Journal of the Association for Information Systems

Volume 15 | Issue 7 Article 1

7-23-2014

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Recommended Citation

Sandberg, Johan; Mathiassen, Lars; and Napier, Nannette (2014) "Digital Options Theory for IT Capability Investment," *Journal of the Association for Information Systems*, 15(7), .
DOI: 10.17705/1jais.00365
Available at: https://aisel.aisnet.org/jais/vol15/iss7/1

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Journal of the Association for Information Systems
JAIS

Research Article

Digital Options Theory for IT Capability Investment

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Abstract

While research has shown that investments in IT capability may translate into improved firm performance, how and why they do is still a source of debate. Drawing on financial options thinking, recent research suggests that managers can support appropriate investment decisions by examining digital options. However, current research has not effectively translated the financial options construct into the IT domain, which makes it difficult to rigorously examine digital options. To address this void, we revisit general options theory and review current notions of digital options. To support understanding, we extend current theorizing by offering a rigorous conceptual foundation that defines the digital option lifecycle and relationships to neighboring constructs. To support practice, we present principles for examining digital options for a specific business process. To illustrate the detailed workings of the theory, we examine a production planning process in the dairy industry to arrive at a set of desirable and feasible IT capability investments. Our proposed theory supports managerial practice by offering a rigorous and actionable foundation for digital options thinking. It also sets an agenda for academic research by articulating theory-based constructs and principles that are subject to further empirical and theoretical investigation.

***Keywords**: Digital Options, IT Capability Investments, Information Requirements, Process Innovation, IT Strategy.*

* Fred Niederman was the accepting senior editor. This article was submitted on 7th November 2012 and went through two revisions.

Volume 15, Issue 7, pp. 422-453, July 2014

1. Introduction

Although it is well known that investments in information technology (IT) can improve firm performance, scholars still debate how managers should approach investment decisions in IT strategizing (Bharadwaj, 2000; Brynjolfsson & Hitt, 1998; Kohli & Devaraj, 2003; Wade & Hulland, 2004). Observing that the performance impact of IT is best examined related to specific business processes (Ray, Barney, & Muhanna, 2004; Pavlou & El-Sawy, 2006), we suggest that managers may adopt such a focus to identify desirable and feasible IT capability investments. A firm's IT capabilities represent the application of physical or intangible IT resources such as technology, knowledge, practices, relationships, management skills, business process understanding and human resources to further organizational goals (Mathis, & Goodhue, 1996, Bharadwaj, 2000; Bhatt & Grover, 2005; Peppard & Ward, 2004).

With endless technological choices available, Sambamurthy, Bharadwaj, and Grover (2003) suggest managers use digital options thinking to identify which IT capability investments may provide performance gains. An option captures a specific investment opportunity and gives the holder a preferential advantage in eventually making the investment. In the management literature, options thinking supports strategy "as a process of organizational resource investment choices" (Bowman & Hurry, 1993, p. 760). As such, a firm's options stem from its capabilities and environmental opportunities. Translating this general notion to the IT domain, Sambamurthy et al. (2003) argue IT capability investments result in specific digital option characteristics that support different competitive actions. Managers may therefore draw on digital options thinking to examine IT capability investments without obligation to pursue them, to evaluate and bundle options into proposed investment actions, and to selectively invest in specific IT capabilities. Accordingly, we consider a firm's bundle of digital options as possible investments in or liquidation of IT capability enabled by its current capabilities and expectations regarding future opportunities.

Although Sambamurthy et al. (2003) convincingly position digital options to support IT capability investments, their translation of the financial option construct into the IT domain can be rendered more effective. In particular, their theorizing does not provide a clear understanding of how digital options relate to current and to future IT capabilities; it does not account for differences that may exist between managing financial investments and IT capability investments; it defines a restricted repertoire of digital option characteristics; and it does not take into account how the meaning of options change as an investment process progresses. As a result, it is difficult to apply current theorizing to rigorously examine digital options.

To move our understanding of digital options forward, this paper extends current theorizing in two ways. First, we provide a rigorous conceptual foundation that supports understanding of digital options through analysis and description (Gregor, 2006, p. 619). We present a conceptual model of digital options and neighboring constructs such as information requirements, IT capability, and process performance, and we draw on general options theory to distinguish between available, actionable, and realized digital options. Second, we rely on this conceptual foundation to provide principles for practical examination of digital options through prescription (Gregor, 2006, p. 619). The principles describe the relationship between information requirements, IT capability investments, and digital options characteristics, and they explicate how to iteratively examine digital options for a specific business process.

We illustrate the detailed working of the proposed theory by examining IT capability investments into a distributed production process in the dairy company Norrmejerier in Northern Sweden. Focusing on the production planning process, we analyze its performance, elicit the information requirements for each process task, and identify a set of actionable digital options that represent desirable and feasible IT capability investments. Although the case mainly serves illustrative purposes in the paper, we developed the presented theory by iteratively moving between detailed analyses of the empirical material, exploring general options theory, and critically reviewing current digital options theorizing.

2. Understanding Digital Options

Drawing on Gregor's (2006) taxonomy of goals for information systems theory, we extend current theorizing by presenting a digital options theory that 1) supports understanding through analysis and description, and 2) supports practice through prescription. In this section, we begin by reviewing general options theory and current translations into the IT domain. We identify key characteristics and limitations in current theorizing and present the conceptual foundation for the proposed digital options theory.

2.1. Existing Theory on Digital Options

Financial options capture a specific investment opportunity to which the holder has preferential advantage. Such options are acquired by a first small investment and activated by a second larger one if and when certain events make it profitable to do so (Black & Scholes, 1973). Holding options is intuitively attractive in decision making, both in personal matters and in organizational decision-making since it enables a multitude of future actions. Options may be available for acquisition, be available for activation, be struck, and, at a certain point, expire. Applied to organizational strategy, options reflect incremental decision making on resource investments to frame future actions rather than to merely constitute a specific path (Bowman & Hurry, 1993; Luehrman, 1998). Available resources and capabilities generate different options (e.g., Coca-Cola has other technological investment opportunities than the local pizza establishment due to differences in available capital, business process maturity, and technological capability).

While financial options have important similarities to strategic options, there are also differences. Financial options are first acquired and then activated through simple transactions on financial markets. Although strategic options also depend on previous investments, they are mainly acquired through analysis of a firm's actions and resources. Focusing on options thinking in relation to strategy, Bowman and Hurry (1993) describe a lifecycle model (the options chain) that reveals the incremental nature of investment decisions and the propensity of acquired resources to create new options. In the options chain, options can take three forms: shadow options, real options, and struck options. A firm normally has a large number of unknown investment alternatives available, but the opportunity to activate them requires that they are recognized. Options that are available but await recognition have been referred to as shadow options (Bowman & Hurry, 1993). Through recognition and sometimes by strengthening connections to the option, shadow options may become real options that await activation. Decision makers may at a later point strike an option by making the related resource investment, which may then generate new shadow and real options.

In the IS field, options have primarily been used to examine valuation of IT investments (e.g., Benaroch, 2002; Fichman, 2004). As an alternative, Sambamurthy et al. (2003) emphasize how options can support an organization's ability to translate IT capability into business performance. Specifically, they argue digital options, entrepreneurial alertness, and agility are dynamic capabilities that enable a portfolio of competitive actions. They describe IT as a digital options generator and state that "digital options develop through an iterative learning process of integrating information technologies with business processes and knowledge" (2003, p. 253). Such efforts require strategic foresight and systemic insight into current practices and configurations to anticipate discontinuities in the business environment, marketplace, and IT space. Defining digital options as "a set of IT-enabled capabilities in the form of digitized enterprise work processes and knowledge systems" (p. 247), they propose digital options vary along two characteristics: process vs. knowledge capital and reach vs. richness. For each of the resulting four option types, they outline how to evaluate an organization's current state, the benefit of exercising the option, and salient enabling ITs.

While Sambamurthy et al. (2003) persuasively position options thinking for IT capability investments, they fail to effectively translate options constructs into the IT domain. First, they do not provide a rigorous definition of how digital options relates to neighboring constructs such as current and future IT capabilities. As a result, it is difficult to appreciate important nuances in their argument. Second, they neglect important differences between financial and strategic options: financial options are acquired through a first, simple monetary transaction; in contrast, strategic options are acquired through recognizing opportunities and resources. Their theorizing therefore remains vague on what is involved in acquiring a digital option. Third, their theorizing only considers reach and richness characteristics. As a result, they restrict the generative power of digital options thinking to a limited repertoire for how IT investments can address business process requirements. Finally, Sambamurthy et al. (2003) do not explicate option dynamics (i.e., interactions between available options awaiting recognition, actionable options awaiting activation, and realized options), which makes it difficult to practically examine IT capability investments based on options thinking. Against this backdrop, we propose a re-conceptualization of digital options.

2.2. A Conceptual Foundation of Digital Options

To support understanding, theories should describe key constructs and their relationships (Gregor, 2006, p. 619). Accordingly, we examine the constructs of IT capability investment, process performance (Novak & Cañas, 2008; Wand & Weber, 2002), information requirements, and digital options.

2.2.1. IT Capability Investment

IT capability stems from a firm's previous investments in IT resources such as acquiring new technology, developing IT competence, and learning how to further organizational goals. To improve performance, managers can consider new investments in IT infrastructure, the portfolio of applications, IT skills and processes, and IS-business partnerships (Bharadwaj, 2000; Bhatt & Grover, 2005; Peppard & Ward, 2004). For example, based on investments in telemedicine to facilitate partnerships with remote physicians, a rural hospital may consider new IT capability investments such as purchasing mobile devices, providing technical training for hospital staff, and deploying new diagnostic software.

2.2.2. Process Performance

While IT capability impact on organizational performance is not easily measured, scholars have argued that it is best examined in relation to specific business processes (Barua, Kriebel, & Mukhopadhyay, 1995; Pavlou & El Sawy, 2006; Ray et al., 2004). Accordingly, we develop digital options thinking for improving a specific business process through IT capability investments. A process can be described as "a specific ordering of work activities across time and place, with a beginning and an end, and clearly defined inputs and outputs: a structure for action" (Davenport, 1993, p. 5). A process perspective focuses on the main area for IT-enabled firm performance (Barua et al., 1995; Pavlou & El Sawy, 2006; Ray et al., 2004); it affords consideration of IT capability in inter- and intra-firm interactions (Tallon, 2007); it offers interpretive flexibility in moving between very broad, comprehensive processes and more narrow, dedicated processes (Davenport, 1993); and it brings the considerable body of practical knowledge on business process transformation into play (Grover & Markus, 2008).

2.2.3. Information Requirements

To identify digital options for a specific business process, we draw on classical insights on organizational information processing (Watson & Frolick, 1993; Wetherbe, 1991). Our starting point here is Daft and Lengel's (1986) distinction between the uncertainty and equivocality requirements of a specific task, and we add connectivity requirements to reflect that business processes consist of several separate tasks (Davenport, 1993) that need to be integrated across organizational boundaries (Malhotra, Gosain, & El Sawy, 2005). Hence, business processes may vary in terms of the need to share information across boundaries (connectivity), the availability and reliability of information (uncertainty), and the complexity and ambiguity of information (equivocality). For example, in diagnosing tasks that are ambiguous and open to multiple interpretations (high equivocality), a rural hospital may lack IT capability to share patient records with larger hospitals for diagnostic purposes (high connectivity) although the information is locally available and reliable (low uncertainty). Each such combination of information requirements suggests different types of IT capability investments (Goodhue & Thompson, 1995).

2.2.4. Digital Options

We translate the general options chain (Bowman & Hurry, 1993) to distinguish between digital options that are available, actionable, or realized. Available digital options are potential investments—enabled by existing IT capabilities and addressing relevant business opportunities—which lay dormant awaiting recognition by an organization. During a process improvement effort, available options may be systematically examined in terms of desirability and feasibility and to recognize the most suitable as actionable digital options. Eventually, if a decision is made to invest in the proposed IT capability, the digital option is activate and becomes a realized digital option.

Table 1. Digital Options Chain

Financial options		Digital options	
Construct	**Definition**	**Construct**	**Definition**
Shadow option	An investment opportunity in the option bundle that awaits recognition	Available digital option	An IT capability investment opportunity in the option bundle that awaits recognition
Real option	An option to which you make a small initial investment to obtain preferential access to a future investment	Actionable digital option	An IT capability investment that has been examined and found to be both desirable and feasible
Struck option	An option that is activated through a larger investment	Realized digital option	An IT capability investment that has been made

2.2.5. Construct Relationships

Having outlined the key constructs of our theory, we describe their relationships in a conceptual map (Figure 1). The map's left side captures how information requirements suggest desired IT capability investments that, in turn, generate specific digital option characteristics, which, eventually, address the information requirements. The map's right side captures how digital options promise improved process performance, and, as such, the digital options may frame evaluation of the impact of specific IT capability investments. In this conceptual map, we are not claiming causal relationships, but simply clarifying how examining information requirements may help identify IT capability investments through digital options thinking. Also, although we identify information requirements for individual tasks to support practical examination, digital options apply more broadly to a business process at large because tasks are related and may hold great resemblance.

Returning to a rural hospital's service delivery process, the diagnostic task may require medical expertise that is not locally available. Instead of referring patients to a larger hospital, this information requirement suggests examining IT capability investments in telehealth infrastructure. To identify suitable investments, the hospital could examine which digital options characteristics they need to generate to address the identified information requirements (i.e., affording collaboration with remote medical experts to enable local diagnosis of more patients). To evaluate the desirability of adopting telehealth, the rural hospital would then examine whether the framed investment impacts the hospital's health delivery performance as promised.

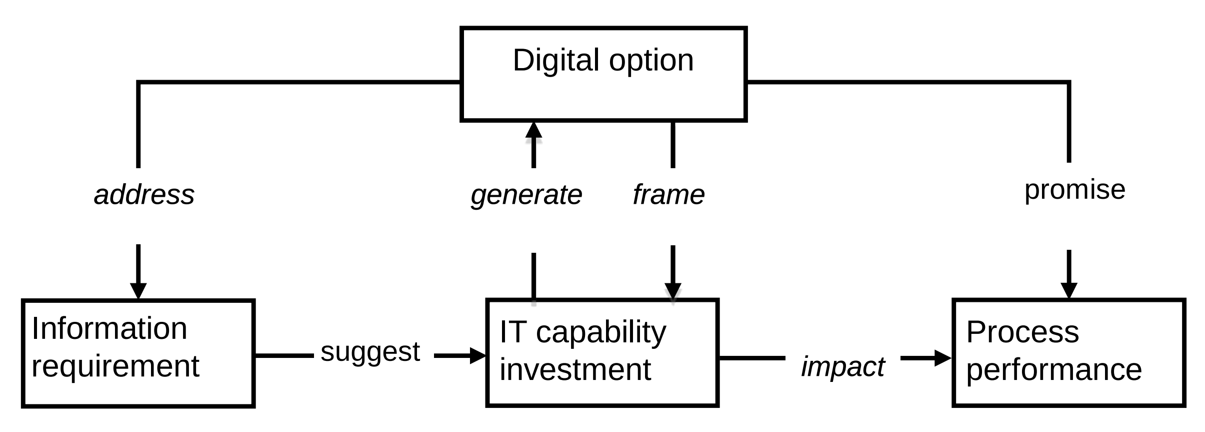

Figure 1. Conceptual Model of Digital Options

3. Examining Digital Options

To support practice, we provide prescriptive digital options theory for examining IT capability investments into a specific business process. In keeping with the prescriptive goal, we identify actionable principles [1] starting with the implications of the relationships between IT capability investment, process performance, and digital options in the conceptual model of digital options (Figure 1):

Principle 1a: *Digital options thinking can frame examination of how IT capability investments may impact business process performance.*

Principle 1b: *Digital options generated by IT capability investments should address the information requirements of individual process tasks.*

In Sections 3.1 to 3.3, we examine connectivity, uncertainty, and equivocality information requirements and how digital options characteristics may address them. Then, in Section 3.4, we present a four-step process for recognizing available digital options and making them actionable.

3.1. Connectivity

A key challenge in business process management is to coordinate dependencies between tasks to make sure that resulting services or products are well integrated. Business process management therefore requires information to be accessed and shared across organizational and geographical boundaries (Davenport, 1993; Malhotra et al., 2005). Depending on the nature of and relationships between individual tasks, there are varying requirements for boundary spanning information processing (Malhotra et al., 2005). Connectivity requirements represent the extent to which information must be shared across boundaries and hence the gap between existing and required access to relevant information between tasks and entities.

If the connectivity requirements are high, actors need to access information from other tasks or entities, but technical or social barriers stop them from doing so. When relevant information for task execution cannot be accessed, managers should consider how IT capability investments could generate options with reach characteristics. Reach refers to the number information sources that can be accessed during task execution (Evans & Wurster, 2000). In most cases, reach may be increased by formalizing connections and by sharing syntactic and semantic definitions to establish shared

[1] The starting point for our theorizing is the theory's purpose. In this section, the word "principle" reflects that we provide prescriptive theory. As Gregor (2006, p. 619) explicates: "Research begins with a problem that is to be solved or some question of interest. The theory that is developed should depend on the nature of this problem and the questions that are addressed.".

meanings (Malhotra et al., 2005). For example, investing in a supply chain management system would allow a firm to access information about orders and products from its suppliers and logistics partners and to share this information with customers through web services.

If connectivity requirements are low, actors can access appropriate information sources across geographical and functional boundaries. Low connectivity requirements indicate there is little need for information sharing or that effective mechanisms already ensure requisite connectivity. Either way, extending reach is no longer a priority; instead, managers should consider how IT capability investments could generate richness characteristics. Richness reflects the number of data points available regarding a given object during task execution (Evans & Wurster, 2000; Fleisch & Tellkamp, 2006). Increased information depth will add richness by focusing on the level of details available for given events over time, the level of decomposition of observed objects, and the variety of data concerning each observed object (Fleisch & Tellkamp, 2006). For example, in a supply chain, we may increase the granularity of data by putting RFID tags on each individual product instead of each container of products.

Hence, managers may generate digital options to address connectivity requirements according to the following principle:

Principle 2: *High connectivity requirements suggest examining IT capability investments that generate options with information reach characteristics, while low connectivity requirements suggest examining investments that generate options with information richness characteristics.*

3.2. Uncertainty

Uncertainty requirements represent the availability and reliability of information and hence the gap between what actors know and what they need to know in task execution (Galbraith, 1973; Mintzberg, 1983). Information service theory suggests that uncertainty requirements can be addressed by constantly balancing information production and information consumption (Mathiassen & Sørensen, 2008; Ramaprasad & Rai, 1996). Information production occurs when actors generate information based on stimuli in the business process and its environment, whereas information consumption turns available information into business process actions.

If the uncertainty requirements for a task are high, actors need to gather more information, increase the accuracy of information, or enhance the reliability of information. In such high uncertainty situations, actors do not want to rely too heavily on consuming existing information. Instead, managers should consider IT capability investments that supports further information production needed for task execution that positively reinforces the production-consumption cycle to support process efficiency and continuous learning (Ramaprasad & Rai, 1996). For example, investing in an IT-enabled loyalty program would allow a firm capture more information about customer buying patterns and generate personalized marketing offers to increase sales.

If the uncertainty requirements for a task are low, information is readily available and trustworthy. Further information production is not required and managers should instead consider investing in information consumption to stimulate action taking based on available information. Organizations can, for example, make data-driven decisions to improve performance based on the use of business intelligence systems to slice-and-dice data and generate informative reports. Accordingly, we suggest the following:

Principle 3: *High uncertainty requirements suggest examining IT capability investments that generate options with information production characteristics, while low uncertainty requirements suggest examining investments that generate options with information consumption characteristics.*

3.3. Equivocality

Equivocality requirements represent confusion and lack of shared understanding, or the level of complexity and ambiguity in a task's information processing. A key question in examining equivocality requirements is whether actors rely on situated or codified knowledge (Badaracco, 1991; Hansen et al., 1999; Nonaka, 1991). Situated knowledge is highly contextual and based on personal experiences, and it is therefore challenging to transfer. In contrast, codified knowledge is formal and generic and can therefore be used by anyone that understands the underpinning codes. Wegner (1997) makes a similar distinction: he discusses algorithmic and object perspectives on information processing: algorithms are "sales contracts" delivering an output in exchange for an input, while objects are ongoing "marriage contracts". Highly equivocal tasks require situated knowledge is developed though IT-based relationships, whereas codified knowledge can be developed to support non-equivocal tasks through IT-based encounters (Mathiassen & Sørensen, 2008, p. 319).

If a task's equivocality requirements are high, successful completion requires relationship characteristics in which actors have high levels of mutual understanding and trust. Equivocal tasks are highly context specific and do not follow a standardized procedure. IT capability investments with relationship characteristics focus on capturing and supporting situated knowledge (Mathiassen & Sørensen, 2008), take context and preference into account by sharing information across subsequent episodes, and require trust between the involved actors (Gutek, 1995). Medical diagnosis and treatment is an example of a highly equivocal task in which electronic medical records can support collaboration between physicians and the patient, which ensures that relevant information is stored in a centralized system.

If a task's equivocality requirements are low, it can be successfully completed by IT-based encounters following standardized procedures. Encounters are limited in both time and flexibility, and this uniformity allows such services to be delivered efficiently (Gutek, 1995). IT capability investments with encounter characteristics focus on codified knowledge and algorithms. For example, in searching for available flights and prices, a search engine can efficiently provide travelers with detailed information about choices without much consideration of their background.

Hence, we suggest that distinguishing between IT-based encounters and relationships can help recognition of digital options that address equivocality requirements:

> **Principle 4:** *High equivocality requirements suggest examining IT capability investments that generate options with information relationship characteristics, while low equivocality requirements suggests examining investments that generate options with information encounter characteristics.*

As a further contribution to the conceptual foundation for the proposed digital options theory, Table 2 summarizes the constructs involved in the principles for how managers can generate digital options based on information requirements.

Table 2. Information Requirements and Digital Options Characteristics			
Information requirement		**Corresponding digital option characteristic**	**Example of IT capability investment generating the characteristic**
Connectivity: extent to which information must be shared across several entities and hence the gap between the existing and required access to relevant information sources in other tasks and entities.	**High**	**Reach**: the number of information sources that can be accessed through IT during task execution	A supply chain management system providing access to information about orders and products from suppliers and logistics partners
	Low	**Richness**: the number of data points available through IT about a given object during task execution	RFID tags at the product level instead of the container level increasing the granularity of collected data
Uncertainty: availability and reliability of information needed to execute the task	**High**	**Production**: the extent to which IT supports the creation of information from stimuli	IT-enabled loyalty program to capture more information about customer buying patterns
	Low	**Consumption**: the extent to which IT support translation of information into action taking	Business intelligence systems to slice-and-dice data and generate informative reports to improve performance
Equivocality: complexity and ambiguity in a task's information processing	**High**	**Relationship**: extent to which IT supports contextual consideration and development of trust by adaptation and sharing of information across subsequent episodes	Electronic medical records to support patient-physician collaboration based on historic information about diagnoses and treatments
	Low	**Encounter**: IT that is based on a standardized approach without variation across customers; limited in terms of time and flexibility but efficient due to uniformity	Dedicated search engine to provide air travelers with detailed information about available flights and prices

3.4. An Iterative Approach to Digital Options Examination

We suggest four key activities to examine digital options based on Principles 1-4: context appreciation to identify a suitable process, process characterization to map and understand tasks that lead to process execution, information requirements analysis to outline information processing in task execution, and digital options examination to recognize actionable digital options that are both desirable and feasible. Accordingly, we suggest the following principle:

> **Principle 5:** *Using digital options to frame IT capability investments into a business process requires context appreciation, process characterization, and information requirements analysis.*

We derived this iterative approach from the theoretically grounded Principles 1-4 and refined them through the practical analyses of the Norrmejerier case. Our own practical application of Principles 1-4 suggested that the logical sequencing of the four activities often needs to be complemented by iteration since the application of results from an activity in a subsequent activity might reveal new insights that require revisions as Figure 2 illustrates.

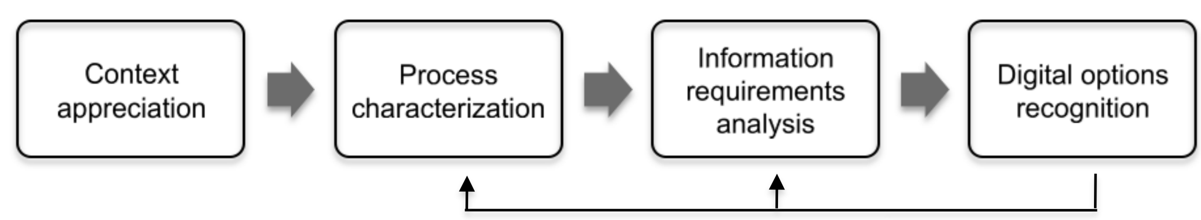

Figure 2. An Iterative Approach for Digital Options Examination

The logical dependencies between activities suggest, for example, that information requirements analysis is based on the specific tasks identified in the process characterization activity. Also, each activity depends on appreciation of the process and its context. Even managers who work in a business process should conduct a proper analysis to understand task dependencies and external information sources in order to critically scrutinize current practices. In fact, while familiarity with operations might reduce the effort needed to understand a process, it could also cause analysts to overlook opportunities by taking certain assumptions for granted (Glaser & Strauss, 1967). In the following paragraphs, we discuss the four activities in the further detail.

Context appreciation has the dual goal of understanding the context and identifying suitable business processes for IT investment. Suitable processes may be identified based on characteristics such as current performance, high impact on organizational performance, external pressure, internal re-organization, and technological infrastructure (Davenport, 1993; Davenport & Short, 2003). Relying on a contextualist approach that highlights the social and cultural environment in which organizational change occurs (Pettigrew, 1987), this activity should reveal the rich interplay between social and technological phenomena (Avgerou, 2001). Avgerou (2001) proposes three guiding principles for contextual appreciation: to consider technology innovation in relation to socio-technical change, to include technical and rational decisions and cultural, social, and cognitive forces, and to consider the organizational, national, and international context in analyses of technical innovation. **Process characterization** involves identifying and describing key tasks and their interdependencies, the nature of the information processing involved in each task, current IT capability, and performance implications. While existing process characterizations can provide guidance in this activity, examining digital options as any analytical process requires critical scrutiny of assumptions that may be taken for granted (Glaser & Strauss, 1967). During **information requirements analysis,** each task is analyzed and characterized according to its information requirements. The examination of digital options is facilitated by critically dissecting each task's information processing requirements, including its relationships to other tasks. Finally, **digital options recognition** is creative in nature and involves moving between the results from process characterization and information requirements analysis. The existing IT capability and its performance implications provide guidance on what needs to be addressed, while Principles 1-4 suggest how to do so. Options are derived from specific principles and each option may address multiple information requirements. While the principles and related constructs (Table 1) guide the examination of digital options by suggesting IT capability characteristics needed to improve process performance, converting option characteristics into specific IT capability investments requires understanding the repertoire of possible IT investments and how they apply to the considered process. Initially, the focus is on generating many desirable investment alternatives without particular concern for their practical implications, but their feasibility must eventually be accounted for by considering available resources and implementation conditions.

4. Application of Constructs and Principles

We applied the proposed constructs and principles to a case study of the dairy production network at Norrmejerier. Case studies are appropriate for exploratory research to develop new theory (Yin, 2003) and they allow for in-depth examination of the dynamics present in a setting (Huberman & Miles, 2002). Hence, though the case mainly serves illustrative purposes in the paper, our theorizing was based on iteratively moving between detailed empirical analyses of the Norrmejerier case, exploration of general options theory, and critical review of current digital options theory. We adopted an interpretive epistemology (Klein & Myers, 1999; Walsham, 1993) in an "attempt to understand phenomena through assessing the meanings that people assign to them" in the considered context (Orlikowski & Baroudi, 1991, p. 5). Consequently, we relied on observations, document analysis, and interviews with key stakeholders. We initiated collaboration with Norrmejerier in November 2007 to investigate the impact of an ERP system on business performance. Initially, the study focused on understanding Norrmejerier's business processes and information management needs, and the primary recommendation was to improve IT support for production planning. At a board meeting in September 2009, it was decided to further investigate how this could be achieved.

4.1. Research Site

Norrmejerier is a dairy company in Northern Sweden that is owned by over 600 local farmers and delivers 195,000 tons of milk annually. As a relatively small player with 5 percent of the Swedish dairy market, the company employs approximately 500 persons at four distributed production units. The market leader, Arla, exports to more than 100 countries and has a 30-fold greater turnover. This positions Norrmejerier as a "local alternative" that serves the sparsely populated areas in Northern Sweden.

Norrmejerier is highly dependent on IT capability for its coordination because of its distributed nature, the very limited durability of dairy products, and the supplier ownership. Consequently, Norrmejerier must constantly adapt its production to the amounts of milk the farmers produce and maximize the price paid for milk. To better meet these goals, the company adopted a new strategy in 2005: it switched from producing high-durability products sold at low prices to undertaking contract manufacturing for other companies with stricter timing demands. The resulting need to balance supply and demand required improved information processing throughout the production chain.

While the company's implementation of enterprise resource planning (ERP) during 2001-2002 led to substantial standardization of many transactions, it required constant adaptation due to user resistance and the dairy industry's unique process characteristics. These adaptations significantly increased the complexity of ERP upgrades and the technology never supported all aspects of production planning. Hence, despite considerable investments over the past decade, Norrmejerier had not successfully aligned its IT capability with its strategic shift to dynamically balance supply and demand. As a result, management considered how further IT investments could improve firm performance.

4.2. Theory Application

As initial explorations of the empirical material helped stabilize our digital options theorizing, we systematically applied the resulting approach to the production planning process at Norrmejerier through the approach in Figure 2. In the following sections, we explain the individual activities and how we executed them.

4.2.1. Context Appreciation (November 2007-June 2010)

To better understand Norrmejerier's operations and identify a suitable process for examination, the first author used a variety of data collection techniques including semi-structured interviews, observation, documentation, and informal conversations. He conducted a total of 27 semi-structured interviews that were organized according to an interview guide, recorded, and transcribed for later analysis. He also conducted another eleven interviews that were documented by taking detailed notes rather than being recorded. The first round of interviews occurred during December 2007 and January 2008 and focused on assessing IT capability, current problems, strategic vision, and information needs in and across units. We selected the initial interview participants for their breadth of knowledge and overall perspective. The insights gained led to the selection of additional participants with more specialized knowledge of systems and processes. Overall, we interviewed seven people.

In May and June 2009, the first author was physically located at Norrmejerier for three weeks. During this time, he observed the organization's information processing and IT capability. He participated in meetings, spoke informally with employees, conducted interviews, and toured three production sites. We created a new interview guide to focus on current problems and opportunities and the effectiveness of current systems. During this time, the first author made extensive field notes (Yin, 2003). Each day, he documented meetings, conversations, and his overall impressions and important insights from Norrmejerier's operations. To further understand how the ERP system worked, he used a demo version of the system. In addition, he gained insights from internal and public company documents such as an overall process map and analyses of information management in the production chain.

In spring 2010, we conducted an additional round of data collection to understand the impact of current IT capability on production planning performance. To obtain a comprehensive view of the production planning process, we selected informants across the five management processes from the SCOR model (Huang, Sheoran, & Keskar, 2005): plan, source, make, deliver, and return. Another important data source was the requirements specification for a decision support system for production planning that revealed the information needs of different actors in the process. At this stage, we generated a written report summarizing current IT capability and five recommendations for improving business performance. We shared this report with Norrmejerier managers, including those that were interviewed, the research sponsor, and the CIO.

4.2.2. Process Characterization (November 2010-December 2010)

During process characterization, we looked in detail at production planning. First, we created a process map for which we identified all tasks and the information needed for each task. In particular, we reviewed and extended the process maps that Norrmejerier provided based on case data and supply chain management theory (Huang et al., 2005). Second, we performed a task-level analysis of the case data (Mathiassen & Sørensen, 2008). We created a coding scheme based on the identified tasks and looked for additional information about IT capability and performance. There were three main categories of codes: IT capability, production chain processes, and production planning. We developed the codes for IT capability using established definitions (Bharadwaj, 2000; Bhatt & Grover, 2005; Peppard & Ward, 2004); we based the production chain process codes on the SCOR model (Huang et al., 2005); and we based the codes for production planning on the identified tasks. Using the Atlas.ti qualitative analysis software package, the first author then applied the coding scheme to the entire set of data sources. Finally, we all reconsidered the results. In doing so, we identified new tasks and combined others to come up with a final set of tasks, a list of related information processing requirements, the associated IT capability, and performance issues (Table 4 in Section 5.2). We iterated these analyses until all three authors agreed that the summary table provided a coherent and satisfactory explanation of the data (Langley, 1999).

4.2.3. Information Requirements Analysis (January 2011-March 2011)

Next, we conducted an information requirements analysis for each production planning task (Mathiassen & Sørensen, 2008). We started by describing the information processing needs for each task in general terms. We then used this description and the definitions for connectivity, uncertainty, and equivocality (Table 2) to assess the information requirements as being either low or high. Finally, we debated and revised the assessment based on information from the case study database. The output from this activity lists each task and its information requirements (Table 4).

4.2.4. Digital Options Recognition (April 2011-May 2011)

Finally, to recognize actionable digital options, we analyzed tasks for which performance issues were identified during the process characterization activity. We considered the information requirements of these tasks and applied Principles 1-4 to identify digital options' characteristics (e.g., greater process reach or richness) that would address them. Because converting characteristics into specific IT capability investments is a creative process at the border of our theorizing, we brainstormed to identify a large number of potential investments that we later scrutinized in terms of their desirability (promise to impact process performance by addressing identified information requirements) and feasibility (level of resource investments and compatibility with Norrmejerier's infrastructure and culture) (Checkland, 1981). That led to recognition of seven actionable digital options (Table 5) that we corroborated through discussions with a production planner (mainly focusing on desirability) and the CIO (mainly focusing on feasibility).

5. Examination of Digital Options at Norrmejerier

This section provides a detailed account of production planning at Norrmejerier. Here, we emphasize how IT capability translates into firm performance and how considering information requirements guided our examination of digital options.

5.1. Context Appreciation

Norrmejerier could not control its supply of raw material (whole milk), and the profitability of its different product compositions varied substantially. Consequently, to perform well, the company needed to continuously adapt production based on the day-to-day supply of raw materials and the current demand for lucrative products. Such adaptation is heavily dependent on production planning, so the process must be well connected to all parts of the distributed production chain via appropriate IT capability. We used the supply chain operations reference (SCOR) model (Huang et al., 2005) to obtain an overview of the five high-level processes: plan, source, make, deliver, and return. We characterize each process in terms of goals, key actors, information management, and related IT capability (Table 3).

5.1.1. Plan

This process leads to production plans that balance demand and supply by assessing levels of resources and prioritizing requirements (Huang et al., 2005). A tactical planner, four production planners, and several operational managers were responsible for the process at three distinct levels. Important related actors include those involved with the logistics of sourcing and delivery, sales and marketing, supplier services, production staffing, and warehousing. The planning process was highly adaptive to whole milk supply, variations in milk quality, production capacity, minimum batch sizes, and market demand:

> *There is seasonal variation in the supply of milk, it is not the same throughout the year ... the amount of milk is greatest during spring and lowest during the fall. The milk also has different components and varies in terms of its content of fat and protein… The result is that different product mixtures vary in profitability throughout the year. At the same time, we sell more or less the same amount of consumer milk during the year… A specific product mix will only work on one day of the whole year; at other times, a different mix will be needed.* (The tactical planner)

The tactical planner managed high-level and long-term planning such as the amount of cheese manufactured and the overall product mix profitability. Most of the information used for this planning stemmed from the ERP system and was analyzed using the Insikt and Power Play decision support systems (DSS). In addition, the planner used information on macroeconomic developments from web sites to identify and adapt to factors that may affect Norrmejerier's operations. Using directions provided by the tactical planner as a foundation, the four production planners created operational plans. These plans were based on estimated levels of demand and (for some less profitable products) the expected quantity of raw material. We describe the production planning process in detail in Section 5.2.

5.1.2. Source

This process results in the procurement of the material required to meet the existing demand. The most important aspect involved helping farmers with cattle management and short-term storage, and secure transportation of whole milk to the four production sites (Huang et al., 2005). The key actors were farmers, farmer service units, source logistics, production sites, and external haulage firms. Whole milk was collected every second day by 21 trucks from 610 farms scattered over an area approximately two times the size of Ireland. While the amounts produced at each farm normally follow a seasonal pattern, some variation does occur, “Problems at farms can cause large variations; illness in the barn, bad feeds, problem with water, and other issues can greatly decrease production, reducing output by up to 50%” (Operational manager, Umeå production site).

Routes were planned by the sourcing logistics unit using a GIS to generate routing guidance based on the locations of suppliers and speed limits. Each truck had a local computer and GPS functionality connected online to the sourcing logistics unit; this configuration reported the truck’s location and captured the collection of whole milk from each farmer and the amount of whole milk carried in the truck. The supply management system (MTC) automatically matched GPS data with farm coordinates, captured the amount collected, and attributed it to the farmer for traceability and payment purposes. The whole milk was delivered to the production sites, where its quantity was re-measured and recorded in the ERP system.

There were specific routes linking individual farms and production sites, but excess whole milk was transported from the other production sites to the central site at Umeå due to the large range of products it could manufacture. However, this was undesirable because it incurred extra transportation costs and overtime payments for personnel. Unfortunately, transportation of this kind often had to be rescheduled on short notice due to limitations in the IT planning systems.

5.1.3. Make

This process involves the transformation of raw materials into finished products. Specifically, it encompasses requesting and receiving material, manufacturing and testing, packaging, and releasing the end product (Huang et al., 2005). The make process was distributed to four production sites, each of which manufactured a distinct product portfolio. Manufacturing times varied greatly between products. For example, fresh milk was made less than twenty-four hours before delivery, while one of the cheeses had to be stored for at least one year to mature before being sold.

Operational managers planned the demand for whole milk on the basis of production orders using Excel spreadsheets that were stored on a server and accessible to all involved actors. The formulae in these sheets, including variables such as the nutritional value of the whole milk, needed to be updated manually by each manager to reflect the current state of the production system. This task was sometimes neglected, causing large errors in prognoses:

> *The IT situation is really messy and causes us to make a lot of bad decisions… We are losing money because we don’t know what we are doing. The sheets I’ve constructed in Excel to integrate data from the dairies are decent but require a lot of manual effort… Much of the information is recorded somewhere, stored in databases or wherever, but we can’t reach it. There hasn’t been any focus on or interest in these issues; people have only recently begun to realize that they can affect our profits. I would like use to have a common database and move away from people using their own Excel sheets with their own numbers, or the ERP system which almost no one can access information from since queries are tricky.* (Operational planner at the receiving unit, Umeå production site)

The limitations of the IT systems used in this process wasted resources and hampered overall performance. A 0.1 percent change in the level of fat in incoming milk could affect the total amount of cream produced by as much as 5 percent, which is a large difference in absolute terms. For example, one interviewee noted that it had been necessary to cancel an expected transport of 10000 liters of cream (corresponding to 80 000 liters of whole milk) to Umeå from Luleå; this volume corresponds to 50 percent of the total amount of milk processed at the Luleå site each day.

> *This is one of the main reasons that we need to integrate our IT support for planning, to plan for transports between different sites and to start talking the same language at dairies. We talk and think about these issues differently. Just minutes ago they called from Luleå and told us that they won’t deliver 10000 liter of cream, which means we’ll be five tons short on butter and we are already running a tight schedule today. This could*

force us to change today's production to ensure there is enough cream to make butter. (Operational planner at the receiving unit, Umeå production site)

5.1.4. Deliver

This process leads to distributed goods to meet expected and planned demand through order management, product inventory management, and distribution management (Huang et al., 2005). The key participants were warehouses, delivery logistics, customer service, production planners, haulage firms, and competitors who co-distributed Norrmejerier's products on the national market. Most distribution had been centralized and went through the central warehouse at the Umeå site.

Orders were typically received via a web service, an automatic phone order system, or as electronic data interchange (EDI) files, all of which were integrated with the ERP system. The delivery of products was supported by Astro, a warehouse and distribution system that was integrated into the ERP system. Astro gave assembly personnel instructions regarding the location and quantity of each product to be collected via their earpieces and produced schedules according to which assembled pallets and trolleys were packed into haulage firms' trucks. Norrmejerier planned and monitored trucks in real-time using a newly-implemented transport planning system (Hogia Haulage) that provided information on truck location, speed, and the temperature in cargo areas.

Norrmejerier and some larger competitors co-distributed their products, which means that competitors delivered the company's products to customers on the national market and vice versa on the local market. Customers placed their orders directly with the co-distributor while Norrmejerier tried to ensure that sufficient amounts were stored at their warehouses. Norrmejerier's IT capability did not allow them to see such orders until they were delivered, so there was no way to tell how much of the current inventory was reserved. Although the sales support system used by the sales force in the field for information management (Genero) could provide clues, it was not easily interpreted.

> *When we plan for these warehouses, the order column is always blank; we have no idea of what their sales plans look like or if a customer has made a large order. All we have are historic numbers, except for when our own sales force leaves signals in another system that customers might buy larger quantities. The downside is that it is not 100% certain that they actually will; the customer might tell our sales person that they will buy it, but decline to do so two months later when he's supposed to make the order. If that happens, we won't know about it. You need to consider this information with some skepticism.* (Production planner)

5.1.5. Return

This process manages the reverse flow of defective products or incorrect deliveries by authorizing, scheduling, receiving, verifying, disposing, and ensuring replacement or credit (Huang et al., 2005). Actors involved at Norrmejerier included farmers, lab, supply logistics, production, warehouse, customer service, and customers.

To ensure quality and traceability, a sample was taken every time milk is collected from farms and lab tests were conducted four or five times a month. If any problems were detected, the farmer was barred from delivering further milk until the source was found. Withdrawing products with quality issues was relatively easy for products that need to mature as part of the production process since there was enough time to respond before delivery. Products that were distributed more or less directly following production could be more challenging and would involve grocery stores or, in extreme cases, consumers. However, this is highly unusual and has only happened twice in 27 years. A more common problem was that customers did not receive ordered products and Norrmejerier then needed to reroute a transport or ensure crediting. Such problems were mainly managed over the phone by customer service.

Table 3. Overview of Processes

Management process	Description (Huang et al., 2005)	Participants	Process activities	IT capability
Plan	Balances demand and supply in production plans by assessing levels of resources and prioritizing requirements.	- Tactical planning - Production planning - Operational management - Supplier services - Production staffing - Warehousing - Sales and marketing - Sourcing and delivery logistics	The tactical planner managed aggregated planning by examining the profitability and feasibility of different product mixtures. Based on demand estimates, four production planners made plans for balancing supply and demand	- ERP (IFS) - Decision support (Insikt, Power Play) - Sales support (Genero) - Web services (e.g., market data and weather) - Excel sheets - Phones
Source	Procures material to meet demand, mainly by assisting with guidance on cattle management and short-term storage equipment, and transporting whole milk to production sites.	- Farmers - Farmer service - Production sites - Source logistics - Haulage contractors	Farmers produced whole milk with the support of service functions. Haulage contractors' employees collected milk from the 610 farms and delivered to the four production sites. The source logistics unit coordinated operations and the maintenance of equipment on trucks owned by Norrmejerier.	- ERP (IFS) - Supply management (MTC) - GIS mapping system (Arcview) - Excel sheets - Phones
Make	Transforms material to finished product by requesting and receiving material, manufacturing and testing, packaging and releasing the end product.	The production sites: Umeå, Luleå, Nordan, and Ånäset	Each production site had a distinct range of products it manufactured. Excess milk at the other sites was transported to Umeå.	- ERP (IFS) - Phones - Excel sheets
Deliver	Distributes goods to meet expected and planned demand through order management, product inventory management, and distribution management.	- Warehousing - Delivery logistics - Customer service - Production planning - Co-distributing firms - Haulage firms - Customers	Orders were typically received as EDI files, through a web service, or via an automated phone order system. Orders were assembled at the central distribution warehouse in Umeå. External haulage firms operated trucks but Norrmejerier coordinated operations.	- ERP (IFS) - Warehouse and distribution (Astro) - Sales support (Genero) - Transport planning (Hogia Haulage)
Return	Manages reverse flow of defective products or incorrect deliveries by authorizing, scheduling, receiving, verifying, disposing, and ensuring replacement or credit.	- Farmers - Lab - Supply logistics - Warehousing - Customer service - Customers	Products were tested, and if quality issues arose, products were withdrawn from warehouses, distribution centers, or stores depending on the time between production and delivery. The customer service unit handled incorrect deliveries by replacing products, re-routing transports or crediting the customer.	- ERP (IFS) - Phones

5.2. Process Characterization

The production planning process generated production orders to balance estimated demand with whole milk supply while complying with durability restrictions on consumer products. Most products were manufactured according to demand estimates (e.g., yoghurt, cheese, and sour cream), but the production of some less profitable products (e.g., milk powder and export butter) depended on the whole milk supply, and a few were made to order (consumer milk and contracted butter). Production planning performance was highly dependent on IT capability for making demand estimates, sensing events, and adapting to them. Next, we describe the information processing involved in each process task (Figure 3), the associated IT capability, and the process performance implications (Table 4).

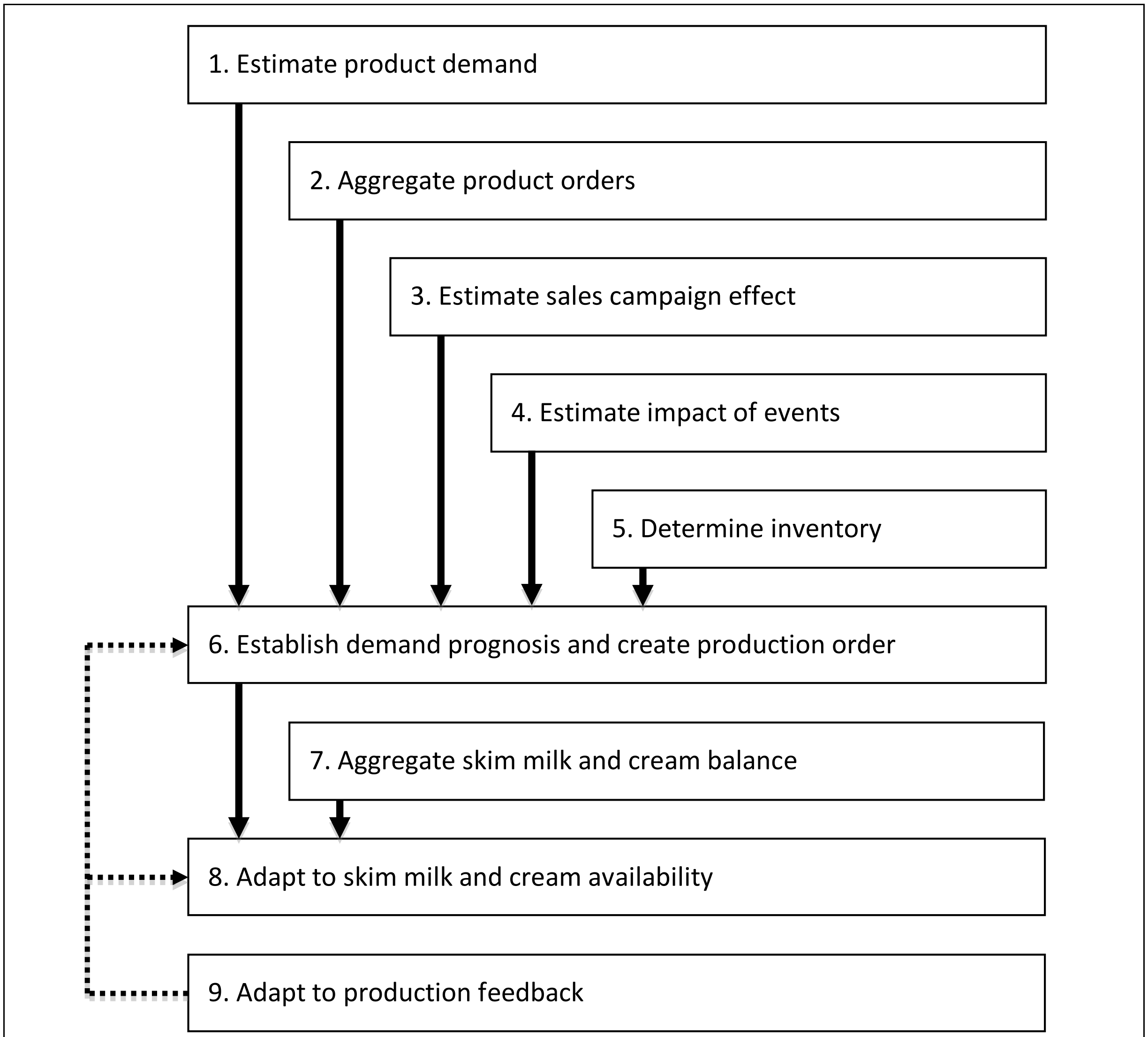

Figure 3. The Production Planning Process

5.2.1. Estimate Product Demand

The ERP system offered prognoses based on the last three years of sales, but these were unreliable due to fluctuations in the historic data stemming from production problems, weather, and sales campaigns. Production planners therefore ignored the automatically generated prognoses and instead made their own rough season estimates based on sales data and experience. Another challenge was that production planners only had access to historic sales data, not to actual customer demand. For example, during stock outages of a particular product, the ERP system did not permit registration of orders. As a result, production planners produced their own Excel reports on delivery rates and problems to inform future demand estimates. The term "secure buffer" (i.e., the amount available in warehouses to ensure delivery of demand while adhering to products' durability restrictions) was used frequently during production planning. Buffer volumes were, however, not defined, nor did Norrmejerier have the IT capability to generate them from historic data.

5.2.2. Aggregate Product Orders

In this task, orders were aggregated across channels. The majority of products could not be made to order due to significant lead times. Nevertheless, orders for some of these products were placed in advance and could be found in the ERP system as a result of sales campaigns or as indicators of unexpected increases in sales. A minority of products was made to order. Short lead-times allowed consumer milk with aggregate quantities to be readily available in the ERP system. Contract manufacturing of cheese and butter was also done to order since customers placed their orders further in advance; this was done through e-mails and production planners manually transferred the information to their Excel sheets. For sales on the national market, customers placed orders with the co-distributor and Norrmejerier only managed the financial transaction; this information was not available to production planners until the products were delivered.

5.2.3. Estimate Sales Campaign Effect

Three different types of sales campaigns affected demand: larger campaigns directed toward the national market, campaigns introducing new products, and smaller campaigns directed toward specific grocery stores. Estimates of effects from upcoming larger sales campaigns and the introduction of new products were communicated to production planners from the sales and marketing units over the phone or in meetings, and sometimes also via the ERP system. There were, however, a number of problems involved with such estimates: they did not take temporal or geographical effects into account, they were not updated during campaigns, and, since they were not evaluated collaboratively, there were no improvements in the ability to predict impact over time. While the sales unit was supposed to make estimates of effects from smaller campaigns and determine whether the necessary amounts could be produced, this was not always done. Increases in the number of advance orders placed could provide production planners with hints on upcoming sales trends. Such information was not available for products on the national market since orders were placed with the co-distributor. The sales force submitted information on potential larger orders into the sales support system Genero. While this information could signal sales increases, it needed to be used with caution because there was no guarantee that these orders would actually be placed. Also, there was no way to decide that an order needed to be removed from the potential list when it was put into effect.

5.2.4. Estimate Impact of Events

The major events that affected sales were holidays, school semesters, and the weather. Historic data could be used to guide estimates, but such information was not easily obtained. While effects from holidays and school semesters could be approximated by manually comparing sales numbers in the ERP system with the calendar, this was a time consuming task. Although only a handful of products were affected by the weather, its impact could be quite dramatic; in some cases, it increased demand by as much as 100 percent. Production planners did consider long-term weather reports, but their unreliability and the potential economic losses from discarding large quantities meant that estimates were mostly based on data from stock outages.

5.2.5. Determine Inventory

The inventory balance for Norrmejerier’s own warehouses was recorded in the ERP system and normally updated through Astro. These data were reliable and easily accessible. Production planners were also responsible for warehouse levels at co-distribution warehouses. The information available to production planners on these inventory balances was unreliable because products reserved for orders were not deducted in Norrmejerier’s ERP system. This is a problem since deliveries from Norrmejerier to these sites were only made on specific days and involve transportation time. As a result, planners could not respond to insufficient inventory levels in a timely manner.

5.2.6. Establish Demand Prognosis and Create Production Order

Based on the outputs of tasks 1-5, prognoses were established and production orders were created at least a week in advance. This was done using the ERP system and Excel sheets that were e-mailed to the operational managers. Duplicate systems were used since the ERP system only held information on the total number of products, while the operational manager was interested in total product quantities. The production planners had therefore created dedicated Excel sheets for this purpose. The operational managers translated the resulting information on production orders into operational schedules that were distributed to relevant actors in and across unit boundaries. This process involved substantial manual transfer of information, increasing the risk of mistakes.

5.2.7. Aggregate Skim Milk and Cream Balance

Based on production orders, operational planners used formulas in Excel sheets to calculate the quantity of raw material that was needed (i.e., the amounts of skimmed milk and cream). These quantities were compared to the current stock and the nutritional value of the current whole milk holdings using another Excel sheet in order to calculate the expected balance. These data were then used to schedule appropriate deliveries. Because the parameters in these formulae were not regularly updated, the predictions made at this stage were often grossly misleading.

5.2.8. Adapt to Skim Milk and Cream Availability

Production planners needed to adapt production according to the overall estimated balance of cream and skim milk. If there was a surplus of cream, production planners made phone calls to customers to explore the scope for increasing the size of their orders for butter or to the tactical planner to see if it was possible to increase cheese production. If none of these alternatives were viable, non-lucrative export butter was produced. If there was a shortage of cream, production planners needed to adapt other production (e.g., by producing low fat cheeses rather than the usual full fat varieties). If there was a surplus of skim milk, powder was produced. All of these alternatives were examined and implemented by negotiating with the involved actors, updating production orders in the ERP system, and distributing new Excel sheets by e-mail.

5.2.9. Adapt to Production Feedback

Production problems and changes in distribution between sites constantly forced production planners to adapt. Feedback was normally received either by examining the manufactured amounts logged in the ERP system or via phone calls from production managers. Production problems were solved by reorganizing production orders according to demand (i.e., iterating task 6) or adding an extra shift of workers. At other times, such as when cheeses did not mature according to plan, Norrmejerier could not deliver products. When adapting to changes in deliveries, production planners iterated the procedures described in task 8.

Table 4. IT Capability and Performance Implications for Production Planning

Task	Information processing	IT capability	Performance implications
1. Estimate product demand	Determine normal seasonal demand by identifying and subtracting the impact of events on historic sales data.	ERP system provided gross sales data for t-3 years and associated prognosis. Effects from events such as holidays or campaigns could not be separated and it was not possible to add notes on events that affected sales. Actual demand was sometimes not measured since out-of–stock products could not be ordered.	Rough estimates were calculated from average sales. To analyze and interpret these data in detail, planners had to rely on personal experiences and retrospective guesses. Learning regarding what drove sales numbers (and hence prognosis creation) was hampered.
2. Aggregate product orders	Summarize existing orders to 1) create production orders for made-to-order products and 2) analyze advance orders for made-to-estimation products to use as input in overall estimation.	For consumer milk that was made to orders: communication channels (web, automated phone system, EDI files or phone) were integrated with the ERP system. Contract manufacturing orders were placed via e-mail sufficiently far in advance to allow planning according to orders. Orders could be made in advance through any of the order channels; such information was available in the ERP system. No access to orders placed with co-distributors.	Most order channels were integrated and the existing orders were hence readily available in the ERP system. Most other production was however made-to-estimation, and so the company faced a tradeoff between discarding products and missing sales opportunities. Planners could not see or respond to large orders placed with co-distributors and so sales opportunities were missed or products discarded.

Table 4. IT Capability and Performance Implications for Production Planning (cont.)

Task	Information processing	IT capability	Performance implications
3. Estimate sales campaign effect	Determine if there were any sales campaigns and estimate their impact on demand, both in terms of delivery time and location, to use as input in estimating overall demand.	Rough estimates of effects from campaigns left through phone. No IT capability for suggesting temporal and geographical distribution, or for collaborative estimations or evaluations of impact. Functionality for campaign alerts in the ERP system production planning view was sometimes used but often without estimates. Sales leads regarding larger orders communicated through Genero, no information on whether or not a real order had been placed.	Planners could consider estimates of expected sales increases. Estimates of campaign impact were made from a sales perspective. No learning from historical impact on production and delivery. Sensing capability within sales unit not incorporated. Information on smaller activities hard to interpret since they often did not include impact estimations.
4. Estimate impact of events	Determine if any demand-affecting events would occur during the period and estimate their impact to use as input in overall demand estimate.	Historical sales data provided by the ERP system. However, the system did not allow separation or knowledge creation on events affecting orders. Instead production planners sometimes manually produced and stored digital or non-digital, information on such events as reminders. They also retrospectively tried to match comparable historic events to estimate impact.	Experienced planners could find and evaluate historical impacts. While production planners normally had a good hunch of impact on their own products, the process was very dependent on personal knowledge.
5. Determine inventory	Determine inventory balance at warehouses, both own and at co-distributors' sites.	ERP system provided accurate inventory balance for own warehouses. For co-distribution sites, production planners could only see actual quantity of products. These could however already have been reserved for customer orders made in the co-distributor's system.	More or less real-time access to in-house inventory balance. For co-distributed markets, reduced delivery reliability and hence larger loss of potential sales and greater quantities of discarded products.
6. Establish demand prognosis and create production order	Aggregate estimates of demand made in tasks 1-4, compare actual and desired inventory levels, calculate production needed and create production order.	Templates in Excel sheets allowed standardized and re-usable tools. ERP system standardized transactions. No support for determining desired buffer levels. Production order entered into both the ERP system and Excel sheets that were e-mailed to operational managers.	Distribution of information standardized. Desired buffers were determined by each production planner and based on experience, caused dependencies. Manual transfer of information, both by production planners and operational managers, increased risks of incorrect information.
7. Aggregate skim milk and cream balance	Compare estimated supply with estimated amount needed in production to calculate overall balance.	Excel sheets for calculating needed amounts of whole milk; those quantities were matched in Excel sheets with expected supply. These sheets were available to affected actors. Due to neglected maintenance of parameters such planning was frequently grossly misleading.	Multi-user access allowed information distribution. Unreliable prognoses of transports and hence frequent with ad-hoc solutions. Such solutions were often more costly or involved re-scheduling operation to a less desirable mixture.
8. Adapt to skim milk and cream availability	Adapt to overall balance by determining most profitable alternative available and produce updated production order for affected products.	ERP system and Excel sheets to examine existing plans and alternatives. Phones used for examining viability with customers and tactical planner. ERP system and Excel sheet for creating new production order.	IT capability allowed production planners to quickly assess current scheduled quantities and examine alternatives through phone. Such responses were however frequently rearranged due to unreliable prognoses on whole milk availability.
9. Adapt to production feedback	Examine production feedback and analyze if adaptations were needed, if so, iterate task 6 or task 8 depending on feedback.	Finished products reported in the ERP system, problems communicated through phones.	Real-time access to production data and up-dates from production managers allowed swift responses.

5.3. Information Requirements Analysis

Next, we examine the information requirements for each task to establish the foundation for recognizing available digital options for IT capability investments to improve process performance. Table 5 summarizes our analysis of information requirements across the production planning process.

5.3.1. Estimate Product Demand

Since Norrmejerier was not involved in actual transactions with the majority of their ultimate customers, it did not receive direct information on customer behavior and changes in demand. While grocery stores had automated inventory management and could sense trends quickly, Norrmejerier did not have access to such information. This gap between desired and current information suggests high connectivity requirements. Moreover, to allow production planners to accurately predict demand based on sales, historic sales data needed to be readily available and separated into normal seasonal demand and demand driven by events. The lack of readily available sales information suggests high uncertainty and the ambiguity in distinguishing between different types of demand suggests high equivocality.

5.3.2. Aggregate Product Orders

Most product orders were made through one of the integrated order channels and automatically aggregated in the ERP system. Some large customers made their orders via e-mail and production planners then transferred the information into their Excel planning sheets. Such information was reliable and clear, suggesting low uncertainty and equivocality requirements low. However, production planners could not access orders placed with co-distributors and instead rely on historical sales data, suggesting high connectivity requirements.

5.3.3. Estimate Sales Campaign Effect

While estimates of overall impact were available, production planners did not have information on when in the campaign period customers might order products or how sales increases relate to geographical markets. The sales team, co-distributors, and grocery stores could provide such information, but, while planners could contact the sales team and their co-distributors via the phone, this was seldom done during campaigns. There was no interaction with grocery stores, but trends identified by the sales force were sometimes informally communicated to production planners when smaller campaigns were to be conducted, either by phone or through the sales support system. Low access to information and large variance in predictions suggest that this task is characterized by high information requirements in all three dimensions.

5.3.4. Estimate Impact of Events

While information about holidays or school semesters can be obtained from calendars, weather prognoses are not very reliable for planning over longer periods. To estimate impacts, planners need to identify historical effects on sales numbers. This task is highly dependent on planner experience since the data can be contradictory and impacts can vary (e.g., depending on when during the week a given holiday occurs). There is no need for increased connectivity, but increasing the availability of detailed historic data could reduce dependence on personal experience, and improved analytical tools could reduce ambiguity. This suggests high uncertainty and equivocality requirements.

5.3.5. Determine Inventory

To assess the inventory held at warehouses operated by Norrmejerier, the ERP system provides more or less real-time access to reliable information. For warehouses operated by co-distributors, the ERP system provides less current information since some of the holdings are already reserved for delivery. Hence, while reliable and univocal information exists, there is a high connectivity requirement to provide planners with appropriate IT-enabled access to inventory levels at co-distributors' sites.

5.3.6. Establish Demand Prognosis and Create Production Order

No analysis of desired inventory levels exists. Instead, planners rely on experience when deciding appropriate levels. Such levels vary substantially between products due to their different levels of durability and turnover rates. While planners have extensive situated knowledge that allows them to make educated guesses for their own products, this information is not readily transferred from one planner or product to another. Production orders are created both in the ERP system and Excel sheets. The trade-off between missed sales opportunities and discarded products is an issue and there is no clear answer as to which is most profitable. The lack of information on desired inventory levels and the situated knowledge required results in high uncertainty and equivocality, while the absence of relevant information sources leads to low connectivity requirements.

5.3.7. Aggregate Skim Milk and Cream Balance

Production orders are fed into Excel sheets with formulas for estimating required amounts of skim milk and cream. These amounts are then compared to the seasonal average quantity of milk delivered to calculate balances. The involved actors can access relevant information in Excel sheets, but the resulting balance estimate is not very reliable since the parameters of the formulae are not calibrated often enough. As such, the connectivity and equivocality requirements are low but the uncertainty requirements are high.

5.3.8. Adapt to Skim Milk and Cream Availability

Based on estimated balances, production planners need to suggest profitable production responses. However, only a few responses are possible. If there is an excess of cream, planners first investigate whether cheese or contracted butter production can be increased by talking to the involved actors. If not, export butter is planned. The resulting changes in production orders are then distributed by e-mail, the ERP system and by phone calls to the operational managers involved. If there is excess skim milk, powder production is increased in the same way. Current prognoses regarding the availability of skim milk and cream remain unreliable and this lead to frequent changes in planned production responses. This reflects high uncertainty requirements while connectivity and equivocality requirements are low.

5.3.9. Adapt to Production Feedback

Production feedback is provided through the ERP system and by phone calls. If the feedback involves production problems, planners must determine whether they can be solved and if sufficient quantities have been produced; if not, the planners adapt by prioritizing production and create new production orders (i.e., iterate task 6). Deviations in the expected availability of skim milk and cream are managed by iterating task 8. The information requirements are contingent on the type of feedback and are either identical to those of task 6 or of task 8. Table 5 summarizes these information requirements.

Table 5. Information Requirements for Production Planning

Task	Connectivity	Uncertainty	Equivocality
1. Estimate product demand	High: increased access to real-time, or relatively current, information on customer behavior and sales trends was highly desirable.	High: more information needed on customer behavior and events affecting historic sales numbers.	High: estimations were based on historic sales data, the impact of temporary fluctuations needed to be removed. Information on the proportion of historic sales related to events and sales campaigns did not exist and estimating it retrospectively resulted in multiple distinct interpretations.
2. Aggregate product orders	High: while orders made to Norrmejerier were readily available, access to information on orders placed with the co-distributor was highly desired.	Low: information on orders existed within the overall process and was reliable.	Low: number of actual orders was a univocal parameter.
3. Estimate sales campaign effect	High: IT-enabled access to information during campaigns from sales, co-distributors, and grocery stores could have increased adaptability during campaigns.	High: information on geographical and temporal aspects was not available and information on total impact was not reliable.	High: estimates of impact were highly subjective.
4. Estimate impact of events	Low: information was not available in other parts of the overall process and existing historical information was accessible.	High: estimations were based on similar historical events' impact on sales. However, historical sales data were not accompanied by explanations and interpretations.	High: isolating similar historical events' impact on sales retrospectively was a highly subjective task.
5. Determine inventory	High: existing information in co-distributing organizations affected inventory but could not be accessed.	Low: reliable information existed within the overall process.	Low: accurate and standardized measurements provided univocal information.
6. Establish demand prognosis and create production order	Low: the necessary IT-enabled access to information across boundaries was present.	High: more information on desired inventory levels required.	High: experiences and situated knowledge generated different interpretations of desired inventory levels.
7. Aggregate skim milk and cream balance	Low: the involved actors had sufficient IT-enabled access.	High: information on required raw material amounts was unreliable since parameters were incorrect and planning was not always done.	Low: formulas provided standardized information.
8. Adapt to skim milk and cream availability	Low: the involved actors had sufficient IT-enabled access.	High: prognoses on skim milk and cream availability were highly uncertain.	Low: the limited range of responses allowed standardized interpretations.
9. Adapt to production feedback	Varied between types of feedback (see task 6 or 8).	Varied between types of feedback, see task 6 or 8.	Varied between types of feedback (see task 6 or 8).

5.4. Digital Options Recognition

To conclude the analysis, we examine how digital options characteristics, generated by IT capability investments, can address the identified information requirements (cf. Principle 1). Table 6 summarizes the resulting actionable digital options for improving the production planning process.

The high connectivity requirements in production planning tasks 1 to 3 reflect Norrmejerier's lack of access to information on end-consumer behavior in grocery stores. While this information exists, production planners could not access it. These connectivity requirements could be addressed by increasing production planners' reach towards grocery stores' inventory management systems (cf.

Principle 2). Such access would provide reliable sales measures for estimating product demand (task 1) and the impact of sales campaigns (task 3), which would reduce due to the lack of information and equivocality due to inadequate analyses of historic information. A first digital option is thus "down-stream integration".

While "down-stream integration" would address the high uncertainty and equivocality requirements of tasks 1, 3 and 4, it would not eliminate them. To further address these, the involved actors would need to more effectively produce, share, and use information. Such collaborative analysis of recent events and prognosis creation could be supported by regularly scheduled video-conferencing involving representatives from sales, distribution, and production planning (cf. Principle 4). The richness provided by such technology would allow the involved actors to share and jointly produce information on recent impact and create more reliable prognoses for upcoming events via negotiating alternatives and explicating underlying assumptions. "IT-enabled estimate reviews" thus constitute a second digital option.

To support information production regarding the impact of events in response to high uncertainty requirements in tasks 1, 3 and 4, Norrmejerier could adapt the ERP system or invest in a DSS to tag volumes related to specific events and to capture information about the circumstances of each event (cf. Principle 3). Producing such information (e.g., for the last week's sales) would create a more solid foundation for reducing the equivocality involved in interpreting historic sales. A third digital option thus concerns "retrospective sales impact measures".

As a complement, or alternative, to manual interpretation of historical impacts on sales, Norrmejerier could employ data-mining technology to analyze sales data. Such technology supports information sharing across subsequent episodes, and thereby reduces the equivocality involved in producing estimates in tasks 1, 3, and 4 (cf. Principle 4). The production of information on relationships between events and product demand could offer important insights into how various events affect demand over time. Such technology should be directed towards identifying and evaluating historical trends and toward providing estimates on the optimal volume of products to be held in warehouses. Hence, a fourth digital option is "data-driven demand prediction".

The connectivity requirements of tasks 2, 3, and 5 are all related to lack of access to existing information held by co-distributors. Increasing reach to this information would allow production planners to use information on existing orders to improve estimates of available inventory levels and the impact of sales campaign (cf. Principle 2). Such information would also reduce uncertainty relating to the geographical impact of sales campaigns. The information could either be provided by exchange using EDI files or by creating interfaces to co-distributors' systems. A fifth digital option is thus "IT integration with co-distributors".

Responding to the uncertainty involved in estimating sales campaigns' impact would require reliable and timely information on potential orders from sales. The available information was unreliable since potential orders could not be distinguished from actual orders. Providing planners with information on the likelihood that potential orders will actually be placed (produced by sales personal as they report them) and real-time information on placed orders would at least address these information requirements (cf. Principle 3). Hence, a sixth digital option is "modification of the sales support system".

The uncertainty requirements of tasks 7 and 8, and the common ad-hoc solutions to issues with skim milk and cream availability in task 9 are all related to unreliable information from local planning. Digital options with information production characteristics could address these requirements. While production planners managed most demand planning, supply planning in the make process is a distributed task with interdependencies that require coordination. The information on this process was unreliable because the underlying parameters and routines for producing information are not standardized. Providing a tool in which operational plans are based on standardized procedures and parameters set by one actor would increase the reliability of information in this process (cf. Principle 3). Hence, a seventh digital option is "IT-enabled adaptive production management".

Table 6. Digital Options for Production Planning

Actionable digital option	Addressed information requirements	Generated digital option characteristics	Framed IT capability investments	Promised performance improvement
1. Down-stream integration Integrate the ERP system with grocery chains' inventory management systems. (Derived from Principle 2.)	- Task 1 (connectivity, uncertainty, equivocality) - Task 2 (connectivity) - Task 3 (connectivity, uncertainty, equivocality)	- Increased reach allows access to information on consumer behavior. - Improved capability to produce timely and reliable information on historical impact.	- Substantial investments in new partnerships with retail grocery chains. - Investments in technological integration.	- Enhanced sensing capability. - Improved demand estimates. - Fewer discarded products and missed sales opportunities.
2. IT-enabled estimate reviews Invest in video-conferencing for collaborative sales prognoses. (Derived from Principle 4.)	- Task 1 (connectivity, uncertainty, equivocality) - Task 3 (connectivity, uncertainty, equivocality, requirements) - Task 4 (connectivity, equivocality, requirements)	- Increased reach and richness allows collaborative analysis of digital material. - Stimulate collaborative information production. - Shared digital material allows relationship interaction for analyses.	- Investments in videoconference tools used in regularly scheduled meetings for sharing, and jointly analyzing, information on upcoming and recent events and campaigns.	- Improved prognoses and learning from evaluation of recent events. - Fewer discarded products and missed sales opportunities. - Decreased dependency on situated knowledge.
3. Retrospective sales impact measures Implement feature in existing systems for creating information on sales impacting events. (Derived from Principle 3.)	- Task 1 (uncertainty, equivocality) - Task 3 (uncertainty, equivocality) - Task 4 (uncertainty, equivocality)	- Stimulate information production on impact of recent events and campaigns, and hence normal demand. - Reduce equivocality involved with retrospectively making estimations of such impact for previous years.	- Adaptations of the ERP system or investments in a DSS that allow amounts to be tagged as belonging to certain events, and information describing them to be produced.	- Improved prognoses on upcoming sales-affecting events and better evaluation of recent events. - Fewer discarded products and missed sales opportunities. - Decreased dependency on situated knowledge.
4. Data-driven demand prediction Implement data mining to analyze sales data. (Derived from Principle 4.)	- Task 1 (uncertainty, equivocality) - Task 3 (uncertainty, equivocality) - Task 4 (uncertainty, equivocality)	- Stimulate information production on historical trends in sales numbers. - Identify triggers for previous customer behavior to adapt to historical preferences.	- Investments in data mining technology applied to historic sales data from the ERP system.	- Improved accuracy in prognoses and identification of required inventory levels through analysis of sales data. - Fewer discarded products and missed sales opportunities. - Decreased dependency on situated knowledge.
5. IT integration with co-distributors Integrate the ERP system with co-distributors order management system. (Derived from Principle 2.)	- Task 2 (connectivity) - Task 3 (connectivity, uncertainty) - Task 5 (connectivity)	- Increased reach allows access to existing orders. - Stimulate information production of effects from sales campaigns.	- Investments in partner relationship resources to exchange EDI files on current orders at regular basis, or to create interfaces to co-distributor system.	- Fewer discarded products at co-distributed sites and missed sales opportunities. - Updated information allows adaptations to current sales trends.

Table 6. Digital Options for Production Planning (contd.)				
Actionable digital option	**Addressed information requirements**	**Generated digital option characteristics**	**Framed IT capability investments**	**Promised performance improvement**
6. Modification of sales support system Adapt current system to provide tracking of potential orders. (Derived from Principle 3.)	- Task 3 (uncertainty)	- Stimulate production of detailed information on the state of potential orders.	- Adaptations to sales support system providing features for production and consumption of detailed information on progress of potential orders.	- Improved sales sensing capability and hence demand prognoses.
7. IT-enabled adaptive production management Invest in production planning system to integrate and standardize procedures. (Derived from Principle 3.)	- Task 7 (uncertainty) - Task 8 (uncertainty)	- Stimulate reliability of information produced during distributed planning by standardizing parameters and procedures.	- Investments in integrated planning system. - Planning processes and practices standardized, clarify roles and responsibilities.	- Reduction of costly ad-hoc solutions, better control and coordination of operations decreases waste, and allow better decision making.

6. Discussion

While applying options thinking to IT capability investments has great potential, theory for understanding and examining digital options is underdeveloped. To this end, this study extends previous theorizing on digital options by developing theory that supports analysis and provides prescription (Gregor, 2006, p. 619). Having outlined the theory and illustrated its applicability, we discuss its contributions, implications, and limitations.

6.1. A Theory of Digital Options

The conceptual foundation of the proposed digital options theory consists of two core elements: a conceptual model (Figure 1) and the digital options chain (Table 1). First, we articulate a conceptual model that captures relationships between the core digital options constructs. Consistent with options theory (Bowman & Hurry, 1993; Luehrman, 1998), we posit that digital options frame plausible IT capability investments and that they promise improved performance, and we argue that information requirements is a fruitful lens for considering tasks leading to process outcomes (Daft & Lengel, 1986; Mathiassen & Sørensen, 2008). To effectively evaluate the impact of IT on firm performance, we propose that an actionable digital options theory preferably is situated in the context of business processes (Pavlou & El Sawy, 2006; Ray et al., 2004), and we draw on earlier research on contextual value of options and IT capability (Amram & Kulatilaka, 1999; Bharadwaj, 2000; McGrath, 1997) to explicate the relationship between information requirements and digital options.

Second, we outline the lifecycle of digital options by translating the options chain (Bowman & Hurry, 1993) into the IT domain. Because previous research has failed to acknowledge how digital options change as an investment process progresses, we adapt the options chain to describe how digital options evolve: an **available option** is an IT capability investment in the bundle of possible investments that awaits recognition, an **actionable option** is an IT capability investment that has been examined and found to be both desirable and feasible, and a **realized option** is an IT capability investment that has been made.

We also provide principles for digital options examination, which specifies the digital option characteristic addressing specific information requirements (Principles 1-4 and Table 2), and an iterative process for digital options recognition (Principle 5 and Figure 2). First, drawing on classical theory on organizational information processing (Daft & Lengel 1986) and acknowledging the integrated nature of processes in complex business networks (Malhotra et al., 2005), we specify three distinct types of information requirements for task execution: connectivity, uncertainty, and equivocality. While uncertainty and equivocality requirements are well established concepts in information processing theory (e.g., Daft & Lengel 1986), we derived connectivity requirements from studies on the transformative effects of IT that emphasize horizontal and vertical transparency of information (Evans & Wurster, 2000; Fleisch & Tellkamp, 2006; Sambamurthy et al., 2003). Further, grounded in theory on information management (Mathiassen & Sørensen, 2008) and ubiquitous computing (Evans & Wurster 2000; Fleisch 2006), we propose that desirable digital options address these information requirements in terms of IT capability for reach and richness features (connectivity), information production and consumption (uncertainty), and relationship and encounter characteristics (equivocality). These principles provide a theoretically grounded foundation for analyzing IT´s implication in the execution of a given process, and they prescribe desired IT capability characteristics in digital options. In addition, we provide an iterative approach for recognizing desirable and feasible (Checkland, 1981) digital options through context appreciation, process characterization, information requirements analysis, and digital options recognition (Principle 5 and Figure 2).

Positioning the digital options theory in relation to IT capability investments into business process affords considerable plasticity in how the theory may be applied. At the highest level of analysis, managers may apply the theory to the core processes of a firm, such as its supply chain, its production process, or its service provision. At a more focused level, managers may apply the theory to zoom in on IT capability investments for processes like payroll, replenishment, or hiring. To afford this plasticity, Principle 5 emphasizes context appreciation and process characterization as the initial activities of examining IT capability investments. Next, the proposed conceptual foundation and principles help managers identify information requirements for identified process tasks and digital options characteristics that address these requirements. Still, the translation of these insights into specific IT capability investments remain a creative process that is at the border of our theorizing and highly dependent on the skills and perspective of the analyst.

6.2. Applying the Proposed Theory

Our analysis in Section 5 illustrates how the theory can guide examination of digital options. In context appreciation, we gained an understanding of Norrmejerier's operations by following Avgerou's (2001) three guiding principles for contextual appreciation. First, one should consider technology innovation in relation to socio-technical change. We followed this principle by emphasizing the interplay between IT capability, information requirements, and process performance. Second, analyses should consider technical and rational decisions and cultural, social, and cognitive forces. Following this principle, we paid specific attention to the intra-organizational context in Norrmejerier's distributed set-up. For example, the first author spent three weeks at the headquarters and participated in meetings and social activities to gain a deeper understanding of the company´s culture. Third, analyses of technical innovation should consider the organizational, national, and international context. While Norrmejerier's operations were limited to the national arena, this principle guided our examination of how technology connected the different processes and tasks involved in the production chain across organizational boundaries (Evans & Wurster 2000; Malhotra et al., 2005; Fleisch & Tellkamp 2006). Further, identifying suitable processes for IT investment is a key activity in the context appreciation activity. At Norrmejerier, we identified production planning as a suitable target for IT investments because of the recent shift in strategy, its high impact on financial performance, and external market pressures for change.

In process characterization, we identified and described key tasks and their interdependencies, the nature of the information processing involved in each task, current IT capabilities, and performance implications. At Norrmejerier, this involved identifying what production planners do and aggregating their activities into generic tasks across different products. Based on this mapping, we moved on to characterize each task. Existing understanding in the firm can guide this activity but the analysis requires critical analysis of assumptions that may be taken for granted (Glaser & Strauss, 1967). For example, although a process map describing Norrmejerier's overall operations was helpful, it did not accurately account for IT-based information processing and resulting process performance.

Information requirements analysis involves analyzing and characterizing each task according to its information requirements (Table 4). These requirements constitute the basis for suggesting digital options characteristics. Accordingly, the first author characterized each task as high or low with respect to each of the three types of information requirements. The characterization was then reviewed and debated with the second and third author; this led to re-characterization of a small number of tasks in Table 5. Debating the characterizations provided investigator triangulation (Miles & Huberman, 1994, p. 267) and a deeper understanding of how individual tasks and related information requirements affected the overall process.

Digital options recognition is the most creative activity: it requires analysts to iteratively move between process characterization and information requirements analysis. The existing IT capability and its performance implications provide guidance on what needs to be addressed, while Principles 1-4 suggest how to do so in terms of describing desired characteristics. Going from characteristics into specific IT capability investments does, however, require significant understanding of IT available for investment and possible application to the considered process. To identify options, many alternatives can initially be discussed focused on promised performance improvements, but the feasibility of options must, eventually, be evaluated by considering available resources and implementation conditions. At Norrmejerier, we discussed a total of fifteen digital options. We combined similar solutions and eliminated others to arrive at seven digital options that were both desirable and feasible (Checkland, 1981). Although each option was suggested in response to a specific principle, some addressed multiple information requirements. For example, although down-stream integration was derived from high connectivity requirements, it also addresses uncertainty and equivocality requirements in tasks 1 and 3. Finally, following Yin's (2003, p. 159) recommendation, we corroborated the actionable digital options (Table 5) by discussing them with a production planner (mainly focusing on desirability) and the CIO (mainly focusing on feasibility).

6.3. Implications and Limitations

The presented digital options theory provides a rigorous conceptual foundation for further empirical and theoretical examination. The theory also provides practitioners with a theoretically grounded prescription (Gregor, 2006) of principles for how to examine digital options to improve business process performance. As new technologies become available and firm processes change, desirability and feasibility of digital options vary. Hence, recognizing a specific digital option as actionable depends on when the examination is made. Managers therefore need to reconsider what the actionable digital options are for a particular business process at appropriate time intervals.

In all theorization, there is a tradeoff between general, simple, and accurate conceptualizations (Weick, 1989). We kept the outlined theory simple for the purpose of usefulness. Moreover, the theory focuses on how to turn available options into actionable options; it does not offer detailed recommendations for how to evaluate and activate them to arrive at realized digital options. As such, the theory is bounded both in terms of application area and activities. We also acknowledge the emergent characteristics of organizational change through IT investments (Leonardi, 2011; Markus & Robey, 1988; Orlikowski, 1992). Digital options thinking does therefore not necessarily lead to improved outcomes. However, if managers identify actionable digital options based on the presented principles, they establish a strong foundation for making IT capability decisions that eventually should improve business process performance. Finally, our research has limitations related to level of analysis and firm context. Although our process level focus help relate IT capability investments to performance, it might lead to neglect of opportunities only apparent at a firm level. We also grounded our theorizing in one organization with particular characteristics (i.e., highly distributed, production focused, market niche player), which suggests that the proposed digital options theory needs to be validated and further developed based on other organizational context and types of business processes.

Future research could develop methods for assessing the value of actionable digital options and for bundling them in order to better guide investment decisions. Moreover, although we corroborated the generated digital options through consultation with key actors in Norrmejerier, the scope and nature of this research project did not allow us to examine how exercising these options affected process performance. Consequently, the proposed model needs to be further empirically examined through studies of digital options realization. Finally, while the iterative approach for generating digital options provides guidance, it could benefit from more granular assessment methods for analysis of information requirements and translation of the process characterization and information requirements analysis into actionable digital options.

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