Exploring process innovation from a lifecycle perspective: Conceptual framework development and empirical investigation

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Exploring technological process innovation from a lifecycle perspective: An empirical investigation in large manufacturing companies

1. Introduction

Innovative operations are recognized as critical determinants of economic recovery and sustained competitiveness by scholars, practitioners and policy makers (Pisano and Shih, 2012; BMBF, 2013; SMLC, 2014). A central domain of innovative operations is technological process innovation (TPI) (Dodgson et al., 2008; Schallock, 2010). TPI can enable increased production yield, lower production costs (Browning and Heath, 2009), improved product and service quality (Reichstein and Salter, 2006), operational flexibility (Upton, 1997), controllability (Zelbst et al., 2012; Gerwin, 1988), environmental sustainability (Kleindorfer et al., 2005), and accelerated time-to-market (Hayes et al., 2005).

Despite the importance of TPI for organizational competitiveness, relatively little is known about the development and implementation of new processes (Frishammar et al., 2012; Hayes et al., 2005; Lager, 2011). Compared with product innovation, research has shown that firms seek TPI for different reasons at different points in time to remain competitive amidst changing market environments (Adner and Levinthal, 2001; Anderson and Tushman, 1991; Utterback and Abernathy, 1975). Managing process development on the operational level has received far less attention in the literature than product development (Frishammar et al., 2013), although it is equally 'enabled through planned, structured, and formalized work processes' (Frishammar et al., 2012).

Existing research has identified different stages of the process innovation lifecycle (ILC) (e.g. Kurkkio et al., 2011; Clark and Wheelwright, 1993; Voss, 1992). Early studies in this context do not distinguish between product and process innovation and suggest the same approaches for both (Utterback, 1971; Hayes et al., 1988). Others treat process innovation as a sub-component of product development or highlight the complementarities between both (Hayes et al., 2005; Wheelwright and Clark, 1994). Clark and Wheelwright (1993), for example, advanced an approach in which companies create products and production processes conjointly through iterations of design-build-test cycles, in which both are conceptualized and tested until a final design is reached. Similarly, Hayes et al. (2005) discuss TPI as an enabler of competitive advantage and complement to product innovation, thus making it pivotal to synchronize product and process development. Despite providing important insights, such contributions do not adequately account for issues specifically related to process development along the ILC.

TPI is a distinctive organizational phenomenon characterised by a firm internal locus and underlying components such as mutual adaptation of technology and organization, technological change, organizational change, and systemic impact (Gopalakrishnan et al. 1999; Lager, 2011; Reichstein and Salter, 2006). In order to treat TPI as a distinct unit of analysis and generate detailed insight on challenges companies face and capabilities they require, such components need to be investigated more closely (Becheikh et al., 2006; Lu and Botha, 2006). Existing work on TPI typically focuses on identifying activities and sequences in the ILC (Lager, 2011; Voss, 1992; Kurkkio et al., 2011, Hayes et al., 2005). Although such studies occasionally refer to specific TPI components, they do not explicitly show how these are addressed at different stages of the ILC. Therefore, a gap remains with regards to understanding the content of the ILC as constituted by TPI components.

Addressing this gap, we explore TPI from a lifecycle perspective with specific attention towards the TPI components. We focus our study on large manufacturing companies, in which TPI affects a large number of interconnected functions and departments. Our guiding question is: *How do large manufacturing companies develop and implement new processes along the different stages of the innovation lifecycle?*

We extend prior research by adopting an ILC perspective for the investigation of four TPI components. Building on empirical evidence from five large manufacturing companies, we elicit the content of mutual adaptation, technological change, organizational change, and systemic impact management across the stages of the ILC and identify patterns of asymmetric adaptation.

The paper is structured as follows: section two develops our conceptual framework. Section three presents the research methodology. Section four presents the results. Section five discusses our findings and concludes with implications for theory and practice.

2. Theoretical background and framework

The theoretical background of our study is informed by operations management (OM) and innovation management (IM) literature. The purpose of our framework is to establish categories in which to explore the content of key TPI components across the ILC.

TPI is defined as the development and implementation of new or significantly improved operations, including production, product development, and administration, which involves the introduction of new technology (Meyers et al. 1999; Oke et al., 2007). TPI is a broad concept, involving the introduction of new hardware and software technology (Carrillo and Gaimon, 2002; Zelbst et al., 2012), but also changes to organizational structures and procedures (Edquist et al., 2001; Parikh and Joshi, 2005). Previous studies in OM have demonstrated the importance of technological and organizational change for operations improvement, such as the implementation of RFID technology or restructuring purchasing processes (Zelbst et al., 2012; Parikh and Joshi, 2005).

Despite this analytical distinction, TPI typically encompasses both technological and organizational changes (Reichstein and Salter, 2006). Process development, thus, needs to account for technological change as well as associated jobs, procedures and work activities (Slack et al., 2013). Particularly in manufacturing industries, the complementarity between technological and organizational change has been highlighted (Jayanthi and Sinha, 1998). Although technological and organizational change may have positive effects on firm performance independent of each other (Georgantzas and Shapiro, 1993), congruency between both is commonly found to be a critical determinant of successful TPI (Battisti and Stoneman, 2010; Ettlie et al., 1984). Gerwin (1988) emphasized the need for complementary skills, support systems, procedures, and social structures to realize the implementation of new computer-aided-manufacturing technology. More recently, Cantamessa et al. (2012) discussed the importance of fit between new technology, existing IT infrastructure, job performance requirements, and operators' skills, for realizing new processes through the adoption of product-lifecycle-management technology. Companies therefore face the challenge of managing mutual adaptation of new technology and existing organization (Leonard-Barton, 1988; Tyre and Hauptman, 1992). As processes are embedded within a broader organizational context, changes to technology or organization may invoke further changes (Gopalakrishnan et al., 1999). Modifying individual process components often results in changes to the components' periphery, making systemic impact a central aspect of TPI (Kurkkio et al. 2011).

This brief review identifies four components underlying TPI: mutual adaptation; technological change; organizational change; and systemic impact. We elaborate on these components in the following sections.

2.1 Process innovation components

Mutual adaptation. Congruency between technology and organization is key to successful TPI (Ettlie et al., 1984). From the outset of an innovation project, new technology is unlikely to fit with a company's existing organization (Tyre and Hauptman, 1992). Mutual adaptation refers to the reconfiguration of new technology and existing organization to achieve a fit between both (Leonard-Barton, 1988). Change may relate to the technology's architecture as well as existing operations, routines, skills, and support systems that constitute the organization (Gerwin, 1988; Tyre and Hauptman, 1992). Mutual adaptation has primarily been studied as an emergent phenomenon during and after technology installation (Leonard-Barton, 1988; Majchrzak et al., 2000; Tyre and Orlikowski, 1994). While the installation of new technology marks a critical point for the management of process innovation (Voss, 1992), the stages prior to installation are equally important as they comprise the planning and development of TPI (Kurkkio et al., 2011; Frishammar et al., 2013). We, therefore, explore how companies address and manage mutual adaptation throughout the entire ILC.

Technological change. Technology refers to hardware and software that support the transformation of inputs into outputs in a company's enabling and core processes (Carrillo and Gaimon, 2002; Schallock, 2010). The introduction of new process technology has been identified as an enabler of efficiency improvements and cost reductions in production and R&D (Dodgson et al., 2008; Zelbst et al., 2012). Technology development and implementation is not a simplistic task. Technology needs to be acquired or developed internally and fit to the context in which it is implemented (Cooper, 2007; Lager and Frishammar, 2010; Tyre and Hauptman, 1992). This invokes equivocality (Frishammar et al., 2011) as well as technological, financial, and social uncertainty, because the technology and its consequences are initially not fully understood (Gerwin, 1988; Stock and Tatikonda, 2004). In this study we seek to understand how issues of technological change are addressed and managed throughout the ILC. To document the management of technological change, we refer to activities, outputs, and problems that relate a technology's relative advantage, complexity, compatibility, and communicability (Rogers, 2003; Tornatzky and Klein, 1982).

Organizational change. Organizational change refers to new ways of organizing work (Edquist et al., 2001). This includes the development and introduction of changed organizational structures, administrative systems, management methods, or existing processes and capabilities (Damanpour and Aravind, 2012; Carrillo and Gaimon, 2002). Organizational change can pertain to the administrative functions within the company, for example, human resources or purchasing (Damanpour and Aravind, 2012) as well as work organization in core operations, such as production (Birkinshaw et al., 2008; Edquist et al., 2001; OECD, 2005). Prominent examples of organizational change include just-in-time production and total-quality-management (Womack et al., 1990). Although organizational change is closely intertwined with technological change (Edquist et al., 2001; Georgantzas and Shapiro, 1993), its purpose and consequences are often less evident to internal stakeholders, making it more difficult to legitimize and implement (Damanpour and Aravind, 2012). Birkinshaw et al. (2008) identify three reasons why organizational change is challenging: it is often tacit in nature and difficult to observe, define, and identify; companies often lack relevant expertise; and it causes ambiguity and uncertainty amongst stakeholders. The coordination of such change has the potential to create conflict within the organization, either due to the alteration of roles, power, and status, or because of discrepancies in expectations and requirements of different stakeholders (Gerwin, 1988). To this background, we seek to understand how companies coordinate organizational changes throughout the ILC.

Systemic impact. Processes consist of inter-connected components that affect multiple functions within the company (Gopalakrishnan et al., 1999; Hayes et al., 2005; Kurkkio et al., 2011). Systemic impact implies that an innovation can only be realized if it is integrated with its broader system

(Chesbrough and Teece, 2003). According to Gatignon et al. (2002), systemic impact emerges from changes in the linking of subsystems (architectural) or changes in subsystems themselves (modular). Systems modularity explains the configuration of subsystems and degree of coupling between them. A modular system comprises of units whose subsystems are strongly connected internally, but weakly connected externally (Baldwin and Clark, 2000; Gomes and Dahab, 2010). Modular systems can be designed independently, but still function as an integrated whole. Thus, depending on the modularity of the organizational system, changes in internal processes can invoke system-wide impacts. Such impacts can render established systems obsolete, leading to the reformulation of existing roles, relationships, and mental models (Tyre and Hauptman, 1992). Systemic impact may not be evident from the outset of an innovation project. Using new information, however, often requires costly revisions of earlier decisions and designs (Terwiesch and Loch, 1999). To this background, we seek to explore how companies manage and cope with systemic impact throughout the ILC.

2.2 Process innovation lifecycle

Existing literature provides several ILC models, which outline different stages and activities for the creation of TPI. Aggregating earlier work, we propose four ILC stages. *Ideation* describes the initial generation of process candidates and is triggered by process related performance gaps (Gerwin, 1988). *Adoption* comprises all activities related to facilitating and making investment decisions. Concept development and preliminary project descriptions aid decision making (Frishammar et al., 2011; Kurkkio et al., 2011; Lager, 2011). *Preparation* comprises technology development and organizational change planning (Gerwin, 1988; Tyre and Hauptman, 1992; Voss, 1992). *Installation* refers to process implementation, including technology set-up and organizational change introduction. Furthermore, we distinguish between task forces (process designers; project management), decision makers (higher-level managers; authorizing investments), and operators (process users; technical and administrative functions) as important stakeholders, but only adopt a task forces' perspective. Figure 1 depicts our research framework.

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3. Methodology

We adopt an exploratory case-research design because of the nascent state of theory; we seek to answer a 'how-question'; and we aim to capture the content of and relationships between TPI components at different ILC stages. Such objectives are best addressed by case-research (Yin, 2003). We use multiple cases to corroborate findings and dissociate emerging patterns from firm specific circumstances, thus generating more analytically generalizable theory (Eisenhardt and Graebner, 2007; Eisenhardt, 1989).

3.1 Empirical setting

The study focuses on large manufacturing companies from different industries. Large, manufacturing companies typically have strong technological competences and make substantial investments in TPI (Cabagnols and Le Bas, 2002). Moreover, they are often characterized by departmentalization and hierarchical structures that impede flexibility (Pavitt, 1991). This constitutes a challenging environment for process development and implementation, and provides a rich grounding for our research. We selected five companies according to criteria such as investments in TPI, main business in manufacturing, and number of employees. Purposeful case selection increases the chances of capturing valid insights (Eisenhardt and Graebner, 2007). To facilitate replication (Yin, 2003), we distinguished between companies reporting on the development of enabling processes or core processes (Table 1).

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3.2 Framework development

The conceptual framework provided relevant categories for our research and was used to guide data collection, analysis, and integration with existing literature (Eisenhardt, 1989; Miles and Huberman, 1994). The framework aggregates different streams of OM and IM literature. It was discussed with selected members of the case companies, as well as other practitioners and academic peers. This led to minor refinements and increased construct validity.

3.3. Data collection

We conducted semi-structured, face-to-face interviews with multiple, knowledgeable representatives from all five companies. During a four month period and 55 sessions, we collected 91.5 hours of recorded interview data. Interviews were retrospective and focused on the respondents' general experiences with regards to various TPI projects. To address potential issues of ex-post sense-making and selective memory, we interviewed numerous informants and captured a variety of experience. This decreases the likelihood of convergent retrospective sense-making and strengthens data validity (Eisenhardt and Graebner, 2007). Visits to manufacturing facilities in four companies provided us with additional opportunities to gain first-hand insights on TPI development and testing. During these occasions we took notes to capture our impressions. This was further supplemented with extensive secondary documentation and follow-up discussions to inquire about particular findings and increase construct validity through triangulation.

3.4 Data analysis

Data were initially coded according to a ‘start list’ of codes based on the categories of our research framework (Miles and Huberman, 1994). We looked at which TPI components (PRV 1-4) the data could be coded and at which ILC stage (ILC 1-4) it had been discussed. We conducted several rounds of iterative coding, during which we created and eliminated emerging sub-categories of our framework. This allowed us to populate the framework with relevant content in each category for every company in our study. The results of this within-case analysis were logged in extensive data tables, as suggested by Miles and Hubermann (1994). We then created new tables, compiling the relevant data for each framework category from all cases under the same label, while maintaining references to the original sources. These tables were used to compare the findings at each category across cases, enforce rigor, and overcome initial impressions and premature conclusions (Eisenhardt, 1989). On this basis we identified similarities and differences across cases, from which we formulated initial working propositions and identified the content for further discussion (Eisenhardt, 1989).

4. Results

This section documents cross-case patterns relating to the TPI components at different ILC stages. Figure 2 provides a summary of the key results across the ILC.

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4.1. Ideation

Mutual adaptation. All companies reported an initial focus on developing or modifying new technology to address performance gaps. Although task force members generally considered organizational change necessary for TPI, the initial appraisal of existing technological infrastructure, processes, and hierarchical structures, serves as a frame for developing and implementing new processes. Anticipation of potential opposition against organizational change and the expectation to deliver solutions with a good chance of realization encourage the task forces to devise process descriptions with a bias towards adapting new technology rather than the existing organization. RailCo and ChasCo, nonetheless, clarified that with the introduction of standard technologies, an early focus on identifying organizational change is necessary to realize and accentuate the benefits of standard technologies, such as cost efficient updates, maintenance, and high modularity.

Technological change. Depending on market availability, the task forces either search for off-the-shelf technologies or technological components for further internal development. We found that the task forces use 'potential compatibility' and 'relative advantage' as primary evaluation attributes. While they considered accurate specification of these attributes as highly desirable, achieving accuracy is challenging, as neither technology nor the expectations towards it are well understood at this stage. Consequently, communicability is generally considered to be low. The case of EleCo, however, showed that limited availability of existing technological solutions and a focus on risk mitigating incremental changes enabled the task force to invest in early research to determine compatibility and relative advantage more accurately. This also facilitated a slight increase in communicability.

Organizational change. All task forces stated that potential organizational change should be considered during ideation, yet they typically reported that only minor attention was paid to it. Organizational change was perceived to create more internal opposition and coordination efforts, especially in the context of complex structures and relationships in large companies. Moreover, the task forces found it difficult to understand necessary organizational changes early on. Consistent with the results on mutual adaptation and technological change during this stage, we found that the existing organization served as a frame of reference in which to evaluate potential new technologies.

Systemic impact. All five companies recognized early systemic impact assessment as important for identifying potential costs and benefits of process ideas. If costs of systemic impact are perceived to outweigh their benefits, ideas are excluded from further investigation. Most task forces, however, explicitly reported that the limited specification of new processes made it difficult to determine their systemic impact. This may even lead to systemic impact being neglected (RailCo). Nevertheless, potential impact can be tentatively described by gathering feedback from key operators with sufficient tacit and explicit knowledge of existing operations.

4.2 Adoption

Mutual adaptation. The task forces in most cases reported that decision makers were generally willing to adopt technological and organizational change, as long as the respective benefits were clearly articulated. RailCo and ChasCo suggested that costs and effort of achieving a fit between technology and organization were the main criteria for decision making. Still, this was considered easier to determine for technological change. Nevertheless, the companies emphasized that organizational change was particularly important for decision making on the introduction of standard technologies. In contrast, the results show that decision making favours technological change for internally developed technologies to facilitate core processes (e.g. production) (EleCo; ChasCo).

Technological change. Technological change was highly important to decision making in all cases. We found that technological concept development either referred to the presentation of technologies by external vendors (CarCo; RailCo; DefCo; ChasCo) or prototype development for company-specific solutions (EleCo, ChasCo). EleCo and ChasCo explicitly highlighted the importance of systematic and early technology evaluation to aid adoption. This comprises pre-studies to minimize uncertainty with regards to compatibility and relative advantage of internally developed solutions (EleCo) or evaluation criteria for vendor solutions (ChasCo). Common thread to decision making was an emphasis on compatibility. We found that several cases emphasized the importance of future compatibility, which they estimate in terms of cost and effort of further technology change or modification once in operation to fit with future developments (e.g. producing a new product). The relative advantage of new technology in terms of improving production efficiency, output quality, and safety, was also central to the investment decision. The task forces, however, expressed difficulty in estimating relative advantage precisely given limited technological understanding. As such, communicability is equally limited. EleCo and ChasCo were exceptions due to the early emphasis on concept development, which increased technological understanding and communicability.

Organizational change. Relative to the ideation stage, organizational change gains importance during adoption because concept development increases clarity on the potential functions that may be affected. Nevertheless, all task forces stated that such considerations were often severely discounted in favour of technology change. The companies reported it as a challenge to coordinate organizational change, especially if different stakeholders had different expectations and requirements. The implementation of standard solutions in particular required significant effort from task forces to persuade relevant stakeholders to agree to and support adoption. Uncertainty, however, makes advocating organizational change difficult. It is, for example, difficult to gather support for eliminating specific roles and functions when their future relevance is not understood clearly (CarCo).

Systemic impact. All task forces considered systemic impact assessment important. Tentative process specification and complex organizational structures make it difficult to carry out impact assessment. Differences thus emerged in the extent to which impact assessment is included in decision making. In some cases (CarCo; RailCo) the added complexity of considering systemic impact often leads decision makers to ignore it. In contrast other companies (EleCo; ChasCo) explicitly include systemic impact in decisions making. This was particularly emphasized in the context of processes linked to core operations. In EleCo, for example, the effect of a new process is always assessed thoroughly to prevent the disruption of production processes during implementation.

4.3 Preparation

Mutual adaptation. Mutual adaptation was considered in every case, yet a general preference for developing or modifying technology to fit with existing organization emerged consistently. Increasing resistance against organizational change among operators encouraged the task forces to follow this pattern. The task forces in CarCo, RailCo, DefCo, and ChasCo pointed out that the limited adaptability of standard solutions was necessary in order not to impede the advantages of standardization. In this context, greater readiness for organizational adaptation was considered necessary. In contrast, EleCo and ChasCo (core) considered it desirable to articulate the firm specific capabilities and seek technological adaptation towards the existing organization when developing core technology internally.

Technological change. During preparation technological change refers to the modification or development of a specific technology to enable a new process. This can include minor adaptations or developing additional functionalities to externally acquired technology as well as full scale proprietary technology development. While the aim is achieving a fit with the process description, compatibility was generally assessed relative to the operators' expectations and requirements. All task forces reported that gathering operators' acceptance was imperative to exploiting process innovation effectively. The task forces reported to shift communication efforts from decision makers to operators, in order to gather feedback on further developments, but also to address uncertainties when opportunities for substantial technological change were limited (CarCo; RailCo; DefCo; ChasCo). Communication, however, was still considered a major challenge across most cases. The main problem was the unfinished state of technology, which hindered communicability and observability. CarCo, for example, explained that if technology was communicated on an abstract level, operators might not understand it. At the same time, presenting unfinished technological solutions could constrain operators' acceptance due to confusion or disappointment.

Organizational change. Despite displaying a preference for technological change, several task forces reported that limited technological adaptability, process standardization across departments, and adoption of standard technologies made organizational change unavoidable. According to these task forces organizational change required coordination across multiple departments and functions. Coordination is particularly challenging when different stakeholders have conflicting interests. Moreover, the task forces typically experienced increasing opposition against organizational change during this stage. We found that it was easier to prepare and implement changes to existing work processes where people had to perform similar tasks slightly differently, rather than preparing and coordinating structural change, in which operators are given new functions and responsibilities (DefCo; EleCo; ChasCo).

Systemic impact. We found that systemic impact becomes increasingly important. Detailed solution development reveals potential impacts more clearly. This is important for planning seamless process implementation without disrupting existing operations, while controlling for potential impact beyond immediately adjacent components throughout the organizational system. The task forces pointed out that such systemic integration was central to the appropriation of process innovations, as it made processes uniquely fit the company and difficult to understand for outsiders. In order to realize such benefits, however, it is important to prepare for coherent adoption of the new process across all departments it affects. Expert review, simulation, and pilot studies help uncovering unanticipated impact prior to implementation.

4.4 Installation

Mutual adaptation. Unanticipated adaptation is generally necessary during this stage, yet time pressure, daily operations, limited resources, and clearly defined project boundaries restricts the opportunities for further change. EleCo explained that the main priority was keeping production running and addressing misalignments in core operations immediately. References across all cases corroborated this insight. To this background the task forces reported a tendency towards technological change, which required less funding, coordination, and time than organizational change. Remaining misalignments often result from discrepancies between task forces' process description and operators' enactments of new processes. Deploying additional training for capability development (e.g. for working with new machines, processes, and/or organizational structures) was consistently suggested as a powerful adaptation mechanism.

Technological change. Similar experiences on technological change during installation were reported in all cases. Typically, new technology is installed and configured, then handed over to operators. At this stage, the technology needs to work in a real operations environment, which makes it crucial to accomplish compatibility with the organization, existing technological infrastructure and operators' skills and expectations. Limited resources and finalized process design only allow for minor technological change. The task forces across all cases further agreed that one of the most critical determinants of successful technology introduction was the extent to which it was accepted and correctly applied by operators. Uncertainty and unintended coping mechanisms often result from the operators' lack of technology understanding, which hinders the effective realization of the technology's relative advantage. While task forces have developed a thorough technological understanding, complexity increases from the operators' perspective. Therefore, the task forces aimed to shape operators' attitude rather than changing technologies. High levels of communicability are therefore necessary during this stage to facilitate knowledge transfer from the task force to operators. In this regard, limited time for training due to daily operations is a common problem.

Organizational change. All cases considered organizational change to be important. Yet, complex, historically grown structures make it difficult to implement it. While there were several references to hierarchical support for enforcing change, we found that structural change needed acceptance among the operators enacting the new process (CarCo; DefCo; ChasCo). Therefore, most task forces agreed that organizational change implementation mainly required addressing operators' resistance. The task forces also explained that further structural changes, such as changed responsibilities and reporting structures, required significantly more coordination than ad-hoc changes to the specification of task performances within existing organizational domains. The task forces in CarCo, DefCo, and ChasCo found that changes to task performance were relatively unproblematic when given sufficient training. Nevertheless, this may incur costly workarounds (RailCo).

Systemic impact. The systemic impact of change becomes fully apparent during installation. Seamless integration largely depends on the work carried out in earlier stages. Managing systemic integration during installation is a delicate issue, as further change requires significant effort, cost, and time. As a precaution, it was mentioned in several cases that ‘emergency’ budgets and time for ad-hoc change scenarios should be reserved. Furthermore, simulation and mock-up environments or successive installation in different facilities are used to manage systemic integration. EleCo reported that flawless systemic integration was particularly important for core processes. If a new technology cannot be integrated with the existing technological infrastructure or operated by operators, it may disrupt the entire operations system, resulting in a lack of output quality or quantity. For less critical processes, the task forces reported that further changes could be postponed to follow-up projects.

5. Discussion

5.1 Adaptation prior to process implementation

Our results suggest that mutual adaptation is an important conceptual perspective for outlining and selecting solutions during early ILC stages. During later stages adaptation is deliberately managed to resolve misalignments between technology, organization, and operators. Complementing earlier studies on mutual adaptation as an emergent phenomenon during and after implementation (Leonard-Barton, 1988; Majchrzak et al., 2000; Tyre and Orlikowski, 1994), our findings document a deliberate process of adaptation occurring prior to implementation. This is particularly relevant given that there is generally limited opportunity for change once a new process becomes operational (Tyre and Orlikowski, 1994). Our findings therefore advocate a holistic perspective on process development and implementation, which comprises the practical development and implementation stages (Gerwin, 1988; Hayes et al., 2005), but also the more conceptual and relatively unexplored ILC front-end (Kurkkio et al. 2011).

5.2 Mutual adaptation as an asymmetric process

Our findings suggest that mutual adaptation enfolds as an asymmetric process. Opposition against organizational change, substantial coordination efforts, and difficulty to understand necessary changes early on, create a preference for technological change within existing organizational structures and processes among task forces (cf. Birkinshaw et al., 2008; Damanpour and Aravind, 2012). As the results clearly show that operators' acceptance was critical to successful implementation, it is likely that task forces may expect greater implementation success when asymmetrically adapting new technology towards the existing organization. Our results, however, suggest that this tendency is moderated by the type of process that companies develop and the technology they adopt. We find that when companies develop proprietary technology for core processes (EleCo; ChasCo) that are unique to their operations, they seek to leverage the competences manifested in the existing technological infrastructure, processes, and operators' skills (low standardization: more technology change, less organizational change). Conversely, we find that externally acquired standard technologies may facilitate efficiency gains through standardization and increased modularity in processes that are not directly related to the company's core operations (CarCo; RailCo; DefCo; ChasCo). In this case, companies seek to exploit the expertise of external technology suppliers (Lager and Frishammar, 2010; Rönnberg-Sjödin, 2013; Stock and Tatikonda, 2004). Across the ILC our results show that in order to do so the task forces restrict technological adaptation to leverage the benefits of standardization. This suggests that standard processes require overcoming preferences for technology change and maintaining the organizational status quo (high standardization: less technology change, more organizational change). In sum, we propose that mutual adaptation is an asymmetric process with the level of desired process standardization affecting the direction of asymmetry (Figure 3).

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5.3 Differences in managing technological change

In line with earlier research, we document user involvement as imperative for preparing for developing transport systems (user interfaces), successful technology installation, and creating a fit between new technology and operators' expectations (Cantamessa et al., 2012; Kurkkio et al., 2011; Leonard-Barton, 1988). Nevertheless, our findings indicate that limited communicability hinders operators' involvement at various stages of the ILC. Our findings reveal that in response, task forces focus on a technology's compatibility with the existing organization to reduce high levels of complexity that are characteristic of early stage technology development (Frishammar et al., 2011; Cooper, 2007). After pre-selection the expectations and requirements of the affected operators can increasingly be taken into consideration as a referent for compatibility. Therefore, the focus of communication increasingly shifts to operators as process development progresses. In this regard, our findings again highlight the differences between the implementation of externally acquired standard solutions (CarCo; RailCo; DefCo; ChasCo) and internally developed core technologies (EleCo;

ChasCo). Relatively less opportunity for technological change in standard technology adoption invokes more efforts to persuade operators to adopt necessary organizational changes.

5.4 Limitations to organizational change

Our results suggest that the existing organization is a known and explicable system to organizational stakeholders and significant uncertainty is involved in the introduction of change. Moreover, we found limited potential for task forces to enforce change top-down, as representatives from operating functions within manufacturing firms are often very powerful (cf. Shields and Malhotra, 2008). Internal opposition requires substantial coordination effort for organizational reconfiguration. When organizational change is unavoidable, our results indicate, it is relatively easier to convince operators to perform existing tasks in a slightly different fashion, rather than introducing new organizational structures or subsystems. We attribute this to the more technical nature of changing work activities, which can be demonstrated, trained, and more clearly expressed. Changes in the organization's architecture represent more radical forms of innovation (Gatignon et al., 2002) and involve more social uncertainty with regards to the operators' employment or authority status (Gerwin, 1988).

5.5 Systemic impact assessment and integration

We found that the task forces generally experience the systemic nature of processes as a key challenge of process innovation (Gopalakrishnan et al., 1999). Nevertheless, our results show significant differences in the ability to articulate systemic impacts moving from ideation stages to installation. In this regard, early investment in concept development and interaction with key operators who possess substantial tacit and explicit process knowledge enable systemic impact assessment along the ILC. While it was reported in some cases that systemic impacts can be addressed after process implementation, our findings concur with earlier research in showing that flawless systemic integration of new processes is imperative for core processes such as production (EleCo; ChasCo), in order not to interrupt existing operations that directly affect firm performance (O'Hara et al., 1993).

6. Conclusions

6.1 Theoretical contributions

Our study contributes to the literature on new process development and implementation from a lifecycle perspective (e.g. Lager, 2011; Voss, 1992; Kurkkio et al., 2011, Hayes et al., 2005) by dissociating process innovation work with regards to four key components – mutual adaptation, technological change, organizational change, and systemic impact – across a generic ILC. While previous studies have empirically and conceptually identified activities, challenges, and sequences that constitute possible variations of ILCs, they have not explicitly accounted for different TPI components. Our study specifically uncovers the content of four central TPI components across the

ILC. In particular, our findings suggest that companies will follow asymmetric approaches to TPI development and implementation, favouring either technological or organizational change depending on the level of standardization desired. In the case of core processes, technology adaptation accentuates existing capabilities, whereas for enabling processes organizational change is necessary to exploit the benefits of standardization. The focus of our study on TPI components demonstrates the relevance of putting greater emphasis on the content of the variables that constitute TPI rather than documenting the sequence of activities within the ILC. We hope this encourages further studies to elaborate on TPI components. This will improve our understanding to which they can, or should, be addressed and how these insights translate into a company's room for manoeuver in TPI development and implementation along the ILC.

6.2 Managerial implications

Several recommendations to practitioners emerge from our study, although they remain tentative due to the exploratory nature of this study. We suggest that there is good rationale for managers working on core processes to give head status to technological change and accentuate existing capabilities. Conversely, for non-core processes, giving head status to organizational change is advised in order to exploit efficiency gains from externally sourced standard technology solutions. Despite a head status being afforded to either technological or organizational change, it is important not to neglect the complementarity of both and focus on mutual adaptation to achieve congruency. These recommendations imply that awareness of existing structures, processes, and technologies, as well as their value to the firm's core and non-core competencies, is a necessary precondition for determining the adequate structure of mutual adaptation. Finally, to address issues of uncertainty and internal resistance, managers need to ensure that changes are transparent to all relevant stakeholders. Although, it may be difficult to achieve high levels of communicability early on, we recommend close contact with operators to address changing expectations and uncertainty and to assess potential systemic impact.

6.3 Limitations

Our findings are based on a limited number of cases, which limits statistical generalizability. Future research should validate our results through statistical analysis. Additionally, longitudinal, participatory research could aim to refine our insights from different stakeholder perspectives and on a more granular level of the ILC.

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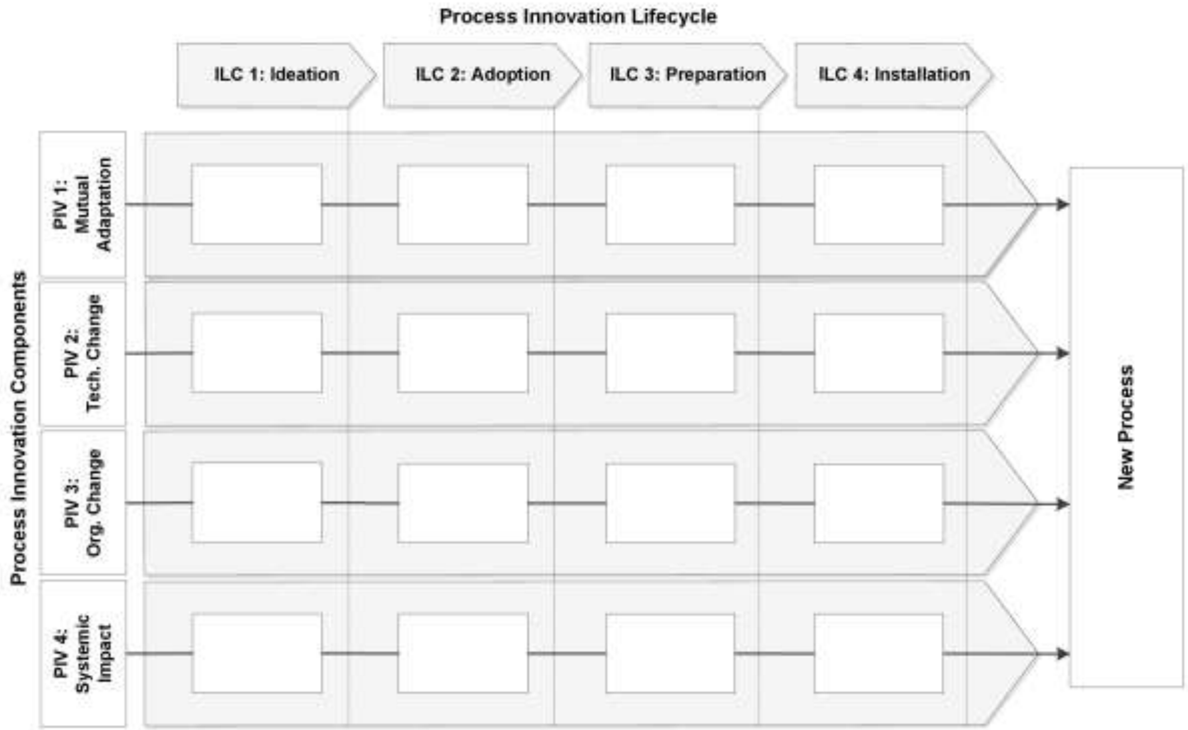
Table 1. Case information

Case	Case background	Type of process	Size (Employees)	Interviewees (Interviews)	Interview hours
1	*CarCo* is a global car manufacturer in the high priced luxury segment. The company's competitive advantage and appropriability regime are determined by the quality of its products and production competencies. The information that *CarCo* provided related to the development and implementation of higher-order enabling processes. These processes use standard IT solutions to coordinate and enable all organizational processes ranging from idea generation to product offer.	Enabling	100,000+	4 (7) [+SD]	10.5
2	*RailCo* is the world's leading manufacturer of braking systems for rail and commercial vehicles. The company has global manufacturing operations that work independently. The information that *RailCo* provided related to the development and implementation of IT-driven, enabling processes. This involves the introduction of externally acquired standard technology solutions, which drive efficiency.	Enabling	20,000+	4 (9) [+FN; +SD]	15
3	*DefCo* is a global leader in non-nuclear submarines and high-level naval vessels. They have a strong focus on product differentiation. Production predominantly relies on skilled, manual labour rather than automated processes and robotic support. Nevertheless, *DefCo* has started to research advanced technologies to support production. The information that *DefCo* provided mainly relates to the development and implementation of externally acquired standard IT solutions for production.	Enabling	8,000+	9 (12) [+FN]	20
4	*EleCo* is a global electronics company that produce switches and connectors for the automotive industry. The company has a high quality focus, but, due to ease of imitation, competes using a high production volume leveraging specific production competencies. The information that *EleCo* provided related to the development and implementation of an internally developed production technology in the company's core operations.	Core	100,000+	9 (14) [+FN; +SD]	23.5
5	*ChasCo* is a major global supplier of automotive driveline and chassis technology. The company develops and manufactures high quality products and has pronounced product development and production competencies. *ChasCo* provided information on the development and implementation of higher-level enabling processes and core production processes via externally acquired and internally developed technology respectively.	Enabling / Core	80,000+	7 (13) [+FN; +SD]	22.5

+FN: additional field notes were taken during visits to manufacturing plants; +SD: company provided additional secondary data.

Figure 1. Conceptual framework



NOTE: The framework comprises four TPI components and four stages of the ILC. The small squares connected by the line of the arrow Represent the categories in which we explore the content of the TPI components throughout ILC.

Figure 2. Cross-case results

	ILC 1: Ideation	ILC 2: Adoption	ILC 3: Preparation	ILC 4: Installation
PIV 1: Mutual Adaptation	**Enabling Process**: • Initial focus on developing or modifying new technology.[A, B, C, D] • Additional focus on organizational change to benefit from standard solutions.[B, D] **Core Process**: • Strong focus on developing or modifying new technology.[D, E]	**Enabling Process**: • Decision making open towards organizational changes for the adoption and exploitation of standard technologies. [A, B, C, E] **Core Process**: • Decision making favours technological change for accentuating existing core processes.[D, E]	**Enabling Process**: • Technological and organiyational change important but general preference for technology change. [A, B, C, E] • Limited adaptability of standard solutions to exploit benefits of standardization.[A, B, C, E] **Core Process**: • Preference towards technology change to articulate unique firm characteristics.[D, E]	**Enabling Process**: • Restricted opportunities for adaptation. [A, B, C, E] • Misalignments between process description and operators' activities. [A, B, C, E] **Core Process**: • Bias towards technology change. [D, E] • Misalignments not acceptable if core process affected. [D, E]
PIV 2: Tech. Change	**Enabling Process**: • Compatibility and relative advantage as primary evaluation attributes.[A, B, C, E] • Communicability of attributes low due to limited understanding.[A, B, C, E] **Core Process**: • Compatibility and relative advantage as primary evaluation attributes.[D, E] • Medium communicability of attributes due to early research.[D]	**Enabling Process**: • Presentation of technologies by external vendors.[A, B, C, E] • Compatibility and relative advantage primary decision making criteria, but difficult to estimate due to limited understanding[A, B, C, E] **Core Process**: • Prototype solutions for company-specific solutions.[D, E] • Technological evaluation guide adoption decision.[D, E]	**Enabling Process**: • Substantial communication effort to address uncertainty as technological adaptability limited.[A, B, C, E] • Operator acceptance imperative for implementation.[A, B, C, E] **Core Process**: • Development of technology to fit with different functions of the core process.[D, E] • Operator acceptance imperative for implementation.[D, E]	**Enabling Process**: • Compatibility with operators' skills necessary. [A, B, C, E] • Changing operators attitudes rather than technology to cope with complexity. [A, B, C, E] **Core Process**: • Compatibility with operators' skills necessary. [D, E] • Changing operators attitudes rather than technology to cope with complexity. [D, E]
PIV 3: Org. Change	**Enabling Process**: • Typically neglected due to limited process specification. [A, B, C, E] • Used as a reference frame for new process technology. [A, B, C, E] **Core Process**: • Typically neglected due to limited process specification. [D, E] • Used as a reference frame for new process technology. [D, E]	**Enabling Process**: • Concept development used to clarify functions affected.[A, B, C, E] • Significant effort required to gain stakeholder support. [A, B, C, E] **Core Process**: • Concept development used to clarify organization functions affected.[D, E] • Discounted in favour of technology change. [D, E]	**Enabling Process**: • Organizational change unavoidable due to need for standardization in process.[A, B, C, E] • Increasing opposition from stakeholders requires coordination.[A, B, C, E] **Core Process**: • Minor focus on organizational change to accentuate distinct core process.[D, E]	**Enabling Process**: • Ad-hoc structural change requires significantly more coordination than changes to task performance. [A, B, C, E] **Core Process**: • Change not considered. Training used as an enabler for task performance. [D, E]
PIV 4: Systemic Impact	**Enabling Process**: • Important for identifying potential cost-benefits.[A, B, C, E] • Limited Process specification impedes assessment.[A, B, C, E] • Tentative assessment from operator feedback[B, C, E] **Core Process**: • Important for identifying potential cost-benefits.[D, E] • Tentative assessment from early research and operator feedback.[D]	**Enabling Process**: • The complexity of systemic impact can lead decision makers to ignore it.[A, B] **Core Process**: • Explicitly included systemic impact in decision making relating to core processes. [D, E]	**Enabling Process**: • Potential impact more clear.[A, B, C, E] • Systemic integration planning imperative to the appropriation of standard processes.[A, B, C, E] **Core Process**: • Potential impact more clear.[D, E] • Systemic integration crucial for the accentuation of core processes.[D, E]	**Enabling Process**: • Impact becomes apparent. [A, B, C, E] • Simulation and mock-up environments for managing integration. [A, B, C, E] **Core Process**: • Impact becomes apparent. [D, E] • Flawless integration is imperative. [D, E] • Simulation and mock-up environment for managing integration. [D, E]

Note: A=CarCo; B=RailCo; C=DefCo; D=EleCo; E=ChasCo

Figure 3. Asymmetric adaptation