Proposed Paper for 2018 DRUID Academy
Title: Shining a light on how digitization tools enable innovation processes
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Abstract:
This paper for DRUID will describe the planned PhD research project to shine a light on the transition from innovation to digital innovation, which begins on 1 December. This DRUID overview will describe each subtopic (planned papers) along with proposed methodological approaches to accomplish the research objectives and understand the anchoring theories for each paper. It will also discuss potential approaches and challenges related to creating a typology and categorization framework for understanding digitization tools’ antecedents, mechanisms, effects, and placement within the innovation value system; and, research-based potential initial interview questions; theoretical issues, challenges, and potential new theoretical logics related to digitization tool use within the organization’s innovation value system.
Digital innovation advancements are creating an industrial revolution (Brynjolfsson and McAfee, 2011). Digital innovation? refers to use of cyber-physical digital technology during the process of innovating (Nambisan et al., 2017). Companies are urged to rapidly digitize their manufacturing and innovation processes while at the same time avoid the pitfalls of injecting too much complexity into their systems (Stentoft, Rajkumar and Madsen, 2017; Boston Consulting Group (BCG) and Innovationsfonden, 2016; BCG and Google Inc., 2016), especially since this digital maelstrom is dislocating the value propositions of many existing companies and as a result it is altering their market? (Brem and Viardot, 2017). However, firms face a confusing array of ill-explained digitization tool options, scant information about the specific ways that these tools can be deployed within a firm’s innovation framework and even less information about effects and implications that occur when digitization tools are in use within product and service innovation, process innovation, organizational innovation and marketing innovation dynamics. This lack of knowledge about cyber-physical tools involved in the transition to digital innovation hinders companies from adopting and benefitting from these advancements (BCG and Innovationsfonden, 2016: 8). Researchers have begun exploring digitized production-related innovations (Industry 4.0?), but much is still unknown; and beyond product-related innovation it is rare to find research about digitized tools and dynamics within
other types of process innovation, organizational innovation, and marketing innovation (exceptions include Nambisan, 2013; Lyytinen, Yoo & Boland, 2016; and Nambisan et al., 2017). This is problematic because although digitization can create an integrated, automated and optimized production flow, it also changes interactions within innovation value systems (Nambisan et al., 2017; Yoo et al., 2012; Research Policy Call for Papers, 2017) and challenges existing theoretical logics (Nambisan, 2013; Nambisan et al., 2017) in unknown ways. Furthermore, digitization tools are very context-specific (Benerecetti, Bouquet and Bonifacio, 2001) and dynamics are not yet well-explored. Most existing literature comes from an Information Systems perspective (Nambisan, 2013) or from conference papers or grey literature (Liao et al., 2017), and lacks a comprehensive explanation of digitization occurrences, usage, roles and relationships within the context of innovation processes. Without this knowledge, it is difficult to understand how to implement digital technologies to improve or manage innovation (European Journal of Innovation Management special issue proposal, 2017). This research is intended to answer the following research questions: How may digitization tools be used in support of innovation processes and what are the effects when such digitization tools are in use? The project seeks to fill a gap by providing an integrative view through creation of a typology and categorization framework within which to show where and how digitization tools operate in the context of the innovation value system (placed alongside existing theories related to the occurrence and use of these tools), and then by theorizing on new effects. The discussion will include each planned paper and significant literature drawn from innovation management (and some from information systems research) along with key concepts that will require further exploration in regards to their effects (e.g., operand/non-autonomous and operant/autonomous aspects). ?

References


References

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Yoo, Y., Boland, R. J., Lyytinen, K., & Majchrzak, A.
Purpose

This paper for DRUID lays out planned PhD research (which began on 1 December 2017) for the following expected project outcomes:

1. the formation of an organizing framework by which to understand digital innovation within an organization’s innovation value chain; this framework must be able to combine and organize knowledge from emerging research streams that are varied and fragmented;

2. the exploration and mapping of actual digitization tool usage within case companies with a microlevel focus to understand features, structures and processes yet with an ability to show occurrences where, when, and why digitization tools span organizational boundaries; the approach must be robust enough to capture myriad ways digitization tools are in use; interactions occurring within the internal environment (between humans and machines, or from machine to machine); interactions occurring between the internal and external environments; the nature of these tools; and effects of their implementation;

3. the understanding of ways digitization tools enable innovation performance and other effects of their usage within an organization’s innovation value chain; and

4. changed or new theoretical logics because of digital innovation, with relevant associated insights for innovation management.

Organization

Each section of this DRUID paper discusses a paper planned for accomplishing the above PhD project objectives. The first part of each section offers an existing (or in some cases planned) state of the art discussion including significant literature and research gaps drawn from innovation management (and some from information systems research) along with any theoretical arguments related to key concepts or changing logics that will require further exploration. The next part of each section then discusses the proposed methodology relevant for the tasks associated with the paper. This paper is being submitted during the first week of the PhD study, so no results are offered. The later papers will naturally build on the earlier papers and there is not yet much to discuss.

Since this paper is written during such a preliminary stage, for purposes of feedback from DRUID reviewers: related to the effort of making context-specific sense of digitization tools and their potential linkage with innovation performance in this vastly fragmented field, the plan for this study is to investigate a small number of cases (so although the results will not be generalizable, the goal is to contribute insights for innovation management). What I find most challenging (so I am still searching for approaches and solutions and it would be most helpful to have comments) is to know whether I have created an approach that will enable adequate collecting and framing of data for a robust analysis? Specifically:

- In Paper I, Table 1: are potentially important research streams missing?
- In Paper I, Table 2: is the proposed matrix for organizing the literature going to be sufficient or is there a preferred/recommended way to approach this task?
- In Paper II, Table 3: the range of topics is vast – how best to focus on the most relevant aspects (and are the most relevant aspects listed?)
- In Paper II, Figure 3: this is the most challenging aspect for me (what structural/processual framework makes sense, for capturing information about digital innovation and possible linkages with performance)
- In Paper III, any suggestions/recommendations you can make regarding the methods would be extremely appreciated
- In Paper IV, I built Table 4 using the Brown and Eisenhardt (1995) framework—but is this an optimal approach for helping to organize concepts and build theory?
Paper I: Understanding digitization tools within an innovation value chain: a literature review.

The project begins with a comprehensive literature review drawing on innovation management and information systems research for understanding digitization tools in terms of their antecedents, mechanisms, effects, and placement within the context of the innovation value chain. A goal is to identify an initial set of interview questions related to the range of constructs. A preliminary literature review was conducted for purposes of the PhD project proposal; a subsequent review is described in Methods, below.

State of the art

Digital innovation advancements are creating an industrial revolution (Brynjolfsson and McAfee, 2011). “Digital innovation” refers to use of cyber-physical digital technology during the process of innovating (Nambisan et al., 2017). Companies are urged to rapidly digitize their manufacturing and innovation processes while at the same time avoid the pitfalls of injecting too much complexity into their systems (Stentoft, Rajkumar and Madsen, 2017; Boston Consulting Group (BCG) and Innovationsfonden, 2016; BCG and Google Inc., 2016), especially since this “digital maelstrom is dislocating the value propositions of many existing companies and as a result it is altering their market” (Brem and Viardot, 2017). However, firms face a confusing array of ill-explained digitization tool options, scant information about the specific ways that these tools can be deployed within a firm’s innovation framework and even less information about effects and implications that occur when digitization tools are in use within product and service innovation, process innovation, organizational innovation and marketing innovation dynamics. This lack of knowledge about cyber-physical tools involved in the transition to digital innovation hinders companies from adopting and benefitting from these advancements (BCG and Innovationsfonden, 2016: 8).

After an extensive search of literature for concepts related to digitization of innovation and computer aided innovation, reviewing three recent journal special issue proposals, and examining papers from CINet’s conference on digitization (September 2017), clearly as Liao et al. (2017) also found in their systematic literature review, there is growing interest in digitization but academic research is scarce. One issue is that much existing literature focuses on a subset of digitization related to production (frequently referred to as “Industry 4.0”). Another issue is, as Stentoft, Rajkumar and Madsen (2017) note in their empirical investigation of Industry 4.0 in Denmark, “most academic articles are found in conference contributions (Liao et al., 2017),” and other available literature “is dominated by technical contents (e.g. what it is, conceptualization)” and “by grey literature from consultants such as Colotla et al. (2016), Deloitte (2015), Dujin et al., (2014) McKinsey (2015), and white papers from commissions (e.g. IEC, 2015).” Also within the subset of product-related Industry 4.0 literature, Liao et al. (2017) advise that a priority for Industry 4.0 academic research is an accurate identification and understanding to help determine ‘Which are the enabling features of Industry 4.0?’ (following Kagermann, Wahlster, and Helbig, 2013). Beyond matters specifically related to Industry 4.0, existing literature covers a range of non-synthesized topics. Nambisan et al. (2017: 224) note a recent expansion of research “identifying and articulating unique aspects of digitization in industries, specific organizational domains, or product families” (for example, Nambisan et al. (2017) cites Agrawal et al., 2013; Anderson and Agarwal, 2011; Greenstein et al., 2013; and Xue et al., 2013). Other research identifies “paradoxes and dilemmas that digitization creates for organizations” (e.g., Demirkan, Spohrer, & Welser, 2016; and as cited in Nambisan et al., 2017: Breshnahan and Greenstein, 2014; Kallmikos et al., 2013; Tilson et al., 2010; Tiwana et al., 2010; Yoo et al., 2010). Kornish and Hutchison-Krupat (2017) find that advances in technology play dual roles in innovation: they first affect the objectives and they also affect the process. The underlying problem is that existing research lacks an integrative view to address how digitization tools may support innovation processes and what are the effects when such tools are in use.

Fragmented Terminology

An aspect of the problem of a missing overview of digitization within innovation value chains, is the issue of fragmented terminology. How do we define what these digitization tools and phenomenon are along the
innovation value chain? As noted above, some research discusses Industry 4.0, which refers to a subset of cyber-physical web-based concepts and technologies that are usually related to production. The broader term “digital innovation” refers (according to Nambisan et al., 2017) to the use of cyber-physical digital technology during the process of innovating. Such technology is sometimes called by other names (for example Computer Aided Innovation (CAI), Information Technology, Information Systems, or Digitization). A report by BCG and Innovationsfonden (2016) says digitization includes “the Internet of Things (IoT), which enables connectivity of a vast array of objects, and remote monitoring and control through online platforms, as well as big data analytics, advanced robotics, and new forms of visualization through augmented and virtual reality” (p. 9). Again regarding digitized production, Blichfeldt, Faullant and Gerstlberger (2017) describe Industry 4.0’s building blocks as the existence of an Internet of Things (IoT) on the manufacturing firm level (also known as Industrial Internet of Things, or IIoT), a systematic combination of digital tools via online connection (following Drath and Horch, 2014; Colotla et al., 2016), and specific production technologies such as advanced industrial robotics, additive manufacturing characterized by advanced technology, process technology innovation, extended use of simulation, system integration and big data analysis (following Liao et. al., 2017). Other digitization terms also include such things as crowdsourcing, digitized knowledge gathering (big data, Deep Learning, Cloud-enabled ideation), Web 2.0-enabled idea management, artificial intelligence (AI), Cloud Robotics, Social and Smart (SaaS), learning algorithms, social sensing, Machine Learning (which Lyytinen, Yoo and Boland Jr., 2016, describe as the ability of computers to learn without being explicitly programmed), edge computing, predictive analytics, computer-aided creative design (CADD), information and communication technologies (ICT), and additional advances in digital technologies.

Existing research discusses aspects of digitization, but not within a comprehensive innovation value chain framework. For instance, Tsekeris & Katerelos (2012) define Web 2.0 complex networks and virtual communities; Tsvetkova et al. (2017) describe eight types of Human-Machine Networks (HMNs) (including public-resource computing, crowdsourcing, web search engines, crowdsensing, online markets, social media, multiplayer online games and virtual worlds, and mass collaboration); Chang, Chen and Lee (2014) discuss typical and proposed types of crowdsourcing schemes; Lemus et al. (2017, following Munoz, 2014) define machine learning as a combination of several disciplines such as statistics, information theory, algorithms, probability and functional analysis and which explores the construction of algorithms for predictions, classification, through building models from sample inputs). Schreckling and Steiger (2017) provide a digital innovation and transformation framework with associated lists of preparation questions. Clearly missing from the array is a framework for synthesizing and understanding the innovation enabling functions of digitization tools in the context of organizations’ innovation value chains and ecosystems. Where are these tools appearing, and how are their features enabling innovation capacities?

The fragmentation problem also relates to digitization tool categories and driving conditions (descriptions of which vary widely). For example, Kohnke (in Oswald and Kleinemeir ed., 2017: 70 citing Harvard Business Review Analytic Services, 2014 and Wade and Marchant, 2014) claims that there are currently four technologies associated with digitization: analytic technologies and applications including ‘big data’ that allow innovative forms of information processing; mobile technologies like smartphones and tablets that enable new business scenarios; cloud technologies and solutions that offer flexible and shareable digital capabilities; and social media technologies and applications that facilitate new forms of social interactions. McAfee and Brynjolfsson (2017) think the shift to digitization requires three fundamental changes, grouped as an integration of minds and machines, of products and platforms, and of the core and the crowd. According to Brem and Viardot (2017), there are six driving forces of the digital revolution: digital technology, mobile communication, social networks, instant (real-time) data, virtual platform (cloud), and startups/venture capitals (VCs). Related to Industry 4.0 (i.e., innovation production aspects), Liao et al. (2017) identify five categories of topics that appear most frequently in the literature: 1) main components of a smart factory; 2) product life cycle; 3) standards; 4) enabling technologies; and 5) features. Stentoft, Rajkumar and Madsen (2017) offer three categories of
production-related Industry 4.0 technologies (following Deloitte, 2015, and Dujin et al., 2014) including: materials and manufacturing smart technologies; connectivity smart technologies; and computing and big data and they describe how each category is operationalized into specific areas or technology tools. BCG and Innovationsfonden (August 2016) surveyed over 500 Danish companies to discover their attitude towards a list of sixteen technologies across four dimensions (operational improvements, performance improvements, people involvement, and Industry 4.0 Foundation (referring to the backbone that supports further implementation projects and includes data security and data infrastructure)). Kowalkiewicz et al. (in Oswald and Kleinemeir ed., 2017: 60-62) see seven core areas for businesses to successfully thrive in the digital economy (digital attention; digital signals; digital capital; digital community; digital access; digital assets; and new digital products). Furthermore, “the shift in the economies—from the age of automation to the age of digitization requires entrepreneurs and executives to re-imagine and re-design the way they create revenue,” because the age of automation (which they call the “Economy of Corporations”) is characterized by economics of scale, cost efficiency and is analysis intensive while the age of digitization (“Economy of People”) is characterized by mass personalization, revenue resilience and is designer intensive. Other researchers and consultants provide different categories to describe digitization tools (Liao et al., 2017; Stentoft, Rajkumar and Madsen, 2017; Deloitte, 2015; Dujin et al., 2014; BCG and Innovationsfonden, 2016). Additionally, according to the BCG and Innovationsfonden report (2016), Industry 4.0 will occur through nine technology drivers that enable production of the future, including: Big Data and analytics; additive manufacturing (e.g. 3D printing); simulation; horizontal / vertical integration; Industrial Internet of Things (IIoT); cyber-security; Cloud; advanced robotics; and augmented reality. Marinkovic et al. (2011) study and categorize ICT enhancing service innovation processes. Therefore, the first planned outcome of this project is a meta level description of tool options, categories, features, and conditions synthesized within a framework for giving order and better understanding how these tools relate to and within each other and the innovation value chain.

Theoretical Contexts

Most existing studies show little to no connection between implementation of digitization tools within innovation value chains and theoretical perspectives that can lead to an understanding of the changing relationships occurring in the innovation ecosystem as an effect. Okhuysen and Bonardi (2011: 6) urge development of theoretical perspectives combining multiple lenses, especially in situations where the tendency is to create isolated silos of knowledge that reflect specialization (which Nambisan et al. (2017) and Yoo (2013) say is the case with digital innovation). Some exceptions exist. For example, Nambisan et al. (2017: 234) provide one of the few studies that focus on theoretical aspects, and they emphasize the need for making contextual connections with new theoretical logics to better understand digital innovation, because digital technologies “fundamentally transform firms and industries and question the key assumptions and themes that underlie innovation management. Research in this area will need to consider theoretical concepts and constructs that reflect and capture the myriad ways by which digital material can change both innovation processes and outcomes.”

According to McCaffrey (2012: 216, citing Duncker, 1945), a classic innovation obstacle is functional fixedness, which is described as the tendency to fixate on the typical use of an object or one of its parts, to the detriment of its potential for being used in a new way for solving a problem (e.g., “if someone needs a paperweight, but they only have a hammer, they may not see how the hammer can be used as a paperweight”). A similar phenomenon happens when new technologies are introduced: humans tend to use them in ways that are familiar. One way to potentially avoid the pitfalls of functional fixedness is by taking into consideration existing and new theoretical explanatory frameworks related to the use of digitization tools within innovation processes. Therefore, it is important to understand the various ways that researchers can approach and understand these phenomena. The problem is, how to organize the lenses.

A wide variety of contextual approaches to understanding digital innovation exists including, for example, some that are anchored in a resource based view and some in a process view (Nambisan, 2013; Cho, Mathiasson...
and Nilsson, 2008; Kaghan and Bowker, 2001; Klein, 2014; Lyttinen, Yoo and Boland, 2016; Lemus et al., 2017; Yu et al., 2010; among others). Nambisan et al. (2017) propose the notion of **orchestration** as a theoretical lens to examine “questions related to how digital technologies shape the nature and form of innovation as a collective action gain heightened significance”, explaining that this perspective builds on their previous conceptualization of digital innovation in terms of **dynamic problem-solution design pairing** related to an associated new organizational form that Afuah and Tucci (2012) call **problem-solving organizations**. Hylving (2015) uses the **competing values framework** as a theoretical lens to explore dynamic capabilities leading to control and stability yet originating and innovating from digitalization.

Researchers recognize that new technologies may challenge current research and development (R&D) and traditional manufacturing models, processes, and materials, especially since digitization tools enable rapid incremental and radical new product features and support much earlier customer integration in the design phase (Blichfeldt et al., 2017, following Conner et al., 2014; Hermann et al., 2015; Boer, 2016). Additionally, theoretical context is especially important when understanding digitization tools (Benerecetti, Bouquet and Bonifacio, 2001). However, the lenses through which to view these challenges vary widely.

It is clear from the preliminary literature review that a few aspects of digitization will be particularly important to examine: the autonomous (operant) versus non-autonomous (operand) nature of the tools and the effects digital innovation tools have on organizational changes due to fluid boundaries, agency ambiguities and changed knowledge interactions (Nambisan et al., 2017). Following is a brief description of these topics and related constructs.

### Autonomous (operant) versus non-autonomous (operand) digitization tools

Whether a digitization tool is human-controlled or autonomous is posited to have important effects related to a variety of theoretical logics (Nambisan et al., 2017). Nambisan (2013: 217) uses the terms “operand” and “operant” to explain the difference between non-autonomous (operand) and autonomous (operant) digitization tools, as follows: “operand resources are those resources (often tangible and static) that an actor uses in executing a task, whereas operant resources are those resources (often intangible and dynamic) that act on other resources to produce effects; that is, they act or operate on other things rather than being operated on.” According to this definition, autonomous tools are operant and non-autonomous tools are operand. Pratt (2015) says that some new operant technologies have the greatest potential for transforming innovation processes. Existing theoretical models largely ignore the potent new active role that operant technologies may play (Nambisan et al., 2017; Lyttinen, Yoo and Boland, 2016). Tools that have the capacity to be operant are frequently discussed as if they are solely operand, such as big data and cloud computing within CAI when they act as enablers of processes (Hüsig & Kohn, 2009), or as a support for decision making (McAfee and Brynolfson, 2012) rather than how CAI may itself accelerate and/or become an integral actor within innovation processes. Similarly, researchers focusing on information technology and big data within the innovation process mainly approach the topics in terms of their supportive capacity (as operands) rather than as active participants (as operants), thereby overlooking potential driving or other interactive effects. A notable exception is Lyttinen et al. (2016), who raise the prospect of understanding new product development in terms of the role digitization (big data/cloud computing) will play in reinventing/re-visioning existing products. These are rationales for capturing operand and operant aspects of digitization tools in the typology and focusing at a minimum on potential related theoretical lenses and effects.

Table 1 lists other potentially important theoretical constructs related to digitalization, which may be helpful for identifying research streams.

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<tr>
<th>THEORETICAL CONSTRUCTS RELATED TO DIGITALIZATION OF INNOVATION</th>
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<td>Fluid boundaries, duality and flow</td>
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<td>• Dynamic problem-solution design pairing, acknowledging fluid boundaries of the innovation space and potential for innovation agency to be distributed (Nambisan et al., 2017)</td>
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- Socio-cognitive sensemaking, acknowledging fluid boundaries of the innovation space and the heterogeneous actors that populate it (i.e., distributed innovation agency) (Nambisan et al., 2017)
- Technology affordances and constraints, acknowledging the receding distinctions (and the accompanying duality) between innovation processes and outcomes (Nambisan et al., 2017)
- Orchestration, problem-solution matching acknowledging the fluid boundaries of the innovation space and the potential for innovation agency to be distributed (Nambisan et al., 2017)
- Parallel concurrent innovation processes occur on multiple functional levels (Sommer et al., 2015)
- Flow of content out and ideas back (accordion model) within an open innovation context (Saldanha, Cohendet and Pozzebon, 2014)
- Idea generation processes interface with knowledge management processes through “coupling mechanisms” that link to idea-to-launch innovation processes (Cohendet and Simon, 2015)
- Core interaction model between direct and autonomous learning, acknowledging the variability of the boundary between proven knowledge and hypothetical knowledge, limitations in knowledge accumulations, and complementarity and conflict between direct and autonomous learning; direct learning and proven knowledge equate to closed innovation while autonomous learning and hypothetical knowledge constitute open innovation (autonomous learning is required for intelligent robots, autonomous vehicles, next-generation individual smartphones, and open innovation strategy and business model building) (Yun et al., 2016)
- Digital innovation activities include the coordination of increasingly complex “coordination arenas” or organizational platforms and three activities can be supported through these platforms: iteration and experimentation to support knowledge mobility; joint problem solving to support technological innovation appropriability; and balancing network stability with fluid network boundaries (Lakemond and Windahl, 2017)
- Integrating digital technology in industrial applications “alters system architectures into increasingly layered architectures, affecting the division of innovative labour across many different actors, and requires new approaches for recombinative innovation” (Lakemond and Windahl, 2017: 354, following Yoo et al., 2010; Lee and Berente, 2016; Nambisan et al., 2017)
- Design flow space that maps and integrates knowledge inspiration and knowledge flows related to computer-aided creative design (CADC) (Yang et al., 2016)
- Three traits common to digital technology innovations including the importance of digital technology platforms; the emergence of distributed innovations; and the prevalence of combinatorial innovation (Yoo et al., 2012)
- Dynamic innovation networks work via ‘fluids’ or ‘wakes’ rather than as traditional market ‘pushes’ and ‘pulls’ (Lyytinen et al, 2016)

### Agency and ambiguity / roles

- “A multiplicity of context-aware applications—each independently designed by different people—interact with each other to achieve goals that were not given in advance. In such a scenario, each application can have a different goal, and control can be distributed over a collection of autonomous, heterogeneous entities (software components, human users, etc.), henceforth called agents. This is what we call a distributed context-aware system—namely, a system where a collection of autonomous context-aware applications (co-)operate with each other (or with human agents) to achieve their own objectives or, as a special case, joint goals” (Benerecetti, Bouquet and Bonifacio, 2001)
- Issues of participation and control based on Actor-Network Theory (ANT) (Cho, Mathiassen and Nilsson (2008), following Latour and Callon (as described in Latour, 2001); Hinds et al., 2014), as well as other relevant logics of theorizing encountered during the literature review.
- Technology and the people in a work system are interdependent; technology affects the behavior of people, and the behavior of people affects the working of the technology (sociotechnical theory (STS); Klein, 2014)
- STS ideas on interactive planning can be combined with concepts from Actor-Network Theory (ANT) to investigate interdependent processes of invention and innovation in large sociotechnical networks (Kaghan and Bowker, 2001)
- Questions related to Actor-Network Theory (ANT): one network; different networks; connections between networks? Related: *Loose and Tight Coupling*; centralized / decentralized structure; context / agent / distributed goals (Latour, 2001)
- Questions related to innovation occurring in an actor-to-actor (A2A) network (Lusch & Nambisan, 2015) (because how do we define the role of operant AI?)

### Knowledge interactions

- Digitization redistributes control and increases the demand for knowledge coordination across time and space, presenting challenges for knowledge creation, assimilation and integration (Lyytinen, Yoo, and Boland, 2016).
- Role of software in supporting inter-functional cooperation and the coordination of knowledge and activities depends on the organization’s ability to nurture integrating routines which support two-directional translation
flows between ‘local’ (function-based) and ‘global’ (computer-embedded) knowledge and activity levels. These mechanisms also lie at the heart of dynamic capabilities’ creation and maintenance (D’Adderio, 2001)

- Harnessing of knowledge and knowledge integration requires “constructing hybrid human technology KM solutions (not machine-based KM solutions) [because] Human beings are better at “knowledge skills” while computers are more adept at “information tasks” such as collecting and categorizing highly structured information that changes rapidly. To interpret knowledge within a broader context or to combine it with other types of information, or to synthesize unstructured knowledge, humans and machines must complement each other” (Goh, 2005: 12)

- Technologies and social systems are equally important in knowledge management, and knowledge management is best carried out through optimization of technological and social subsystems; “When environment is dynamic, and complex, it often becomes essential for organizations that they continually create, validate, and apply new knowledge into their products, processes, and services for value-addition.” (Bhatt, 2001)

- Network orchestration dimensions include knowledge mobility, innovation appropriability, and network stability; and, “the technological platform itself (the demonstrator) seems to serve as the orchestrator” (Lakemond and Windahl, 2017: 360, following Nambisan, 2017)

- Multiagent learning: competitive learning, where agents work asynchronously on the same problem; and cooperative learning, where the final output result is a fusion or aggregation of the individual results of some agents. Also, ensemble learning models and single learning models (Yu et al., 2010)

- Machine Learning has better results when there is a pre-processing stage (Lemus et al., 2017)

- Characteristics related to service-dominance logic for understanding how innovation processes incorporate customers and other stakeholders as co-innovators who exchange and integrate resources to co-create value (Mele, Spena and Colacurcio, 2010)

- Knowledge transfer and knowledge integration relationships (D’Adderio, 2001; Singh, 2008; and Yun et al., 2016)

Other (integration, innovation types, architectural approaches etc.)

- Three necessary integration factors for digitization within innovation processes: horizontal integration, vertical integration, and end-to-end digital integration (Liao et al., 2017)

- Digitalization provides possibilities for new kinds of products, new kinds of processes. new kinds of enabling platforms and associated interface standards (Lyytinen, Yoo, and Boland, 2016)

- Architectural approaches in terms of innovation, technology and organization related to digital technology platforms and applications in different types of contexts, with Airports as new metaphor; Airports resemble a platform characterized by a central focus on safety and security, but once in place represents a number of recombination possibilities to bring together a number of affordances, including to let travelers (users) flexibly reach a number of different destinations, airport shops and other businesses surrounding airports. Consequently, recognizing that there is more to a city than a bazaar and a cathedral, we conclude that, in order to move the field forward and support further convergence in terms of generativity, safety, and security, digital platform and application development need new metaphors to inspire further development.” (Holmberg et al., 2017)

- Digital technologies increase innovation network connectivity and increase the speed and scope of digital convergence; four types of emerging innovation networks supported by digitization: project innovation networks; clan innovation networks; federated innovation networks; & anarchic innovation networks (Lyytinen, K., Yoo, Y., Boland Jr, R.J., 2016)

- Digital technologies share three traits: (1) the importance of digital technology platforms, (2) the emergence of distributed innovations, and (3) the prevalence of combinatorial innovation (Yoo et al., 2012)

- The Industrial Internet of Things (IIoT) triggers three novel business models (BMs), including Cloud-based BMs, Service-oriented BMs, and Process-oriented BMs (Arnold, Kiel and Voigt, 2017)

**Methods**

The research for Paper I includes three stages. The first stage was the initial literature search conducted in September using a systematic approach including keyword searches on the University of Southern Denmark (SDU) “summons”, and EBSCOhost Web (Academic Search Premier and Business Source Complete) and Wiley Online Library databases, and (outside the SDU system) on Web of Science. Keywords included stemmed iterations of “digital innovation”; digitization; “Industry 4.0”; “ideation platform”; “virtual platform”; “operand & operant & “innovation process”; “predictive analytics & “innovation process”; “cloud innovation process”; “internet of things (OR IOT)” & “innovation process”; “cyber-physical system” & “innovation process”; “information and communication technologies” (OR ICTs) & “innovation process”; “information and communication technologies” (OR ICTs) & “in innovation process”; “artificial intelligence” (OR AI) and
“innovation process”; “human-computer-interface” (OR HCI) & “innovation process”; “machine learning”; “deep learning” & “innovation process”; “virtual (OR augmented) reality” & “innovation process”; “Social and Smart (OR SandS)”; “cloud robotics”; “Web 2.0” & “innovation process”; “learning algorithm” & “innovation process”; “actor network theory machine learning and innovation” and “embedded knowledge” & digitization; and “big data” & analytic & “innovation process”. Additionally, I searched EBSCO host Journal of Human-Computer-Interaction (scholarly peer-reviewed) using the following keywords: “operand & operant & innovation & process”; “operand & operant”; “autonomous & learning & innovation & process”; and “autonomous OR ‘machine learn’ & innovation & process”. I also reviewed abstracts of all papers presented at the September 2017 18th International CINet Conference themed “Digitalization and Innovation: Designing the organization of the future.” Relevant studies are saved in an EndNote library (n= 708 potentially useful articles). After an abstract review and keyword search using EndNote, I added relevant articles into NVivo Pro (n= 155 items).

The second stage will be to assess the evidence base of qualitative and quantitative studies in order to identify research streams. An aspirational goal for the synthesis is to follow Brown and Eisenhardt’s (1995) seminal integrative innovation management work, which enables recognition of how the literature is organized in streams of empirical research perspectives, each with benefits and deficits. Such comparative analysis allows “complementary and sometimes overlapping insights” and a new integrative model.

At the same time, a goal of the research is to investigate potential linkages between digital tool features and innovation performance. This means the literature review needs to define innovation performance, and define tool-related aspects that may connect to innovation performance.

Following is a preliminary matrix designed for the second-round review of the literature to capture relevant aspects of digital innovation research, enable recognition of complementarities and insights, and set conditions for deriving potential hypotheses.

### Table 2: Proposed Matrix for Organizing IM and IS Literature Regarding Digitization Tools Within the Innovation Value Chain

<table>
<thead>
<tr>
<th>Study Author, year</th>
<th>Digitization Tool Mechanisms</th>
<th>Context</th>
<th>Measures</th>
<th>Effects (especially as may be relevant for innovation performance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DT1) Digitization Tool Name (delivery model), Product Description, features and examples (Oswald &amp; Kleinemeir, 2017)</td>
<td>DT2) Purpose: Generation (development) or adoption (use) of new ideas or behaviors (Damapour et al. 2012 based on Amabilie, 1988; Van de Ven, Angle, &amp; Poole, 2000; Zaltman, Duncan &amp; Holbek, 1973) DT3) Type of digitization (Operand / Operant) (Nambisan, 2011)</td>
<td>C1) Phase(s) when tool is used (initiation, development, implementation/termination) (Tidd &amp; Bessant, 2013) C2) Occurrence within the organization’s innovation value chain (functional ‘location’) C3) Interface within the innovation value chain C3i) functional responsibility area(s) C3ii) internal and/or external interface C4) interaction characterized as human-to-computer (H-C), computer-to-</td>
<td>P1) Pervasiveness within the organization’s innovation value chain P1i) digital assets P1ii) digital usage P1iii) digital workers P2) Digitization tool is explicitly connected with co-creation P3) Digitization tool is explicitly connected with co-production P4) Digitization tool capabilities are being fully utilized</td>
<td>E1) Improved performance (time to market, novelty, etc.) E1) Organizational effects related to theory (boundaries; knowledge; agency; etc.) (Nambisan, 2013; Nambisan et al., 2017); platform-related new dynamics within organizations (Gobble, 2014; Valkokari, 2015; Wallner and Menrad, 2011; Rabelo and Bernus, 2015; Carayannis and Campbell, 2009 and 2011) &amp; other (tbd)</td>
</tr>
</tbody>
</table>
2013; Nambisan et al., 2017)
DT4) Type(s) of integration (Minds & Machines / Products & Platforms / Core & Crowd) (McAfee & Brynjolfsson, 2017)
DT5) Cyber-physical technology driver(s) (BCG and Innovationsfonden, 2016)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>computer (C-C), or computer-to-human (C-H)</td>
<td>P5) Reduced time to market</td>
</tr>
<tr>
<td>CS) Type of innovation (product &amp;/or service, process; organizational; marketing (OECD Oslo Manual, 2005)</td>
<td>P6) Increased novelty</td>
</tr>
<tr>
<td></td>
<td>P6) Other...</td>
</tr>
<tr>
<td>E2) Role as supportive enabler OR integrative part of service delivery</td>
<td>E3) Type of innovation (radical, incremental, architectural, or modular (Smith, 2010: 32 based on Henderson, R.M. and K.B. Klark, 1990)</td>
</tr>
<tr>
<td>E4) Other...</td>
<td></td>
</tr>
</tbody>
</table>

For the third stage, it will be helpful to use information systems knowledge mapping techniques to assist with identifying and analyzing research streams because terms, concepts, and theoretical lenses are so diverse and fragmented, (Dang et al., 2011). I will first conduct word frequency queries to make word clouds, tree maps and cluster analyses using NVivo 11 Pro. I will widen the keyword search for additional literature if the clustered words do not seem sufficient for capturing target topics. Then I will use VOSviewer to search for research topic clusters and streams. Figure 1 is a word cloud example from the current NVivo article set and Figure 2 is representative of a visualization that can be created using VOSviewer.

**Figure 1** Word cloud from searched articles loaded into NVivo 11 Pro

**Figure 2** Representative depiction of VOSviewer visualization

The fourth stage involves writing and disseminating the review, including research stream analysis and insights leading to proposed hypotheses for studying how digital innovation tools enable innovation performance. The finished review will provide the basis for Papers II, III, IV and V.

**Paper II. Framework for categorizing and creating a typology for understanding occurrences, usage, roles and relationships of digitization tools in the context of product and service innovation, process innovation, marketing innovation, and organizational innovation processes.**

The goal of Paper II is to create a categorization and/or typology framework by which to understand digital innovation tool use and effects throughout an organization’s innovation value chain. This is not intended as a method for gathering an exhaustive list of every possible tool, but rather as a framework including the questions to ask for explaining tool types, features, potential usage, whether operand or operant, interfaces between humans and machines, interfaces between machines, whether tools are used as intended, and innovation performance indicators connected with digital innovation.
State of the art

A useful analytical framework by which to understand the occurrence and effects of digitization tools within innovation value chains should incorporate relevant categorization and typology aspects of both innovation management (IM) and information systems (IS) management. Paper II will provide an integrative theory-based framework and approach for investigating the occurrence of digitization within organizational innovation value chains, and potential effects. Once a framework is established with key aspects identified, it will be possible to derive appropriate questions by which to describe the organization’s digitization tools.

There are a variety of approaches proposed in both fields. For example from the IS literature, Ralyté, Rolland, and Deneckère (2004: 204-205) classify types of method engineering (ME) approaches then provide a meta-tool for change-centric ME based on a set of ME operators (called “Operator-driven Method Engineering Framework”) and a meta-model “which has been designed to highlight characteristics of models involved in a ME activity and therefore to permit to identify the fundamental construction and transformation operations which can be executed on a model.” On the other hand, from innovation management literature, Cheng, Chang and Liu (2013) offer a conceptual model with an integrated framework involving antecedent paths to successful product innovation, and Smith (2010) offers a typology to differentiate four types of innovation based on systems and components and their associated changes.

The to-do list includes further study to find and integrate categorization and typology approaches from both literatures, and then determine the most important aspects to study to understand linkages between digitized tool use and innovation performance.

Table 3 includes preliminary considerations found during the partial literature review.

<table>
<thead>
<tr>
<th>Table 3 Potential Research-based Categorizations to Incorporate in the Typology</th>
</tr>
</thead>
<tbody>
<tr>
<td>• categories provided by Stentoft, Rajkumar and Madsen, 2017 (following Deloitte, 2015, and Dujin et al., 2014); BCG and Innovationsfonden, 2016: 8, and basic information about the tool’s:</td>
</tr>
<tr>
<td>o purpose</td>
</tr>
<tr>
<td>o information type (text, sound, image, voice, other sensory information)</td>
</tr>
<tr>
<td>o presence: physical object or nonphysical model</td>
</tr>
<tr>
<td>o algorithm that influences the tool or digitization technique</td>
</tr>
<tr>
<td>• ascertain perception of the degree to which the digitization tool (following Hinds et al., 2014):</td>
</tr>
<tr>
<td>o is an automatic/mechanical “instrument”</td>
</tr>
<tr>
<td>o has aspects that make it seemingly a conscious/emotional “collaborator”</td>
</tr>
<tr>
<td>• assess the degree to which the tool is (following Lytinen et al., 2016; and based on Nambisan, 2013) an:</td>
</tr>
<tr>
<td>o operand resource (defined as an often tangible and static resource that an actor uses in executing a task)</td>
</tr>
<tr>
<td>o operand resource (defined as an often intangible and dynamic resource that acts on other resources to produce effects; that is, it acts or operates on other things rather than being operated on).</td>
</tr>
<tr>
<td>• characterize whether employees view the digitization tool as:</td>
</tr>
<tr>
<td>o operating autonomously (indicating operand tools such as artificial intelligence, machine learning, Cloud Robotics, etc.)</td>
</tr>
<tr>
<td>o operating non-autonomously (indicating aspects that are mechanical, instrumental and/or operand).</td>
</tr>
<tr>
<td>• assess the degree of alignment between how the employees characterize the digitization tool and the way the developers characterize the digitization tool along the above (and potentially other) dimensions</td>
</tr>
<tr>
<td>• characterize whether the knowledge transfer and knowledge integration relationship of the implemented digitation tool during each specific point in the innovation process represents an interaction as:</td>
</tr>
<tr>
<td>o local (“function-based”) (D’Adderio, 2001)</td>
</tr>
<tr>
<td>o global – computer-embedded (D’Adderio, 2001)</td>
</tr>
<tr>
<td>o human-to-human</td>
</tr>
<tr>
<td>o human-to-computer</td>
</tr>
<tr>
<td>o computer-to-computer</td>
</tr>
<tr>
<td>o computer-to-product</td>
</tr>
<tr>
<td>o computer-to-Cloud</td>
</tr>
</tbody>
</table>
• characterize the types of knowledge the tool creates (following Singh, 2008; and D’Adderio, 2001):
  o Tacit knowledge (implied, and/or difficult to transfer to another actor by means of writing it down or verbally communicating it)
  o Explicit knowledge (recorded/codified, and/or easy to access, verbalize, or otherwise transmit to others)
  o Embedded knowledge
    ▪ Software-embedded knowledge
    ▪ People-embedded knowledge
    ▪ Knowledge which resides in systemic routines, and can be analyzable in systems terms (following Badaracco, 1991)
  o Formal or informal
  o Background knowledge and foreground knowledge (Bhatt, 2001)
  o Knowledge (“the context within which information is interpreted”) vs concrete information (“facts” about products, processes, and markets); and general knowledge vs abstract knowledge (general and abstract knowledge has to be combined with concrete information, because one also has to attend to the ‘details’ that are typically ignored by abstract representations” (Arora and Gambardella, 1994)

• characterize types of knowledge transfer being handled by digitization tools, following Yun et al. (2016):
  o direct learning leading to proven knowledge (closed innovation)
  o autonomous learning leading to hypothetical knowledge (open innovation)
  o some other configuration not captured by Yun’s model e.g., Bhatt (2001): “technical artifacts are enablers to organize data into information, and people are endowed with interpretative capabilities” (will autonomous tools challenge this assertion?)

• describe where and how user interfaces occur

• describe context within which the digitization tool operates (internal to firm; external to product; external to another computer; external to Cloud); context is an important consideration related to ANT

• characterize aspects of the digitization tool according to issues of participation and control (following Cho, Mathiassen and Nilsson, 2008; based on Latour and Callon’s (1986) Actor Network Theory (ANT) as described in Latour, 2001):
  o Actor (or actant) – “Any material, that is, human beings or nonhuman actors”
  o Actor-network – “Related actors in a heterogeneous network of aligned interest”
  o Translation – “How actors generate ordering effects by negotiating or maneuvering others’ interest to one’s own with the aim to mobilize support”
  o Inscription – “Embodied translations into a medium or material”
  o Enrolment – “Mobilize support by creating a body of allies through translations”
  o Irreversibility – “The degree to which it is subsequently impossible to go back to a point where alternative possibilities exist”
  o Immutable mobile – “A materialized translation that can be interpreted in essentially the same way in a variety of contexts”
  o Black box and punctualization – “A temporary abstraction of a network that acts as a single unit so the network effaces into one actor”

• describe the degree of alignment between employees who have user interface with the digitization tool and developers of the digitization tool, along the above dimensions

**Methods**

The first and most crucial stage is the challenge to identify approaches and components that should be in the framework so that it can describe and map digitization tool features and their linkage to innovation within the organization’s innovation value chain in a meaningful way that allows for analysis and theorizing about their enabling effects. This requires a literature search and review of existing studies and approaches.

From an IM perspective, it could be useful A useful foundation for this framework is based on a model by Crossan and Apaydin (2010: 1167), which provides a multi-dimensional framework of organizational innovation connecting process theory with dimensions of innovation including innovation as a process and innovation as an outcome. Then, within a process level of analysis, at a minimum the digitization tools and their features should be tracked to/with operation of innovation processes in three phases: ideation (i.e., idea generation, evaluation, and selection), invention (i.e., prototype development and testing), and exploitation (i.e., large scale production and commercialization) (Gerke et al., 2017 following Bergendahl & Magnusson, 2015; Damanpour & Schneider, 2006; Dougherty, 1992; Roberts, 2007; Schweisfurth & Herstatt, 2016). The
framework also should try to capture if the tool features have separate or integrated parallel innovation efforts related to product innovation (and/or service innovation), process innovation, organizational innovation and marketing innovation), as defined by the OECD Manual (2005), as well as any predetermined theoretical constructs and areas of inquiry that come from the literature review. It will be important to capture information that can help assess performance connected with digitization tool features.

Taking a process approach does not imply that this will be a linear effort. As Tsekeris and Katerelos (2012) explain, when Web 2.0 is added to the mix we are looking at “ultra-complex networks exchanging or co-creating information and knowledge, ceaselessly re-constituting and re-shaping the social structure.” Zhan et al. (2017) call for a model that can capture Accelerated Process (A), Connection (C), and Ecosystem (E) aspects of digitized innovation. Jea Hoo et al. (2017) provide an interesting model related to the design innovation spectrum, which may be possible to adapt for this project. The framework used for this PhD project must also be able to show digitization tool-enabled internal and external knowledge flows. From the IS perspective, Hevner et al. (2004) explain that information technology implementation should be considered within a specific contextual environment and knowledge base to provide relevance and rigor; they offer a design-science research framework which integrates the implementation of information technologies.

Clearly, this part of the project requires further investigation to find or create a model that captures the tasks and enables an analysis leading to optimal categorization and potential typologies.

The second stage involves building hypotheses, and designing a study (stage three) that tests them with appropriate and robust data validation methods. This can occur once the framework is determined and involves creation of the data collection tools including qualitative interviews and quantitative survey questions that will be used for the case studies. To the extent possible, questions will be adapted from pre-validated studies. Additionally, during this stage it will be possible to identify any additional quantitative data that should be collected in support of the project (e.g., organizational charts, digitization tool descriptions, organizational policy guidelines regarding digitization tool use, etc.)

The fourth stage is to conduct a test of the categorization framework interview and survey tools with a focus group of students who have innovation management training, to ensure the concepts are clear. Before conducting onsite interviews and surveys, I will conduct a test of the interviews and surveys with students who have experience with digitization and innovative processes, to ensure the study design enables appropriate actions and reactions of the subjects and draws causal relations that can be analysed. Based on this input, it will be possible to adjust and prepare for deploying the qualitative and quantitative tools needed for Paper III.

**Paper III. Mapping digitization tools within organizational innovation operations.**

**State of the art**

On the to-do list for Paper III is a review of IM and IS literature to understand how best to map occurrences of digitization tools in use within organizational value systems. At a minimum, I would like to show three layers of information related to occurrences and activity patterns of digitization tool usage (especially the operant variety): where is tool use happening or not happening; where are human-computer and computer-computer interfaces; and where is innovation performance in relation to digital tool usage.

**Methods**

The research setup will involve mixed methods with a mostly qualitative approach including semi-structured interviews, observational activity, and case studies of participating firms, and with supportive analyses of quantitative data collected from questionnaires. Analyses will also include secondary data obtainable about the digitization tools such as product promotional materials, guidelines, reports, and other available information about deployment of the tools within the company. For Web-connected tools and platforms, I am consulting
with a software engineering colleague from SDU’s TEK to find out how to capture the information that will be needed to describe utilization data.

By this point in the project I will have conceptualized and developed the categorization framework and now will be the time for ensuring a robust research design and one final test before deploying it (stage one). I will consult and follow works by Eisenhardt (1989) and Yin (2014) regarding case study conditions to establish and processes to follow to enable grounded theory building (theorizing will occur during the next phase of the project - Paper IV).

For stage two, the developed framework will help me identify my “best case” scenarios. I will create a case selection matrix to help during my search. The proposed selection criteria will include large companies in the high tech industry because the MGI Industry Digitization Index (Manyika et al., 2015), indicates highest digitization scores for this sector. I will also use CIS and EMS data to help identify candidate cases.

Following Yin (2014), the third stage involves pilot testing the interview and survey questions (developed during Paper II) with two innovation managers from case companies. The purpose is to show them the proposed qualitative and quantitative questions and ask for feedback to ensure the questions are understandable and able to identify conceptual areas of interest to the project and the managers. Once the protocol is tested, it will be possible to create an interview guide for standardization and quality control purposes. Interviews and the survey tool will be translated and back translated to get correct terminology, so employees can respond in their native language; responses will be translated into English.

The fourth stage is the actual data collection using the interview guide and protocol. To avoid possible hierarchical effects and cluster effects during the analysis phase, instead of looking within just one company I will conduct the study with a variety of companies. I will gather data in Denmark, Germany, and the U.S.A. (the three countries compared in the BCG and Innovationsfonden (2016) report), and possibly Sweden. After onsite interviews with innovation project managers to find out about the digitization tools that are currently in use in the firm’s innovation processes, and collection of logged usage data from the machines, I will conduct a preliminary mapping of discussed digitization tools’ and their characteristics into the draft typology framework.

For the fifth stage, based on an assessment of knowledge gaps I will adjust the typology categories and interview questions before going back to the company to conduct a semi-structured qualitative interview and brief quantitative survey (questionnaire) with persons who interface with the digitization tools to understand how these tools may enable an organizations’ product (and service) innovation, process innovation, organizational innovation, and market innovation. This onsite study phase will be with a cross-section of employees who are familiar with the innovation process and with the involvement of digitization tools (front line to executive leadership levels, and from a variety of departments). To minimize alienation and pre-response bias, I will include a vertical cross-section of respondents from multiple levels within the hierarchy, and include departments that have varying lengths of experience with the innovation processes and digitization tools. I will also investigate attributes of the digitization tools themselves. This part of the research will focus on mapping and understanding roles of humans and digitization tools within innovation processes.

By the sixth stage I will have data to work with to conduct data analysis. Even though the data analysis is listed here as a ‘stage,’ analyses will be conducted in an iterative manner (following Eisenhardt, 1989) from the pre-interview stage (when it will be important to analyze the organizational structure and conceptually understand how the tools are deployed in the organization, in order to request interviews with appropriate personnel) as well as during interviews, (when it will be important to recognize when fluid boundaries, knowledge dynamics, or ambiguous agency situations are present and perhaps offer an opportunity for further questioning). This iterative analysis is especially important because innovation processes run parallel to each other and digitization tools may be also used differently for each process, as well as differently for various innovation types and organizational circumstances.

Digitization tools are very context-specific and dynamics are not well-explored, so I am not certain whether cross case analysis using Eisenhardt’s (1989) tactic of selecting a dimension, and considering similarities and
differences between cases in the context of that dimension will be useful (although, following Hedman and Kalling (2002), the process will involve asking the same question regarding each digitization tool element within the firm’s innovation processes). In any case, during the analysis stage it will be important to look for synergies and contractions that can be understood when comparing the data with findings in existing studies. Where the results seem to diverge from the literature, I will use appropriate reliability and validity tests.

After analyzing the data, it will be possible (in stage seven) to visualize and report the collected data. For example, Figure 4 shows a representative heat map that may be useful for indicating where and how much the digitization tools are used within the organizational value system (following Boye et al., 2017). It will also be useful to find relationships and interactions among digitization tools and humans (human-computer-interactions, or H-C-I), as well between digitization tools; network analysis enables a visualization of degree centrality and betweenness which can help identify the most important actors in the network (Figure 5 and Figure 6 show representative visualization examples). It may also be helpful to adapt methodology and variables Boudreau et al. (2014) created to measure “information diversity and the approach used to index the temporally correlated heterogeneous behavior of activity.” Figure 7 shows an example of an activity pattern analysis which would be useful to adapt because it shows functional as well as dysfunctional activity (following Boudreau et al. (2014)). Finally, there will also be a visualization to show connections between the digitalization tools and innovation performance (not shown here, but which I conceive of as a blend of Figures 5 and 6).

**Figure 4** Representative depiction of heat map visualization

**Figure 5** Representative depiction of network analysis visualization

**Figure 6** Representative depiction of internal and external H-C-I interactions (based on airline route map)

**Figure 7** Representative depiction of activity pattern analysis (helpful for capturing bursts of activity as well as identifying poorly coordinated activity)
Paper IV. New theoretical logics related to digitization tool use in the organization’s innovation value chain, and innovation management considerations when converting from innovation to digital innovation.

State of the art

The approach for this part of the project will be to first explore the range of existing and new theoretical lenses and logics to better understand potential dynamics and effects occurring when digitization tools are introduced and operating, then to test whether/which lenses are applicable related to digitization tool use at various points within the innovation value chain. It will be useful at this point to refresh the literature review and look for topics that appear to be most relevant, following the data collection.

Methods

After completing Papers I, II, and III it will be possible to scrutinize the information and search for existing and potential newly grounded theoretical logics that are supported by observation.

<table>
<thead>
<tr>
<th>TABLE 4 PROPOSED MATRIX FOR COMPARING RESEARCH STREAMS (ADAPTED FROM BROWN &amp; EISENHARDT, 1995)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparison of Research Streams</td>
</tr>
<tr>
<td>Key idea</td>
</tr>
<tr>
<td>Theory</td>
</tr>
<tr>
<td>Methods</td>
</tr>
<tr>
<td>Product</td>
</tr>
<tr>
<td>Market</td>
</tr>
<tr>
<td>Senior management</td>
</tr>
<tr>
<td>Project team</td>
</tr>
<tr>
<td>Communication</td>
</tr>
<tr>
<td>Organization of work</td>
</tr>
<tr>
<td>Project leaders</td>
</tr>
<tr>
<td>Customers</td>
</tr>
<tr>
<td>Suppliers</td>
</tr>
<tr>
<td>Other... ...</td>
</tr>
<tr>
<td>Performance (dependent variable)</td>
</tr>
</tbody>
</table>

Finally, I will analyze hypotheses in terms of employee responses and mined data, theorize on ways digitization tools may be antecedents of or otherwise interact within an organization’s innovation value chain, and identify and validate results that are especially relevant for innovation managers’ understanding of how digitization tools may enable innovation processes.

Paper V. Revolution, Machine-workers and Organization Studies

(Company: Rasmus Koss Hartmann, Anders Dahl Krabbe, and Vella Somoza Sanchez)

*How new technology is poised to change the object of organization studies, namely work as it gets done in organizations.*

This purely conceptual work is designed to be thought-provoking about ways new technology and cyber-technical relationships within organizational innovation value chains are paradigm shifting organization studies. Drawing from ‘tried-and-true’ IM arguments (e.g., Brown and Eisenhardt, 1995), the article will pose challenging questions to encourage new thinking. For example:
• When ‘Watson’ joins your innovation value chain, can Watson serve as an effective gatekeeper?
• Can ‘Watson’ be an effective ambassador for your company?
• Once ‘Watson’ learns how to understand nuances, make sense of fluid conditions, and offer critical insights to break down cross-functional barriers, will Watson take on organizational leadership roles?
• Until ‘Watson’ can explain its decision-making processes, how should humans incorporate Watson’s recommendations?
• When ‘Watson’ grows up, will organizations no longer need humans?

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