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Research Paper

Exploring sustainability integration and expected outcomes of a digitalized product innovation work process for non-assembled products

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Sustainability and digitalization are currently strategic priorities for manufacturing companies to be globally competitive, and one option is to incorporate these aspects in a company product innovation work process; the topical area for this study. An exploratory inquiry has been conducted with nineteen global manufacturing companies in six sectors of the process industries, including the chemical industries. The findings indicate that the case-companies already have come far on the road in institutionalizing sustainability aspects in raw material selection, process technology development and product design. However, the study discloses a need for a more in-depth understanding how best practices and tools in a more systematic approach can make sustainability an integral part of the work process. The case-companies have not yet come far on their journeys with respect to digitalization of their product innovation work process, but particularly stress the importance of digitalization of customer and product information.

1 Introduction

For all manufacturing industries, and in particular companies in the process industries being suppliers of commodities, functional products, or both, sustainability and digitalization are currently top strategic priorities to continue to be a globally competitive and sustainable organization (Chen et al., 2020; Neef et al., 2018; Shang and Zhang, 2022; Ukko et al., 2019). Sustainability is of importance and of growing urgency to companies (Kaplinsky and Morris, 2018), and environmental innovations give opportunities to respond to concerns over the depletion of natural resources, and the use of raw materials with negative environmental impacts (Yu et al., 2016). Moreover, Industry 4.0 offers the potential for increased automation and flexibility in production, thus digitalization is driving new process innovations (Blackburn et al., 2017; Iansiti and Lakhani, 2014). The opportunities create a need for process innovation processes to consider the integration between individual equipment, connected smart devices, dynamic software systems, smart logistics systems and suppliers (Horváth and Szabó, 2019). However, the transition to digitalization and sustainability requires new strategies, work processes, organizational structures, operation modes, and capabilities (Chirumalla, 2021; Sehnem et al., 2021). Consequently, company product innovation must in the future in an inclusive operational mode both individually and conjointly consider product innovation in the perspective of both sustainability and digitalization (Lichtenthaler, 2021).

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The cluster of process industries spans the industrial sectors, Mining and Metals Industries, Mineral and Materials Industries, Chemicals and Petrochemical Industries, Pulp and Paper Industries, Food and Beverages Industries, Generic Pharmaceuticals, Steel and Utilities (Lager, 2017a). For a formal definition of process industries, see Appendix A. An important aspect on product innovation, related to the difference between companies in the process industries and in other manufacturing industries, is that products delivered from them are non-assembled products principally serving business-to-business (B2B) customers (Frishammar et al., 2012). Not only are they often intermediate actors in long industrial supply/value chains, but their product innovation is also strongly intertwined with process technology development and raw material characteristics (Lager and Blanco, 2010a); both aspects may influence company advancement and inclusion of both sustainability and digitalization. Since product innovation and renovation is a strong strategic company concern (Rothwell and Gardiner, 1985), such activities are usually administered as a formal work process (Melan, 1992), often in a format of a Stage-Gate decision model (Cooper and Sommer, 2016), preferably within a framework of business process management (Jeston and Nelis, 2018). Such a continually improved and customized work process adapted to company operational and product-market conditions, driving development and delivery of new or improved products on the market, therefore constitutes an important intangible asset and a dynamic capability (Teece, 2009). In particular, it impacts the way a company design products and production system such as product innovation work process e.g. (Hallstedt et al., 2013).

Current insights identify the important role that pilot, and demonstration plants can play in creation of sustainable production technologies (Hellsmark et al., 2016), which underscores the necessity for an early integration of raw material properties and production technologies in innovation. Pujari et al. (2004) thus conclude that environmental activities should be incorporated in the front end of a work process and include an analysis of the lifecycle impacts of products and production. In sum, from initial selection and use of environmentally acceptable raw materials and ingredients, use of sustainable energy efficient (fossil free) production technologies, and ending up with recyclable products and packaging, companies in the process industries can play an important role in circular economy founded upon a holistic view on the total product innovation work process (Lager and Simms, 2023).

Smart manufacturing forms a key component of Industry 4.0, but such considerations are still rarely linked to product development and are not yet captured in product innovation work processes. Yet, within the process industries the interlinkages between raw materials, production processes and the final product necessitates a consideration of digitization in the design of an improved product innovation work process. Moreover, and during recent years, there has been growing interest to integrate the two mega trends of sustainability and digitalization to exploit the potential interdependencies or cross-fertilization effects (e.g., (Aksin-Sivrikaya and Bahattacharya, 2017; Chen et al., 2020), and some researchers have already begun to discuss concepts like “digitainability” (Lichtenthaler, 2021) or “smart circular economy” (Kristoffersen et al., 2020).

Hence, there is a need to further the understanding on how digitalization and sustainability could individually and jointly provide competitive advantage in industrial companies, and in the design of a product innovation work process. Moreover, not only is research on the product innovation work process for non-assembled products scarce (Lager and Bruch, 2021), but how sustainability and digitalization perspectives could be more integrated in company work process design is not yet well-addressed and understood. This study is aiming to close this gap, and in an exploratory survey mode of inquiry to informants in nineteen global manufacturing companies in six sectors of the process industries, to develop a preliminary framework for the inclusion and integration of sustainability and industrialization in an enhanced work process for non-assembled products.

This exploratory study is one out of several “key research areas” within a broader research initiative and project, focusing on innovation work processes for non-assembled products in the process industries (Lager and Simms, 2023). The general research question for the total research project is: What are the main building blocks, incorporated concepts, and related constructs of a generic “structural process model” intended to serve as a guiding template for company design or reconfiguration of a formal innovation work process for the development of non-assembled products? Following this general research question, the study addresses the following research questions:

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RQ1. *How far have companies in the process industries come with regards to securing sustainability considerations in their product innovation work processes for non-assembled products?*

RQ2. *How far have companies in the process industries come in digitalization of their product innovation work processes for non-assembled products?*

The article is organized as follows: First, and in a frame of refence the process industries are presented, a generic model for the innovation work process is introduced and sustainability and digitalization related to work process design are reviewed. The research design, selection of case-companies and the deployment of the research instrument are then presented. Afterwards, the empirical findings are presented, and in the discussion a preliminary agenda for further research is proposed. Finally, research limitations and management implications are given together with conclusions.

2 Frame of reference

There are a number of potential strategic and operational activities to pursue in order to institutionalize the areas of sustainability and digitalization in corporate life, and one avenue to follow is to integrate both perspectives in the company product innovation work process.

2.1 Introducing the "family" of process industries and its product innovation intricacies

There are a number of manufacturing characteristics related to the process-industrial material transformation system from incoming raw materials to finished products, that define the process-industrial production and operational environment (Lager, 2017a), see Figure 1.

In a Resource Based View (Barney et al., 2001), the asset-intensive production process and the reliance on raw material from suppliers or from captive supplies differentiate the process industries from other manufacturing industries. In some sectors, company start-up and development have relied on the availability of company-owned raw materials or the access to well-secured raw material resources (Lager and Blanco, 2010b). Furthermore, the specification of incoming materials determine the selection of the design of the production system but generally influence product quality as well (Samuelsson et al., 2016). Such idiosyncrasies have important consequences with regard both to sustainability and digitalization in the process industries.

Being producers of commodities, functional products or both, successful product innovation depends on an understanding of the chain-like structures of companies in the process industries (Tottie and Lager, 1995), and a company position within such complex supply/value chains will critically influence product life cycle assessment. Furthermore, whilst product innovation in assembly-based

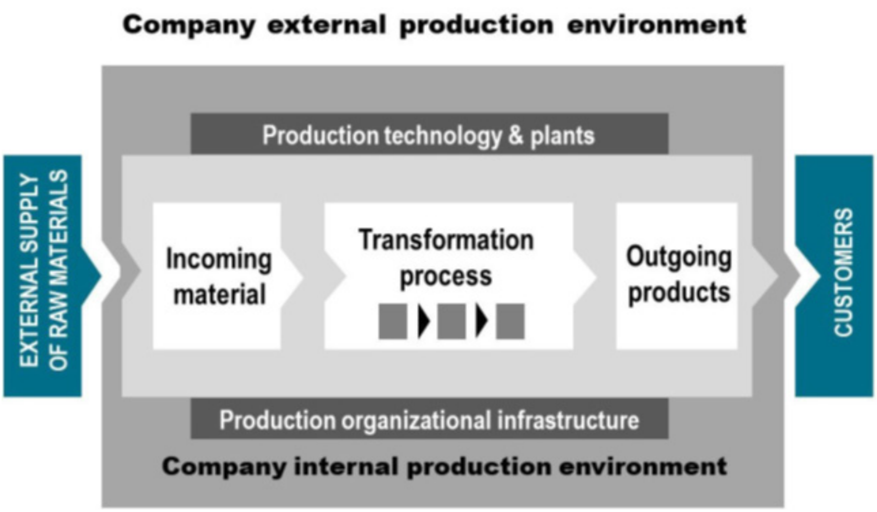

Figure 1 A simplified structural model of the production system in the process industries (Lager, 2019; Lager et al., 2017).

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industries is transferred from the R&D organization to the manufacturing organization when the product design is ready after prototyping (Lakemond et al., 2013), innovation of non-assembled products in the process industries focuses on early experimental work in laboratories or pilot plants (Frishammar et al., 2014). Moreover, an interdependency between product and process innovation is often necessary for successful product innovation (Lager, 2002b) in many process-industrial sectors, and Reichstein and Salter (2006) argued that they should be regarded as "brothers" rather than "distant cousins". A fact that also will influence sustainability perspective integration in the different phases of the product innovation work process.

2.2 Formal work processes and a generic "structural process model" for the development of non-assembled products - a point of departure

A formal structured and delineated explanation of how work should be accomplished, clarifying ownership and process users, process input and output, decision structures and checklists, is usually denominated a "formal work process" (Andersen et al., 2008; Lager et al., 2010; Melan, 1992). Such formal work processes allow new employees to familiarize with company best practices and enable seasoned practitioners to develop and accumulate new knowledge for enhanced work process execution. However, such formal processes are rarely designed to meet future company needs, because they have gradually emerged over longer periods with regards to more circumstantial operational challenges. Cooper and Kleinschmidt (1986) early depicted a product innovation work process as a number of Stages separated by Gates as decision points, from idea to product launch; the Stage-Gate product innovation process. Further research by Cooper (1994b) and other scholars (Bower and Keogh, 1996), suggest that such work processes should be more flexible and adaptable to different project characteristics (Cooper and Sommer, 2016).

The Stage-Gate process can be regarded as a "de-facto decision model" for product development work processes, forming "a blueprint and conceptual map to move from idea to launch" (Cooper, 2008: p. 214). Even if Cooper and Edgett (2012) have demonstrated that an efficient Stage-Gate process drives business performance, the model has been criticized for lack of iterative loops. In spite of doubts raised by Eisenhardt and Tabrizi (1995) with regards to the model's inflexibility (Unger and Eppinger, 2009), a visual shared model of the product innovation work process must be admitted to be a success factor in product development (Cooper, 1994a; Cooper, 2012; Cooper and Kleinschmidt, 1993; Lee-Hansen and Ahmed-Kristensen, 2011; Unger and Eppinger, 2009).

In a previous part of this research initiative, a theoretical model has been developed and empirically tested (Lager and Simms, 2023), as a five-stage generic "structural process model" of the innovation work process for non-assembled products (see Figure 2). The model incorporates the three main building blocks, Pre-product development, Product development, and Post-product development, anteceded by a Contextualization phase and supplemented by a Post launch follow-up phase. From early concept development during pre-product development (Lager et al., 2023) to industrialization in post-product innovation, the integration of product innovation and process innovation must be executed in a rather iterative fashion. The product development phase contains the activities of "test marketing" and "process testing" when advanced process test-work also give samples for test marketing with customers. In consequence, the further development of a product concept into a final product design is thus actually the undertaking of a further development of an associated process concept into a final process design and production set-up.

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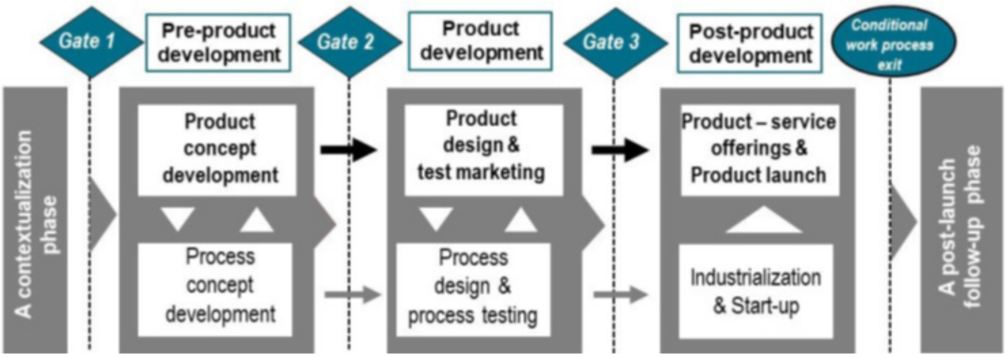

Figure 2 A generic "structural process model" for company design of a product innovation work process for the development of non-assembled products, adopted from Lager and Simms (2023)

2.3 Sustainability and digitalization in the perspective of process-industrial product innovation and work process design

2.3.1 Sustainability perspectives

Cheng and Shiu (2012) classified innovations as organizational, product, process and within the process industries the latter two are interconnected and provide a possibility for sustainability improvements. Environmental innovations, incorporate a variety of innovation types throughout the innovation's lifecycle (De Marchi, 2012; Kemp, 2010), and innovations are of a significant importance in a process industry context. Process industries can play a crucial role in a 'cradle-to-cradle' approach to innovation founded upon effective use of raw materials, sustainable production processes, and a reduced consumption of fossil fuels (e.g. (Eppinger, 2011)). With respect to manufacturing, approximately thirty percent of global energy usage and CO_2 emissions are attributed to manufacturing industries (International Energy Agency, 2007), of which the process industries constitute a considerable part.

In a study of key elements for implementing a strategic sustainability perspective in the product innovation process in a large manufacturing company, Hallstedt et al. (2013), concluded that: "currently there is a very strong focus on technical aspects and business opportunities of product concepts being explored, but very little consideration of the sustainability implications of these concepts". Moreover, a more proactive approach from purchasing is desired with regards to materials for new products, and their stronger involvement in the product innovation work process. Brockhaus et al. (2019) conclude that the issue of how companies effectively make sustainability considerations an integral part of their new product development process (NPD) still remains elusive. In order to avoid the fallacy of "trickle-down" product sustainability, they advocate that true codification of sustainability in NPD goes far beyond simply adding auxiliary sustainability goals for products and institutionalizing product sustainability as a NPD target equal to "traditional" targets. Nevertheless, they fail to deliver more substantial guidelines how to further administrate such a process. In a study of German consumer goods manufacturers, Petersen (2021) observe that human factors like competences and attitudes have a decisive impact on product innovation, when sustainability considerations are to be integrated as an extra layer of product requirements, and hard-to-make decisions on tradeoffs. In sum, and in spite of the very large number of publications related to the development of sustainable products (Thomé et al., 2016), there are still a surprisingly few publications related to HOW sustainable perspectives could be integrated into formal product innovation work processes in general, and for non-assembled products in particular.

2.3.2 Digitalization perspectives

Industry 4.0 incorporates technologies that enable automated and digital manufacturing and can furthermore include digitization of the company's supply chain (Oesterreich and Teuteberg, 2016). Increased use of internet and cloud technologies, sensors, and machine learning in a manufacturing environment (Sung, 2018), can facilitate and open up new avenues for production in extended

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communication in-between objects, machine learning and autonomous robots (Valenduc and Vendramin, 2016). Smart Manufacturing, which is one component of Industry 4.0, consists of integrated manufacturing systems that are able to meet the demands of the plant itself, supply networks, and customer needs in real time (Kusiak, 2018).

Several researchers describe how advanced digital technologies can play a role in product- and process innovation in the process industries. In the process industries, Qian et al. (2017) examined digitalization for realizing four goals in firms' production and operation: agility, high efficiency, environmental sustainability, and safety. Through the continuous adjustment and optimization of the processes online, digital technologies aim to improve processes' flexibility and reliability, maximize the yield, and improve the product quality and maintenance practices (Branca et al., 2020). Herzog et al. (2017) emphasized that smart sensor technology, combined with advanced digital models, as well production planning and control systems provides quality improvement and production cost reduction together with process flexibility along the entire production value chain. Porter and Heppelmann (2015) described that a series of existing digital technologies may facilitate disassembly as well as the taking back and reuse of structural steel components, thereby improving resource efficiency and opening up new business paradigms. Hakanen and Rajala (2018) found that IoT-enabled material intelligence with a digital identity can effectively support trace-and-track items with detailed properties information, enabling a number of services using AI that facilitate the product usage in cross-organizational collaboration. Moreover, Chirumalla (2021) investigated how digitalization can support process innovation work processes from dynamic capabilities perspective and proposed sensing, seizing, and reconfiguring dynamic capabilities for digitally-enabled process innovation. The study found four key enablers for digitally-enabled process innovation, including infrastructure and methodological definition, preparation for predictive and analytical readiness, proactive management practices, and plan for a digital matureness for each function and department.

Further, several researchers presented insights on the impact of digitalization for innovation process in general. Marion and Fixson (2021) examined the transformation of the innovation process by using digital tools and found that digitalization not only affect output and process efficiency, but they also lead to rearrangement of the entire innovation processes, enable new configurations of people, teams, and firms. Further, innovation processes are gradually being compressed with the use of digital technologies, anticipating, and enhancing the phases in which customer feedback is gathered and employed (Agostini et al., 2020). Additionally, Aaldering & Song (2021) indicated that not all process industries can be regarded as laggards in terms of incorporating digital capabilities. "Biotechnology", "Pharmaceutical", "Food and Beverage", "Energy" and "Oil and Gas" demonstrated a higher IT-affinity, thus presenting themselves as digital leaders within the process industries. They also confirmed that each segment of the process industries has adopted a unique pathway towards unlocking digital transformation opportunities.

Unlike in discrete manufacturing industries, companies in process industries generally contain multiple mutually coupled processes in production systems, making digitalization difficult to realize (Qian et al., 2017). Gao et al. (2019) identified challenges facing firms in the metals and mining industry, including the inability to change, goal ambiguity, poor applicability of technologies to current processes, and external constraints. Therefore, adopting digitalization remains a concern for many firms in process industries, and the potential of many data sources remain unexplored by firms, particularly those related to developing new processes (Hakanen and Rajala, 2018). Yuan, Qin, and Zhao (2017) examined the oil and petrochemical industry and found that smart manufacturing should combine information, technology, and human ingenuity to bring about a rapid revolution in the development and application of manufacturing intelligence as well as improve agility, flexibility, productivity, and quality.

2.3.3 Perspectives on sustainability integration and digitalization

A recent international survey revealed that 96% of 765 decision makers in 12 industrial segments acknowledge that digitalization is essential for achieving sustainability objectives and increase their investments in advanced digital technologies (IntelliSurvey, 2021). Hence, one can observe that many industrial companies as well as technology providers such as ABB, Ericsson, and Siemens are defining sustainability strategies and targets to reduce annual CO_2 emissions in their overall operations. However,

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Chen et al. (2020) found that digitalization in manufacturing contributes positively to environmental sustainability by increasing resource and information efficiency. They, however, stressed that applying Industry 4.0 technologies throughout the product lifecycle also cause negative environmental burden due to increased resource and energy use, as well as waste and emissions from manufacturing, use, and disposal of the hardware.

2.3.4 Methodologies and tools for sustainability integration and digitalization in product innovation

Since the use of methodologies and tools have demonstrated improved company performance (Thomke, 2006; Nijssen and Lieshout, 1995), the use of methodologies for product innovation is one avenue to follow (Nijssen and Frambach, 2000; Lager, 2005). However, it is important not only to consider methodology selection and company organizational solutions for making them sustainable (Day, 1993), but furthermore, to secure that they are able to address critical sustainability needs in the future (Hallencreutz et al., 2020; Deleryd and Fundin, 2020). In a study of methodology selection for sustainable product development (SPD), Buchert et al. (2017) selected 29 methods for SPD, but in the plethora of methodologies related to sustainability assessment and product innovation, process industrial idiosyncrasies must be considered and how they can be employed as supporting instruments for the product innovation work process. One methodology that combine both digitalization of customer and product information with an integration of sustainability requirements in product design is Quality Function Deployment (Akao, 2003; Mizuno and Akao, 1994). As one of the most commonly used methodologies in product development Puglieri et al. (2020), reviewed 29 alternative QFD approaches for product ecodesign, with respect to the inclusiveness of environmental requirements and operational requirements. Because of the need for a more structured approach in the merging of general customer requirements on new or improved products with the emerging large number of sustainability related requirements a large number of hybrid QFD methodologies are surfacing (Ocampo et al., 2020). In the use of the well-proven QFD methodology for the development of non-assembled products (Lager, 2019), and in the development of a "House of Sustainability" (Rihar and Kusar, 2021), the further employment of the methodology for process-industrial applications could be of interest to explore.

3 Research design

In this discovery-oriented project, an abductive research approach was considered appropriate, since such an approach can lead to new insight about existing phenomena by examining them from a new perspective (Kovacs and Spens, 2005). Whilst inductive research primarily tries to generalize research findings to a larger population, an abductive research approach predominantly aims to understand new phenomenon (Alvesson and Sköldberg, 2009). One important characteristic of abduction is the process of iterating between theory and empirical evidence (often called "theory matching"), when data collection and analysis generally overlap (Dubois and Gadde, 2002). The problematization of the topical area in this study was not mainly driven by gaps in the literature but by a need for new knowledge in both practice and theory (MacCarty et al., 2013: p. 945). After an initial review of the general literature related to work processes and product innovation work processes in particular, the literature related to the key research areas of sustainability and digitalization were afterwards successively reviewed alongside with the empirical analysis – a procedure suggested by Dubois and Gadde (2002: p. 559).

Research results are sometimes presented in a wise that it is hard to figure out if the findings are prescriptive (normative) for what a company should aim at, or if they are only descriptive and just a snapshot of company "state-of-affairs" of a topical area; a problem well presented by Cobbenhagen et al. (1990):

On the one hand we find descriptive models which merely answers the question, why are we the way we are. The manager … "will in most cases merely take note of this announcement, and just think: So what? Normative ideas and models, on the other hand provide a direction towards which an organization must proceed in order to innovate successfully."

However, the descriptive element in innovation management, as an applied science, is likely to be of more importance than in basic research (Foellesdal et al., 1990). Even if some

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parts of the questionnaire in this study and in the total project contain questions of a more descriptive nature, the majority of questions are of a normative, problem-solving kind, inquiring about informants' advice on how to further improve the performance of a product innovation work process for non-assembled products.

3.1 Deployment of a in a survey mode of inquiry

The population of interest for this study is the process industries worldwide, and the selected study population comprised selected companies from the "family" of process industries, as defined in Appendix A; the level of analysis is the product innovation work process. In reference to Patton (1990), the use of a non-probability sampling strategy was selected in this study. Since, the credibility of such a purposeful sampling strategy is dependent on a clarification of criteria deployed in the selection process, the following guidelines were used in this study:

- Focusing on a subgroup of companies with similar contextual conditions within the manufacturing industries, only companies belonging to the "family" of process industries were selected. The sampling could in this respect be categorized as homogenous sampling (Henry, 1990).

- It was additionally also of interest to disclose any possible idiosyncrasies among different sectors of the process industries. In this perspective the company selection could also be categorized as heterogenous sampling (Henry, 1990); in search of diverse conditions within the total group.

In sum, the selection process could thus be described as "stratified purposeful strategy" (Patton, 1990). Palinkas et al. (2015) recommend selecting individuals or groups that are especially knowledgeable about or experienced with the phenomenon of interest and have the ability to communicate experiences and opinions in an articulate, expressive, and reflective manner. The final individual criteria for case-company selection was world-leading companies, located in different countries, and possessing process-industrial characteristics.

Thirty companies were invited through an e-mail with an attached presentation of the total research project. Of these companies, 20 agreed to participate in the study, and 19 ultimately provided responses. The companies belonged to the following sectors: Chemical Industries (five), Steel Industries (five), Forest Industries (five), Food & Drink Industries (two), Mineral Industries (one) and Packaging Industries (one). In the selection of case companies, the Chemical, Steel, and Forest Industry sectors were targeted to create three sub-groups to identify possible within and between sectoral (dis)similarities. The case-companies have registered offices in Sweden (four), Finland (two), Denmark (one), Germany (two), Switzerland (two), USA (one), Brazil (four), Chile (one) and Japan (two). To ensure the case-company firm desire for anonymity, each company's name, production data and country affiliation is not disclosed in our results. The companies are world-leading global corporations within their industry sectors, and many are major players in the marketplace. In the view of the supply/value chain, some companies are both upstream and downstream operators, and some cover the total supply/value chain from in-situ raw materials to end users. Only the two companies in the Food and Drink industries have mainly B2C customers, while others have primarily B2B customers.

3.2 Case-company informants and the deployment of the research instrument

In this study, the participating individual experts in the case-companies are called "informants", satisfying an early definition by Yin (1994: p. 84),

"*In some situations, you may even ask the respondent to propose his or her insight into certain occurrences and may use such propositions as the bases for further inquiry. The more a respondent assists in this latter manner, the more that the role may be considered one of an "informant" rather than a respondent.*"

Wagner et al. (2010) have elaborated the concept of "key informants" as:

"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."

The group of company representatives in this study can thus be viewed as "multiple informants" since their answers often are grounded in their intimate knowledge also about similar

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sectoral conditions outside their own company (Samuelsson and Lager, 2019; Wagner et al., 2010). The informants were thus asked to contribute with their answers to several close-ended and complementary open-ended questions in a questionnaire something which could be looked upon as the informants' pre-conception of the subject matter.

The use of a questionnaire was considered appropriate for the study aims and the difficulties associated with collecting information from geographically dispersed companies, combined with few opportunities for in-person meetings with company representatives during the COVID-19 pandemic, and favored the development of a detailed and comprehensive questionnaire as a research instrument. In crafting the questionnaire, close-ended questions were developed and complemented with related open-ended questions. The draft first questionnaire was pilot tested by one industry professional and an academic scholar to improve the formulation and clarity of the questions. The final questionnaire was converted into an electronic document, which enabled the informants to respond and provide comments online. With the questionnaire, the informants received an additional document explaining the aim of the research project, practical information, and recommendations. The selected mode of answering the questionnaire varied; most often, one or two informants were chosen, while in some cases the questionnaire was answered in a group session. After case-companies agreed to participate, the questionnaire and instructions were sent to the contact person. This article will be submitted for publication and will afterwards be sent to the informants, post publication.

As a final perspective on methodological use and the generalization of research findings, the informants were asked to answer both close-ended and complementary open-ended questions in the questionnaire as "judges" of new and industrial concepts-in-use (Barrett and Oborn, 2018). The statistical analysis of the quantitative ordinal data (a five-point Likert ordinal scale was used) was not intended to be deployed in any kind of statistical generalization of the findings. The intension was afterwards to do a cross-case analysis of the combined quantitative and qualitative information from the informants in an analytical mode of generalization (Yin, 1994, p.30), but not to do an "in-depth" investigation of each case-company's work process in a customary case-study approach.

4 Empirical findings

Due to space limitations, all original questions and in the questionnaire are presented in this section, and the full questionnaire is not appended. Comments from informants are presented, and each sentence ending with sector specification represents a comment from a separate company. Comments from the three main industry clusters Chemical, Steel and Forest are sometimes separated. Two slightly different formats has been used and some questions, associated results, and comments from informants are presented in running text, while others are presented in tables labeled Q.X.

4.1 Sustainability perspectives on the product innovation work process in a process-industrial context

The informants were initially asked a number of questions (see Table 1, Q.1 – Q.4) related to sustainability integration in the product innovation work process in view of raw material selection, production process technology, and finished products.

The informants were afterwards asked (Q.5): What is your company's current opportunities and flexibility in raw material selection in the perspective of the raw material's environmental impact? On a five-point Likert ordinal scale (1 = Very limited; 5 = Very high) the mean value was 3.7 (S.D. 1.3; Skew – 0,5). The sectoral distributions are further illustrated in Figure 3.

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Table 1 Sustainability perspectives on the product innovation work process for non-assembled products.

Question No.	Answer			Comments from informants
	Mean	Std. dev.	Skew	
(Q.1) To what extent does your product innovation work process consider and ensure a low environmental impact of selected raw materials and ingredients for a new or improved product? (1= Not at all; 5 = Very much)	4.4	0.9	- 1.6	***Raw materials that have environmental impact are excluded in product development (Chemical)***; *Quality & Price is our main concern (Steel); We focus development on renewable sources, compostable, recyclable, biodegradable (Forest); We are looking into all touchpoints to become more sustainable as a company (Food & Drinks); We are integrating this, based on our own priorities and customer demands (Packaging)*
(Q.2) To what extent does your present product innovation work process ensure a low environmental impact of the selected production technology for a new or improved product? (1= Not at all; 5 = Very much)	4.2	0.9	- 0.5	***Only in some cases, production technology can reduce the environmental impact of products. (Chemical); A main driver for our development work (Chemical);*** *Everything we launch must fit with the energy balance at the production unit (Forest); Sustainability is main Unique-Selling-Point for us (Forest); Our focus is primarily on the product and materials at this time (Packaging)*
(Q.3) To what extent does your product innovation work process consider and ensure a low environmental impact and recyclability of a new or improved product? (1 = Not at all; 5 = Very much)	4.1	1.1	- 0.9	***Balancing recyclability and product functionality is a difficult issue (Chemical); We have a recycling platform including mechanical and chemical recycling (Chemical);*** *To change production processes to avoid hazardous elements is ongoing (Steel); It varies a lot between product groups. It's part of our process, but knowledge gaps are limiting factors (Steel); I believe we should find ways really early in the process (Food & Drink); This is the key selling point of paperboard packaging (Packaging)*
(Q.4) To what extent does your product innovation work process consider and ensure recyclability of a new or improved product packaging solution? (1 = Not at all; 5 = Very much)	3.9	1.3	- 1.0	*We do work with packaging and recyclability, but it's not part of our innovation process (Steel); This is already in place (Food & Drink)*

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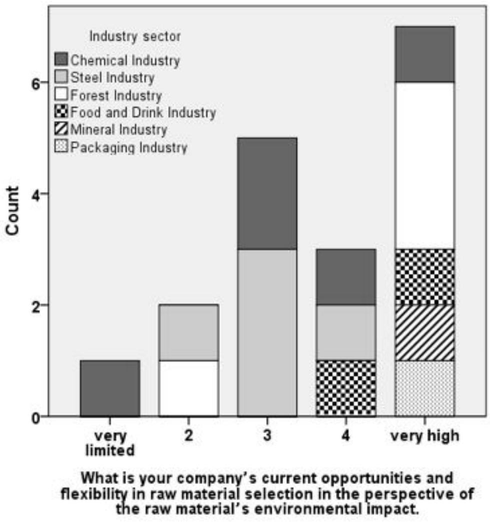

Figure 3 (Q5) Company flexibility of raw material selection in the perspective of raw material environmental impact.

Comments from informants were:

- The flexibility is not very limited due to the purchase of multiple raw materials (Chemical); The main recurring "raw material" considered here is electricity (Chemical)
- Many of the processes allow very few possibilities for flexibilization in raw materials selection (Steel); Current and potential flexibility varies a lot between products and processes (Steel)
- We mainly work with raw materials from renewable sources that are recyclable (Forest); Our raw material is based on sustainable managed forests (Forest)
- Key focus area for the company (Food & Drink); We are working a lot with new materials and natural chemicals (Packaging)

It must first be noted that it was inquired about raw material flexibility with regard to environmental impact. In that respect the high figures for companies in the forest industries and related comments indicate that the high figure on flexibility is more related to different kinds of raw materials, since many companies solely rely on captive raw materials; a similar comment is related to the Mineral Industries. *The bimodal distribution could partly reflect the fact that companies in the Chemical Industries usually are positioned as intermediaries in long, and often complex supply chains from in-situ raw materials to customer end-users.* In a similar vein the low figures for companies in the Steel Industries is most likely related to the same situation.

The informants were further inquired if ensuring sustainability perspectives in the product innovation work process as presented in questions Q1 – Q4 in Table 1 with regard to the total production system could be of value to introduce and deploy in an improved product innovation work process (Q.6). The average YES figure for all individual areas were 83 % with a rather even distribution between the different areas.

In a final question related to the area of sustainability, the informants were inquired (Q.7): At what stage do you consider sustainability issues within your product development work process? The answers were:

- *Throughout the total work process **15***
- *Beginning during the Pre-development phase **1***
- *When the Development phase begin and throughout **1***
- *When the Post-development phase start **0***
- *For the moment not at all **0***

Comments from informants further emphasized the overall high importance of this area: It's starting to be a question with its own headline (Steel); As sustainability is a central theme of our company, this is always on top of our minds (Forest); It's a key focus area for the company and will continue to be so (Food & Drink); Increasingly our projects are driven by these considerations. Materials use by customers is often dictated by sustainability (Packaging).

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A preliminary synthesis

A preliminary synthesis of the research results reveal that the area of sustainability among case-companies is of an overall high importance. A strong majority of all case-companies answered that sustainability should be introduced in an enhanced product innovation work process and as such not only as early as possible but throughout the total work process.

The figures and comments display that sustainability considerations already are in focus in product innovation and in company product innovation work processes, but in “gate to gate”, “cradle to gate” or even “cradle to grave” perspectives, raw material, process technology, and product intertwinement in the process industries put severe demands on how the different aspects could be integrated, and how to configure the overall work process. ”.

4.2 Digitalization of the product innovation work process

After the inquiry on sustainability perspectives, the informants were initially asked a number of questions (see Table 2, Q.8 – Q.11) related to digitalization of the product innovation work process. The questions, ratings and related comments are presented in Table 2.

The sectoral distribution how far case-companies have come in the digital transformation of their product innovation work process (Q.8) is illustrated in Figure 4.

The sectoral distribution to what extent the case-company present product innovation work process considers and ensure digitalization of customer and competitive product information and data (Q.10) is illustrated in Figure 5.

A preliminary synthesis

The preliminary findings (Q.8 mean value 2.9) indicate that the case-companies not yet have come far on the road to institutionalize digitalization in their product innovation work processes, and comments from informants like “we are on our way”, “not yet a focus”, and “it is not a current priority” illustrate this state-of-affairs. In reference to Figure 4, and comments from informants in the Steel Industries could indicate some sectoral differences. With regards to the use of supporting tools for work process digitalization, the importance rating of this area is high (Q.9 mean value 4.0), but the general nature of the comments indicates a low awareness and present use of such instruments. Case-company present digitalization of customer and competitive product information and data (Q.10 mean value 3.5) follow the low estimates in Q.8 and comments like “we recognize the importance of this matter, but concrete measures have been delayed”, and “would like to implement more agile ways of working”. The sectoral distribution in Figure 5 shows a rather scattered picture of present “state of affairs”. In reference to the final question related to integration of supply chain members, comments indicate an area that relate to previous Q.11 and digitalization of customer data. In sum, the preliminary findings show that in spite of a general consensus that this area is of interest to further pursue, case-companies have not yet come far on their digitalization journey in this area.

4.3 Expected outcomes from a digitalized work process

Finally, the informants were asked to rate a number of potential expected outcomes of a digitalized product innovation work process.

The proposed expected outcomes and the importance ratings of the informants are presented in Table 3, and sectoral distributions are further illustrated in Figure 6 and Figure 7.

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Table 2 Digitalization perspectives on the product innovation work process for non-assembled products.

Question No.	Answer			Comments from informants
	Mean	Std. dev.	Skew	
(Q.8) ***How far have you come*** *in the digital transformation of your current product innovation work process? (1 = We have not started yet; 5 = It is already totally transformed*	**2.9**	**0.8**	**0.2**	*We have already taken some initiatives and many more are on the way (Steel); We are only the very early stages yet (Steel); Not yet a focus! Efforts were being directed to existing production lines and new investments (Forest); We have focused on digitalization efforts on the production side of our operations (Forest); Just completed the transformation of the innovation work process (Food & Drink);* ***We are on our way*** *(Food & Drink); It is not a current priority (Packaging)*
(Q.9) How important is digital transformation and ***the use of digital supporting tools*** *for improving your product innovation work process performance? (1 = Not important; 5 = Very much)*	**4.0**	**1.2**	**- 1.2**	*Fast and easy access to information is one of the strongest tools for innovation (Steel); For the moment not, but when in place it'll hopefully be a help (Steel); There is awareness, but very limited resources and focused activities (Steel); It will most probably become important. (Forest); Strong impact on the time to market and cost! (Food & Drink)*
(Q.10) To what extent does your present product innovation work process consider and ensure the ***digitization of customer and competitive product information*** *and data? (1 = Not at all; 5 = Very much)*	**3.5**	**1.3**	**- 0.6**	***We recognize the importance of this matter, but concrete measures have been delayed (Chemical)****; Not making the process data available to everybody is important since that's core businesses and not to be shared (Steel); We have the supporting tools, but not more than that so far (Forest); Would like to implement more agile ways of working (Food & Drink).*
(Q.11) To what extent could digitalization of your current product innovation work process better enable the ***integration of supply chain members*** *in your company product development? (1 = Not at all; 5 = Very much)*	**3.6**	**1.1**	**- 0.1**	*Very low integration is needed between the product development and supply chain departments (Steel); Considering internal supply chain members (Steel); A trend! Having digitalization and digital remote access help to improve solutions, processes monitoring, closer follow up of product development (Forest); Could definitely be of value (Food & Drink); It would offer more opportunities, but this is not a current focus for us. We are currently prioritizing sustainability issues (Packaging)*

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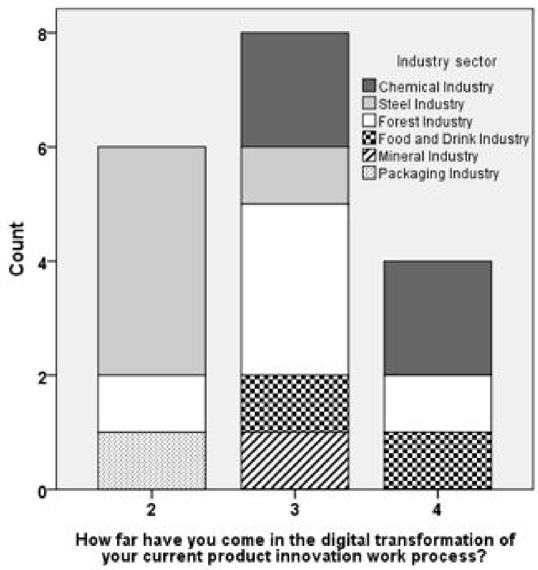

Figure 4 (Q.8) Case-company digitalization maturity with regards to the product innovation work process (unselected categories are not displayed).

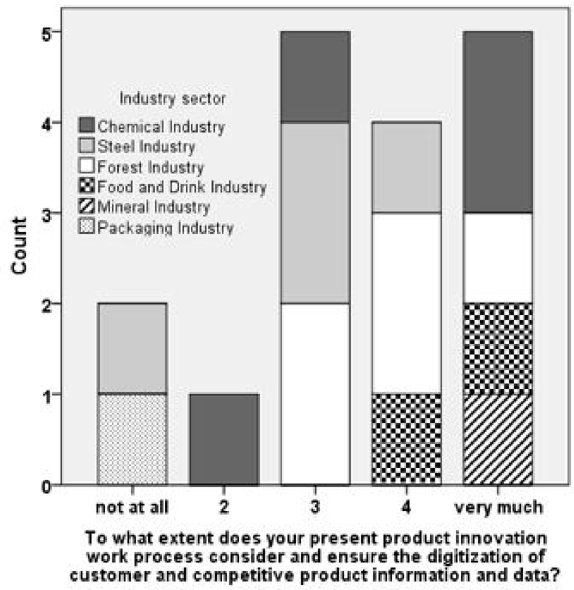

Figure 5 (Q.10) Case-company digitalization of customer and competitive product information and data.

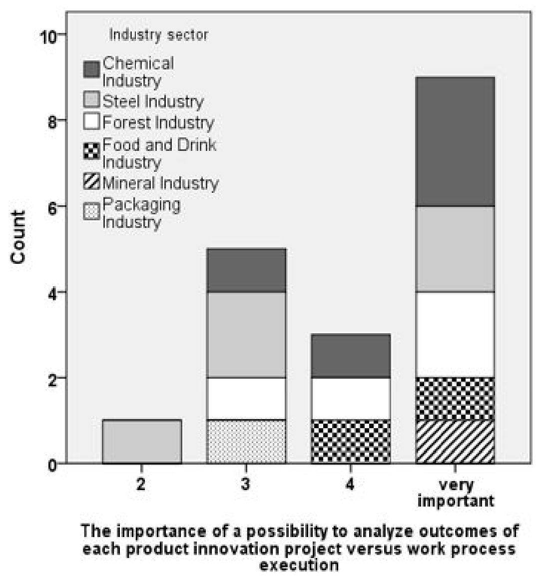

Figure 6 (Q.17) A possibility to analyze outcomes of each product innovation project versus work process execution (unselected categories are not displayed)

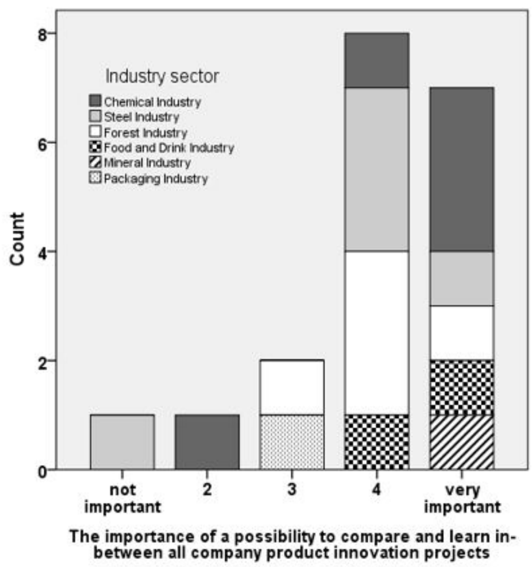

Figure 7 (Q.14) A possibility to compare and learn in-between all company product innovation projects

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Table 3 Company importance ratings of expected outcomes of a digitalized product innovation work process. The different topical areas are re-grouped in ranking order of number of fives.

Question No.	Expected outcome from a digitalized product innovation work process	1 = not important; 5 = very important					Mean (SD); (Skew)
		1	2	3	4	5	
Q.12	Digitalized customer information in general		1	3	5	10	4.3 (0.9); (-1.0)
Q.17	A possibility to analyze outcomes of each product innovation project versus work process execution		1	5	3	9	4.1 (1.0); (-0.6)
Q.13	A digitalized platform of knowledge for "next generation" product development projects		2	1	7	8	4.2 (1.0); (-1.2)
Q.15	An instrument for organizational learning about company best practice product innovation		1	2	8	8	4.2 (0.9); (-1.0)
Q.14	A possibility to compare and learn in-between all company product innovation projects	1	1	2	8	7	4.0 (1.1); (-1.4)
Q.16	An instrument for adapting the product innovation work process to project complexity			5	7	7	4.1 (0.8); (-0.2)

A preliminary synthesis

In view that the case-companies have not come far in the digitalization of their product innovation work processes, the overall high ratings of all six potential expected outcomes indicate that digitalization of the work process is considered to be an activity of strong company importance and usefulness. Since the informants were introduced to a number of general, but most likely rather novel areas of work process advantages, one can assume that the figures represent "top of mind" ratings of the somewhat new perspectives.

Out of six proposed expected outcomes from a digitalized product innovation work process, digitalized customer information rated highest (4.3) on a Likert five-point scale. However, the corresponding question in Table 2, on how well digitalization of customer and competitive product information already is considered in the work process, got a comparatively low rating figure (Q.10 mean value 3.5), which was supported by informant comments like "we recognize the importance, but concrete measures are delayed", and "would like to implement more agile ways". The combined information creates a benchmarking perspective with a high importance rating but a present low capability, creating an incentive for companies to pursue such an activity.

In general, proposed potential expected outcomes from digitalization were commonly given high importance ratings including areas like an instrument for best-practice organizational learning, learn in-between product innovation projects, and a possibility to analyze outcomes of each innovation project versus work process execution. The sectorial distributions (see Figure 6 and Figure 7) show a surprisingly large spread within sectors, and no sector idiosyncrasies are distinguished.

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5 Discussion and a preliminary agenda for further research

5.1 Theorizing sustainability and digitalization in the perspective of the product innovation work process for non-assembled products

In Figure 1, the process-industrial production system is introduced, distinguishing the indirect transformation process in the process industries from an assembly-based process in other manufacturing industries. The intimate coupling between raw materials, process technology and delivered product properties in the transformation process, pinpoint the importance of conjointly consider sustainability aspects in all three areas from ideation to product launch. In Figure 2, the generic model of the product innovation work process for non-assembled products depicts a proposed integrative operational mode in between product innovation and process innovation, throughout the total work process from ideation to market launch.

In conclusion and in a process-industrial context, sustainability aspects should not only be included in the development of product concepts during the pre-product development phase, but also included in the development of the related process concepts (including raw material concepts). In a similar vein, and in the consecutive product development phase, further sustainability perspectives on product design are to a large extent dependent on an integration of sustainability aspects in the preliminary design or reconfiguration of the related production process. In sum, and with regards to the forementioned issues and the empirical findings from Q.7 on sustainability integration in the total work process, a very early and in-depth consideration of sustainability aspects during pre-product development is recommended, as illustrated in Figure 8. In reference to the importance of digitalization of customer and product information (Q.12), digitalization of the work process should incorporate work process phases from contextualization and further extended into the post-launch follow-up phase.

From the perspective of digitalization, and even if some companies in the process industries already have come far on their digitalization journeys (Chirumalla, 2021), the area of digitalization of the product innovation work process is still in need of further clarification and guidelines (Marion and Fixon, 2021), and the findings in this study confirm this "state of affairs". The proposed different expected outcomes from a digitalization of the product innovation work process can from another perspective be regarded as "drivers" for such an activity. The high rating figures of all expected outcomes thus constitutes a clear indication that a digitalized work process should be high on a company improvement agenda because of the strategic importance of a well functioning product innovation work process. Furthermore, the proposed expected outcomes are pointing out that technology related issues are not of a primary importance for the digital transformation of a product innovation work process but rather the organizational change, learning, and management aspects. In consideration of this view, earlier researchers adopted People, Process and Technology dimensions (Yuan et al., 2017; Sjödin et al., 2018) to holistically analyze the impact of digitalization on innovation, which can be a way forward in further research. Moreover, in this direction, the proposed simplified conceptual model could provide a foundational basis to make a further detailed analysis on how to integrate digitalization aspects in all phases of product innovation work process. As emphasized by Aaldering & Song (2021), each sector of the process industries can adopt a unique pathway towards digital transformation, which also is a suggested analytical perspective for future research.

The topical area of integration of sustainability and digitalization was not included in the questionnaire, but the two areas were addressed in an inclusive manner indicating a potential association. As illustrated in the simplified conceptual model, both sustainability and digitalization could contribute and complement the product innovation work process from different angles, which could provide a unique competitive advantage. It is of interest to further explore when and how these two mega trends support and substitute each other in the product innovation work process to understand potential interdependencies and cross-fertilization effects.

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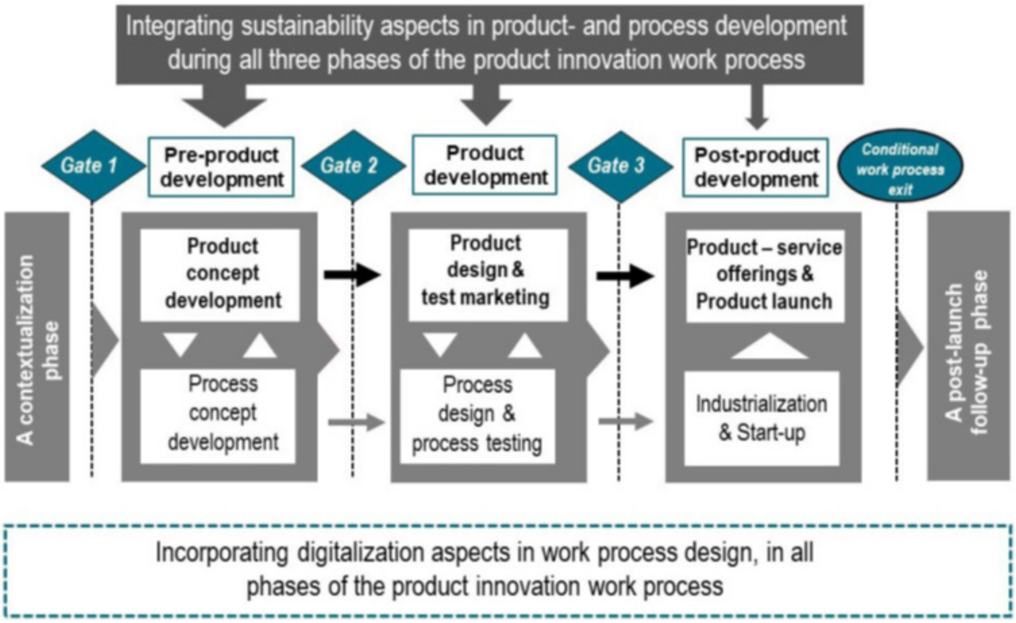

Figure 8 A simplified conceptual model of sustainability integration and digitalization of the product innovation work process for non-assembled products.

6 Theoretical contribution, research limitations, and management implications

In use of the theoretical lens of Dynamic Capabilities (Teece, 2009; Teece and Linden, 2017), integration of sustainability and digitalization perspectives in the product innovation work process for non-assembled products have been explored. According to Teece (2009: p. 48), such capabilities are mainly associated with managerial processes:

… there is much management can do to simultaneously design processes and structures to support innovation while unshackling the enterprise from dysfunctional processes and structures designed for an earlier period.

In this study, a generic "structural model" of the product innovation work process for non-assembled products was selected as a point of departure and platform for the inquiry. In reference to the above quote, incorporating sustainability and digitalization aspects in a company product innovation work process crave such dynamic capabilities, since their proper integration will most likely not only require new incremental operational procedures, but possibly even more radical strategic and organizational solutions for a well-functioning work process. In reference to the scientific utility of a theoretical contribution (Corley and Gioia, 2011), this study provides the following contributions.

First, the study focuses on the integration of both sustainability and digitalization in the product innovation work process, which is still an unexplored area in the process industries, and the study thus contributes to the emerging discussion of "digitainability" (Lichtenthaler, 2021) or "smart circular economy" (Kristoffersen et al., 2020). Even if it was not inquired HOW sustainability and digitalization activities could support each other in this explorative study, it provides the perceptions and the status of nineteen global manufacturing companies from six sectors of the process industries, including a simplified conceptual model of sustainability integration and digitalization of the product innovation work process for non-assembled products. We believe that this study provides a preliminary outlook on the process-industrial context regarding the integration of two mega trends of sustainability and digitalization in the product innovation work process.

Second, six "expected outcomes" (potential "drivers" for such an endeavor) specifically related to a digitalized work-process were initially developed and introduced to the informants. Their high rating of all outcomes, demonstrate their process-industrial relevance irrespective of sector belonging. However, the generic nature of the expected

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outcomes could make them of potential interest also for company use in other manufacturing industries.

Third, the preliminary findings indicate that companies in the process industries already have come far in consideration and ensuring that sustainability perspectives are taken into account in their present product innovation work processes. However, companies in the Forest Industries and Mineral Industries, generally with captive raw material supplies of sustainable raw materials, face different challenges compared with companies in the Chemical Industries and some Food and Drinks Industries, dependent on their position in the supply/value chains. Even if this exploratory study did not further inquire HOW sustainability aspects were institutionalized in the case-companies, general comments from informants indicate, that a more systematic mode of introduction of sustainability aspects could be of interest to develop and pursue.

A final, but minor contribution is the "conceptual model" presented in Figure 8, which in a rather simplistic manner could function as a "trigger" for company further delineation and inclusion of both sustainability and digitalization aspects in the product innovation work process. The conceptual model can contribute and provide a point of departure for further research in the area of product innovation work process design for non-assembled products. The question HOW sustainability and digitalization activities could support each other, was not further inquired in this study, since this is in need of an in-depth case-study approach. Because the importance of digitalized customer and product information scored highest out of all expected outcomes, and that the importance of using supporting tools in the digital transformation of the work process also scored high, highlight the potential use of the QFD methodology. As an instrument for combining general customer requirement on a product and specific sustainability requirements "House of Sustainability" (Rihar and Kusar, 2021), with digitalization of customer and product information (Lager, 2019), this could be one out of several supporting methodologies for an enhanced product innovation work process.

The use of a well-defined questionnaire supports the reliability of the research findings. With respect to the validity of the research results, the combination of both quantitative and qualitative information from experts in the specific topical area demonstrates the study's construct validity. With regard to the external validity and the generalization of the research findings, the theoretical findings from the study population could presumably be generalizable to a well-defined population of interest (the process industries) (Meredith, 1998: p. 450). The reliance on single informants from the companies is a limitation of the case study methodology. Nevertheless, the cross-case analysis based on the amalgamation of quantitative and complementary qualitative case-company information is argued to be robust, and a foundation for an analytical generalization of the research findings (Yin, 1994).

In the perspective of present low digitalization maturity and on-going activities with regard to digitalization of the product innovation work process, and in view of the high rating of potential outcomes and magnitude of company potential benefits from such a digitalization, the preliminary findings should incentivize companies to accelerate the digitalization of this area and take advantage of already available tools and methodologies.

7 Conclusions

Manufacturing industries are considering sustainability and digitalization as a top strategic priority, but it is generally experienced that they sometimes have difficulties to embrace these approaches in an operational mode, and the product innovation work process could therefore provide a central arena for companies in the process industries to anchor and integrate sustainability and digitalization aspects within their organizations. However, not only is research on the product innovation work process for non-assembled products scarce, but how sustainability and digitalization perspectives could be more integrated in company work process design is not yet well-addressed and understood. The purpose of this study is thus to explore current perceptions in companies in the process industries with regards to integrating sustainability and digitalization aspects in their product innovation work processes. Involving informants in nineteen global manufacturing companies in six sectors of the process industries, sustainability, and digitalization integration in the innovation work process for non-assembled products has been explored.

The preliminary findings indicate that the case-companies already have come far in institutionalizing sustainability perspectives in raw material selection, process technology development and product design. However, the study

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further discloses a need for a more in-depth inquiry and understanding on HOW alternative operational best practices and tools in a more systematic approach can make sustainability an integral part of this work process. The empirical results further demonstrate that the case-companies not yet have come far on their journeys with respect to product innovation work process digitalization. The case companies rated all proposed potentially expected outcomes high in such digitalization, and in particular digitalization of customer and product information should incentivize companies in the process industries to put this topical area higher on their digitalization agenda. The paper contributes to the growing interest how to integrate the two mega trends of sustainability and digitalization and concepts like "digitainability" and "smart circular economy" in product innovation work process for non-assembled products. The preliminary findings and proposed simplified conceptual model could provide a good foundational step for further discussion on sustainability integration and digitalization of the product innovation work process for non-assembled products. Further, the paper fulfills the need of further understanding on how digitalization and sustainability could individually and jointly provide competitive advantage in industrial companies, through a design of an enhanced product innovation work process.

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URN: urn:nbn:de:hbz:6-30069531636
DOI: 10.17879/30069520962

References

Aaldering LJ and Song CH (2021): Of leaders and laggards -Towards digitalization of the process industries. Technovation 105.

Agostini L, Galati F and Gastaldi L (2020): The digitalization of the innovation process. European Journal of Innovation Management 23(1): 1-12.

Akao Y (2003) The leading edge in QFD: past, present and future. International Journal of Quality & Reliability Management 20(1): 20-35.

Aksin-Sivrikaya S and Bahattacharya CB (2017): Where Digitalization Meets Sustainability: Opportunities and Challanges. In: Lohrmann TOC (ed) Sustainability in a Digital World: New opportunitis Through New Technologies.: Berlin: Springer.

Alvesson M and Sköldberg K (2009): Reflexive methodology. London: SAGE Publications Inc.

Andersen B, Fagerhaug T, Henriksen B, et al. (2008): Mapping Work Processes. Milwakee: American Society for Quality; Quality Press.

Barney J, Wright M and Ketchen J, David J (2001): The resource-based view of the firm: Ten years after 1991. Journal of Management Information Systems 27: pp. 625-641.

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

Blackburn M, Alexander J, Legan JD, et al. (2017): Big data and the future of R&D managemnet. Research Technology Management 60(5): pp. 43-51.

Bower DJ and Keogh W (1996): Changing patterns of innovation in a process-dominated industry. International Journal of Technology Management 12(2): 209-220.

Branca TA, Fornai B, Colla V, et al. (2020): The Challenge of Digitalization in the Steel Sector. Metals 10.

Brockhhaus S, Petersen M and Knemeyer AM (2019): The fallacy of „trickle-down“ product sustainability: Translating strategic sustainability targets into product development efforts. International Journal of Operations & Production Management 39(9/10): 1166-1190.

Buchert T, Halstenberg FA, Bonvoisin J, et al. (2017): Target-driven selection and scheduling of methods for sustainable product development. Journal of Cleaner Production 161: 403-421.

Chen X, Despeisse M and Johansson B (2020): Environmental Sustainability of Digitalization in Maufacturing: A Review. Sustainability 12.

Cheng CC and Shiu EC (2012): Validation of a proposed instrument for measuring eco-innovation: an implementation perspective. Technovation.(32): pp. 329-344.

Chirumalla K (2021): Building digitally-enabled process innovation in the process Industries: A dynamic capabilities approach. Technovation 105.

Cobbenhagen J, den Hertog F and Philips G (1990): Management of innovation in the processing industry: a theoretical framework. In: Freeman C and Soete L (eds) New Explorations in the Economics of Technological change, London: Printer Publishers, 55-72.

Cooper R (1994a) Perspective: Third Generation New Product Processes. Journal of Product Innovation Management 1: 3-14.

Cooper RG (1994b): Perspective. Third-generation new product processes. Journal of Product Innovation Management 11(1): 3-14.

Cooper RG (2008): Perspective: The Stage-Gate Idea-to-Launch Process - Update, What's New, and NexGen Systems. J PROD INNOV MANAG 25(3): 213-232.

Cooper RG (2012): Best Practices in the Idea-to-Launch Process and Its Governance. Research-Technology Management March-April: 43-54.

Cooper RG and Edgett SJ (2012): Best Practices in the Idea-to-Launch Process and its Governance. Research-Technology Management 55(2): pp. 43-54.

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URN: urn:nbn:de:hbz:6-30069531636
DOI: 10.17879/30069520962

Cooper RG and Kleinschmidt EJ (1986): An investigation into the new product process: steps, deficiencies and impact. Journal of Product Innovation Management 3(2): 71-85.

Cooper RG and Kleinschmidt EJ (1993): Screening New Products for Potential Winners. Long Range Planning 26(6): 74-81.

Cooper RG and Sommer AF (2016): The Agile-Stage-Gate Hybrid Model; A Promising New Approach and a New Research Opportunity. J PROD INNOV MANAG 33(5): 513-526.

Corley KG and Gioia DA (2011): Building theory about theory building: What constitutes a theoretical contribution. Academy of Management Review 36(1): 12-32.

Day RG (1993): Quality Function Deployment - Linking a Company with Its Customers. Milwaukee: ASQ Quality Press.

De Marchi V (2012): Envionmental innovation and R&D cooperation: Emperical evidence from the Spanish manufacturing firms. Research Policy 42(3): pp. 614-623.

Deleryd M and Fundin A (2020): Towards societal satisfaction in a fifth generation of quality – the sustainability model. Total Quality Management & Business Excellence. DOI: 10.1080/14783363.2020.1864214. 1-17.

Dubois A and Gadde L-E (2002): Systematic combining: an abductive approach to case research. Journal of Business Research 55: 553-560.

Eisehardt KM and Tabrizi BN (1995): Accelerating adaptive processes: Product innovation in the global computer industry. Administrative Science Quarterly 40: 84-110.

Eppinger S (2011): The Fundamental Challenge of Product Design. Journal of Product Innovation Management.(28): pp.399-400.

Foellesdal D, Walloe L and Elster J (1990): Argumentationsteori språk och vetenskapsfilosofi. Oslo: Universitetsförlaget.

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(4): 468-488.

Frishammar J, Söderholm P, Bäckström K, et al. (2014) :The role of pilot and demonstration plants in technological development: synthesis and directions for future research. Technology Analysis & Strategic Management 27(1): 1-1819.

Gao S, Hakanen E, Töytäri P, et al. (2019): Digital Transformation in Asset-intensive Businesses: Lessons Learned from Metals and Mining Industry. The 52nd Hawaii International Conference on System Sciences. 4927-4936.

Hakanen E and Rajala R (2018): Material intelligence as a driver for value creation in IoT-enabled business ecosystems. Journal of Business & Industrial Marketing 33(6): 857-867.

Hallencreutz J, Deleryd M and Fundin A (2020): Decoding sustainable success. Total Quality Management & Business Excellence. DOI: 10.1080/14783363.2020.1863779. 1-11.

Hallstedt SI, Thompson AW and Lindahl P (2013): Key elements for implementing a strategic sustainability perspective in the product innovation process. Journal of Cleaner Production 51: 277-288.

Hellsmark H, Frishammar J, Söderhlm P, et al. (2016): The role of pilot and demonstration plants in technology development and innovation policy. Research Policy 45: pp. 1743-1761.

Henry GT (1990): Practical sampling. London: SAGE Publications.

Herzog K, Winter G, Kurka G, et al. (2017): The Digitalization of Steel Production. BHM 162(11): 504-513.

Horváth D and Szabó RZ (2019): Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? Technological forecasting and Social Change.(146): pp. 119-132.

Iansiti M and Lakhani K (2014): Digital ubiquity: How connections, sensors and data are revolutionizing business. Harvard Business Review 92(11): pp. 90-99.

Vol. 20, Iss.2, June 2023
URN: urn:nbn:de:hbz:6-30069531636
DOI: 10.17879/30069520962

IntelliSurvey (2021): Billions of Better Decisions: Industrial transformation's new imperative. (accessed 1st of March).

Jeston J and Nelis J (2018) Business Process Management: Practical guidelines to successful implementation. New York: Routledge.

Kaplinsky R and Morris M (2018): Standards, regulation and sustainable development in a global value chain driven world. Internatiional Journal of Technological Learning, Innovation and Development 10(3/4): 322-346.

Kemp R (2010): Ecoinnovation: definition, measurement and open research issues. Economia Politica 27(3): pp. 397-420.

Kovacs G and Spens MK (2005): Abductive reasoning in logistics research. International Journal of Physical Distribution & Logistics Management 35(2): 132-144.

Kristoffersen E, Blomsma F, Mikalef P, et al. (2020): The smart cirkular economy: A digital-enabled circular strategies framework for manufacturing companies. Journal of Business Research 120: 241-261.

Kusiak A (2018): Smart manufacturing. International Journal of Production Research 56(1-2): pp.508-517.

Lager T (2002b) :A structural analysis of process development in process industry - A new classification system for strategic project selection and portfolio balancing. R&D Management 32(1): 87-95.

Lager T (2005): The industrial usability of quality function deployment: a literature review and synthesis on a meta-level. R&D Management 35(4): 409-426.

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(3): 189-219.

Lager T (2019): Contemporary Quality Function Deployment for Product and Process Innovation. London: World Scientific.

Lager T and Blanco S (2010a): The Commodity Battle: a product-market perspective on innovation resource allocation in the Process Industries. International Journal of Technology Intelligence and Planning 6(2): 128-150.

Lager T and Bruch J (2021): Innovation and production management in the process industries - in search of a conjoint approach. Technovation 105: 1-4.

Lager T, Hallberg D and Eriksson P (2010): Developing a Process Innovation Work Process: The LKAB experience. International Journal of Innovation Management 14(2 (April)): 285-306.

Lager T, Samuelsson P and Storm P (2017): Modelling company generic production capabilities in the process industries: A configuration approach. International Journal of Operations & Production Management 37(2): pp. 126-161.

Lager T and Simms C (2023): From customer understanding to design for processability: Reconceptualizing the formal product innovation work process for non-assembled products. Technovation 125.

Lager T, Simms DC and Frishammar J (2023): Managing ideation and concept integration in the product innovation work process for non-assembled products. International Journal of Innovation and Technology Management 20(3): 32.

Lakemond N, Magnusson T, Johansson G, et al. (2013): Assessing interface challanges in product development projects. Research Technology Management Jan-Feb: 40-48.

Lee-Hansen Z and Ahmed-Kristensen S (2011): Global product development: The impact on the productdevelopment process and how compnies deal with it. . Internatiional Journal of Product Development 15: 205-226.

Lichtenthaler UC (2021): Digitainability: The Combined Effects of the Megatrends Digitalization and Sustainability. Journal of Innovation Management 9(2): 64-80.

MacCarty BL, Lewis M, Voss C, et al. (2013): The same old methodologies? Perspectives on OM research in the post-lean age. International Journal of Operations & Production Management 33(7): 934-956.

Vol. 20, Iss.2, June 2023
URN: urn:nbn:de:hbz:6-30069531636
DOI: 10.17879/30069520962

Marion TJ and Fixon S, K (2021): The Transformation of the Innovation Process: How Digital Tools are Changing Work, Collaboration, and Organizations in New Product Development. Journal of Product Innovation Management 38(1): 192-215.

Melan EH (1992): Process Management - Methods for improving products and service. New York: McGraw-Hill, Inc.

Meredith J (1998) Building operations management theory through case and field research. Journal of Operations Management 16(4): 441-454.

Mizuno S and Akao Y (1994): QFD: The Customer-Driven Approach to Quality Planning and Deployment. Tokyo: Asian Productivity Organization.

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

Neef C, Hirzel S and Arens M (2018): Industry 4.0 in the European Iron and Steel industry: Towards an overview of implementation and perspectives. . Reportno. Report Number|, Date. Place Published|: Institution|.

Nijssen EJ and Frambach RT (2000): Determinants of the Adoption of New Product Development Tools by Industrial Firms. Industrial Marketing Management 29: pp. 121-131.

Nijssen EJ and Lieshout KFM (1995): Awareness, use and effectiveness of models and methods for new product development. European Journal of Marketing 29(10): pp. 27-44.

Ocampo LA, Labrador JJT, Jumao-as AMB, et al. (2020): Integrated multiphase sustainable product design with a hybrid quality function deployment – multi-attribute decision-making (QFD-MADM) framework. Sustainable Production and Consumption 24: 62-78.

Oesterreich TD and Teuteberg F (2016): Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. Comput. Ind. (83): pp.121-139.

Palinkas LA, SHorwitz SM and Green CA (2015): Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. Adm Policy Ment Health 42(5): 533-544.

Patton M (1990): Qualitative evaluation and research methods. Beverly Hills: Sage.

Petersen M (2021): How Corporate Sustainability Affects Product Developers´Approaches Toward Improving Product Sustaniability. IEEE Transactions on Engineering Management 68(4): 955-969.

Porter ME and Heppelmann JE (2015): How Smart, Connected Products Are Transforming Companies. Harvard Business Review 93: 1-37.

Puglieri FN, Ometto AR, Salvador R, et al. (2020): An Environmental and Operational Analysis of Quality Function Deployment-Based Methods. Sustainability 12(8): 3486.

Pujari D, Peattie K and Wright G (2004): Organizational antecedents of environmental responsiveness in industrial new product development. Industrial Marketing Management 33(5): pp. 381-391.

Qian F, Zhong W and Du W (2017): Fundamental Theories and Key Technologies for Smart and Optimal Manufacturing in the Process Industry. Engineering 3: 154-160.

Reichstein T and Salter A (2006): Investigating the sources of process innovation among UK manufactuting firms. Industrial and Corporate Change 15(4): 653-682.

Rihar L and Kusar J (2021): Implementing Concurrent Engineering and QFD Method to Achieve Realization of Sustainable Project. Sustainablility 13(1091): 1-28.

Samuelsson P and Lager T (2019) Managing product variety under operational constraints: A process-industrial outlook. Journal of Business Chemistry 2(6): 134-147.

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(5): pp. 662-691.

Vol. 20, Iss.2, June 2023
URN: urn:nbn:de:hbz:6-30069531636
DOI: 10.17879/30069520962

Sehnem S, de Queiroz AAFSL, Pereira SCF, et al. (2021): Circular economy and innovation: A look from the perspective of organizational capabilities. Business Strategy and Environment. DOI: 10.1002/bse.2884.

Shang Z and Zhang L (2022): The sustainable digitalization in the manufacturing industry: A bibliometric analysis and research trend. Mobile Information Systems.

Sjödin DR, Parida V, Leksell M, et al. (2018): Smart Factory Impementation and Process Innovation. Research-Technology Management 61(5): pp. 22-31.

Sung TK (2018): Industry 4.0: A Korea perspective. Technological forecasting and Social Change.(132): pp. 40-45.

Teece DJ (2009): Dynamic Capabilities & Strategic Management Oxford University Press.

Teece DJ and Linden G (2017): Buiness models, value capture, and the digital enterprise. Journal of Organization Design 6(8).

Thomé AMT, Scavarda A, Ceryno PS, et al. (2016): Sustainable new product development: a longitudinal review. Clean Technologies and Environmental Policy 18(7): 2195-2208.

Thomke SH (2006): Capturing the Real Value of Innovation Tools. MIT Sloan Management Review 47(2): pp. 24-32.

Tottie M and Lager T (1995): QFD-Linking the Customer to the Product Development Process as a Part of the TQM Concept. R&D Management 25 (July)(3): 257-267.

Ukko J, Nasiri M, Saunila M, et al. (2019): Sustainability strategy as a moderator in the relationship between digital business startegy and financial performance. Journal of Cleaner Production 236.

Unger D and Eppinger S (2009): Comparing product development processes and managing risk. Internatiional Journal of Product Development 8(4): 382-402.

Valenduc G and Vendramin P (2016): Work in the Digital Economy;: Sorting the Old from the New.

Wagner SM, Rau C and Lindeman E (2010): Multiple Informant Methodology: A Critical Review and Recommendations. Sociological Methods & Research 38(4): 582-618.

Yin RK (1994): Case Study Research; Design and Methods. Thousand Oaks: Sage Publications.

Yu X, Geng Y, Dong H, et al. (2016): Emergy-based sustainability assessment on natural resource utilization in 30 Chinese provinces. Journal of Cleaner Production. pp. 18-27.

Yuan Z, Qin W and Zhao J (2017): Smart Manufacturing for the Oil Refining and Petrochemical Industry. Engineering 3: 179-182.

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Appendix A Product innovation in the process industries

An intentional definition by Lager (2017a) has been selected in this study:

"The process industries are the portion 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 relatively continuous flow pattern."

A number of industrial sectors have been selected from all manufacturing industries which are included in the statistical classification of economic activities in the European community (NACE, 2006). The following sectors are thus included in the cluster of process industries (NACE codes in parentheses):

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

