with each success factor.

3.2 Testing the industrial usability of the candidate success factors in an exploratory survey

Using surveys for the collection of information from managers in manufacturing industries is becoming increasingly cumbersome because of a generally experienced "survey fatigue" among industry professionals. Potential respondents' low willingness to participate in surveys thus makes it difficult to use classical probability sampling techniques in management research. An alternative approach to overcome this difficulty, based on the researchers' own knowledge and personal judgement, is to locate knowledgeable groups of information-rich informants as respondents. Such a nonprobability sampling strategy does not serve the classical objective of generalization of research findings, but it does make it possible to improve the understanding of the subject matter through input from a limited number of respondents. Such a theoretical sampling, also called "purposeful sampling", is thus the common strategy for case selection in multiple case studies. The sampled individuals are then approached as "key informants" rather than respondents as in a classical inquiry (Wagner et al., 2010 pp. 583):

"Key informants report their perceptions of these constructs, rather than personal attitudes or behaviours. In this respect, informants need to be distinguished from respondents who give information about themselves as individuals."

In this respect, the respondents in this survey can thus be viewed as "multiple informants" (see, e.g., Barrett and Oborn, (2018).

3.2.1 The sampling strategy for the exploratory survey

In order to explore the industrial usability of the candidate success factors for process technology transfer, the decision was made to test them on a group of industry professionals from the "family" of process industries. The intention was not only to explore their industrial relevance in process technology transfer but also to provide an illustrative case, thus facilitating a further industrial understanding and deployment of the success factors as an instrument for enhanced process technology transfer. Since one of the authors works in a company in the petrochemical and refinery industrial sector and planned to attend a major international conference for the Petrochemical and Refining Industries, this offered an opportunity to recruit respondents for the exploratory survey. The decision was thus made to approach selected delegates at the GCPA Research & Innovation Summit (GPCA, 2017) to supply some empirical information, and their companies became the selected "study population".

Although the "population of interest" is the international process industries in general and the global petrochemical and refining industry in particular, the decision was made to deploy this somewhat unconventional sample selection strategy for the study in order to overcome the problem described above. The attending author's first-hand knowledge of these industries and network of industry professionals visiting the conference simplified the selection of the study population, as well as the contact with knowledgeable company respondents, which aided in the later conducting of the survey. During the conference, the attending author reviewed the list of delegates, approached selected informants, and gauged their willingness to respond to a future inquiry. All candidate informants responded positively, and the author collected their business cards and explained the intention of the upcoming survey. The final group of respondents were representatives from equipment suppliers, service providers, and oil and gas operating companies in the international arena.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

3.2.2 The questionnaire and response rate

The framework and related success factors to be deployed in the questionnaire were first thoroughly reviewed and discussed in a separate pilot test in one of the authors' companies. English was the language used in the questionnaires for all respondents, since English is often the "working language" in the industrial corporations targeted in this survey. The respondents were asked in the questionnaire to give their "importance ratings" for each candidate success factor using a five-point ordinal scale (1 = Not important; 2 = Of minor importance; 3 = Important; 4 = Very important; 5 = Decisive to success), but were also encouraged to present potential new success factors. In order to ascertain whether the importance ratings varied between process technology transfer of "Well-proven technology (incremental development)" and "New technology (more radical developments)", the respondents were asked to give separate importance ratings for each kind of technology transfer. Additionally, they were also asked to benchmark their organization's capability level in process technology transfer for each success factor on a five-point ordinal scale (1 = Poor; 2 = Not so good; 3 = Good; 4 = Very good; 5 = Excellent).

The questionnaires were distributed by electronic mail, and the respondents could answer directly using the attached document. The questionnaire was answered by only one respondent from each company; thus, in some multidivisional organizations, the answers may represent only one division of the organization. The respondents were sent reminders via e-mail about six weeks after the questionnaires were sent. The final response rate was about 20 % (14 responses) out of 72 questionnaires sent out. In the discussion, possible non-response bias is further discussed.

4 Presentation of the candidate success factors and the empirical findings

The empirical results from this study are presented in Tables 1- 4. For each success factor, the mean value and standard deviation are presented, and for "New technology" their Skewness is also presented. The total number of "fives" reported by the respondents are also included, and the success factors have been rearranged in ranking order, starting with the success factor with the highest number of fives using only the importance ratings of "new technology".

The letters and numbers related to each success factor are only inserted to make them traceable to the inquiry.

4.1 Success factors for improving the process company's R&D organization's transmitting (desorptive) capabilities

Comments from respondents:

- *Not sure of the issue C1.1*
- *R&D in the current low price oil and gas market is not a major priority as clients are not willing to pay. R&D is driven by client willingness to pay extra for advanced technology.*

One comment from a respondent:

- *I think it is essential that a company develops a culture of innovation among its staff to enable the acceptance of new technology. The company should have some incentives for persons in production to taking the risk of change, which is associated with the process of transfer of a new technology.*

4.2 Success factors for improving the process company's production organization's absorptive (receiving) capabilities

One comment from a respondent:

- *An additional success factor could be the importance of testing, feedback and technology improvement. The technology supplier is dependent on the receiving company allowing full testing, especially if that testing requires operating the technology off design for extended periods.*

5 Discussion

The inquiry touched upon an important area for many informants (respondents), thus stimulating the further development of the conceptual framework. Kumar et al. (1993 pp.3) elaborate the key informant concept as follows:

"Researchers do not select informants to be representative of the members of a studied organization in any statistical sense. Rather, they are chosen because they are supposedly knowledgeable about the issue being researched and able and willing to communicate about them."

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

This study is inquiring about intra-firm process technology transfer in the process industries and is thus, in strict adherence to the recommendations by Reisman (1989) previously presented in Section 2.1, accurately specifying "for what type of technology" and "for what part of transfer environment" the results are relevant; furthermore in clarifying relevant "success factors and transfer mechanisms".

5.1 From candidate success factors to critical success factors

In this study a number of potential success factors were initially developed, relying on the authors' previous industrial experiences with process technology transfer in two different sectors of the process industries. The development was supported by a literature review of technology transfer in general and more specifically intra-firm technology transfer. Afterwards, the ***potential success factors*** were refined and reformulated into a number of ***candidate success factors*** that were included in the questionnaire in the exploratory survey. In the literature on success factors, both notations are often used in an interchangeable manner.

In this study a distinction is made between ***candidate success factors*** (nice-to-have capability) and ***critical success factors*** (must have capability). In company implementation and use of the presented success factors, it is thus suggested that a company should rate the importance and benchmark each success factor in a "company contingency perspective". However, the exploratory results from the survey are intended to give a supplementary "out-of the box" perspective on company internal importance ratings. Based on the empirical findings from the survey, two top-ranked success factors within each category group, have been selected and re-named as ***critical success factors***. The selection criterion between candidate and critical success factors is thus somewhat arbitrary in this study, but is primarily deployed in order to illustrate the conceptual idea behind a necessary company importance rating and classification of success factors.

5.1.1 Critical success factors for improving the process company's R&D organization's desorptive (transmitting) capabilities

Technology-related success factors

C 1.4 The R&D organization is good at analysing the "applicability" of new technology for the process company's production environment.

C 1.5 The R&D organization has a strong ability to "customize" new technology for the process company's internal production environment.

Cultural and organizational climate-related success factors

C 2.2 The ability of the R&D organization to get the production organization interested to test new technologies.

C 2.3 The R&D organization is securing frequent communication between R&D and production in "face-to-face" contacts, especially during technology transfer.

Work-process-related success factors

C 3.1 The company has a well-delineated work process and associated guide for internal technology transfer from R&D to production.

C 3.6 One or more of the R&D team members involved in the technology transfer has had previous production experience.

5.1.2 Critical success factors for improving process companies' production organization's absorptive (recieving) capabilities

D 1.6 The production organization is prepared to accept necessary test runs and trial-and-error activities and some production disturbances in the introduction of new technology.

D 1.2 The technology that is transferred has been previously tested in pilot plant operations or in a demonstration plant in order to eliminate operational difficulties.

Referring to the comments from respondents, a new success factor was proposed recognizing the importance of an allowance period of operating the technology for extended

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

Table 1 Technology-related success factors (own representation).

	How important for my company?							How good is my company?		
Success factors for imprroving the process company's R&D organisation's transmitting (desorptive) capabilities	Well-proven technology (importance rating : 1 = unimportant 5 = very important)			New technology (importance rating: 1 = unimportant 5 = very important)				1 = poor 5 = world class		
Technology-related success factors	No. of fives	Mean	Std. Dev.	No. of fives	Mean	Std. Dev.	Skew.	No. of fives	Mean	Std. Dev.
C 1.4 The R&D organization is good at analysing the "applicability" of new technology for the process company´s production environment.	5	3.9	1.6	5	4.4	0.9	-1.0	5	4.0	1.4
C 1.5 The R&D organization has a strong ability to "customize" new technology for the process company's internal production environment. (Levin, 1993)	4	3.6	1.5	5	4.4	0.9	-1.0	4	4.3	0.9
C 1.3 The R&D organization is good at estimating of necessary efforts (cost and necessary internal resources) as well as identifying barriers to implementation of new technology.	4	3.8	1.4	4	4.4	0.7	-0.8	4	3.9	1.4
C 1.1 The R&D organization recognizes that technology transfer is essentially a "knowledge accumulation task" and is ensuring that team members from R&D and production are well-aware of this, and thus spend sufficient time on "learning activities" during the technology transfer process. (Levin, 1993); (Burnett and Williams, 2014)	3	3.9	1.2	4	4.3	1.0	-0.8	2	4.0	1.0
C 1.2 The R&D organization is good at analyzing and understanding the need and drivers (problems/opportunities) for new production technology. (Malik, 2002); (Lager and Hörte, 2005b)	1	2.9	1.4	4	4.4	0.7	-0.8	3	4.3	0.7

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

Table 2 Cultural and organizational climate-related success factors (own representation).

	How important for my company?							How good is my company?		
Success factors for imprroving the process company's R&D organisation's transmitting (desorptive) capabilities	Well-proven technology (importance rating : 1 = unimportant 5 = very important)			New technology (importance rating: 1 = unimportant 5 = very important)				1 = poor 5 = world class		
Technology-related success factors	No. of fives	Mean	Std. Dev.	No. of fives	Mean	Std. Dev.	Skew.	No. of fives	Mean	Std. Dev.
C 2.2 The ability of the R&D organization to get the production organization interested to test new technologies. (Leonard-Barton and Deschamps, 1988); (Lager and Hörte, 2005b); (Lager, 2010); (Badruzzaman, 2003)	2	3.5	1.4	3	4.0	0.9	0.0	3	3.9	1.1
C 2.3 The R&D organization is securing frequent communication between R&D and production in "face-to-face" contacts, especially during technology transfer. (Malik, 2002); (Trott et al., 1995); (Lager, 2010) ; (Daghfous, 2004); (de Souza Andrade et al., 2017); (Mamat and Roslan, 2012); (Chuan, 2018)	2	3.5	1.3	3	4.0	0.9	0.0	2	3.9	0.8
C 2.1 The process company's R&D culture is actively promoting cross-functional collaboration and the bridging of organizational interfaces. (Lager and Hörte, 2005a); (Chuan, 2018)	0	2.5	0.8	2	4.0	0.8	0.8	2	3.9	0.8
C 2.4 The whole R&D development team (or at least the core members) are kept together during the total lifetime of the project, including also the technology transfer. (Lager and Hörte, 2005a)	1	3.1	1.1	1	3.4	0.9	0.5	2	3.9	0.8

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

Table 3 Work-process-related success factors (own representation).

Success factors for imprroving the process company's R&D organisation's transmitting (desorptive) capabilities	How important for my company? Well-proven technology (importance rating : 1 = unimportant 5 = very important)			How important for my company? New technology (importance rating: 1 = unimportant 5 = very important)				How good is my company? 1 = poor 5 = world class		
Technology-related success factors	No. of fives	Mean	Std. Dev.	No. of fives	Mean	Std. Dev.	Skew.	No. of fives	Mean	Std. Dev.
C 3.1 The company has a well-delineated work process and associated guide for internal technology transfer from R&D to production. (Lager, 2010)	1	3.5	0.8	4	4.3	0.9	-0.6	3	4.0	1.1
C 3.6 One or more of the R&D team members involved in the technology transfer has had previous production experience.	4	4.0	1.1	4	4.1	1.0	-0.3	3	3.6	1.3
C 3.2 New technology is always well-documented by R&D in internal reports and in operating manuals for the production organization's use of the technologies. (Jung, 1980); (Malik, 2002)	3	3.8	1.0	4	4.1	1.0	-0.3	1	3.6	0.7
C 3.7 If problems occur during implementation of new technology (which is not uncommon), the R&D organization will act as an expert facilitator between technology suppliers and production.	3	3.9	1.0	4	4.1	1.0	-0.3	3	1.4	1.0
C 3.4 The team responsible for the development of new technology will afterwards be heavily involved in the introduction and start-up of the technology together with the production organization. (Leonard-Barton and Deschamps, 1988); (Malik, 2002); (Lager, 2010)	2	3.1	1.2	3	4.0	0.9	0.0	3	4.0	1.1

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

Table 3 continued Work-process-related success factors (own representation).

	How important for my company?							How good is my company?		
Success factors for imprroving the process company's R&D organisation's transmitting (desorptive) capabilities	Well-proven technology (importance rating : 1 = unimportant 5 = very important)			New technology (importance rating: 1 = unimportant 5 = very important)				1 = poor 5 = world class		
Technology-related success factors	No. of fives	Mean	Std. Dev.	No. of fives	Mean	Std. Dev.	Skew.	No. of fives	Mean	Std. Dev.
C 3.3 The development results are "packaged" in an understandable manner and are efficiently "sold" to the production organization. (Leonard-Barton and Deschamps, 1988); (Lager and Hörte, 2005a); (Badruzzaman, 2003)	2	3.4	1.4	3	3.9	1.1	-1.4	3	3.8	1.3
C 3.5 Key individuals from the R&D organization with expert knowledge will transfer with the new technology—an "into-firm" technology transfer process. (Leonard-Barton and Deschamps, 1988); (Malik, 2002); (Langrish, 1971); (Lager, 2010); (Lavoie et al., 2017)	1	2.8	1.3	1	3.1	1.2	-0.3	1	3.1	1.1

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

Table 4 Cultural and organizational climate-related success factors (own representation).

	How important for my company?							How good is my company?		
Success factors for imprroving the process company's R&D organisation's transmitting (desorptive) capabilities	**Well-proven technology (importance rating : 1 = unimportant 5 = very important)**			**New technology (importance rating: 1 = unimportant 5 = very important)**				**1 = poor 5 = world class**		
Technology-related success factors	**No. of fives**	**Mean**	**Std. Dev.**	**No. of fives**	**Mean**	**Std. Dev.**	**Skew.**	**No. of fives**	**Mean**	**Std. Dev.**
D 1.6 The production organization is prepared to accept necessary test runs and trial-and-error activities and some production disturbances in the introduction of new technology. (Lager and Hörte, 2005a); (Lager, 2010)	2	4.0	0.8	4	4.4	0.7	-0.8	5	4.3	1.4
D 1.2 The technology that is transferred has been previously tested in pilot plant operations or in a demonstration plant in order to eliminate operational difficulties. (Lager and Hörte, 2005a)	2	3.3	1.5	3	4.4	0.5	0.6	5	4.1	1.4
D 1.7 The "hand over" process between R&D/technology suppliers and production is well-delineated and agreed upon from the outset of the technology transfer process. (Leonard-Barton and Deschamps, 1988)	1	3.5	0.9	3	4.0	0.9	0.0	4	4.0	1.1
D 1.3 The production organization is prepared to take a "calculated risk" in the transfer and use of new technology. (Lager and Hörte, 2005b)	2	3.4	1.4	3	3.8	1.4	-1.1	3	3.6	1.5
D 1.1 The production organization trusts the R&D organization and their ability to transfer well-functioning and cost-efficient new technology (strong mutual trust). (Jung, 1980); (Levin, 1993); (Malik, 2002); (Lager and Hörte, 2005a); (Mohamed et al., 2012); (Chuan, 2018)	3	3.9	1.1	2	4.1	0.6	-0.1	5	4.1	1.1

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

Table 4 continued Cultural and organizational climate-related success factors (own representation).

Success factors for imprroving the process company's R&D organisation's transmitting (desorptive) capabilities	How important for my company? Well-proven technology (importance rating : 1 = unimportant 5 = very important)			New technology (importance rating: 1 = unimportant 5 = very important)				How good is my company? 1 = poor 5 = world class		
Technology-related success factors	**No. of fives**	**Mean**	**Std. Dev.**	**No. of fives**	**Mean**	**Std. Dev.**	**Skew.**	**No. of fives**	**Mean**	**Std. Dev.**
D 1.5 The production organization is aware of organizational issues related to implementation of new technology and has an ability to adapt its organization and working practices in the use of the new technology. (Levin, 1993); (Lager and Hörte, 2005a); (Daghfous, 2004)	3	3.8	1.2	2	4.1	0.6	-0.1	5	3.9	1.6
D 1.8 The production organization is good at optimizing the use of new technology after a successful first implementation phase.	3	3.8	1.0	1	3.8	0.7	0.4	4	4.1	1.1
D 1.9 The production organization understands that the introduction of new technology in one part of the production system may give new opportunities or disadvantages in related other areas of the production structure (an attention to additional operational improvements). (Levin, 1993); (Daghfous, 2004)	2	3.5	1.2	1	3.8	0.9	-1.0	2	3.6	1.1
D 1.4 A representative from the production organization was partly or fully involved in the development of the technology. (Leonard-Barton and Sinha, 1993); (Lager and Hörte, 2005b); (Lager, 2010); (Daghfous, 2004)	1	2.9	1.5	0	2.9	1.4	-0.6	2	2.9	1.6

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

periods. This issue is related to success factor D.1.8.

5.1.3 Differences in importance ratings between individual groups and between "well-proven technology" and "new technology", and benchmarking of company capabilities

Comparing the results from individual groups of success factors, using the often more discriminating measure of the number of "fives" instead of importance rating figures, the cultural issues seem to have less industrial importance than technology-related issues. Furthermore, the desorptive capabilities of the R&D organization are regarded to be more important than the absorptive capabilities of the production organization. Moreover, the importance ratings of success factors for new technology are generally higher compared with the importance ratings of well-proven technology; while this is a rather reasonable outcome this is also the reason behind selection of success factors for new technology in the ranking. It certainly also highlights the importance of analyzing technology transfer in a "newness dimension" in reference to previously presented Figure 1. The importance ratings of company capabilities for technology transfer are generally very high, but one must consider the possibility that the respondents have a general bias in their estimation of their own companies' technology transfer capabilities.

5.2 Major findings and theoretical contribution

One criterion of "good research" is how usable the research results are. This question is further stressed in the presentation of "grounded theory", where the pragmatic criterion of truth is its usability (Glaser and Strauss, 1967). Related to this philosophical standpoint, Whetten (1989) and Corley and Gioia (2011) cogently defined "theoretical contribution" as the ability to produce thinking that is original in its insight and useful in its application. With regard to the notion of "originality," a theoretical contribution can be categorized as advancing understanding either incrementally or in a more revelatory or surprising manner (Corley and Gioia, 2011). Regarding practical utility, Corley and Gioia suggest "prescriptions for structuring and organizing around a phenomenon."

First, success factors for intra-firm process technology transfer in the cluster of process industries have, to the best of the authors' knowledge, not been previously presented and operationalized for company deployment and use. The *candidate success factors* are new findings that often have more or less strong support not only from the literature review but also from the high importance ratings of the informants. The presented success factors sometimes lack any support from the literature review, but are new potential success factors based on the authors' practical experiences. However, the high importance ratings from the informants qualify them as *candidate success factors*. When success factors have support from the literature review, this does not mean that they have been explicitly formulated before; only the the general idea has been recognized before. In that respect, the research results advance the scientific position, since, in reference to Corley and Gioia (2011), they "improve the conceptual rigor or the specificity of an idea and/or enhance its potential to be operationalized and tested."

Second, it is indicated that the research findings can be deployed both for improving company capabilities in process technology transfer and in the development of a company guiding framework for technology transfer. In consideration of the "utility" aspect, it is thus advocated that the presented success factors provide industry professionals with an instrument and tool for "structuring around a phenomenon" — the area investigated in this study. It is further argued that the results from this study thus fulfil the criteria for a theoretical contribution since the results have originality and the utility is high for both academics and practitioners.

5.3 Research limitations and further research

A number of different aspects of technology transfer in general, and the transfer of process technology in the process industries in particular, have been studied. However, this study does not address specific contextual issues like project complexity and the industrial environment for technology transfer in detail; nor does it address success factors at a personal level of analysis. Moreover, the detailing and formalization of individual stages and components of a technology transfer work process are only touched upon. The development and refinement of the individual success factors, supplemented with the high ratings of all success factors in the exploratory survey, only indicate that the success factors are understandable and can be favorably deployed in one sector of the process industries; the petrochemical industries.

A consequence of a low response rate is not only that the sample size is reduced but also that the non-responding

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

companies may represent a select group that could give deviant answers. There are three major causes of non-response: no contact, refusal to answer and inability to answer, and in this study 11 company representatives could not be contacted, 8 company representatives declined to answer because of confidentiality reasons. Nonetheless, the non-responding company characteristics do not indicate a bias in the empirical results. However, the low response rate makes it difficult to draw any conclusions regarding the "critical success factors" or the generalizability of the findings to other sectors of the process industries. The total number of ***candidate success factors*** can thus to be regarded as a number of propositions to be tested in further research.

The low response rate makes it difficult to draw any firm conclusions regarding the generalizability of the results to other sectors of the process industries and even the petrochemical industries as such. However, there is no reason to suspect that participation in this conference as such should give any bias on respondents' answers. In future research, the usability of the success factors in other sectors of the process industries would be of interest to study, since in the era of company digital transformation and work process digitalization, excellence in technology transfer will continue to be of increasing importance.

6 Managerial implications

The high importance ratings of the ***candidate success factors*** not only indicate their apparent relevance for industry professionals but also suggest that they could be deployed as a "checklist" for companies' intra-firm process technology transfer. Furthermore, by utilizing the proposed success factors as company ***candidate success factors*** in an internal company survey, specific company importance ratings of individual success factors can be established, and company capabilities in all areas can be benchmarked.

To the best of the authors' knowledge, the presented success factors have not been previously reported in the literature, including the success factor: *The company has a well-delineated work process and associated guide for internal technology transfer from R&D to production.* This success factor received high importance ratings among cultural and organizational climate-related factors, indicating that process companies could benefit from the use of an internal guide and manual for carrying out process technology transfer projects. The success factors that have been developed in this study could be useful components in the development of such a manual. Moreover, the results can serve as guidelines both for new company technology transfer projects and in a company improvement program for technology transfer. From the perspective of company digital transformation and digitization, the importance of company excellence in intra-firm technology transfer must also be recognized and highlighted.

7 Conclusions

In this study, success factors for intra-firm process technology transfer have been developed for use in the family of process industries. As a point of departure and in light of the lack of a suitable theoretical framework, a simplified conceptual framework was initially developed. The necessary reciprocal information sharing (organizational transmitting and receiving capabilities), highlights the misleading nature of the concept "technology transfer", as it seems to indicate a one-way communication process. Based on the authors' previous industrial experiences with the transfer of process technology in particular, and an in-depth literature review of technology transfer, 25 candidate success factors were developed and operationalized for process-industrial use. The success factors were thereafter used in the development of a questionnaire for an exploratory survey disseminated to professionals in the petrochemical industry in order to serve as an illustrative case to facilitate company implementation and use of the presented results.

Critical success factors for improving the process company's R&D organization's desorptive (transmitting) capabilities were categorized in the bottom-up clustering exercise as technology-related, work-process-related, and cultural & knowledge related. Of these, one of the top-ranked success factors was: *the R&D organization is good at analyzing the "applicability" of new technology for the process company's production environment.* Critical success factors for improving the process company's production organization's absorptive (receiving) capabilities were in the clustering exercise categorized only as cultural & organizational climate related. Of these, one of top-ranked success factors was: *the production organization is prepared to accept necessary test runs and trial-and-error activities and some production disturbances in the introduction of new technology.*

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

The general high importance ratings of nearly all candidate success factors indicate that they could be deployed in a "checklist" for company intra-firm process technology transfer. The findings indicate that process companies would benefit from the use of an internal guide and manual for carrying out process technology transfer projects. The success factors that have been developed in this study could be useful components in the development of such a manual. Moreover, the results can serve as guidelines both for new company technology transfer projects and in a company improvement program for technology transfer.

To the best of the authors' knowledge, success factors for intra-firm process technology transfer in the cluster of process industries have not previously been presented and operationalized for company deployment and use. It is argued that the results from this study thus fulfil the criteria for a theoretical contribution, since the results have originality and their utility is high for both academics and practitioners.

Acknowledgements

We sincerely thank all company representatives that took part in the survey and spent their valuable time responding to the questionnaire. Many thanks are due to Mrs. Gunilla Bergdahl for research assistance and help with the survey. The permission from ADNOC Refining to publish this article is also recognized and appreciated. The financial support from the XPRES project is gratefully acknowledged. Last but not least, the authors sincerely acknowledge valuable ideas and suggestions from anonymous referees.

References

Badruzzaman, A. (2003): Critical success factors for technology transfer: Sharing a perspective. SPE Asia Pacific Oil and Gas Conference. Indonesia: Society of Petroleum Engineers.

Bagsarian, T. (2001): Avoiding startup stumbles. Iron Age New Steel, **17**, pp. 16-19.

Barrett, M. and Oborn, E. (2018): Bridging the research-practice divide: Harnessing expertise collaboration in making wider set ofcontributions. Information and Organization, **28**, pp. 44-51.

Behane, T. and Grobbelaar, S. S. (2018): The process of intra-firm technology transfer: A case study of a marine mining company. South African Journal of Industrial Engineeering, **29**.

Binder, M. and Edwards, J. S. (2010): Using grounded theory method for theory building in operations management research: a study on inter-firm relationship governance. International Journal of Operations & Production Management, **30**, pp. 232-260.

Burnett, S. and Williams, D. (2014): The role of knowledge transfer in technological innovation: an oil and gas industry perspective. Knowledge Management Research & Practice, **12**, pp. 133-144.

Chai, K.-H., Gregory, M. J. and Shi, Y. S. (2004): An Exploratory Study of Intrafirm Process Innovation Transfer in Asia. IEEE Transactions on Engineering Management, **51**, pp. 364-373.

Chuan, R. (2018): Intra-firm technology transfer is one of the most knowledge-intensive activity in MNC. SING35010 International Competitiveness and Innovation. University of Manchester.

Cohen, W. M. and Levinthal, D. A. (1990): Absorptive Capacity: A new Perspective on Learning and Innovation. Administrative Science Quarterly, **35**, pp. 128-152.

Corley, K. G. and Gioia, D. A. (2011): Building theory about theory building: What constitutes a theoretical contribution. Academy of Management Review, **36**, pp. 12-32.

Daghfous, A. (2004): Organizational learning, knowledge and technology transfer: a case study. The Learning Organization, **11**, pp. 67-83.

De Souza Andrade, H., Borges Silva, M., Moraes Rosa, A. C., Gatto Chimendes, V. C. and De Freitas Chagas Jr, M. (2017): Risk and Success Factors in Technology Transfer. Int. Journal of Engineering Research and Application, **7**, pp. 66-71.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

Distanont, A., Khongmalai, O. and Kritpipat, P. (2018): Factors affecting technology transfer performance in the petrochemical industry in Thailand: A case study. WMS Journal of Management, **7**.

Dussauge, P., Hart, S. and Ramanantsoa (1987): Strategic Technology Management, New York, John Wiley & Sons.

Festel, G. (2013): Technology transfer by new ventures within the chemical and pharmaceutical industry. Journal of Business Chemistry, **10**.

Frishammar, J., Lichtenthaler, U. and Kurkkio, M. (2012): The front end in non-assembled product development: a multiple case study of mineral- and metal firms. Journal of Engineering and Technology Management (JET-M), **29**, pp. 468-488.

Gans, M., Kiorpes, S. A. and Fitzgerald, F. A. (1983): Plant startup-step by step. Chemical engineering, pp. 74-100.

Giroud, A. and Mirza, H. (2006): Multinational Enterprise Policies towards International Intra-firm Technology Transfer: The case of Japanese Manufacturing Firms in Asia. East Asia, **23**.

Glaser, B. G. and Strauss, A. L. (1967): The dicovery of grounded theory: strategies for qualitative research, New York, Aldine de Gruyter.

GPCA (2017): 4th GPCA Research and Innovation Summit, Dubai, United Arab Emirates, pp. 11-13.

Holden, P. D. and Konishi, F. (1996): Technology Transfer Practice in Japanese Corporations: Meeting New Service Requirements. TECHNOLOGY TRANSFER, Spring-Summer, pp. 43-53.

Jung, W. (1980): Barriers to Technology Transfer and their elimination. Journal of Technology Transfer, **4**, pp. 15-25.

Khabiri, N., Rast, S. and Senin, A. A. (2012): Identifying main influential elements in technology transfer process: A conceptual model. Procedia - Social and Behavioural Scieces, **40**, pp. 417-423.

Kumar, N., Stern, L. W. and Anderson, J. C. (1993): Conducting Interorganizational Research Using Key Informants. Academy of Management Journal, **36**, pp. 1633-1651.

Kundu, N., Bhar, C. and Pandurangan, V. (2015): Development of framework for an integrated mode. Indian Journal of Science and Technology, **8**.

Lager, T. (2002): A structural analysis of process development in process industry - A new classification system for strategic project selection and portfolio balancing. R&D Management, **32**, pp. 87-95.

Lager, T. (2010): Managing Process Innovation - From idea generation to implementation, London, Imperial College Press.

Lager, T. (2012): Startup of new plants and process technology in the process industries: organizing for an extreme event. Journal of Business Chemistry, **9**, pp. 3-18.

Lager, T. (2017): A conceptual analysis of conditions for innovation in the process industries and a guiding framework for industry collaboration and further research. International Journal of Technological Learning, Innovation and Development, **9**, pp. 189-219.

Lager, T. and Hassan Beck, H. (2020): Managing inter-firm process technology transfer: success factors and organizational perspectives. International Journal of Innovation Management, Forthcoming.

Lager, T. and Hörte, S.-Å. (2005a): Success factors for the development of process technology in process industry Part 1: a classification system for success factors and rating of success factors on a tactical level. Int. J. Process Management and Benchmarking, **1**, pp. 82-103.

Lager, T. and Hörte, S.-Å. (2005b): Success factors for the development of process technology in process industry Part 2: a ranking of success factors on an operational level and a dynamic model for company implementation. Int. J. Process Management and Benchmarking, **1**, pp. 104-126.

Langrish, J. (1971): Technology Transfer: Some British Data. R&D Management, **1**, pp. 133-135.

Lavoie, J., Jisun, K. and U, D. T. (2017): A technology transfer framework: A case study from the energy sector. International Journal of Innovation , Management and Tecnology, **8**.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

Leitch, J. (2004): Effective new plant startup increases asset's net present value. Hydrocarbon Processing, pp. 95-98.

Leonard-Barton, D. and Deschamps, I. (1988): Managerial Influence in the implementation of new technology. Management Science, **34**, pp. 1252-1265.

Leonard-Barton, D. & Kraus, W. A. (1985): Implementing new technology. Harvard Business Review, November-December, pp. 102-110.

Leonard-Barton, D. & Sinha, D. K. (1993): Developer-user interaction and user satisfaction in internal technology transfer. Academy of Management Journal, **36**, pp. 1125-1139.

Levin, M. (1993): Technology transfer as a learning and development process: an analysis of Norwegian programmes on thechnology transfer. Technovation, **13**, pp. 497-518.

Lichtenthaler, U. (2006): External technology commercialisation as an alternative mode of technology marketing. International Journal of Technology Marketing, **1**, pp. 411-430.

Magnusson, T. and Johansson, G. (2008): Managing internal technology transfer in complex product development. European Journal of Innovation
Management, **11**, pp. 349-365.

Malik, K. (2002): Aiding the technology manager: a conceptual model for intra-firm technology transfer. Technovation, **22**, pp. 427-436.

Mamat, F. B. and Roslan, S. (2012): Critical success factors (CSFs) on technology transfer effectiveness in manufacturing industry: a critical review. International Journal of Business Economics and law, **1**, pp. 2289-1552.

Markus, H. (1977): Self-Schemata and processing information about the self. Journal of Personality and Social Psychology, **35**, pp. 63-78.

Mings, J., Mason (1999): Technology Transfer: A Shortcut in Danger of Short Circuit. Journal of Technology Transfer, **23**, pp. 3-6.

Mohamed, A. S., Sapuan, S. M., Megat Ahmad, M. M. H., Hamouda, A. M. S. and Hang Tuah Bin Bahrudin, B. T. (2012): Modelling the technology transfer process in the petroleum industry: Evidence from Libya. Mathematical and Computer Modelling, **55**, pp. 451-470.

NACE (2006): Statistical classification of economic activities in the European Community Rev 2. Luxembourg: Office for Official Publications of the European Communities.

Petronia, G., Verbano, C. and Venturini, K. (2015): Determinants and catalysts in intrafirm technology transfer: Learning from case studies. Journal of Technology Management & Innovation, **10**.

Reisman, A. (1989): Technology Transfer:A Taxonomic View. TECHNOLOGY TRANSFER, Summer-Fall.

Reisman, A. and Zhao, L. (1991): A Taxonomy of Technology Transfer Transaction Types. TECHNOLOGY TRANSFER, Spring, pp. 38-42.

Stewart, C., T, JR. (1987): Technology Transfer vs. Diffusion. Journal of Technology Transfer, **12**, pp. 71-78.

Tidd, J. (2010): Gaining Momentum: Managing The Diffusion Of Innovations, London, Imperial College Press.

Trott, P., Cordey-Hayes, M. and Seaton, R. A. F. (1995): Inward technology transfer as an interactive process. Technovation, **15**, pp. 25-43.

Wagner, S. M., Rau, C. and Lindeman, E. (2010): Multiple Informant Methodology: A Critical Review and Recommendations. Sociological Methods & Research, **38**, pp. 582-618.

Whetten, D. A. (1989): What Constitutes a Theoretical Contribution? Academy of Management Review, **14**, pp. 490-495.

Zahra, S. A. and George, G. (2002): Absoptive capacity: A review, reconceptualizatio, and extension. Academy of Management Review, **27**, pp. 185-203.

[JOURNAL OF
BUSINESS CHEMISTRY]

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119501230
DOI: 10.17879/60119500685

Appendix 1: The process industries

An intentional definition of the process industries is as follows (Lager, 2017):

"The process industries are a part of all manufacturing industries, using raw-materials (ingredients) to manufacture non-assembled products in an indirect transformational production process often dependent on time. The material flow in production plants is often of a divergent v-type, and the unit processes are connected in a more or less continuous flow pattern."

The concepts unit operations and continuous flow exclude industries that process solid raw materials, but not in a process that would normally be associated with the process industries. The criteria indirect transformational process, dependency on time and the divergent material flow, are characteristics of high construct validity.

In light of the revised intentional definition of the process industries, it was not considered necessary to alter a previous extensional definition (Lager, 2010). A number of industrial sectors and industries have been selected from all manufacturing industries presented in the statistical classification of economic activities in the European community (NACE, 2006). The following industrial sectors are thus suggested for inclusion in the cluster of process industries, and the associated NACE codes are presented in parenthesis:

- Mining & metal industries (05; 06; 07; 24)
- Mineral & material industries (minerals, cement, glass, ceramics) (08; 23)
- Steel industries (24.1; 24.2; 24.3)
- Forest industries (pulp & paper) (17)
- Food & beverage industries (10; 11)
- Chemical & petrochemical industries (chemicals, rubber, coatings, ind. gases) (20; 22)
- Pharmaceutical industries (incl. biotech industries and generic pharmaceuticals) (21)
- Utilities (electricity & gas, water, sewerage, waste collection & recycling) (35; 36; 37; 38)

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

Research Paper

Thorsten Bergmann* and Timo Rothausen**

Supporting start-ups in the process industries with accelerator programs: Types, design elements and success measurement

Accelerators support the fast-track development of start-ups. Although their emergence and popularity has increased during the last years, limited research exists on accelerator types and whether the organizational context (e.g. nature of business, industry) influences their five design elements: 1) funding structure and governance, 2) strategic goals and focus, 3) selection process, 4) program package, and 5) alumni relations. For the identification of accelerator types in the context of the process industries, ten interviews with accelerator managers were conducted. Three different accelerator types were found: 1) Corporate accelerator, 2) Public accelerator, and 3) Hybrid accelerator. This study provides an overview of each accelerator type and their respective design elements. In addition, for each accelerator type, success factors, key challenges, and success measurements are presented. The results of this study will help those, who fund, setup, manage and operate accelerators in the process industries to design their program appropriately in order to attract, select, and fully exploit the economic potential of participating start-ups.

1 Introduction

A wide range of support forms for nascent ventures like start-ups exist such as incubators, venture studios, start-up competitions or business angel investors (Cohen et al., 2019). One of these support forms is an accelerator program, which is also called seed accelerator, start-up accelerator or business accelerator (hereafter we refer to them merely as accelerators) (Cohen et al. 2019). Accelerators are a relatively novel phenomenon to foster entrepreneurship, but their emergence and popularity has increased during the last years since the foundation of the Y Combinator program in 2005 and provide new research opportunities (Battistella et al., 2017; Cohen et al., 2019; Drover et al., 2017; Hallen et al., 2020; Y Combinator, 2020). Since 2005, Y Combinator has funded over 2,000 start-ups and these companies (e.g. Dropbox, Airbnb, stripe) have reached a combined valuation over 100 billion US$ (Y Combinator, 2020).

Therefore, accelerators represent a rapidly growing format to "*accelerate*" the development of start-ups (Cohen et al., 2019; Wright and Drori, 2018). Existing literature gives an overview about the current state of research regarding the definition of accelerators and their design (Cohen et al.,

* Institute of Business Administration at the Department of Chemistry and Pharmacy, University of Münster, Leonardo-Campus 1, 48149 Münster, Germany & Center for Industry and Sustainability (ZIN), Provadis School of International Management and Technology, Industriepark Höchst, Building B852, 65926 Frankfurt am Main, Germany, thorsten.bergmann@uni-muenster.de
** Institute of Business Administration at the Department of Chemistry and Pharmacy, University of Münster, Leonardo-Campus 1, 48149 Münster, Germany, t.rothausen@uni-muenster.de

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

2019; Pauwels et al. 2016). However, research on this new organizational form is still evolving (Cohen et al., 2019). While taking a closer look at accelerators, differences in their types and strategic goals can be observed resulting in different designs (Kohler, 2016; Moschner et al. 2019; Prexel et al., 2019; Shankar and Shepherd, 2019). Shankar and Shepherd (2019) posed the research question whether the organizational context (e.g. nature of business, industry) matters for how an accelerator is designed and run. Thus, it becomes increasingly important to investigate which accelerator types are used in different industries, and which accelerator types and designs are most suitable for certain industries and businesses (Shankar and Shepherd, 2019). In general, most research on accelerators has focused on start-ups dealing with digital media and relating to the IT industry (Crișan et al., 2019; Malek et al., 2014). For this reason, little is known about accelerator types, which support start-ups in other areas such as advanced materials, biotechnology, and clean energy (Malek et al., 2014). For example, Malek et al. (2014) investigated a typology of accelerator capabilities that are relevant for the development and commercialization of start-ups in the clean technology industry. In doing so, they helped researchers and practitioners to enhance their understanding of how capabilities of accelerators can vary to meet different goals (Malek et al., 2014). In addition, Malek et al. (2014) showed with their research and focus on a specific industry how accelerator managers can align their program to the needs of the respective industry and the corresponding characteristics of start-ups in this area. Currently, no research on accelerator types and their design in the context of the process industries exists. The process industries cover multiple industrial sectors, which also compose a substantial part of the entire manufacturing industry including petrochemicals and chemicals, food and beverages, mining and metals, mineral and materials, (bio) pharmaceuticals, pulp and paper, and steel and utilities (Lager, 2017; Lager et al., 2013). Table 1 lists the industrial sectors and industries with their associated NACE codes that belong to the cluster of the process industries in alphabetical order according to Lager (2016) and Lager (2017).

Lager et al. (2013) characterize the process industries as rather conservative with predominately long, complex, and rigid supply and value chains. In the process industries, companies are often very asset-intensive and highly integrated in one or a few physical locations which reduces their ability to respond quickly to changes in the short-term (Lager et al., 2013). Further, Lager et al. (2013) highlight that research and development (R&D) and innovation in the process industries play a crucial role for future success.

Accelerators could help to rejuvenate process industries by stimulating entrepreneurship while combining and integrating resources from an innovation ecosystem with start-ups and their entrepreneurial teams (Cohen et al., 2019). For instance, Berger et al. (2019) emphasize the relevance of start-ups for the chemical industry in a current study,

Table 1 Industrial sectors and industries belonging to the process industries (source: Lager, 2016 and Lager, 2017).

Industrial sectors and industries	NACE codes
Chemical and petrochemical industries (chemicals, rubber, coatings, industrial gases)	20; 22
Forest industries (pulp and paper)	17
Food and beverage industries	10; 11
Mining and metal industries	05; 06; 07; 24
Mineral and material industries (minerals, cement, glass, ceramics)	08; 23
Oil and gas industries	06; 19
Pharmaceutical industries (including biotech industries and generic pharmaceuticals)	21
Utilities (electricity and gas, water, sewerage, waste collection and recycling)	35; 36; 37; 38
Steel industries	24.1; 24.2; 24.3

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

which they conducted for the German chemical industry association (Verband der Chemischen Industrie e.V.). In their study, Berger et al. (2019, p.2) define chemical start-ups as *"young firms that offer goods and services based on chemical knowledge and chemical technologies".* Berger et al. (2019) mention that start-ups can generate innovative ideas, stimulate competition, develop new applications and technologies (in particular if low demand is not sufficiently attractive for established and large companies to engage in new areas), transfer research results into commercial products, or compensate losses while creating new jobs in the chemical industry. Moreover, Berger et al. (2019) found that chemical start-ups often aim at new business areas and models outside of traditional chemistry and offer specialized services like R&D services to third parties (34%), produce chemical goods (19%), or provide IT services relating to chemistry (13%), while another third is still in the R&D phase (34%). However, in the process industries such as the chemical industry, start-ups face various challenges and rarely achieve market breakthroughs because of their resource constraints (van Gils and Rutjes, 2017). In addition, they do not possess manufacturing equipment or distribution channels that established companies have, or must overcome the liability of newness (van Gils and Rutjes, 2017; Yin and Luo, 2018). Thus, accelerators could play a crucial role in supporting start-ups to overcome these challenges to create novel and valuable solutions, which could enhance R&D and innovation, while contributing to future success of the process industries. Therefore, the purpose of this study is to provide an overview of accelerator types and their design elements, which have emerged in the context of the process industries. For each accelerator type, success factors, key challenges and success measurements are also presented. The results of this study will help those, who fund, setup, manage, and operate accelerators in the process industries to design their program appropriately in order to attract, select, and fully exploit the economic potential of participating start-ups.

This study is structured as follows. The second chapter explains the theoretical background of accelerators and presents the research questions. Then, the third chapter describes the method and research design, followed by the fourth chapter presenting the findings of our study and discussing them. Finally, the last chapter provides theoretical and managerial implications, while also giving an outlook for further research.

2 Accelerators

In general, accelerators aim at rapid acquisition or even failure of start-ups by exposing them quickly to the market to test their solution, while using minimal resources (Stayton and Mangematin, 2019). Cohen et al. (2019, p. 1782) define an accelerator as *"a fixed-term, cohort-based program for startups, including mentorship and/or educational components, that culminates in a graduation event"*, while Pauwels et al. (2016, p.15) introduced a definition based on six characteristics including *"(1) Possible offer of upfront investment (£10k–£50k), often in exchange for equity (~5–10%); (2) Time-limited support, comprising programmed events and intensive mentoring; (3) An application process that is "in principle" open to all, yet highly competitive; (4) Cohorts or classes of start-ups rather than individual companies; (5) Mostly a focus on small teams, not individual founders; (6) Periodic graduation with a Demo Day/Investor Day"*.

Subsequently, the design elements of an accelerator are presented.

2.1 Design elements

Pauwels et al. (2016) conducted a repertory grid construction and cross-case analysis with 13 accelerator cases and found five common accelerator design elements among them: 1) *Funding structure*, 2) *Strategic focus*, 3) Selection process, 4) *Program package,* and 5) *Alumni relations*. For the five design elements, they identified 17 constructs. Figure 1 contains all design elements and the respective constructs based on Pauwels et al. (2016). Some design elements and constructs were adapted or renamed in Figure 1 based on other existing literature and due to the research questions of this study. Subsequently, the five design elements of Pauwels et al. (2016) and their extensions will be presented since they build the theoretical foundation of this research.

2.1.1 Funding structure and governance

The first design element concerns the ***funding structure and governance*** of the accelerator. Vandeweghe and Fu (2018) highlight that accelerators manage relationships with internal and external stakeholders, which affect the achievement of the program's goals. Internal stakeholders are sponsors, directors and staff/team, whereas external

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

stakeholders are partners, investors and portfolio start-ups (Vandeweghe and Fu, 2018).

Sponsors fund the accelerator. Cohen et al. (2019, p. 1788) define program sponsors as *"external institutions that provide financial or in-kind support, including office space, professional services, mentors, and endorsement, to accelerator programs"*. Pauwels et al. (2016) propose four possible funding sponsors: private investors, corporations (hereafter we refer to them merely as corporates), public authorities, or alternative revenues. Alternative revenues may originate from investments in supported start-ups or through the organization of events and workshops (Pauwels et al., 2016). Malek et al. (2014) argue that the funding structure and operations of an accelerator are inter-related, since the available financial resources determine the opportunities in supporting start-ups, or to which extent they will fund and take equity of new ventures.

Concerning the governance of an accelerator, directors or managers are responsible for the strategy of the program, while the accelerator's staff/team execute the operational day-to-day activities (Vandeweghe and Fu, 2018). In this study, organizational governance refers to the operational model of the accelerator and how it is run (e.g. by an internal team/department or operations are outsourced to an external service provider). Therefore, organizational ***governance*** was added to the design element ***funding structure***, since the entity or organization that is responsible for running the program may not belong to the sponsor organization of the accelerator.

2.1.2 Strategic goals and focus

The design element ***strategic goals and focus*** describes the strategic choices of accelerators concerning their industry/ sector and geographical focus (Pauwels et al., 2016). The industry/sector focus can vary from very generic (no vertical focus at all) to very specific (focus on a specific industry/ sector/technology) (Pauwels et al., 2016). Additionally, accelerators can choose between being locally versus internationally active which refers to the geographical focus (Pauwels et al., 2016). Leatherbee and Gonzalez-Uribe (2018a) emphasize the close relation between the funding of accelerators and their corresponding goals and focus. Therefore, ***strategic goals*** were added to the design element ***strategic focus*** in Figure 1. Finally, Pauwels et al. (2016) highlight that the goals of the accelerator's key stakeholders, which fund or support the accelerator, are the main driver for the orchestration of an accelerator's activities.

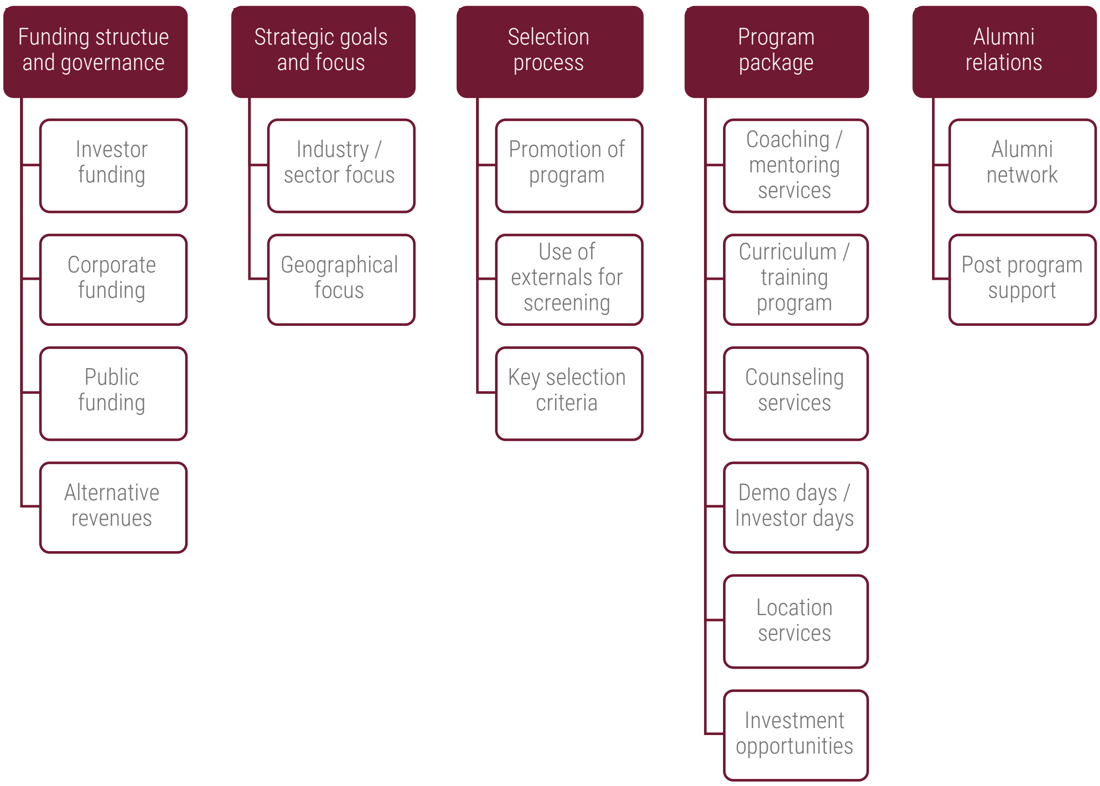

Figure 1 Accelerator design elements and their respective constructs (adapted from Pauwels et al., 2016).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

2.1.3 Selection process

The design element ***selection process*** refers to the accelerator's choice of start-ups for the next cohort (Pauwels et al., 2016). Pauwels et al. (2016) found that accelerators use a rigorous, multi stage selection process to attract and identify suitable start-ups for the program, which will be subsequently described. Usually, the application form is online on a software platform and may include a brief pitch deck and video. For the selection of suitable start-ups, all applications are screened and shortlisted by the accelerator team, usually with the involvement and use of externals. Pre-selected start-ups are invited to a pitch day at which they present their ideas and solutions to a selection committee that consists of members from the accelerator team and relevant externals like mentors, investors or alumni. The pitch day represents the final-selection stage. After the end of the pitch day, the selection committee chooses the final start-ups, which will form the next cohort of the accelerator (Leatherbee and Gonzalez-Uribe, 2018b).

Pauwels et al. (2016) found that the main selection criterion was the team. In contrast, Leatherbee and Gonzalez-Uribe (2018b) showed that selection criteria can differ among different accelerator types. Thus, team may not only be the primary selection criterion of accelerators in the context of the process industries and the construct team was renamed into ***key selection criteria*** in Figure 1.

2.1.4 Program package

The design element ***program package*** concerns all service offers of an accelerator (Pauwels et al., 2016). Mentoring services are a central pillar of an accelerator (Pauwels et al., 2016). In Figure 1, ***Coaching*** was added to the construct ***Mentoring services*** of Pauwels et al. (2016), since no explicit distinction in literature exists concerning the definition and roles of both functions (Crişan et al., 2019; Roberts and Lall, 2019). Both, mentors and coaches fulfill equal or similar roles while providing assistance to start-ups in the accelerator (Crişan et al., 2019; Roberts and Lall, 2019). For instance, coaches and mentors help start-ups to define and validate their business model, or to connect with customers and investors. Usually, an accelerator has a structured ***curriculum*** or ***training program***, which covers a wide range of topics among finance, marketing, management and others like pitching that are often taught in expert workshops or lectures (Pauwels et al., 2016). Furthermore, accelerators offer ***counselling services*** on a regular basis, e.g. in form of weekly "office hours", in which start-ups can ask for support, or their progress is assessed and monitored (Pauwels et al., 2016). ***Demo and investor days*** provide the opportunity for participating start-ups to network and to present their solution to potential customers and investors (Cohen et al., 2019; Pauwels et al., 2016). ***Location services*** refer to the offer of co-working spaces to enhance collaboration and peer learning among participants (Pauwels et al., 2016). Finally, start-ups normally receive a small amount of funding in exchange for equity (***investment opportunity***) ranging from 3-10% according to Pauwels et al. (2016). In general, the program has a duration of three to six months (Bliemel et al., 2019), but can also last between four weeks and one year (Cohen et al., 2019).

2.1.5 Alumni relations

The last design element ***alumni relations*** covers the interaction of the accelerator with alumni after the end of the program (e.g. through regular events) (Pauwels et al., 2016). Pauwels et al. (2016) highlight the value of successful alumni as potential mentors and references for success stories which also increase the reputation of the accelerator.

2.2 Types

Cohen et al. (2019) mention that most existing research has considered accelerators as largely homogenous in their business model and does not take into account that accelerators vary strongly in their design. They revealed that the design of accelerators may vary because of a strong correlation between the type of funding sponsor (e.g. corporate, investor, academia, foundation, or government) and the background of founding managing directors (e.g. prior investor, entrepreneur, corporate, university, or government experience). Founders of the accelerator may design their program differently according to their objectives (Cohen et al., 2019). This influences and causes differences in the performance of participating start-ups (Cohen et al., 2019).

Pauwels et al. (2016) found that accelerators varied in their architecture according to their approach to each of the design elements. In total, Pauwels et al. (2016) identified three different accelerator types with an own design theme: 1) ***ecosystem builder***, 2) ***deal-flow maker,*** and 3) ***welfare stimulator***. The ***ecosystem builder*** aims at matching

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

customers with start-ups and to build-up a corporate ecosystem. The ***deal-flow maker*** has the goal of identifying investment opportunities for investors and is comparable to a venture capital program. The ***welfare stimulator*** pursues the goal of stimulating start-up activity and economic growth, and is typically financed by local, national or international funding schemes. Pauwels et al. (2016) argue that the design theme determines how an accelerator orchestrates and connects the different design elements.

For the identification of different accelerator types and the further classification of each type into sub-types, researchers can use the identified design elements of Pauwels et al. (2016). In doing so, it is possible to investigate similarities and differences between accelerators by taking a design lens approach as an appropriate theoretical framework (Pauwels et al., 2016). For instance, Prexel et al. (2019) looked at differences and similarities among corporate accelerators exhibiting the ***ecosystem builder*** theme of Pauwels et al. (2016) and classified their results into five ecosystem builder accelerator sub-types: 1) *Start-up accelerator*, 2) *Idea-lab accelerator*, 3) *Intrapreneurship accelerator*, 4) *Venture-client accelerator,* and 5) *White-label accelerator*. Furthermore, Moschner et al. (2019) identified four different corporate accelerator types: 1) *In-house accelerator*, 2) *Hybrid accelerator*, 3) *Powered by accelerator*, and 4) *Consortium accelerator*. Moreover, Kanbach and Stubner (2016) also found four corporate accelerator types: 1) *Listening Post*, 2) *Value Chain investor,* 3) *Test laboratory*, and 4) *Unicorn hunter*.

Shankar and Shepherd (2019) proposed to investigate whether the organizational context (e.g. nature of business, industry) matters for how an accelerator is designed and run, thus revealing which accelerator types are used in different industries and which accelerator types and designs are most suitable for certain industries and businesses. Currently, existing literature mainly provides an overview of different corporate accelerator types, and hence research on other accelerator types and their design is missing. Therefore, this study addresses this research gap while taking into account the organizational context of the process industries.

2.3 Success measurement

In this study, success measurement concerns the qualitative and quantitative success metrics of the interviewed accelerators, which are used for measuring the achievement of their objectives. Regarding the measurement of an accelerator's success, Leatherbee and Gonzalez-Uribe (2018a) emphasize the relevance of selecting the right key performance indicators (KPIs) to assess its progress, even though these KPIs can vary strongly among different programs depending on the accelerator type and its goals. As a result of a systematic literature review, Crișan et al. (2019) found that the top four outcomes at accelerator level are the number of applicants, number of participants, survival rate of start-ups, and funds provided to start-ups. Concerning different accelerator outcomes, Bliemel et al. (2019) differentiate between the participating start-up's growth metrics (follow-on funding, revenues of start-ups, job creation, new customers, exit valuation multiples, and survival rate), the accelerator's operational metrics (satisfaction, application numbers, and the number of mentors), and the accelerator's productivity measures (e.g. occupancy rate or profit margin).

For corporate accelerators, Richter et al. (2017) found that they rarely use success and performance metrics (e.g. such as KPIs), although they are important for the management of the program. In literature, a lack of performance metrics could be a result of confidentiality reasons as corporates are unwilling to share their internal KPIs (Richter et al., 2017). However, corporates must measure the success of their investments concerning the return on investment (ROI) and achievement of strategic goals (Richter et al., 2017). In doing so, KPIs play an important role in measuring the success of and justifying financial spending for the program. Therefore, corporate accelerators may not only be interested in measuring the satisfaction of participating start-ups and their success, but also the contribution to strategic goals in terms of accessing new markets or increasing market share, the cost effectiveness of the program and what has been learned (Richter et al., 2017). Indeed, Richter et al. (2017) showed that the use of KPIs varies highly among corporate accelerators. Some corporate accelerators implemented KPIs, while others found them useless.

In general, publicly funded accelerators tend to have KPIs concerning the socioeconomic development of a region like relocation of start-ups, number of jobs created, or taxes paid (Leatherbee and Gonzalez-Uribe, 2018a; Pauwels et al., 2016).

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

2.4 Research questions

Shankar and Shepherd (2019) suggest that the organizational context (e.g. nature of business, industry) matters for how an accelerator is designed and run. Pauwels et al. (2016) highlight that by focusing on one specific industry/sector, the accelerator management team can develop the required industry/sector-specific knowledge and expertise to identify and exploit the full economic potential of participating start-ups. In this study, we focus on the process industries, which include petrochemicals and chemicals, food and beverages, mining and metals, mineral and materials, oil and gas, (bio) pharmaceuticals, pulp and paper, and steel and utilities (Lager, 2016; Lager, 2017; Lager et al., 2013). Moreover, Pauwels et al. (2016) propose to investigate success factors and challenges faced by distinct accelerator types and to define suitable success metrics for measuring the achievement of their objectives.

Therefore, the following three research questions (RQ) will be discussed by drawing on the theoretical background of this study and the results from qualitative expert interviews with ten accelerator managers:

- RQ1: Which accelerator types exist and how are they designed?
- RQ2: What are success factors and key challenges of different accelerator types?
- RQ3: How do different accelerator types measure their success?

3 Method and research design

3.1 Data collection and sample

To get an in-depth and better understanding of the accelerator types and their design in the context of the process industries, we conducted semi-structured interviews with ten accelerator managers. The research design follows a qualitative research approach, which includes a literature review as a starting point to identify relevant research questions resulting in the development of a semi-structured questionnaire for this exploratory research. The developed semi-structured questionnaire consists of five topics, in which the first four refer to the design elements of Pauwels et al. (2016), while the last one addresses the qualitative and quantitative success metrics that are used by the interviewed accelerators to measure the achievement of their objectives: 1) *Strategic focus* (which includes also the funding structure and organizational governance of the accelerator), 2) *Selection process*, 3) *Alumni relation*, 4) *Program package*, and 5) *Success measurement*. A definition for each topic was given in the questionnaire to create a common understanding between the interviewer and interviewee. For the validation of the questions regarding their relevance for research and practice and the questionnaire's comprehensibility, the final draft of the questionnaire was tested with two researchers and one accelerator manager. No questions were excluded and all questions were evaluated as understandable and relevant. The questionnaire can be found in the appendix.

In this study, the interviewed accelerators exhibit one of the following characteristics: 1) explicitly tailored program for start-ups with a process industry background, 2) program with focus on one or several sectors of the process industries, or 3) program that has no focus on one or several sectors of the process industries, but which is also open for the participation of start-ups with a process industry background. In total, ten expert interviews with accelerator managers were conducted, which mainly focus on the chemical industry. Relevant accelerators were found in a white paper on *European Startup Accelerators in the Chemical Industry* indicating 19 programs with a partial or main focus on chemistry and other sectors of the process industries (Asano and Kirchhoff, 2019). For the search of corporate accelerators, statistics regarding chemical companies with the highest turnover in 2017 and 2018 were also used (Hohmann, 2019). Finally, other international and well-known accelerators were approached for an interview, when they fulfilled the required characteristics for this study. Potential candidates for an expert interview received an invitation by e-mail with a short overview of the study including the key research questions. In total, 30 accelerators were approached. Seven accelerators (23%) declined an interview due to a lack of time. Another reason was the lack of knowledge and a missing relation to process industries. Further, 13 accelerators (43%) did not reply. Finally, ten accelerators (33%) confirmed their interest and participated in this study. The interviewees received the questionnaire in advance. All interviews were conducted between November 2019 and January 2020 with an arithmetic average duration of 47 minutes. The interviews were conducted in German or English, and either by telephone or web call. After their transcription, the German interviews were translated into English. Table 2 provides an overview of all interviewed

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

accelerators for this study.

3.2 Data analysis

For the data analysis, the qualitative content analysis of Mayring (2016) was conducted due to the exploratory nature of this research (Krüger and Riemeier, 2014). All interviews were recorded and transcribed. Subsequently, they were transformed into a coherent written text. Then, data were coded based on the design elements and constructs of Pauwels et al. (2016) and new codes were added as long as novel aspects occurred. This process has an iterative character and data interpretation depends on the researcher (Mayring and Gläser-Zikuda, 2008; Ramsenthaler, 2013). The objectivity and quality of results can be improved through interrater-reliability (Krüger and Riemeier, 2014). Therefore, a second researcher checked and verified the coding of the qualitative content analysis. The software tool f4 by audiotranskription was used to support the data analysis. For triangulation of data, information was gathered from the respective websites of the interviewed accelerators.

4 Findings and discussion

Our data revealed three different accelerator types in the context of the process industries: 1) *Corporate accelerator*, 2) *Public accelerator*, and 3) *Hybrid accelerator*. The two authors compared and discussed all cases based on the five design elements of Pauwels et al. (2016) which allowed for comparability among the interviewed accelerators. The accelerator types were then clustered based on the funding sponsor. This construct belongs to the design element *funding structure and governance*. Table 3 provides an overview of the three different accelerator types with their differences and similarities concerning the five design elements of Pauwels et al. (2016). Further, Table 4 contains exemplary representative quotes from interviewed accelerator managers regarding their strategic goals and industry/sector focus. Table 5 gives an overview of the qualitative and quantitative success metrics that are used by the interviewed accelerators at three different points in time: 1) before the start (promotion and recruitment), 2) during (execution), and 3) after the end (evaluation) of the program. Some success metrics are used among all three accelerator types. Finally, Table 6 shows exemplary representative quotes from interviewed accelerator managers concerning their qualitative and quantitative success metrics that they use.

In the following, each accelerator type is described in detail.

Table 2 Accelerator descriptives (own representation).

Accelerator type	Accelerator pseudonym	Founding year	Accelerator location	Accelerator duration	Maximum funding per start-up	Interview duration
Corporate	Acc-01	2019	USA	3 months	25,000 US$	68 min
Corporate	Acc-02	2017	Germany	3 months	Varying	54 min
Corporate	Acc-03	2015	Germany	3 months	50,000 €	50 min
Corporate	Acc-06	2013	Germany	3 months	22,000 €	26 min
Hybrid	Acc-05	2017	UK	4 months	100,000 £	28 min
Hybrid	Acc-07	2018	Germany	<1 months	No funding	47 min
Hybrid	Acc-08	2016	Spain	6 months	No funding	50 min
Public	Acc-04	2010	Chile	6 months	80,000 US$	22 min
Public	Acc-09	2019	Germany	4 months	No funding	54 min
Public	Acc-10	2017	Germany	6 months	No funding	37 min

JOURNAL OF BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

Table 3 Overview of accelerator types and their design elements in the context of the process industries (own representation).

Accelerator type	**Corporate accelerator**	**Public accelerator**	**Hybrid accelerator**
Number of interviews	4	3	3
Design element: Funding structure and governance			
Funding sponsor	■ Corporate funding (e.g. corporate or business units)	■ Single or multiple public funding sources (e.g. from regional, national, and/or supranational government)	■ Multiple funding sources: funded by private sponsors (e.g. private university), public sponsors (regional or national government) and multiple corporates (often main sponsors
Organizational governance	■ Independent entity or separate department belonging to corporate innovation department ■ Accelerator team members are corporate employees, mostly from corporate innovation department	■ Independent entity ■ Technology park ■ Research institute	■ Publicly initiated hub ■ Technology center ■ Private university
Key challenge	■ (Voluntary) Involvement of internal partners from business units	■ Search for financial sustainability ■ Experimenting with funding structure and revenue model	■ Involvement of corporate sponsors ■ Search for financial sustainability ■ Experimenting with funding structure and revenue model
Design element: Strategic goals and focus			
Strategic goal	■ Mainly exploitative search of start-ups with solutions related to the corporate's current business activities and specific internal problems ■ Search for new business models ■ Brand enhancement and marketing ■ Increased visibility in the start-up scene	■ Diversification of local economy and economic growth within a specific geographic region without or by specializing on a specific sector or topic ■ Development of rather explorative and novel technologies ■ Attraction of entrepreneurial talent and local settlement of start-ups ■ Creation of new spin-offs (e.g. from research institutes and universities)	■ Economic growth and regional development by specializing on a sector or topic ■ Establishment of cooperations/ projects between start-ups and corporates ■ Development of rather explorative and novel technologies ■ Attraction of entrepreneurial talent and local settlement of start-ups ■ Brand enhancement and marketing
Industry/sector focus	■ Focus on one or several industry sectors or topics, which are in interest of business units	■ (Partly) Very broad industry/ sector focus among different topics	■ Focus rather on one or several related industry sectors or topics
Geographical focus	■ Accelerator takes place at one location (normally at corporate headquarters) ■ National and international start-ups	■ Accelerator takes place at one location in the country or region where it is funded ■ National and international start-ups	■ Accelerator takes place at one location in the country or region where it is funded ■ National and international start-ups

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

Table 3 continued. Overview of accelerator types and their design elements in the context of the process industries (own representation).

Accelerator type Number of interviews	Corporate accelerator 4	Public accelerator 3	Hybrid accelerator 3
Design element: Selection process			
Key selection criteria	■ Favor start-ups in later stages with presentable prototype/ proven track record ■ Strategic fit to existing core businesses ■ Potential for partnership with corporate ■ Focus on teams ■ Team constitution and availability	■ Open to start-ups in all development stages dependent on individual program ■ Strategic fit to program objectives ■ Focus on teams, but also open to individuals ■ Team constitution and availability ■ Requirements of public sponsors	■ Open to start-ups in all development stages dependent on individual program ■ Strategic fit to program objectives ■ Focus on teams, but also open to individuals ■ Team constitution and availability ■ Requirements of private and public sponsors
Design element: Program package			
Program duration	■ 3 months	■ 4-6 months	■ <1-6 months
Funding	■ Funding provided, but amount varies among corporates	■ No or funding provided dependent on individual program	■ No or funding provided dependent on individual program
Equity taken	■ No equity taken	■ No equity taken	■ No equity taken
Curriculum/ training program	■ No compulsory curriculum ■ Tailored trainings according to start-up needs ■ Technical and business trainings	■ Flexible or compulsory curriculum ■ Standardized and/or tailored trainings according to start-up needs ■ Technical and business trainings	■ Flexible or compulsory curriculum ■ Standardized and/or tailored trainings according to start-up needs ■ Technical and business trainings
Coaching/ mentoring services	■ Coaching services and corporate mentors	■ Coaching and mentoring services	■ Coaching and mentoring services
Location services	■ Co-working space ■ Internal laboratory space on request ■ Networking events	■ Usually co-working space ■ Laboratory space on request through accelerator network ■ Networking events	■ Usually co-working space ■ Laboratory space on request through accelerator network ■ Networking events
Demo days/ investor day	■ Internal demo day and external demo/investor day (but format can vary)	■ Demo/pitch day	■ Demo/pitch day or final boot camp
Design element: Alumni relations			
Alumni network and post program support	■ Strength of alumni network dependent on individual program and its age ■ Usually no specific post program support	■ Strength of alumni network and post program support dependent on individual program and its age	■ Strength of alumni network and post program support dependent on individual program and its age

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

Table 4 Exemplary representative quotes from interviewed accelerators regarding their strategic goals and industry/sector focus (own representation).

Construct	Representative quotes
Strategic goal	■ "We want to work with customers and to advance sustainability in chemistries [and] to business development effort." [Corporate Acc-01] ■ "[The business area] is the main stakeholder or partner in the interaction with the start-ups. The business area wants to extract [strategic] added value from the accelerator program for its business units." [Corporate Acc-02] ■ "For us in the accelerator program it is important that the start-ups have a strategic fit with the company. This means that we are interested in the industries in which our company is also active." [Corporate Acc-03] ■ "(...) we are looking for new technologies and solutions that can either complement our existing portfolios or improve our current processes and products. Perhaps even once after completely new business models." [Corporate Acc-06] ■ "Our hub is focused on the topics of [digitalization of] chemistry and pharmacy in order to simplify, enable and support the cooperation between start-ups and established corporations, especially in the respective country. (...) Furthermore, the visibility of the chemical industry and digitalization is important to us." [Hybrid Acc-07] ■ "Our mission is to help to develop the next generation of industrial companies, which create a competitive economy and reinforce the industrial sector. (...) our focus is to help creating industrial companies. Because we are in a region with traditional industries. [And a region] with a strong industrial sector, those [industrial companies] create qualified jobs and (...) competitive economies." [Hybrid Acc-08] ■ "We are looking to diversify and sophisticate our local economy." [Public Acc-04] ■ "[Our goal] is to promote start-ups in the field of natural sciences with a focus on material science here at the site. And, of course, because it is a publicly funded program, it is also intended to facilitate and promote the establishment [of start-ups] at the respective location. This is clearly one of the program's goals, which is why one of the prerequisites for participation is the interest in founding a company or the establishment of a company in the state." [Public Acc-09]
Industry/sector focus	■ "(...) meet the criteria of what our corporate is trying to do (...) and that was in three categories: circularity in plastics, battery materials and digital innovations." [Corporate Acc-01] ■ "With our Accelerator program we focus [in relation to the chemical industry] on the hardware-related start-ups." [Corporate Acc-02] ■ "Where we are still specifically looking for start-ups are in our innovation fields. We currently have three fields of innovation. These are Bio Sensing Interfaces, Liquid Biopsy Technology and Clean Meat." [Corporate Acc-03] ■ "(...) our main focus is on digital chemistry start-ups, or start-ups with digital solutions for the chemical industry. We do work together with wet chemical start-ups only rarely." [Hybrid Acc-07] ■ "Our focus is mainly on hardware products like medical devices, robotics, agrotech, foodtech [and] always have innovative technologies and a part of that is the new material and chemicals. So adhesives, new materials, additives things like that." [Hybrid Acc-08] ■ "The technical focus [of the accelerator] is on life and material science. This means natural sciences, such as materials science, health and medicine, chemistry and bio economy. Cross-sectoral industries and technologies also play a role, i.e. IT and software development." [Public Acc-09] ■ "[In our program] we accept life science start-ups, and they come from the biotech, medical technology and digital health sectors." [Public Acc-10]

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

Table 5 Qualitative and quantitative success metrics used by the interviewed accelerators for success measurement (own representation).

Point in time	Qualitative and quantitative success metrics
Before the start of the program (Promotion and recruitment)	**All accelerator types:** ▪ Absolute number of applications and participants including descriptive start-up indicators (e.g. geographical origin, age, team diversity)
During the program (Execution)	**All accelerator types:** ▪ Active participation of start-ups ▪ Fulfillment of milestones
After the end of the program (Evaluation)	**All accelerator types:** ▪ Internal assessment of cooperation with accelerator partners ▪ External feedback from start-ups and accelerator partners ▪ Extension of accelerator network ▪ Extension of alumni network **Corporate accelerator:** ▪ Number of implemented cooperations/projects between start-ups and business units ▪ Internal assessment of cooperation with business units ▪ Shift of corporate culture towards open innovation ▪ Enhancement of corporate's innovation activities and brand through association with the start-up scene **Public and hybrid accelerator:** ▪ Number of implemented cooperations/projects between start-ups and corporates ▪ Amount of public funding received or private investment attracted by start-ups ▪ Economic and social impact (e.g. number of established companies, jobs created, taxes paid) ▪ Survival rate of start-ups

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

Table 6 Exemplary representative quotes from interviewed accelerators regarding their success measurements (own representation).

Construct	Representative quotes
Success measurement	■ "The open innovation culture is a soft target, it does not have a very hard measure but I think it is a very important one, because I think going forward into the future, some types of collaboration are the ones that are going to be the winning business opportunities of the future." [Corporate Acc-01] ■ "Our goal is to create at least one cooperation out of the accelerator program, however it is structured. We also want to become better known in the start-up scene through this accelerator program. I think we have already achieved this quite well. We have communicated with various postings in social media, but also through normal, classic press releases, which has already increased our level of awareness a bit. We were also approached by other corporates. They find this [interesting], especially because of the [difficult] material environment and the knowledge gain behind it." [Corporate Acc-02] ■ "(…) we have changed a little bit our program. We have moved from an early stage program, which I understood to be more of a classic accelerator program, to a more partnership-based program, which of course has changed the KPIs. Therefore, it is a little bit difficult to compare success over time. At that time, I was not involved in the program as a manager, but as far as I know there were no real hard KPIs at that time [before the program change]. For example, there was [a KPI] on how many start-ups were on boarded, or how the financing rounds of the start-ups went afterwards, but I'm not quite sure. It was more of a tryout back then. What can we as a company do with the Accelerator program, where do we want to go?" [Corporate Acc-03] ■ "We measure an overall performance across three different areas. One is the number of applications and geographic spread for the applications. We measure things like gender, diversity and thus other things of application step stages and that kind of things. We measured a number of demographic types of measures for the application. And then when the start-ups are here, we measure them against the milestones, and many other things, like their attendance and their spent. When they release the program, we [are] monitoring them for four or five years and once a year we check in with them to check things like the status of technology, having field trials, revenue, profit, jobs created, investment raised, locations in terms of offices and warehouses etc. And we also measure gross value add, so we measure things like foreign deployments or successful commercial deployments of the technology, how much it is receiving per year, how many deployments did they have? How long do they expect then to retain competitive advantage? Our hard target is greater than 50% survival rate beyond five years, but we would like a greater than 90% survival rate." [Hybrid Acc-05] ■ Of course, we collect feedback from the start-ups and the companies. Did you like it, how was the selection of the start-ups, how was the performance of the start-ups, how much is the interest in the start-ups? The same is true for start-ups. How were the talks, what did they result in, what is your assessment? This is practically right after the program. [Hybrid Acc-07] ■ "And also, how many agreements we managed to close between the large companies looking for innovation and start-ups having innovations." [Hybrid Acc-08] ■ "Of course we ask the participants about the program. For example with a questionnaire with which the start-ups can evaluate the event or components of the Accelerator. What they were able to take away positively, or which contacts are helpful for them afterwards." [Public Acc-09] ■ "We also look at the survival rate, but the question is always, how do you measure success in life science? Hence the question: If the team is still alive, is it a success? Or if the team has found an investor, is it a success? Or if the team is already on the market, but that is unrealistic, depending on the biotech team, it will not be on the market within three years that is impossible. (…) For us it is important to know how many teams have found an investor. Because that's one of our goals. So far we have 43 teams in the program. And nine of them have found an investor, and that is actually a very good rate in the life science sector." [Public Acc-10]

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

4.1 Corporate accelerator

4.1.1 Funding structure and governance & Strategic goals and focus

The *corporate accelerator* is an accelerator type, which is funded and set up by a single corporate with the strategic goal to collaborate with start-ups in mainly exploitative (and less explorative) projects, what means that start-ups offer solutions that are related to the corporate's current business activities and specific internal problems. Thus, start-ups are selected based on the corporate's business unit needs as highlighted by accelerator manager Acc-06: ***"(…) we are looking for new technologies and solutions that can either complement our existing portfolios or improve our current processes and products."*** In addition, some interviewed corporates search new business models, and have the aim of enhancing their brand and marketing, while also increasing their visibility in the start-up scene as stated by accelerator manager Acc-02: ***"We also want to become better known in the start-up scene through this accelerator program."***

The industry/sector focus varies among the interviewed accelerators. Some focus on one, whereas others on several industry sectors or topics. Regarding the geographical focus, corporate accelerators are open for applications of national and international start-ups, while the program normally takes place in one physical location. Normally, the accelerator is located at the corporate's headquarter.

Usually, internal stakeholders of the corporate accelerator are top management and the financial sponsors of the program (e.g. corporate and business units) as stated by accelerator manager Acc-02: ***"[The financial sponsoring] is decided on a group level by the board, which of course had to stay behind the project [accelerator program], because we needed the backing of the top management. Then, there is a business sponsor that is a Business Area [Business Area holds several Business Units]."*** With the exception of corporate Acc-06, an internal accelerator team is responsible for the program consisting of a maximum of three full time employees (FTEs), who mostly come from the corporate innovation department and receive additional support from temporary employees such as working students. The accelerator team members normally have a broad network within the corporate to identify relevant business units' needs and to facilitate communication between internal partners and start-ups. In three of the four cases, the accelerator was internally set up, either within the corporate innovation management department or in a separate department that reports to corporate innovation. In contrast, corporate Acc-06 was established as an independent entity of the corporate, and the accelerator team consists of nine to ten FTE. In this context, accelerator manager Acc-06 mentions the advantage of greater flexibility, since the accelerator is not part of the corporate structure: ***"We [accelerator] are a separate company, which can therefore also act more flexibly. We are therefore a bit more free [in the room for maneuvers] than in a normal group structure, and we are also responsible for this. We are active since 2013 and our core team consists of nine to ten people."***

4.1.2 Selection process

Corporate accelerators promote their program through social media and other marketing activities, often with the help of external partners. The application for the program is online. They also scout actively promising start-ups and involve external partners in these scouting activities. In the selection process, all interviewed corporate accelerators use internal corporate colleagues from business units, and also often externals for screening and short-listing the applications. Internal corporate colleagues from business units have the appropriate technical and business/industry expertise to assess the start-up's solution, and are further involved in the final selection of the start-ups. The final selection format varies among the interviewed corporate accelerators (e.g. pitch day, 2-day boot camp with final pitch, or 3-day workshop "launch pad").

In general, the interviewed corporate accelerators favor start-ups in later stages with an already developed prototype or proven track record, since this is very important for the involvement and cooperation with internal business units as highlighted by accelerator manager Acc-06: ***"[The start-ups] need at least one reasonable, presentable prototype. Furthermore, they should perhaps even already have their first customers. We have recently (re)oriented ourselves and decided to [choose] start-ups in the later [venture] phase. We have noticed that when [the start- ups] are in the development phase at an early stage, it is very difficult to set up joint pilot projects with our business unit."*** Other key selection criteria are the strategic fit of start-ups to existing core businesses and their potential for a partnership with the corporate as emphasized by accelerator manager Acc-01: ***"(…) The last one was the potential for partnership and***

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

that was what we are looking for. We wanted to make sure that whoever we selected was in a place for a partnership. We have one [start-up] for example that was very far already and has a lot of backing from other companies. That is why we score them a little bit lower in that area, because we just [not] wanted contribute to much to them, they had financial and other corporate backers they were working in the space that we are interested, but the train has lost the station is the best way to say it. All of the criteria were very important. You cannot look [at] them in isolation because when there is no potential for partnership it really did not matter if this [start-up] was a great team." Furthermore, the interviewed corporate accelerators focus on start-up teams and not on individuals. Here, they look at the team constitution, its availability, and willingness to participate in the program.

4.1.3 Program package

During the program, the participating start-ups receive funding from the corporate, but the amount of funding varies among the interviewed programs. No interviewed corporate accelerator takes equity in exchange. Also, the programs have no compulsory curriculum, rather they offer tailored trainings according to the technical and business needs of the participating start-ups. Furthermore, they provide coaching services and corporate mentors. These corporate mentors help start-ups to find their way through the corporate structure to connect with the right internal colleagues as noted by accelerator manager Acc-01: *"We also have what we are calling corporate mentors. Each start-up has two to four corporate mentors, and it is our job to make sure that they have a good connection with our corporation. (…) Being the one point of contact to the start-up so that they do not have to find their way through a larger organization like ours, because that would be very difficult from outside."* Regarding the location services, the interviewed programs provide co-working space, laboratory space on request, and networking events. Finally, the program normally ends with a (internal or external) demo/investor day at which the start-ups present their solution to business units, potential customers or investors. All interviewed corporate accelerators have a duration of three months.

Concerning the program package, accelerator manager Acc-03 summarizes the benefits of their corporate accelerator for participating start-ups as follows: *"For most start-ups it is important to have access to our internal resources. Like internal employees, internal experts, customers from us, processes from us that is as an extern not so easy to get. And that, I believe, is our USP as an accelerator program. I think the motives are relatively obvious. We are the only accelerator program in the world that can give start-ups access to our company. And for the most of the start-ups we work with, the motive is to win our company as a business partner, customer or development partner. This is a door opener to our ecosystem. [Therefore,] I think that the financial aspect [50,000 Euro funding without shares] is not the most important aspect for the start-ups participating in our program."*

4.1.4 Alumni relations

After the end of the accelerator, no interviewed corporate accelerator provides any post program support. If no cooperation between a start-up and a business unit is achieved, no further assistance to the start-ups is provided. However, the interviewed corporate accelerators include the start-ups in their alumni network. The strength of the alumni network depends on the individual program and its age. No interviewed corporate accelerator has a structured alumni network program in place as one accelerator manager Acc-01 exemplarily states: *"If there is an opportunity to go forward with anyone of these [it has to be mutual] than we would do that individually afterwards. If not, and that is fine, we leave it. (…) To put them in our network in a way that we can always reach out in the future if needed and they can do the same [makes sense]."*

4.1.5 Success factors and key challenges

The interviews with the four corporate accelerators revealed that the commitment and involvement of top management for the program is very important. Kohler (2016) also found that top management engagement is crucial to enable open innovation with start-ups and to prevent that start-ups end up in interest conflicts with current businesses. Therefore, the CEO's support will increase the internal buy-in of business units and involvement of employees, since corporate employees are usually involved on a voluntary basis. Hence, it is important to keep their time involved to a minimum, while identifying the relevant business unit needs for the search of suitable start-ups, or when involving them in the selection process to assess strengths and weaknesses of interesting start-ups. The early involvement of business units in the selection process increases the commitment and acceptance of internal partners for the program. In

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

addition, Kohler (2016) highlights that an early involvement of business units can help to mitigate challenges when setting up a follow-up project between a start-up and a business unit after the end of the program. This aspect is also emphasized by accelerator manager Acc-03 as follows:

"With our [program] form that we currently have, it is very important that we work closely with our internal partners. The internal experts have no specifications in their KPIs, they do not have to work with us. We are dependent on the goodwill and curiosity of our [internal] partners. We try to involve our partners as early as possible in the process, because they are the ultimate customers of the service we offer [as accelerator]. It is important to have a good relationship with the partners and also to integrate the internal partners as early as possible in the whole process so that no misinterpretation occurs. Therefore, at the beginning of our scouting phase, we always consult with the business development teams of the different sectors and with various technology scouts. We then summarize roughly what the business sectors are currently working on and which topics are of interest to them. Whatever topics are on the strategic roadmap. And we also communicate this to experts that we are actively looking for start-ups in these areas. [Hereby] we try to arouse the interest of internal partners as early as possible. When the internal partners find start-ups they are interested in, they are usually willing to participate in such Boot Camps [of our program]. We also try to keep the time [of the experts] to a minimum. Therefore, they do not have to keep the two days free, but one to four hours [for the Boot Camp]."

Moreover, corporate mentors are very important that help and guide start-ups through the complex corporate structure and its decision making process, while connecting them with the right colleagues (Pauwels et al., 2016).

Success stories are very important for the internal and external promotion of the accelerator in order to attract high-quality start-ups, to increase internal involvement of business units, and in order to extend the program as mentioned by accelerator manager Acc-01: *"How to say going forward, you [need to] have really huge success and then say we can duplicate this with dedicated FTEs and resources to be able to execute [by an own department]"*.

Concerning the key challenges, the interviews revealed that a clear communication about goals and coordination of activities among internal and external partners is necessary as described by accelerator manager Acc-03: *"[A shared culture of communication] is indeed not easy, especially when it comes to setting it up in such a way that clear communication exists, so that it is not confusing for the start-ups on the one hand, and for the [accelerator] partners on the other. (…) I believe that you simply have to communicate this well beforehand and be clear about what agenda your partner might also have and address it openly so that there are no conflicts of goals afterwards."*

Furthermore, a short program duration represents a challenge for the development of physical solutions that may require more time, and hence suitable start-ups must be carefully selected as indicated by accelerator manager Acc-02: *"We firmly believe that it is simply much more difficult to create an accelerator program that promotes hardware-related start-ups. (…) This is also the feedback we have received from the start-ups. We have learned from the feedback that accelerators are mainly designed to sharpen the business plan [with] relatively fresh [start-ups] and perhaps also to perform a POC [proof of concept] as part of a software solution. But to get some results in the hardware environment within a short period of three months is actually quite difficult. That is why you have to take a close look at the project."*

4.1.6 Success measurement

One key success metric of the interviewed corporate accelerators is the establishment of cooperations and implementation of projects between the participating start-ups and its internal business units after the end of the program as emphasized by accelerator manager Acc-03: *"For us, the most important KPI is "Qualified cooperation projects according to the accelerator program", i.e. how many start-ups per batch could we really link to internal partners and then initiate cooperation projects with the start-ups."* In this context, they also assess the cooperation with the corporate's business units. Another rather qualitative success metric is the shift of the corporate culture towards open innovation as stated by accelerator manager Acc-01: *"The open innovation culture is a soft target, it does not have a very hard measure but I think it is a very important one, because I think going forward into the future, some types of collaboration are the ones that are going to be the*

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

winning business opportunities of the future." In addition, they use general qualitative and quantitative success metrics concerning the absolute number of applications and participants, active participation of start-ups and fulfillment of milestones during the program, or assess the cooperation with accelerator partners and stakeholders, and gather their feedback.

The ***corporate accelerator*** type and its further classification into sub-types was already found and discussed in existing literature (Kohler, 2016; Moschner et al., 2019; Pauwels et al., 2016; Prexel et al., 2019). Pauwels et al. (2016) found that the ***ecosystem builder*** type is set up by a corporate to develop an ecosystem around the corporate consisting of customers and stakeholders. In contrast, in our study, corporate accelerators rather search start-ups with solutions that help business units to exploit current businesses and existing technologies, or to solve specific internal problems. Hence, they do not directly aim at establishing or enhancing the corporate ecosystem, although start-ups may become potential suppliers or customers of the corporate or part of the corporate's ecosystem through the alumni network. Our findings are in line with the strategic goals and characteristics of a corporate accelerator sub-type *"In-house accelerator"* described by Moschner et al. (2019). In accordance with Richter et al. (2017), we also found that the use of success metrics varies strongly among the different interviewed corporate accelerators.

4.2 Public accelerator

4.2.1 Funding structure and governance & Strategic goals and focus

The ***public accelerator*** type is funded by local, national or supranational (e.g. European) funding schemes, and thus has public authorities as main stakeholders. The strategic goal of the ***public accelerator*** is to enhance start-up activity and in doing so to foster economic growth within a specific region (e.g. federal state or country), either without or by specializing on a specific sector or topic (e.g. technological domain). In this context, the main strategic goal is the attraction of entrepreneurial talent and the local settlement of start-ups, and to facilitate the transformation of scientific inventions into innovations by supporting the creation of local spin-offs (e.g. from research institutes or universities). In general, the interviewed publicly funded accelerators also aim at the development of rather explorative and novel technologies. This should contribute to a diversification of the local economy, while increasing the competitiveness of the respective region and reducing the dependence on a single industry. Therefore, the interviewed publicly funded accelerators are open for national as well as international start-ups with promising solutions, but start-ups must participate on-site in the program. The program takes place in the region or country in which it is funded. Accelerator manager Acc-09 summarizes this as follows: *"[Our goal] is to promote start-ups in the field of natural sciences with a focus on material science here at the site. And, of course, because it is a publicly funded program, it is also intended to facilitate and promote the establishment [of start-ups] at the respective location. This is clearly one of the program's goals, which is why one of the prerequisites for participation is the interest in founding a company or the establishment of a company in the state."*

The organizational governance of the three interviewed publicly funded accelerators was organized differently. In one case, an independent entity with 20 FTEs was responsible for running the accelerator, whereas in the other two cases, the accelerator was run by a technology park and a research institute at a university with less FTEs.

The industry/sector focus of the interviewed public accelerators is partly very broad and covers various different topics depending on the individual program.

4.2.2 Selection process

Public accelerators use several channels to promote their program including social media activities and through their accelerator network consisting of partners, mentors and other relevant stakeholders. For the scouting of suitable start-ups for their program, they exchange with universities, incubators and technology transfer units. The application for the program is online. In the selection process, all interviewed public accelerators use externals for screening and short-listing the applications. These externals are often industry representatives, mentors/coaches, alumni or investors from the accelerator network and possess the necessary technical and business/industry expertise to appropriately assess the applicants and their fit to the program as accelerator manager Acc-10 describes: *"And finally, we forward the applications [which have not been filtered out by us beforehand] to our jury, which ultimately makes the decision. This jury examines the start-ups more*

JOURNAL OF BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

intensively, for example with regard to patents, if the teams have patents. The jury consists of three people. These are industry experts on the one hand and patent experts from technology transfer offices on the other. Sometimes mentors from large business plan competitions such as ScienceforLife also participate. They have already seen many start-ups and know whether [the solutions of the] start-ups are up to date or whether they have simply been there ten times before." These externals are also involved in the final selection of the start-ups at a pitch day.

The interviewed public accelerators are generally open to start-ups in all development stages, and hence the maturity of solutions of the participating start-ups may differ strongly. Accelerator manager Acc-09 considers this as an advantage of the program, since start-ups can learn from each other and provide feedback to their peers: *"Whereby we have now noticed from the experiences of the Pilot Accelerator that it really works surprisingly well when the teams are in different phases. In the pilot project, we had two teams that had not yet been established, but were still carrying out a spin-off as a start-up project at an institute or research institution. Then, we had a start-up that was already established, and a start-up that was established during the course of the accelerator. It was really astonishing how good these different perspectives are for both the young or still current start-up projects and the participants who have not yet founded a spin-off. Simply because you get feedback from the more experienced participants where there are still stumbling blocks and you should take a closer look. (…) On the other hand, it was also astonishing to see that even the young start-up projects or those that have not yet been established were able to offer added value to those who have already started up. This is simply because one has a completely different view of the product. And above all, and this is ultimately also a characteristic of these founders, that there is a high level of professional expertise. And through this, the young founders can also give feedback on the products of the already founded companies, at least from their professional perspective. This means that biochemists can now provide feedback on start-up projects that focus on genetic aspects. This means that there is a surprisingly good network and added value for both sides."*

In general, the interviewed public accelerators rather focus on start-up teams, but are also open for individuals and help those to find the right team members. In fact, the team constitution, availability, and willingness to participate in the program are important selection criteria as highlighted by accelerator manager Acc-09: *"The diversity of the team also plays a role. This means that if [the members of the team] are purely scientific, experience shows that it is more difficult than start-ups with members who have a clear economic background. [It is also important] whether the team consists of several founders. If there are one or two people involved in the start-up, this tends to be more difficult than if there are perhaps already three or four founders who can share the tasks accordingly. [At best, the founders] have different professional focuses and a different appearance. Because especially for the first start-up phase it is crucial how well the team works."*

For the intake in the program, start-ups must also fulfill requirements of the public sponsors (e.g. local settlement and physical participation in the program on-site).

4.2.3 Program package

Regarding the program package, two of three cases do not provide any funding for participating start-ups. However, participation is free of charge. The third case provides up to 80,000 US$ of funding, but takes no equity in exchange. Furthermore, the interviewed public accelerators have either a flexible or standardized curriculum. Accelerator manager Acc-04 compares the curriculum and organization of their program with the structure of a university course: *"Mainly every week [the start-ups] have activities. We will give them something that is called a playbook. The playbook is basically everything that is going to happen inside of the accelerator. When they start the first day, they will have a calendar with all the activities that they will have during the program until being at the [end of the] program. They have activities pretty much every day. You have sessions, you have workshops, you have talks, you have events, you have mentor hours. Everything is planned ahead. Think about the accelerator is like going into a university. You are coming to the university, you start your workshops or whatever, they will give you a plan of the course that you are taking, right? It is a kind of this scheme."* Therefore, standardized, but also tailored trainings according to the start-up needs are offered as indicated by accelerator manager Acc-10: *"[In our program] we accept life science start-ups, and they come from the biotech, medical*

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

technology and digital health sectors. (…) These start-ups have very special needs, which are very different from e.g. IT start-ups, simply because the market in the business is very complex and also very regulated." In addition, both, technical and business trainings are offered. Besides, the interviewed public accelerators provide coaching and mentoring services. Concerning the location services, they usually offer co-working spaces and networking events. Access to laboratory space can be provided on request through the accelerator network (e.g. at a university or research center) as described by accelerator manager Acc-09: *"We do not offer offices, but a co-working space is available. Because we are working together with the research facilities on campus and also want to set up a workshop ourselves, laboratories and workshops will be available for the teams during their participation in the project. For this purpose, we have also planned the necessary personnel, who will also be available in the workshop, for example. This means a technical assistant who will give an introduction to the workshop, an introduction to the equipment that has perhaps not yet been used, so that a competent person will be available there to supervise this. And in the laboratories it can then be a possibility to give something like a training or workshop with the experts from the research institutions. For areas that are then relevant for the start-ups. But we do not provide the raw materials themselves."*

Finally, the program normally ends with a demo/pitch day or boot camp at which start-ups have to opportunity to present their solution to potential customers or investors in order to obtain a follow-up investment. In general, program duration varies from four to six months.

4.2.4 Alumni relations

After the end of the program, the strength of the alumni network and post program support depends on the individual program. All interviewed public accelerators highlight the value of a strong alumni network and their efforts to stay in contact with alumni. Successful alumni can promote and support the program as mentors or provide valuable networking opportunities for future participants of the program as accelerator manager Acc-10 illustrates: *"We have an alumni program. We write to the alumni regularly. We invite them to our events, also to our Demo Days. Sometimes we also get requests from trade fairs, where we get free tickets and distribute them to the alumni. So we make sure that we stay in contact. Some alumni we have even taken on as mentors, for example if they have a certain expertise."* Accelerator manager Acc-09 states that their program actually consists of two parts. The accelerator is for the fast-track development of a start-up, while a second consecutive program will ensure long-term growth support for the start-up's scale-up and internationalization activities: *"Now in the new planning [of the Accelerator] we will have this Accelerator Program [as compact support], but after the end of the class [cohort] the support will not stop, but a further support of the start-ups will take place via this longer-term [growth program] with further individual coaching or also topics on internationalization. In other words, this program is actually two-track. On the one hand we have the Accelerator Program and on the other hand this further growth support."*

4.2.5 Success factors and key challenges

Success stories of alumni are very important for public accelerators to demonstrate their added value for society in terms of increasing start-up activity and fostering economic growth within a specific region and justifying the spending of public funding. For the attraction of promising start-ups, success stories and a strong accelerator network including high-quality coaches and mentors, industry representatives, investors, and alumni are essential.

A key challenge for public accelerators is the search for financial sustainability to reduce dependency on public funding. For this reason, this accelerator type must experiment with their funding structure and revenue model to secure existing, but also to attract new funding sources to ensure the continuation of the program (Pauwels et al., 2016).

4.2.6 Success measurement

The interviewed public accelerators measure their success in terms of positive impact on the socioeconomic development of a region as summarized by accelerator manager Acc-04: *"We measure everything basically. Our KPI regards to global ecosystem impact, economic impact and social impact like employment, taxes gathered by the public sector through the sales that start-ups are making."* Additionally, one important success metric is the survival rate of start-ups, which participated in the program. However, this can be difficult to measure and is only possible after some time, since development processes within the process industries may especially require some time as indicated by accelerator

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

manager Acc-10: *"We also look at the survival rate, but the question is always, how do you measure success in life science? Hence the question [is]: If the team is still alive, is it a success? Or if the team has found an investor, is it a success? Or if the team is already on the market, but that is unrealistic, depending on the biotech team, it will not be on the market within three years that is impossible."* Further, they also use general qualitative and quantitative success metrics regarding the absolute number of applications and participants, active participation of start-ups and fulfillment of milestones during the program, or internally assess the cooperation with accelerator partners and stakeholders, and gather their feedback concerning the program.

In our study, the ***public accelerator*** type is similar to the ***welfare stimulator*** type that was found by Pauwels et al. (2016), but differs slightly in the definition of the different design elements. The success metrics used by the interviewed public accelerators are similar to those mentioned by Leatherbee and Gonzalez-Uribe (2018a) and Pauwels et al. (2016).

4.3 Hybrid accelerator

4.3.1 Funding structure and governance & Strategic goals and focus

The ***hybrid accelerator*** type has multiple funding sources coming from private and public sponsors. Two cases were initiated by the national government, which also contributes some funding, while the main share of funding is coming from several corporates that also provide support for the program. In contrast, the third case was initiated by a private university. Here, the program is funded by the university itself, but also by multiple corporates and regional public funding as described by accelerator manager Acc-08: *"We are a university based center for entrepreneurship [institute]. (…) Most of the budget is coming from the university itself. (…) Then, the second sponsor is the large companies that are looking for innovation. They pay equal to belong to the community, and they also help us defining some of our activities, like events for instance. And generally minor those is a public funding, which [we] receive a little bit of public funding from the local government."* Therefore, this accelerator type has a hybrid funding structure, since program sponsors have different backgrounds.

The strategic goals of the interviewed accelerators vary. All programs have the strategic goal to enhance start-up activity in a specific region (e.g. federal state or country) by specializing on a sector or topic (e.g. technological domain) to foster economic growth as accelerator manager Acc-07 summarizes: *"Our hub is focused on the topics of [digitalization of] chemistry and pharmacy in order to simplify, enable and support the cooperation between start-ups and established corporations, especially in the respective country. (…) Furthermore, the visibility of the chemical industry and digitalization is important to us. The chemical industry is relatively in the early stages of digitalization, and does not have a huge visibility in the start-up scene."* In the case of the private university initiated accelerator, accelerator manager Acc-08 highlights that the program has two strategic goals. First, they want to enhance the brand of the university regarding entrepreneurship and innovation, and second, they want to educate skilled entrepreneurs for the regional economy: *"Being in the 21'st century, the university realized some years ago, that you cannot leave university without that area on entrepreneurship and innovation with reference in scientific, technical areas. [It is] a question of official branding. (…) Our mission is to help to develop the next generation of industrial companies, which create a competitive economy and reinforce the industrial sector. (…) our focus is to help creating industrial companies. Because we are in a region with traditional industries. [And a region] with a strong industrial sector, those [industrial companies] create qualified jobs and (…) competitive economies."* All interviewed hybrid accelerators have the aim to attract entrepreneurial talent for the local establishment of start-ups in the respective regions. Therefore, in all three cases the program takes place in the region or country in which it is funded. In general, all interviewed programs have a focus on one or several related industry sectors/topics. In doing so, they rather focus on the development of explorative and novel technologies, and are open for national and international start-ups.

The organizational model for the governance of the accelerator was different for every case, ranging from a hub that was initiated by a national government and multiple corporates, a technology center, and a private university. The accelerator team consists of maximum four FTE and is supported by additional staff (e.g. working students).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

4.3.2 Selection process

The interviewed hybrid accelerators promote their program through social media activities and their accelerator network. For the scouting of suitable start-ups for their program, they exchange with and are supported by the corporates that partly fund the program. The application for the program is online. For the screening and short-listing of applications, all interviewed hybrid accelerators use externals during the selection process. These externals are industry representatives from the corporates that fund the program, but also mentors/coaches, alumni or investors from the accelerator network, which possess the relevant technical and business/industry expertise for the assessment of applicants as accelerator manager Acc-05 indicated: *"When the application [phase] is closed, we bring in experts like entrepreneurs, investors, oil and gas experts and executives, who review all the application with us and score each of the videos up to ten."* This is also stated by accelerator manager Acc-07: *"[Within the selection committee] are usually people from the fields of digital innovation, digital transformation and technology scouts. One company, for example, provide the Head of Digital Transformation as a member of the committee. The managing director from our hub is also participating, who worked for one of the companies for 21 years. He has a relatively good feeling about whether or not it can be exciting for such companies. For special areas such as cosmetics, for example, we try to make contact with the corresponding division of one of the companies to ask: Hey look at that, would that be exciting for you?"* These externals are also involved in the final selection of the start-ups at a pitch day.

The interviewed hybrid accelerators are generally open to start-ups in all development stages, which have a strategic fit to the program. The maturity of start-up's solution may differ strongly. However, accelerator manager Acc-08 mentions that a functional prototype is very important in the context of manufacturing industries, since the focus of their program is the up-scaling of production: *"From a maturity perspective, the product should be already a functional prototype, so a TRL-5 [technology readiness level] (…) the case of the prototype is because, the focus of the program is to industrialize start-ups that produce very few units, and the next challenges is to produce 500 units or 5000 units. If you don't have a prototype you are too early for us."* In general, they rather focus on start-up teams, but are also open for individuals and help them to find the right team members as stated by accelerator manager Acc-05: *"We do consider single founder teams. We have experiences so far in both cohorts and being successful in helping them [to] build a good team. So, we are quite happy to take a single founder assuming an exciting technology and a good impact and a strategic fit."* Most teams do indeed consist of at least two members. The team constitution, availability, and willingness to participate in the program are important selection criteria as stated by accelerator manager Acc-08: *"And the last element is the team, [it] should have full-time committed into the venture, so they should not be in five projects. (…) And the question of having a full-time committed team is, because the experience tells us that when they are working on something else, then they neglected the project. The start-up is not developing in that case that it should be developing."*

Finally, for participation in the program, start-ups must also fulfill requirements of the corporate and public sponsors of the program.

4.3.3 Program package

Concerning the program package, two of three cases do not provide any funding for participating start-ups. The third case provides up to 100,000 £ of funding, but takes no equity in exchange. In all cases, participation is free of charge. Besides, the interviewed hybrid accelerators have either a flexible or standardized curriculum depending on the individual program. In addition, standardized, but also tailored trainings including business as well as technical trainings are offered based on the needs of the start-ups. For start-ups with an industrial background, which like to set-up a production, accelerator manager Acc-08 highlights that start-ups require very specific knowledge and trainings regarding the manufacturing of their solution what is not covered by *"usual"* accelerators that merely focus on business aspects: *"This is typically how they arrived to us. And they already went to a couple of accelerator programs. But the acceleration programs that's also a bit the thing, [it] is useful coming from acceleration programs. 98 % of acceleration programs that exist out there, they are suddenly the same. They have the same kind of structure and they all look on the business model, the competitive landscape and things like that. Which is great. But our problem goes into more mature faces, where these things are clear and you need to manufacture. Actually, it is a very complex process, and no one explains how to do that. (…)*

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

we have some curricula sessions so classic lectures, but they are very practical, we call them workshops, because they are very hands-on. And they are typically very much manufactory-oriented and product-oriented, so this is about product testing, product validation, product certification and things like that." Moreover, all interviewed hybrid accelerators provide coaching and mentoring services, who help the start-ups to further develop their market solution as stated by accelerator manager Acc-08: *"Then, we have the coaching/mentoring sessions, so we have head of innovations of large industrial companies and entrepreneurs (…) coaching these entrepreneurs [start-ups]."* Regarding the location services, the interviewed hybrid accelerators normally provide access to co-working spaces and organize networking events with relevant stakeholders as accelerator manager Acc-08 indicates: *"And the third activity that we are running is a community of 30 heads of innovations (…) some of them [are from] chemical companies, but then [also from] other industrial companies, automotive companies or (…) water treatment companies, larges in that field companies, that are looking for innovation outside their boundaries. (…) Either the large company would invest on them [start-ups], or look for ways to acquire license technologies, so that [they] can exploit that technology or to co-develop to tackle that problem [of the company]."* Laboratory space is not provided by the accelerator as part of the program, but could be provided by relevant contacts of the program as mentioned by accelerator manager Acc-05: *"We have workspaces. (…) We also offer the start-ups IT services, tools, infrastructures. (…) We have not the ability to offer laboratories and we do not offer raw materials or chemicals (...) But we are able to signpost them into universities or some place that might be able to help, but that is not something that we offer as part of the program, we connected them with people that might be able to help."*

At the end of the accelerator, the program culminates with a demo/pitch day. Program duration varies from less than a month up to six months depending on the individual program.

4.3.4 Alumni relations

After the end of the program, all interviewed hybrid accelerators have an alumni program, whereas the strength of the alumni network depends on the individual program as exemplarily stated by accelerator manager Acc-08: *"We do have an alumni network, we do activities with them, but it is also true, that we could do a better job there. There are some cohorts, [where the relationships] become strong, and we have groups of within social media apps and some cohort are super active. We do have a community, we meet few times a year to gather together and to have BBQ [Barbecue] and we have drinks and things like that, but these are areas that we would like to reinforce actually."* One case also provides post program support in form of an incubator as indicated by accelerator manager Acc-05: *"After we finish the 16-week accelerator program, we also provide a follow-on program [incubator] for two years. [Here] we give them additional co-working space, board rooms, support and we also give access to additional funding (…) through our institution."*

4.3.5 Success factors and key challenges

The involvement of corporate sponsors is crucial for the successful selection of suitable start-ups for the program. Therefore, a close communication with corporate representatives is necessary to identify their needs and to involve them early in the selection process. This can ensure their commitment and support for the program. Success stories of collaborations between start-ups and corporates can help to promote the accelerator within the sponsor organizations and to increase interest in the program. In this context, accelerator manager Acc-07 emphasizes that the start-ups as well as corporates must have a serious interest in the program: *"An often-underestimated criterion during the selection process is that both sides [start-up and corporate] should be interested in our program."* Besides, successful alumni can attract promising start-ups for the next batch of the accelerator. These success stories can also demonstrate the added value of the accelerator to public authorities, which provide public funding for the accelerator. Finally, hybrid accelerators must experiment with their funding structure and revenue model to secure financial sustainability as mentioned by accelerator manager ACC-05: *"Our institution has a ten-year life cycle, two years are into that [now]. We have aspirations for obviously our accelerator program and another program of our institution be leaf beyond that and continue to add value, so to do that we are needed to become an independent entity or some point with the own funding mechanism."*

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

4.3.6 Success measurement

For the interviewed hybrid accelerators, a key success measurement is the positive impact on the socioeconomic development of a region. Accelerator manager Acc-05 summaries their key success metrics as follows: ***"When they release the program, we [are] monitoring them for four or five years and once a year we check in with them to check things like the status of technology, having field trials, revenue, profit, jobs created, investment raised, locations in terms of offices and warehouses etc. And we also measure gross value added, so we measure things like foreign deployments or successful commercial deployments of the technology, how much it is receiving per year, how many deployments did they have? How long do they expect then to retain competitive advantage?"*** Since corporates are also funding sponsors of the interviewed hybrid accelerators, another key success metric is the number of cooperations and projects between participating start-ups and corporates as highlighted by accelerator manager Acc-08: ***"(…) And also, how many agreements we managed to close between the large companies looking for innovation and start-ups having innovations. Those are indicators for us."*** Regarding general success metrics, the interviewed hybrid accelerators measure the absolute number of applications and participants, active participation and fulfillment of milestones during the program, and collect feedback from participating start-ups and accelerator partners, while also internally assessing the program.

Pauwels et al. (2016) found that accelerator types exist, which exhibit characteristics of two different accelerator types. Our findings are in line with this. Moschner et al. (2019) identified a ***corporate hybrid accelerator***, but this corporate model includes both external start-ups and internal innovation projects from corporate employees in the same program, and thus does not fit to our findings. Moschner et al. (2019) also revealed a ***consortium accelerator*** type. Here, an external accelerator provider offers its services to several corporates (e.g. Startup Autobahn). This definition does not fit to our findings neither, since our cases also have public program sponsors. In addition, our cases pursue distinct strategic goals compared to the ***consortium accelerator*** type described by Moschner et al. (2019). For this reason, the ***hybrid accelerator*** type that we found extends existing literature, while taking into account either private or publicly initiated programs, which are additionally funded and supported by multiple corporates, and hence exhibit a hybrid funding structure consisting of private and public sponsors. In general, Cohen et al. (2019) mention that accelerators often have multiple sponsors. Consequently, further hybrid accelerator types and models may exist. Concerning their success measurement, the success metrics used are similar to those mentioned by Leatherbee and Gonzalez-Uribe (2018a) and concern the socioeconomic development of a region, however providing interesting start-ups for their corporate funding sponsors is also of high relevance for them.

In this study, we revealed three different accelerator types and their design in the context of the process industries based on their funding structure: 1) ***Corporate accelerator***, 2) ***Public accelerator,*** and 3) ***Hybrid accelerator***, and thus answered RQ1. We provide a detailed overview of their similarities and differences in their design elements as visible in our condensed overview in Table 3. We found significant differences in their 1) funding structure and organizational governance, 2) strategic goals and focus, 3) key selection criteria, 4) program package, and 5) alumni relations. Furthermore, we answered RQ2 by identifying success factors and key challenges of each accelerator type as described above. Finally, we answered RQ3 by revealing qualitative and quantitative success metrics, which are used by the interviewed accelerators for their success measurement and present them above for each accelerator type. Table 5 contains these success metrics. Some success metrics are used among all accelerator types (e.g. absolute number of applications and participants, or feedback from start-ups and accelerator stakeholders). However, Bliemel et al. (2019) mention that most accelerators can be considered as "start-ups" themselves and constantly evolve further, and thus their function and objectives may change over time, which they like to measure in terms of success. This was also stated by accelerator manager Acc-03: ***"(…) we have changed a little bit our program. We have moved from an early stage program, which I understood to be more of a classic accelerator program, to a more partnership-based program, which of course has changed the KPIs. Therefore, it is a little bit difficult to compare success over time."***

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

5 Conclusion and implications

This study extends previous accelerator research on different accelerator types and their presence in the context of the process industries by applying a design lens approach while using the five design elements of Pauwels et al. (2016). Our results suggest that the organizational context (industry) of an accelerator influences its design resulting in different accelerator types as proposed by Shankar and Shepherd (2019). We found one accelerator type, namely the ***hybrid accelerator***, which has not been described with this particular design in literature, yet. We found two accelerator types, ***corporate*** and ***public accelerator*** that have already been described in literature. In fact, some design elements of both of these accelerator types in our study differ from other similar accelerator types described in literature. This also supports the previous finding that the organizational context (industry) matters for how an accelerator is designed. Except the three accelerator types, we could not find any other accelerator type from literature in our study. It may be assumed that corporate and publicly funded accelerator types are commonly used in various industries, especially different corporate accelerator types (Moschner et al., 2019; Pauwels et al., 2016; Prexel et al., 2019). However, their design can vary strongly according to their organizational context and the goals of the accelerator's key stakeholders, especially of those stakeholders who are funding and/or supporting the accelerator (Pauwels et al., 2016).

Finally, it seems that accelerators are a relatively novel phenomenon in process industries, since eight of ten interviewed accelerators were five years old or younger as indicated in Table 2 compared to the first appearance of accelerators in other industries in 2005 (Cohen et al., 2019).

5.1 Implications for theory and limitations of this study

In our study, we extended some of the five design elements and constructs of Pauwels et al. (2016) based on our literature review. In doing so, we improve the understanding of these design elements and their respective constructs. We highlight that the organization, which is responsible for running the program may not belong to the funding sponsor of the accelerator. Therefore, further research could investigate potential conflicts of interest between the strategic goals of the funding sponsor and the organization, which runs the program and how to resolve them.

In total, we found three different accelerator types, which differ in satisfying distinct stakeholders' needs (respectively those of corporates, other private organizations and public authorities). The investigation of further success factors and key challenges for each specific accelerator type could be interesting to explore.

In addition, further research on qualitative and quantitative success metrics (such as KPIs) for measuring the achievement of the program's objectives for each accelerator type is necessary. The use of appropriate success metrics could guide the improvements of the accelerators and can help to attract suitable start-ups. The development and introduction of commonly used success metrics would also allow a comparison between distinct programs and different accelerator types.

This study is limited to its qualitative methodology. Therefore, the research questions are answered on the basis of expert interviews with accelerator managers, which may not provide the full range of information concerning the emergence of accelerators in the process industries. More accelerator managers could be interviewed that may provide further important insights to confirm our findings or to refine the accelerator types and their design elements. Further research may also reveal other accelerator types, since our data sample may not represent them. Specific regions/countries or different contexts (e.g. influence of policy, industry, density and economic conditions) may foster or require distinct accelerator types (Pauwels et al., 2016).

Besides, further research is necessary for the classification of each accelerator type into further sub-types in analogy to Prexel et al. (2019), which are used in the context of the process industries.

Another limitation of this study is that the start-ups' point of view was not considered. This complementary research may provide valuable insights how start-ups, which participated in an accelerator, perceive the usefulness of different design elements and constructs by listening to the "voice of the customer", since start-ups represent customers of the accelerators. This may help to adapt design elements and constructs to the expectations and needs of start-ups. In particular, start-ups could provide valuable feedback concerning the design elements ***selection process***, ***program package*** and ***alumni relations***, while also indicating the obstacles and benefits of accelerator participation. In doing

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

so, accelerators could improve their internal processes and program offering to attract suitable start-ups, whereas start-ups could gain more benefits from accelerator participation. In this regard, qualitative as well as quantitative studies are promising for the investigation of the usefulness of different accelerator design elements and their respective constructs for start-ups in the context of the process industries (Cohen et al., 2019).

Finally, an interesting avenue for further research is to study the impact of distinct accelerator types on their start-ups, and to investigate the effectiveness of these types by comparing accelerated start-ups with a control group of non-accelerated start-ups to reveal the contribution of accelerators (Pauwels et al., 2016).

5.2 Implications for accelerator stakeholders and managers

Due to the increasing popularity of accelerators, many organizations such as universities, corporates, and regional development agencies have considered starting their own accelerator (Pauwels et al., 2016). In doing so, universities can promote student entrepreneurship, corporates can access new innovations and talent, whereas development agencies look for opportunities to foster regional development and employment (Pauwels et al., 2016). The results of this study help those, who fund, setup, manage, and operate accelerators in the process industries to design their program appropriately in order to attract, select, and fully exploit the economic potential of participating start-ups.

Our study provides different accelerator types and key design choices for accelerators' key stakeholders (funding sponsors and supporters) and managers when funding and setting-up an accelerator. The identified accelerator types and their design elements can be used to well-position the accelerator in the overall entrepreneurial ecosystem. Moreover, they can be used to appropriately align the program to the context of the process industries in order to attract suitable start-ups that are in accordance with the accelerator's goals. Policy makers can also assess their role in supporting different accelerator types, which rather have medium- and long-term goals such as regional development and employment (e.g. in supporting and funding the set-up of public and hybrid accelerator types).

For start-ups, our research indicates accelerator types and their design at which they should look at before selecting and applying to an accelerator. Advisors of (especially early-stage) start-ups (e.g. government support agencies, or university and technology transfer offices) should consider the different accelerator types and their distinct design, while consulting start-ups on which accelerators they should apply for and that best meet their needs. For instance, our study shows that corporate accelerators rather focus on later stage start-ups, while public and hybrid accelerators are generally open to start-ups in all development stages.

Our study shows that starting an accelerator requires clear strategic goals and focus, which must be precisely defined and communicated among the accelerator's stakeholders and partners. Accelerators must decide whether they take a horizontal, including a variety of industries, or vertical approach by focusing on a specific industry (Kohler, 2016). Besides, accelerators must also consider setting up a physical or virtual accelerator (Kohler, 2016), or combining elements of both approaches in the program. In our study, almost all cases required physical participation to facilitate contacts and stimulate peer learning.

In general, accelerators increasingly face difficulties to fill their program, since more and more programs are emerging (Kohler, 2016; Moschner et al., 2019). For this reason, accelerators must establish a strong network to scout and identify suitable start-ups (Kohler, 2016). Since it is becoming more difficult to attract high-quality teams, accelerators must provide tangible benefits for start-ups. Whereas all corporate accelerators provide funding to start-ups in our study, only one case of the interviewed public and one of the hybrid accelerators provide funding. However, in all cases, accelerator participation was free of charge and those cases, who provide funding did not take any equity in exchange, which represents a significant incentive for start-ups to apply.

Concerning the program package, accelerators must provide tailored and specific trainings according to the start-up's development stage, needs and industry background. In the context of the process industries, technical expertise and industry experience are very important. Therefore, a fit between the start-ups' domain needs and coaches'/mentors' domain experience is necessary (Goswami et al., 2018). Moreover, accelerators must not only provide business trainings including the development of a suitable

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

business model, but must also set a focus on technical trainings according to the start-ups needs.

Success stories and a strong network will result in higher numbers of applications from new start-ups. Thus, successful alumni start-ups of the program can leverage the accelerator's reputation. This improves the accelerator's visibility, network, and access to high-profile mentors and investors.

Moreover, accelerators must continuously assess their offer and services with carefully chosen success metrics (such as KPIs). Leatherbee and Gonzalez-Uribe (2018a) emphasize that selecting the right KPIs is important for measuring the accelerator's progress. By defining suitable success metrics, accelerator managers and their key stakeholders can track to which degree the accelerator's goals and strategy were achieved (Richter et al., 2017). In doing so, they can learn from successes and failures, and can implement organizational or program-related changes. Leatherbee and Gonzalez-Uribe (2018a) propose to carefully select appropriate KPIs, since their measurement requires time and resources, and having a large number of KPIs could rather be detrimental. Thus, accelerators should focus on some relevant KPIs (Gonzalez-Uribe, 2018a). Subsequently, these success metrics must be communicated to the accelerator's partners (Richter et al., 2017).

In the context of the process industries, start-ups which offer digital solutions may be particularly interesting for participation in an accelerator, since they require fewer financial resources and are less asset-intensive. They can help companies from the process industries to build new digital business models around their physical products or to improve R&D, energy efficiency and production processes in the short-term.

Acknowledgements

We would like to thank all interview partners for their time and valuable insights for this study.

References

Asano, M. and Kirchhoff, T. (2019): European Startup Accelerators in the Chemical Industry - White Paper.

Battistella, C., De Toni, A. F. and Pessot, E. (2017): Open accelerators for start-ups success: a case study, European Journal of Innovation Management, **20** (1), pp. 80-111.

Berger, M., Gehrke, B. and Rammer, C. (2019): Innovations-indikatoren Chemie 2019 – Schwerpunktthema: Chemie-Startups – Studie des Verbandes der Chemischen Industrie e. V.

Bliemel, M., Flores, R., De Klerk, S. and Miles, M. P. (2019): Accelerators as start-up infrastructure for entrepreneurial clusters, Entrepreneurship & Regional Development, **31** (1-2), pp. 133-149.

Cohen, S., Fehder, D. C., Hochberg, Y. V. and Murray, F. (2019): The design of startup accelerators, Research Policy, **48** (7), pp. 1781-1797.

Crişan, E. L., Salanţă I. I., Beleiu, I. N., Bordean, O. N. and Brunduchi, R. (2019): A systematic literature review on accelerators, Journal of Technology Transfer, https://doi.org/10.1007/s10961-019-09754-9.

Goswami, K., Mitchell, J. R. and Bhagavatula, S. (2018): Accelerator expertise: Understanding the intermediary role of accelerators in the development of the Bangalore entrepreneurial ecosystem, Strategic Entrepreneurship Journal, **12**, pp. 117-150.

Hallen, B., Cohen, S. L. and Bingham, C. B. (2020): Do Accelerators Work? If So, How?, Organization Science, **31** (2), pp. 378-414.

Hohmann, M. (2019): Umsatzstärkste Chemieunternehmen in Deutschland bis 2018 (Statista), available at https://de.statista.com/statistik/daten/studie/195126/umfrage/fuehrende-chemieunternehmen-in-deutschland-nach-umsatz/, accessed 01 October 2019.

Kanbach, D. K. and Stubner, S. (2016): Corporate accelerators as recent form of startup engagement: The what, the why, and the how, Journal of Applied Business Research, **32** (6), pp. 1761–1776.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

Kohler, T. (2016): Corporate accelerators: Building bridges between corporations and startups, Business Horizons, **59**, pp. 347–357.

Krüger, D. and Riemeier, T. (2014): Die Qualitative Inhaltsanalyse – Eine Methode Zur Auswertung von Interviews, in: Krüger, D., Parchmann, I. and Schecker, H. (ed.): Methoden in der naturwissenschaftsdidaktischen Forschung, Berlin, Springer Spektrum.

Lager, T. (2016): Series on Technology Management – Vol. 17: Managing Process Innovation – From Idea Generation to Implementation, London, Imperial College Press.

Lager, T. (2017): A conceptual analysis of conditions for innovation in the process industries and a guiding framework for industry collaboration and further research, International Journal of Technological Learning, Innovation and Development, **9** (3) , pp. 189-219.

Lager, T., Blanco, S. and Frishammar, J. (2013): Managing R&D and innovation in the process industries, R&D Management, **43** (3), pp. 189–195.

Leatherbee, M. and Gonzalez-Uribe, J. (2018a): Key performance indicators, in: Wright, M. and Drori, I. (ed.): Accelerators: Successful Venture Creation and Growth, Edward Elgar Publishing.

Leatherbee, M. and Gonzalez-Uribe, J. (2018b): Selection issues, in: Wright, M. and Drori, I. (ed.): Accelerators: Successful Venture Creation and Growth, Edward Elgar Publishing.

Malek, K., Maine, E. and McCarthy, I. P. (2014): A typology of clean technology commercialization accelerators, Journal of Engineering and Technology Management, **32**, pp. 26–39.

Mayring, P. (2016): Einführung in die Qualitative Sozialforschung (6th edition), Weinheim, Basel: Beltz Verlag.

Mayring, P. and Gläser-Zikuda, M. (2008): Die Praxis der Qualitativen Inhaltsanalyse (2nd edition), Weinheim, Basel: Beltz Verlag.

Moschner, S.-L., Fink, A. A., Kurpjuweit, S., Wagner, S. M. and Herstatt, C. (2019): Toward a better understanding of corporate accelerator models, Business Horizons, **62** (5), pp. 637–647.

Pauwels, C., Clarysee, B., Wright, M. and Van Hove, J. (2016): Understanding a new generation incubation model: The accelerator, Technovation, **50–51**, pp. 13–24.

Prexl, K.-M., Hubert M., Beck, S., Heiden, C. and Prügel, R. (2019): Identifying and analysing the drivers of heterogeneity among ecosystem builder accelerators, R&D Management, **49** (4), pp. 624–638.

Ramsenthaler, C. (2013): Was ist Qualitative Inhaltsanalyse?, in: Schnell, M. W., Schulz, C., Kolbe, H. and Dunger, C. (ed.): Der Patient am Lebensende - Eine Qualitative Inhaltsanalyse, Wiesbaden, Springer VS.

Richter, N., Jackson, P. and Schildhauer, T. (2018): Outsourcing creativity: An abductive study of open innovation using corporate accelerators, Creativity and Innovation Management, **27** (1), pp. 69–78.

Roberts, P. W. and Lall, S. A. (2019): Observing Acceleration - Uncovering the Effects of Accelerators on Impact-Oriented Entrepreneurs, Cham, Springer Nature Switzerland AG.

Shankar, R. K. and Shepherd, D. A. (2019): Accelerating strategic fit or venture emergence: Different paths adopted by corporate accelerators, Journal of Business Venturing, **34** (5), https://doi.org/10.1016/j.jbusvent.2018.06.004.

Stayton, J. and Mangematin, V. (2019): Seed accelerators and the speed of new venture creation, Journal of Technology Transfer, **44**, pp. 1163-1187.

Vandeweghe, L. and Fu, J.-Y. (2018): Business accelerator governance, in: Wright, M. and Drori, I. (ed.): Accelerators: Successful Venture Creation and Growth, Edward Elgar Publishing.

van Gils, M. J. G. M. and Rutjes, F. P. J. T. (2017): Accelerating chemical start-ups in ecosystems: the need for biotopes, European Journal of Innovation Management, **20** (1), pp. 135–152.

Wright, M. and Drori, I. (2018): Accelerators: Successful Venture Creation and Growth, Edward Elgar Publishing.

Y Combinator (2020): Y Combinator, available at https://www.ycombinator.com/, accessed 11 April 2020.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

Yin, B. and Luo, J. (2018): How do accelerators select startups? Shifting decision criteria across stages, IEEE Transactions on Engineering Management, 65 (4), pp. 574–589.

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119500068
DOI: 10.17879/60119499532

Appendix

Table A1 Questionnaire (own representation).

Design elements	Guiding questions
1. Strategic focus - *concerns the strategic choices of the accelerator regarding industry, sector and geographical focus.*[1]	■ Who is the sponsor of the program? ■ Who is responsible for running the program? ■ At which industry/sector focus the program? ■ Where/In which countries will the program be executed? ■ What are the advantages/disadvantages of the chosen accelerator form? ■ What are the objectives of the program?
2. Selection process - *regards to the choice of start-ups and how they are selected.*[1]	■ How does the selection process work? ■ Which conditions have the potential start-ups to fulfil? ■ Which criteria play a crucial role regarding the selection process?
3. Alumni relation - *describes the relationship between accelerator and start-ups after the program.*[1]	■ Is there an alumni network? ■ Is there a follow-up program for alumni?
4. Program package - *consists of all services the accelerator offers to participating start-ups.*[1]	■ How many hours are planned for the program? ■ Which resources and services are provided for the participating start-ups during the program?
5. Success measurement - *concerns the measurement of achieving the objectives of the accelerator.*[1]	■ How are success measurements carried out?

[1] Pauwels, C., Clarysee, B., Wright, M. and Van Hove, J. (2016): Understanding a new generation incubation model: The accelerator, Technovation, 50–51, pp. 13–24.

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

Research Paper

Magdalena Kohut*, Jens Leker, Stefanie Bröring*** and Nathalie Sick******

Start-ups as an Indicator of Early Market Convergence

Owing to ever shorter innovation cycles, it has become more and more challenging to predict approaching market convergence. This study aims to overcome this problem by providing a novel method for anticipating market convergence using start-up formation as an indicator. Life cycle analysis is employed in this article to examine the anticipation of the convergence process. The analysis is conducted on the field of probiotics in the nutraceutical and functional foods, cosmeceutical and nutricosmetic cross-industry sectors. The results of the analysis, which monitored start-up formation throughout the process, indicate that formation of start-up companies can be used to predict the transition from technology to market convergence. To this end, the present study also proposes a novel approach to identify start-up formation based on data from press releases.

1 Introduction

When two industries converge, the dominant industry logic is subject to significant changes. Established firms need to position themselves adequately in the market, acquire new required competences and increase their awareness of competitors from vastly distinct fields. In order to achieve this, firms must be able to observe the emergence of a new industry (Curran and Leker 2011).

Convergence, defined as 'the blurring of boundaries between formerly distinct industries' (Hacklin 2007) has been seen in several industrial sectors, starting with telecommunications and information technology and more recently between chemicals, food and beverages and pharmaceuticals (Bröring et al. 2006). The three industries of focus in this article - nutraceuticals and functional foods (NFF), cosmeceuticals and nutricosmetics - are convergent sectors developed on the intersection of pharmaceuticals and foods, pharmaceuticals and cosmetics, and foods and cosmetics respectively.

Convergence can be caused by new scientific findings, technological developments as well as changes in customer demand or even regulatory frameworks (Gambardella and Torrisi 1998). In this article the assumption of an idealised

* Institute of Business Administration at the Department of Chemistry and Pharmacy, University of Münster, Leonardo Campus 1, 48149 Münster, Germany, kohut@uni-muenster.de
** Institute of Business Administration at the Department of Chemistry and Pharmacy, University of Münster, Leonardo Campus 1, 48149 Münster, Germany, leker@uni-muenster.de
*** Institute for Food and Resource Economics, Chair for Technology and Innovation Management in Agribusiness, University of Bonn, Meckenheimer Allee 174, 53115 Bonn, Germany, s.broering@ilr.uni-bonn.de
**** School of Information, Systems, and Modelling, Faculty of Engineering and Information Technology, University of Technology Sydney, PO Box 123, Broadway, NSW 2007, Australia, nathalie.sick@uts.edu.au

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

convergence process driven by scientific developments is adopted. The convergence process leads to the launch of hybrid products into the market, which incorporate features of products from different industries. NFF, cosmeceuticals and nutricosmetics are examples of complementary convergence, where the hybrid product increases the utility of the old product in a joint use wherein the former products continue to exist separately (Curran and Leker 2011, Bröring and Leker 2007).

Early prediction of how markets will develop is an essential competitive advantage for firms (Borés et al. 2003). Literature on anticipation and evaluation of convergent processes has addressed the front end of the process in depth, i.e. science and technology convergence (Caviggioli 2016, Curran et al. 2010, Gambardella and Torrisi 1998). During these early stages of convergence scientific publications and patents are used to monitor and anticipate industry developments. Literature on assessment of the next step in the convergence process, i.e. market convergence, is still limited. Recent studies propose a Mergers & Acquisitions (M&A) transaction analysis, which examined the dynamics of market convergence of the biotechnology industry with adjacent market segments (Aaldering et al. 2019). The evaluation of developments on the level of market convergence in the emerging convergent industry and the old industrial segments is currently still primarily addressed by observing convergent product launches (Lee and Cho 2015, Lee et al. 2009). This instrument while useful for evaluation is not sufficient for anticipation of market convergence since companies already launching new products in the market are significantly ahead of the competition. Therefore, there remains a significant knowledge gap with respect to the transition from technology to market convergence, when firms secured patents but products of the convergent industry are not yet observable in the market. Hence, a tool to predict market developments at this stage of the process is desirable. This leads to the research objective to investigate how the gap between the technology and the market convergence indicators can be filled.

To enable a more comprehensive understanding of the transition from technology to market convergence, start-up formation is proposed as a new indicator. Start-ups are an ideal type of organisation to provide transfer of technology into the market since they offer proximity to research-intensive environments as well as organisational flexibility (Swamidass 2013). This approach builds on the previous work of Sick et al., where start-ups were introduced as an indicator in the context of technology life cycles (Sick et al. 2018). This study applies the concept of start-ups to the cross-industry sectors of NFF, cosmeceuticals and nutricosmetics with a focus on probiotics, building on the work of Bornkessel et al. (Bornkessel et al. 2016a).

This study contributes to the theory and practice in several ways. It expands the market forecasting literature on the convergence process where early information on new market developments is crucial. It also contributes to the understanding of the use of the life cycle concept in convergence by applying the life cycle methodology to the new indicator. Furthermore, this paper answers the call for research that bridges the gap at the academia-industry interface by showing that start-up companies are positioned at the intersection of the technology and market indicators of convergence. Established companies can learn from start-ups by considering the combination of their technology and market focus.

The remainder of this article is organised as follows: Section 2 presents theoretical background on indicators of convergence, the life cycle concept, start-ups and probiotics. Section 3 elaborates on the methodology used to obtain the relevant data based on databases of publications, patents and press releases. Section 4 provides discussion of the results, where the new indicator is positioned along the convergence process. Lastly, Section 6 concludes the work and suggests implications of the study and further research.

2 Theoretical Background and Research Questions

2.1 Measurement of Convergence

Convergence can be divided into converging scientific and technological fields, convergence of formerly distinct markets and finally converging industries, where new industry sub-segments emerge (Figure 1) (Curran and Leker 2011, Bröring and Leker 2007, Bröring et al. 2006). The convergence process can be measured through either qualitative or quantitative research methods using data ranging from primary sources, such as expert surveys or case studies, to secondary sources, such as publications, patents, product launches or mergers and acquisitions.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

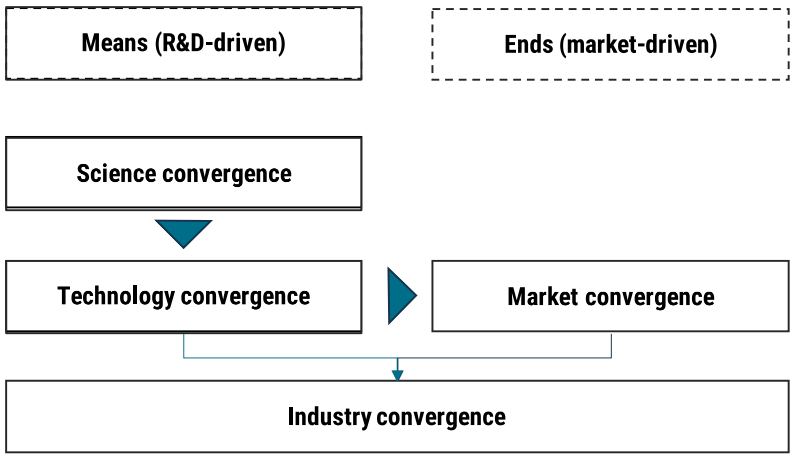

Figure 1 Stepwise convergence process (adapted from Curran and Leker 2011).

More specifically, convergence of scientific fields can be indicated by cross-industry scientific publications, technology convergence by cross-industry patents, market convergence by launches of cross-industry products and industry convergence by fusion of firms or industry segments (Sick et al. 2019, Curran et al. 2010).

Cross-industry scientific publications can be assessed by co-citations, co-authorship and co-word analysis in scientific publications (Rinia et al. 2002). Technology convergence patterns can be found in patent data through growing overlap of Standard Industry Classification (SIC) codes and through an increase in citations between different patent classes (Pennings and Puranam 2001). Lastly, newspaper articles, reports and press releases are considered to be a suitable data source to analyse developments of uncertain market environments in convergence and offer information on both new products during market convergence and firm collaboration patterns during industry convergence (Kim et al. 2015).

2.2 The Life Cycle Concept in Convergence

The convergence measurement methods have been recently expanded by application of the life cycle concept to measure the convergence process, previously used for technology life cycle analysis (Bornkessel et al. 2016a). The technology life cycle consists of phases such as fundamental research, applied research, and application. It has been shown that on a theoretical level the phases in the technology life cycle are parallel to the phases of industry convergence (Figure 2). Fundamental research corresponds to science convergence, applied research to technology convergence and application to market convergence. Regarding the measurement model, the phase indicators in the technology life cycle are respectively scientific publications, patents and new

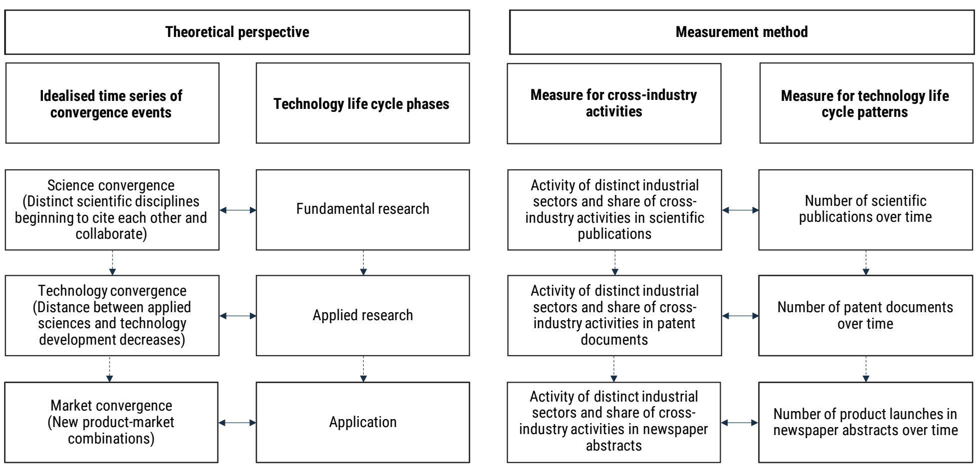

Figure 2 Alignment of the technology life cycle with the industry convergence process (adapted from Bornkessel et al. 2016a).

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

product launches reported in newspaper abstracts, parallel to the measures for cross-industry activities in convergence (Bornkessel et al. 2016a, Watts and Porter 1997).

2.3 The Role of Start-ups in the Technology Life Cycle and Start-up Formation in Convergence

The convergence life cycle comprises of life cycles of scientific publications, patents and newspaper abstracts reporting product launches, which represent science, technology and market convergence respectively (Figure 3) (Bornkessel et al. 2016a). This is based on the patenting activity within a technology life cycle, which describes the evolution process of a technology including phases such as emergence, consolidation, market penetration and maturity (Ernst 1997). In an idealised activity, the life cycle curve is expected to grow during the emergence phase, reach the first plateau in the consolidation phase, grow again during the market penetration phase and reach a final plateau in the maturity phase.

The investigation of convergence processes has so far focused on the examination of universities, research institutes and established firms. Over recent decades, a new type of organisation – start-ups – has however gained an important role in the structural transformation of R&D-intense industries, especially in innovation processes. European Start-up Network (ESN) defines a start-up as "an independent organisation, which (...) is aimed at creating, improving and expanding a scalable, innovative, technology-enabled product with high and rapid growth" (ESN, 2016). Start-ups often arise as spin-offs from universities or other research institutions but are also market-oriented (Zhang 2009). Literature suggests that start-ups form the needed bridge between academia and industry (Festel 2013). Therefore, it may be hypothesized that they are present in the technology and market convergence processes. Start-ups are an important player in technology development and are characterised by organisational flexibility as well as combinative capabilities to exploit their knowledge while exploring the potential of new technologies (Kogut and Zander 1992). This ability to drive technological trends and hence be the first to offer new technologies and products to the market (e.g. new food technologies) is vital in a fast-developing convergence scenario.

In the research on technology life cycles, reported start-up companies formation has recently been shown to act as an early indicator of the application phase in the context of the lithium-ion battery value chain (Figure 4) (Sick et al. 2018). Start-ups have hence been shown to fill the gap in the time lag between technology development and product launch in a technology life cycle.

Considering the parallels between the indicators of the phases of the technology life cycle and the phases of convergence, as depicted in the work of Bornkessel et al. (Bornkessel et al. 2016a), should start-ups be observed in convergence process, it is hypothesised that their formation will occur at the transition from technology to market convergence (Figure 5). It is built on the research objective: to investigate how the gap between the technology and the market convergence indicators can be filled, stated in the Introduction Chapter and the literature background presented in this chapter, to devise the following research questions:

Research question 1: Is start-up formation present when two or more sectors converge?
Research question 2: Can start-up formation act as an indicator of early market convergence?

2.4 Probiotics in nutraceuticals and functional foods, cosmeceuticals and nutricosmetics

To investigate the role of start-ups in convergence processes, the field of probiotics is chosen. Probiotics are a product family present in several cross-industry sectors such as NFF, cosmeceuticals and nutricosmetics. These cross-industry segments have emerged at the intersections of the three previously distant fields – the pharmaceutical industry, the fast-moving consumer goods (FMCG) industry and the cosmetics industry. They belong to the family of process industries, defined as 'industries in which the primary production processes are either continuous or occur on a batch of materials that is indistinguishable' (Institute of Industrial and Systems Engineers), which spans a range of industrial sectors including chemicals, petrochemicals, food and beverages, pharmaceuticals, mining and metals, mineral and materials, pulp and paper, and steel and utilities (Lager 2010). Probiotics are defined as 'a preparation of, or a product containing viable, defined microorganisms in sufficient numbers, which alter the microflora (by

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

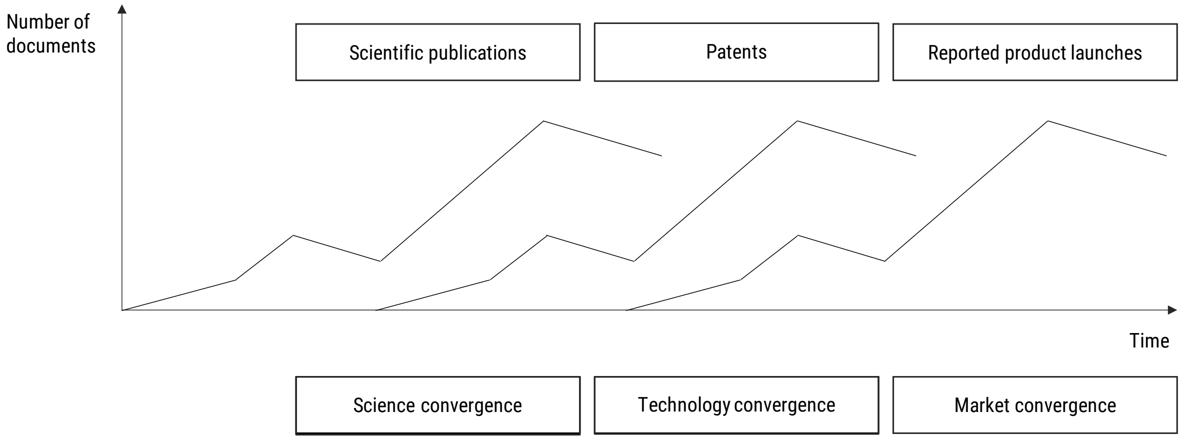

Figure 3 Life cycle indicators along the convergence process (adapted from Bornkessel et al. 2016a).

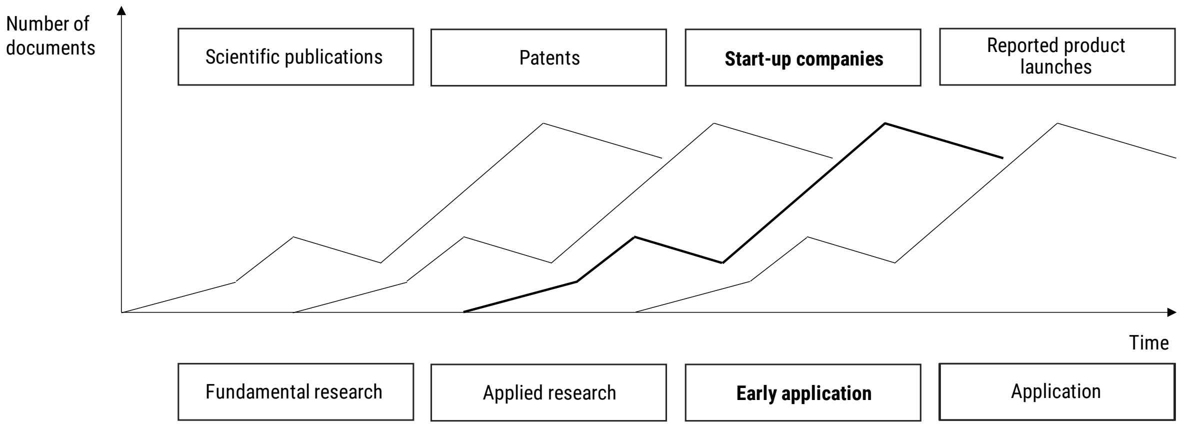

Figure 4 Technology life cycle indicators (adapted from Sick et al. 2018).

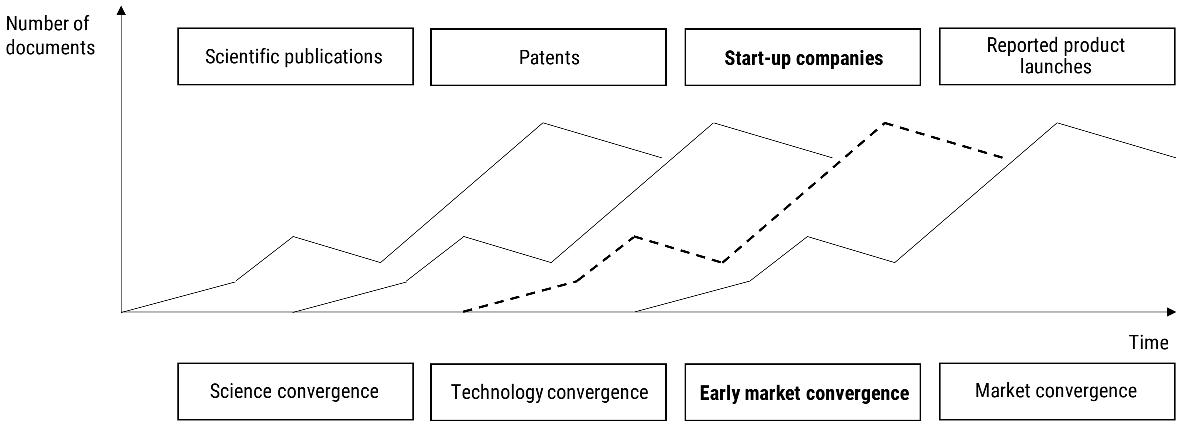

Figure 5 Start-up companies as a proposed indicator for early stage market convergence (own representation).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

implantation or colonization) in a compartment of the host and by that exert beneficial health effects in this host' (de Vrese and Schrezenmeir 2001). Probiotics act on a number of sites in the human body, including the oral cavity, the intestine, the vagina and the skin. Nutraceuticals are defined as 'products isolated from foods, sold in medicinal forms and demonstrated to have a physiological benefit, whereas functional foods are similar in appearance to conventional foods but demonstrated to have physiological benefit beyond the nutritional function' (Curran 2013). For example, dairy products containing probiotics have been among the most successful functional foods on the market (Saxelin et al. 2005). Secondly, cosmeceuticals are defined as cosmetics with drug-like functionalities on the skin (Newburger 2009). Lastly nutricosmetics, the least explored of the segments, are defined as 'foods or oral supplements consumed to produce an appearance benefit' (Anunciato and da Rocha Filho 2012).

Nutraceuticals and functional foods have been extensively studied in the literature in the context of converging industries. The research of Bröring and Curran belong to the most cited in the field. In their research Bröring et al. focus on closing of the competence gaps in firms entering an emerging convergent industry from previously distinct fields. Frequently cited works include the examination of how organisations with different R&D competences are able to seize opportunities for innovation emerging from convergence (Bröring et al. 2006); the study of technology and market-oriented absorptive capacity in the approaches through which firms engage in innovation in convergence (Bröring and Leker 2007); the investigation of the value-creation in new product development exploring projects characterised by different buyer-seller relationships (Bröring and Cloutier 2008); or the inquiry into innovation strategies that firms with different industry backgrounds employ to address new industry segments resulting from industry convergence (Bröring 2010). These studies show how during the convergence process firms identify their competences and competence gaps and how they subsequently position themselves in relation to other firms aiming to close these gaps. Hence, they provide additional relevant background for this work, in which an inquiry into a new type of organisation along the convergence process aims to help researchers and practitioners to understand the players involved in convergence and their positioning. On the other hand, in their work Curran et al. mainly focus on the anticipation and monitoring of convergence. Most popular works include investigations of how publicly available data such as scientific publications and patents can be used to monitor convergence in R&D-intense fields including NFF and cosmeceuticals (Curran et al. 2011, Curran et al. 2010). These works provide a relevant background to the practical measurement of convergence processes, especially their early stage. The convergent area of nutricosmetics remains less explored.

3 Methodology

3.1 Data Collection and Analysis

Quantitative, publicly available data is particularly useful in a highly time-sensitive innovation process (Curran et al. 2010). Therefore, this study uses secondary data sources such as scientific publications, patents and press releases. To identify the specifics of the transition from technology to market convergence in the field of probiotics, life cycle analyses were conducted. Owing to the time lag in publishing patent applications, the analysis included 2016 as the last full year available.

The industry convergence life cycle analysis was conducted based on the abovementioned indicators – scientific publications, patents, start-up companies and reported hybrid product launches (Table 1). Science convergence was captured via scientific publication analysis as carried out by Bornkessel et al. (2016a). The "Web of Science" database was used with the search term "probiotic*" over the 20-year period 01.01.1997 – 31.12.2016. This term was searched for in the "Topic" field, which included the fields of Title, Abstract, Author Keywords and Keywords Plus®. To identify technology convergence, patent analysis was conducted using the "Derwent World Patent Index" as in the work of Bornkessel et al. (2016a). The search term used was "CTB=(probiotic*) AND (PRD>=(19970101) AND PRD<=(20161231))", where CTB stands for a search in title, abstract and claims and PRD stands for Priority Date-Earliest. The records over the time period 01.01.1997 to 31.12.2016 were searched in all collections worldwide, focusing on the earliest priority year in order to identify the first time that an invention was registered. The patents were searched for in patent family groups, where a patent family is defined as all registrations referring to a single invention. This is to avoid counting one invention multiple times because of multiple registrations. Hybrid product launches were depicted using the "LexisNexis®" database of press releases in the manner

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

Table 1 Life cycle indicators and data sources (own representation).

Convergence life cycle stage	Indicator	Database
Science convergence	Cross-industry scientific publications	Web of Science
Technology convergence	Cross-industry patents	Derwent World Patent Index
Early stage market convergence	Start-up companies	Step 1: LexisNexis based on product launch Step 2: Foundation year searched online
Market convergence	Hybrid product launches	LexisNexis

of Bornkessel et al. (2016a) and Sick et al. (2018). The search string was "(new w/5 product*) OR (product w/5 launch) and HEADLINE(probiotic*)". The search was conducted over the 20-year period and restricted to All English Language News. Additionally, duplicates with high similarity level were grouped and non-business news excluded. The resulting documents were carefully reviewed to identify real product launches and exclude irrelevant announcements. For the identification of start-up companies, the companies responsible for the product launches from the "LexisNexis®" database were investigated and their foundation years identified through internet searches, a method developed specifically for this work. The existing methodology of Sick et al. which uses "Crunchbase" database to obtain information about start-ups was investigated, however it proved to be less comprehensive than "LexisNexis®". The companies founded prior to 1997 were classified as established companies. The companies founded over the period 1997-2016 were selected as the start-up companies.

During the data analysis, firstly descriptive information on the four convergence indicators was discussed. The life cycle fragments of the four indicators over the period 1997-2016 were then plotted graphically in order to establish the positions of the indicator curves. The indicator curves were compared to derive the order of events in the convergence process, especially to determine the position of the new indicator curve of start-up formation. The study only investigated the field of probiotics, so greater generalisability and reliability of the findings for other convergent sectors would need to be tested in future research.

4 Results

4.1 Descriptive Statistics

"Web of Science" yields 22,878 scientific publication results for the search term "probiotic*" over the 20-year period 01.01.1997 – 31.12.2016. Increasing publication activity over time is observed and the top five subject categories in which the articles are published are microbiology, food science technology, biotechnology applied microbiology, gastroenterology hepatology and nutrition dietetics. The variety of subject categories reflects the interdisciplinary nature of the probiotic research. The five most active countries with regard to the number of publications are the USA, Italy, China, India and Canada, representing 40% of all publications. Furthermore, the top five institutions with the highest number of publications are the University College Cork (Ireland), the Spanish National Research Council (Spain), the French National Institute for Agricultural Research (France), the University of Turku (Finland) as well as the National Scientific and Technical Research Council (Argentina).

Regarding patents, 40,486 documents in the database were identified, grouped into 16,269 INPADOC families. The two clear leader firms with the highest number of patents are Nestle, with 1,551 INPADOC patent families, and Med Johnson Nutrition with 1,234 patent families. Interestingly, despite having the highest number of patents in the field, these companies were not among the top firms in respect of the number of products launched identified through press releases. Considering five top regions where the patents were registered in order to access these geographical markets, China is at the forefront with 8,413 INPADOC

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

patent family registrations, followed by the World Intellectual Property Organization (2,715 patent family registrations), the USA (2,468), the European Patent Office (2,000) and the Australian Patent office (1,325).

Concerning start-up companies, 1,250 press releases were identified in LexisNexis®, out of which 102 were grouped as duplicates. After manually scanning 1,148 documents, formation of 86 companies was identified in the field of probiotics over the 20-year period. These new companies constitute 32% of all companies launching probiotics over the specified time. The exact market share was not investigated in this study. The identification of start-ups along the convergence process hence allows for a positive answer to the first research question.

Finding 1: When two or more sectors converge, start-up formation is present.

Regarding product launches, 845 new products were identified. 328 of all products come from companies formed between 1997-2016, constituting 39% of all launched products. Although the LexisNexis® database may not have information on all product launches, since it is the main database used to identify product launches in previous literature that this study builds on, it provides an adequate point of comparison. The five companies with the highest number of products launched were: Lifeway Foods, USA (34), Red Mango, USA (28), NextFoods, Netherlands (27), Ganeden Biotech, USA (27) and Danone, France (26), three of which were founded in the 20-year time window 1997-2016. Additionally, Ganeden's probiotic bacterial strains are used as a basis for products of many other companies. The example of Ganeden Biotech illustrates well the possibility of developing bacterial strains separately to their application. The firm offers probiotics-derived ingredients to over 200 companies worldwide for food, beverage and personal care products. Its bacterial strains are shelf-stable and viable throughout most manufacturing processes and can tolerate the low pH of stomach acid. It can be concluded that for start-ups from the biotechnology sector developing probiotic strains, business-to-business (B2B) offering may be more attractive with a lower entry threshold than the business-to-consumer (B2C) model.

4.2 Start-up Formation as a Novel Indicator of Convergence

To assess the suitability of start-up formation as an indicator of early market convergence, we analysed the cumulative growth curves of publications, patent families, start-up companies and product launches for the period 1997-2016 (Figure 6).

The first two indicator curves, namely the scientific publications and patents, both show a slow growth rate at the beginning followed by exponential increase in the later years. The life cycle of patents follows the life cycle of

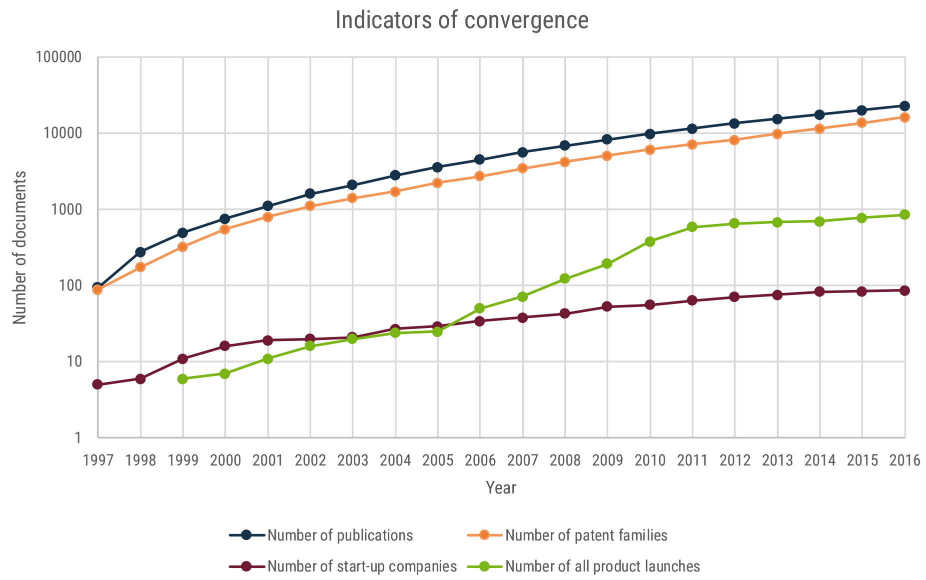

Figure 6 Cumulative growth curves of the different convergence indicators, 1997-2016 (own representation).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

scientific publications, with a time lag ranging from one year at the start of the 20-year interval to around three years in the second half of the specified time interval. Unlike in the battery value chain study of Sick et al. (2018), where no time lag is observed between scientific publications and patents because every technology is tailored to an application, in our study of probiotics the observed time lag indicates a greater distance between scientific research and product development. This is related to the complexity of the technology. Since the complexity of technology in the food sector is lower than in the battery sector, the absorptive capacity is also lower.

The start-up formation growth curve shows more complex behavior compared with the exponential growth observed in publications and patents. The curve could be divided into two areas of growth with a plateau following the first growth period.

The product launch curve can be divided into three stages - emergence (1997-2011), consolidation (2012-2013) and market penetration (2014-2016). A sharper than expected increase in product launches from 2006 could have been stimulated by the NHCR (European Commission 2006). The regulation, postulated in 2006, requires firms across the EU to comply with a set of unified rules on the use of nutrition and health claims. The regulation aimed at ensuring fair competition as well as protecting and promoting innovation. Furthermore, health-promoting properties of functional foods allow firms the opportunity to engage in product differentiation and to gain a strategic competitive advantage (Bröring et al. 2017).

To compare the behavior of the growth curves of start-up companies and product launches over the early convergence years, an enlarged picture of these two curves over the years 1997-2006 is shown in Figure 7.

The life cycle of product launches follows the life cycle of start-up companies with a time lag of two years during 1997-2001 and around one year during 2002-2004. From 2006 the product launch curve overtakes the start-up companies' curve probably because product launches were stimulated by the regulatory-push of NHCR. The presence of start-ups in the early years when product launches are still lagging behind allows for the conclusion that it is a suitable indicator of early market convergence.

Finding 2: Start-up formation can act as an indicator of early market convergence.

A time lag observed between the different indicator life cycles suggest that the different stages in the probiotics value chain are not tightly bound. This also agrees with the high proportion of B2B relationships observed via the press releases on Ganeden Biotech. When comparing all four

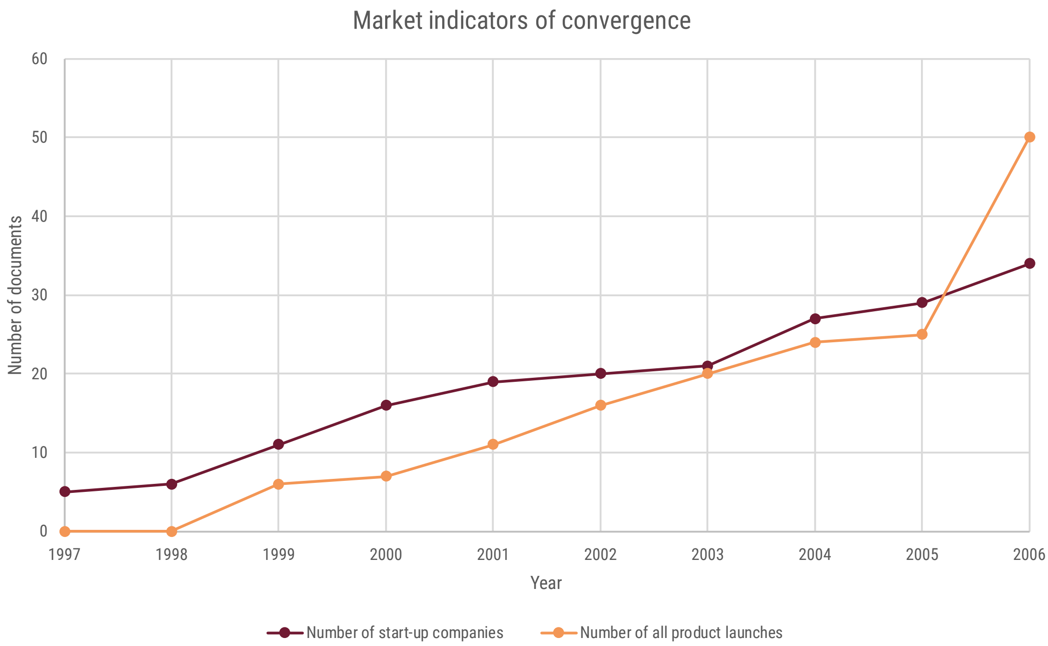

Figure 7 Comparison between cumulative growth curves of start-up formation and product launches, 1997-2006 (own representation).

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

indicators, the growth curves of publications and patents show exponential growth while the growth curves of start-up formation and product launches are more complex. The reason for this could lie in the different nature of these indicators. Start-up companies and product launches are market indicators limited by market demand. On the other hand, scientific publications and patents could behave differently, since they are research indicators and they are not driven by market demand limitations. Furthermore, the documents were studied in an aggregated form under the probiotic topic, where more specific key words or topics were not differentiated. In future work it could be useful to focus on specific keywords or topics and investigate how they reoccur over these years and in consecutive indicators. The picture observed does not fully correlate with the idealised theoretical model of the sigmoidal indicator curves following one another, and this puts the theoretical model into question. This is not surprising since the idealised time series of convergence is a theoretical model, whereas in practice market convergence can occur even without prior technology convergence. It provides an invitation for researchers to revisit the topic of life cycles and suggest a more fitting theoretical alternative, where the indicator curves could be more accurately positioned, for example, possibly underneath one another rather than horizontally shifted.

5 Discussion and Conclusions

When industries converge, previously vertically integrated value chains begin to disintegrate (Hacklin 2007). Cross-industry spill-overs increase, new entrant firms infringe on existing margins and existing firms have to diversify horizontally or specialise vertically. Further in the process vertical deconstruction and horizontal competition increase and a new ecosystem starts to emerge, where established firms have to position themselves in new roles. In order to position themselves adequately in the new industry, established firms have to be able to anticipate and monitor the convergence process. This study addresses convergence anticipation in the transition from technology to market convergence, where no suitable indicator has been available so far. Start-up companies are shown to be a valid indicator at this stage of convergence with one to two-year time lag observed in the growth curves between start-up formation and product launches over the first nine years of the relevant time period.

Established companies coming from the pharmaceutical industry lack the market competences required to successfully bring functional foods to the market (Bornkessel et al. 2016b). Meanwhile, companies stemming from the FMCG industry lack the research competences essential for development of functional foods. Establishing collaborations with partners to gain the relevant competences takes time and pushes incumbents away from the forefront of the emerging new industry. This can be seen for example in the investigation of patents, where it was shown that established companies may be dominant in patents but have few products on the market. Start-ups, which emerge directly at the interface of the two industries, can develop the competences required in both areas from the beginning of their activity.

5.1 Implication for Theory

Start-up formation is introduced as an indicator of early stage market convergence. The work deepens the understanding of the steps in the convergence process. The study extends the previous literature on the connection between the technology life cycle and the convergence process (Bornkessel et al. 2016a) and on the role of start-ups in the technology life cycle (Sick et al. 2018). Hence, this work fills in the existing research gap on the role of start-ups in the convergence process.

From an academic perspective, a more detailed method to analyse convergence processes is also offered. Researchers may include the search of start-up formation as an additional step when investigating convergence processes on top of the searches of scientific publications, patents and product launches as prescribed by previous literature. Moreover, using one database to obtain information on the company formation as well as the product launches extends the currently available methodology. Expanding the conceptual approaches available so far, products are directly linked to the companies from which they originate.

5.2 Implication for Practice

From a practical perspective, the additional indicator allows insight into the critical transition from technology convergence to market convergence, where product launches may not yet be observable. It allows identification of early transfer opportunities along the convergence process. Moreover, practitioners in the field of industry forecasting benefit from having the formation of start-

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

ups as an additional data source for analysis of industry life cycles. The life cycle perspective offers a dynamic view, allowing analysis of current developments and the formulation of predictions. Further managerial implications arise from the strategic importance of converging industries for innovation, enabling firms to identify these processes early and prepare for changes in demand, technology and competition. This allows firms to better analyse the competitive environment as well as to depict newly forming, cross-industry relationships. The results are also of interest to start-ups and other players trying to enter a new field. A further practical application may lie in the transferability of the methodology to other convergence sectors.

5.3 Limitations

The limitations of the study include incompleteness of the databases, in particular LexisNexis®. Not all companies announce their product launches via press releases; hence only a partial view of the market is reported. In future research one could cross-reference data on product launches with other databases such as Mintel or Euromonitor. Our research is also restricted to the given time period, the specified search term and only English language news, which potentially excludes valuable information from some non-English speaking countries. The study also assumes an idealised time series of the four indicators, whereas in practice, the life cycles will not fully take on the idealised shape. Furthermore, multiple industries would have to be analysed to validate the suitability of start-ups as convergence indicators.

5.4 Further Research

Avenues for further research could be derived by addressing some of the limitations of our study. A longer time period could be investigated, including a broader search term and all language news. Furthermore, one should analyse multiple industries to test if the time series of the four indicators is evident in all of them. Lastly, this paper focused on studying the phases of convergence ranging from science to market convergence. An important phase of the convergence process is the industry convergence phase, once technology and market become integrated (Sick et al. 2019). Cross-sector collaboration was previously identified to be the indicator of industry convergence. So far collaborations between established companies were studied in the literature. Since start-ups companies are shown to be an important organisational type in the convergence process in this study, in future research one could investigate collaborations between start-ups and incumbent companies.

References

Aaldering, L.J., Leker, J. and Song, C.H., (2019): Uncovering the dynamics of market convergence through M&A. Technological Forecasting and Social Change, **138**, pp. 95-114.

Anunciato, T.P. and da Rocha Filho, A.P., (2012): Carotenoids and polyphenols in nutricosmetics, nutraceuticals, and cosmeceuticals. Journal of Cosmetic Dermatology, **11**, pp. 51-54.

Borés, C., Saurina, C. and Torres, R. (2003): Technological convergence: a strategic perspective. Technovation, **23**(1), pp. 1-13.

Bornkessel, S., Bröring, S. and Omta, S.W.F., (2016a): Crossing industrial boundaries at the pharma-nutrition interface in probiotics: A life cycle perspective. PharmaNutrition, **4**(1), pp. 29-37.

Bornkessel, S., Bröring, S. and Omta, S.W.F., (2016b): Cross-industry collaborations in the convergence area of functional foods. International Food and Agribusiness Management Review, **19**(1030-2016-83125), pp. 75-98.

Bremmers, H.J. and van der Meulen, B., (2013): Opportunities, problems and pitfalls of nutrition and health claims. APSTRACT: Applied studies in Agribusiness and Commerce **7**(1033-2016-84224), pp. 97-101.

Bröring, S., (2010): Developing innovation strategies for convergence - is "open innovation" imperative?. International Journal of Technology Management, **49**(1), pp. 272.

Bröring, S. and Cloutier, L.M., (2008): Value-creation in new product development within converging value chains: An analysis in the functional foods and nutraceutical industry. British food journal, **110**(1), pp. 76-97.

Bröring, S., Cloutier, L.M. and Leker, J., (2006): The front end of innovation in an era of industry convergence: evidence from nutraceuticals and functional foods. R&D Management, **36**(5), pp. 487-498.

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

Bröring, S., Khedkar, S. and Ciliberti, S., (2017): Reviewing the Nutrition and Health Claims Regulation (EC) No. 1924/2006: What do we know about its challenges and potential impact on innovation? International Journal of Food Sciences and Nutrition, **68**(1), pp. 1-9.

Bröring, S. and Leker, J., (2007): Industry convergence and its implications for the front end of innovation: a problem of absorptive capacity. Creativity and innovation management, **16**(2), pp. 165-175.

Caviggioli, F., (2016): Technology fusion: Identification and analysis of the drivers of technology convergence using patent data. Technovation, **55**, pp. 22-32.

Curran, C.S., (2013): The anticipation of converging industries: A concept applied to Nutraceuticals and Functional Foods. Springer, Heidelberg.

Curran, C.S., Bröring, S. and Leker, J., (2010): Anticipating converging industries using publicly available data. Technological Forecasting and Social Change, **77**(3), pp. 385-395.

Curran, C.S. and Leker, J., (2011): Patent indicators for monitoring convergence–examples from NFF and ICT. Technological Forecasting and Social Change, **78**(2), pp. 256-273.

de Vrese, M. and Schrezenmeir, J., (2001): Probiotics, prebiotics, and synbiotics – approaching a definition. The American Journal of Clinical Nutrition, **73**(2), pp. 361-364.

Ernst, H., 1997. The use of patent data for technological forecasting: the diffusion of CNC-technology in the machine tool industry. Small business economics, **9**(4), pp. 361-381.

European Commission (EC), (2006): Regulation (EC) No. 1924/2006 of the European Parliament and of the Council of 20th December 2006 on nutrition and health claims made on foods. Oj. L404:9-25.

European Start-up Network (ESN), (2016): https://europeanstartupnetwork.eu/vision/, accessed on 16.04.2020

Festel, G., (2013): Academic spin-offs, corporate spin-outs and company internal start-ups as technology transfer approach. The Journal of Technology Transfer, **38**(4), pp. 454–470.

Gambardella, A. and Torrisi, S., (1998): Does technological convergence imply convergence in markets? Evidence from the electronics industry. Research policy, **27**(5), pp. 445-463.

Hacklin, F., (2007): Management of convergence in innovation: strategies and capabilities for value creation beyond blurring industry boundaries. Springer Science & Business Media.

Institute of Industrial and Systems Engineers (IISE), https://www.iise.org/Details.aspx?id=887, accessed on: 27.09.2019

Kim, N., Lee, H., Kim, W., Lee, H. and Suh, J.H., (2015): Dynamic patterns of industry convergence: Evidence from a large amount of unstructured data. Research Policy, **44**(9), pp. 1734-1748.

Kogut, B. and Zander, U., (1992): Knowledge of the firm, combinative capabilities, and the replication of technology. Organization science, **3**(3), pp. 383-397.

Lager, T., (2010): Managing process innovation: from idea generation to implementation. World Scientific Publishing Company.

Lee, M. and Cho, Y., (2015): Consumer perception of a new convergence product: A theoretical and empirical approach. Technological Forecasting and Social Change, **92**, pp. 312-321.

Lee, M., Lee, J. and Cho, Y., (2009): How a convergence product affects related markets: The case of the mobile phone. ETRI Journal, **31**(2), pp. 215-224.

Newburger, A.E., (2009): Cosmeceuticals: myths and misconceptions. Clinics in Dermatology, **27**(5), pp. 446-452.

Pennings, J.M. and Puranam, P., (2001): September. Market convergence and firm strategy: new directions for theory and research. In ECIS Conference, The Future of Innovation Studies, Eindhoven, Netherlands (Vol. 20, No. 23.09).

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

Rinia, E.J., Van Leeuwen, T.N., Bruins, E.E., Van Vuren, H.G. and Van Raan, A.F., (2002): Measuring knowledge transfer between fields of science. Scientometrics, **54**(3), pp. 347-362.

Saxelin, M., Tynkkynen, S., Mattila-Sandholm, T. and de Vos, W.M., (2005): Probiotic and other functional microbes: from markets to mechanisms. Current opinion in biotechnology, **16**(2), pp. 204-211.

Sick, N., Bröring, S. and Figgemeier, E., (2018): Start-ups as technology life cycle indicator for the early stage of application: An analysis of the battery value chain. Journal of cleaner production, **201**, pp. 325-333.

Sick, N., Preschitschek, N., Leker, J. and Bröring, S., (2019): A new framework to assess industry convergence in high technology environments. Technovation, **84**, pp. 48-58.

Swamidass, P.M., (2013): University startups as a commercialization alternative: lessons from three contrasting case studies. The Journal of Technology Transfer, **38**(6), pp. 788-808.

Watts, R.J. and Porter, A.L., (1997): Innovation forecasting. Technological forecasting and social change, **56**(1), pp. 25-47.

Zhang, J., (2009): The performance of university spin-offs: an exploratory analysis using venture capital data. The Journal of Technology Transfer, **34**(3), pp. 255-285.

Appendix

The growth curves of product launches from start-ups and all product launches were investigated separately and shown to have a similar shape (Figure A1). Both curves can be divided into three stages - emergence (1997-2011), consolidation (2012-2013) and market penetration (2014-2016). The information on product launches from start-ups can hence be used as a model for all product launches.

Furthermore, the percentage of products coming from start-ups was examined in relation to all products (Figure A2). Over the 20-year period there is an increase in products from start-ups as a percentage of all products. An unusually steep increase in probiotic products originating from start-ups, from 8% in 2006 to 30% in 2008, may have been caused by the NHCR. The NHCR may be particularly favourable to start-ups since there is no exclusivity on health claims, meaning a company can use a health claim paid for and approved by another company (Bremmers and van der Meulen 2013). Furthermore, to comply with the NHCR, some recipe formulations may have needed redesigning to remove ingredients without a valid health claim. This could be advantageous to start-ups, which enter the market fresh without the need to rethink their products.

JOURNAL OF
BUSINESS CHEMISTRY

Vol.17, Iss.3, October 2020
URN: urn:nbn:de:hbz:6-60119498897
DOI: 10.17879/60119498365

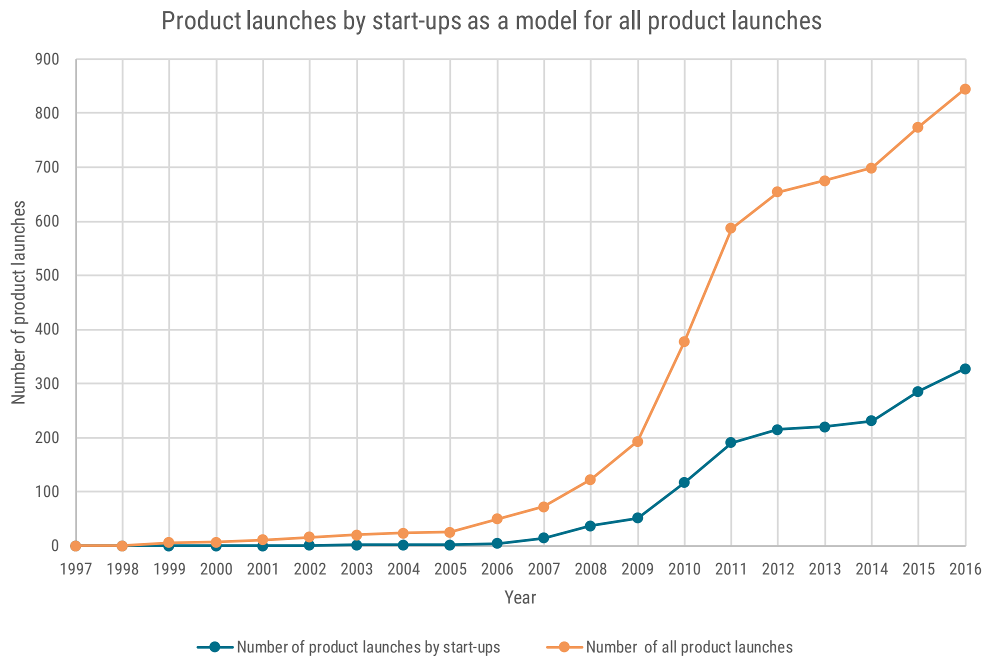

Figure A1 Comparison of product launches from start-ups and all product launches, 1997-2016 (own representation).

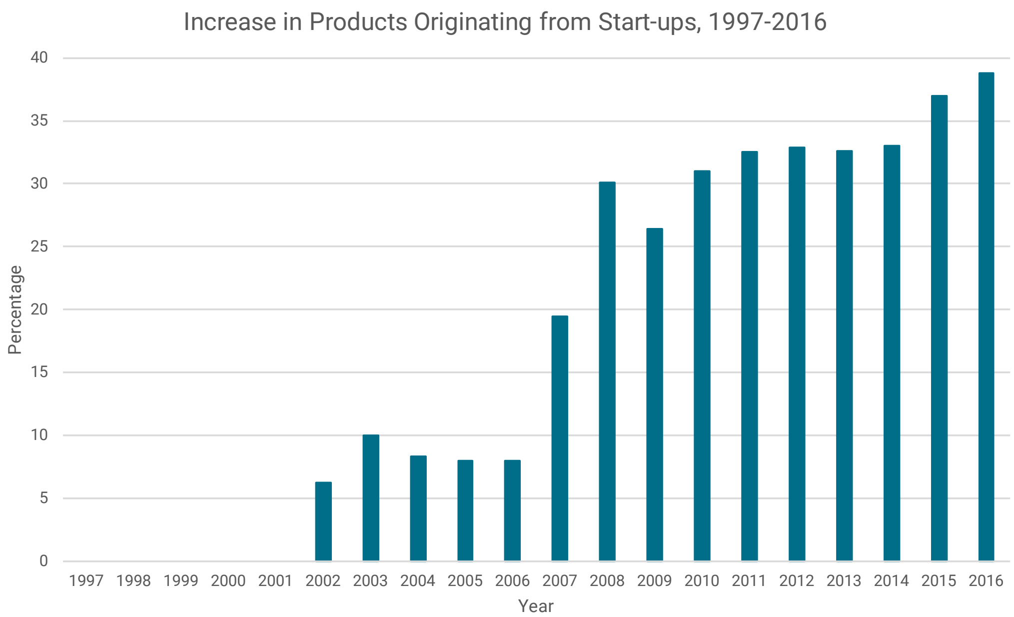

Figure A2 Product launches from start-ups as a percentage of all product launches, 1997-2016.

JOURNAL OF
BUSINESS CHEMISTRY

ISSN 1613-9623