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Causal complexity of new product development processes: a mechanism-based approach

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ABSTRACT

The outcomes of new product development (NPD) processes are dependent on the interplay of several interdependent activities. One product development activity can be dependent on the presence or absence of other activities, different kinds of NDP processes may lead to the same outcome, and specific kinds of activities may have a positive effect in one process but no effect in other processes. However, we currently lack means to examine and explain this causal complexity inherent in NPD processes. To address this issue, we introduce mechanism-based approach as a way to capture conjunctural and equifinal causal relations. We build this approach on the philosophical literature on mechanism-based explanations and the methodological opportunities provided by the qualitative comparative analysis (QCA) to identify how the activities of entities are configured together to generate outcomes. We elaborate this approach by presenting an in-depth historical analysis of the NPD projects of Vaisala, a meteorological instrument company. We discover and suggest that the company's NPD projects were driven by three mechanisms (ideation, evaluation and commercialisation) and that each of them were actualised by a set of different activity configurations. Accordingly, we contribute to the NPD and innovation literature by showing how mechanism-based explanations take into account both the abstract theorisation of NPD processes and their inherent causal complexity.

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Complexity; configurations; mechanisms; new product development process; process research; qualitative comparative analysis

Introduction

Complexity has been identified as a central characteristic of new product development (NPD) projects (Dunne & Dougherty, 2016; Griffin, 1997a; Kim & Wilemon, 2003; Tatikonda & Rosenthal, 2000). Typically, it is related to project size and the nature and interdependence of product development activities (Kim & Wilemon, 2003, 2007). While complexity might not be a serious issue in the development of very simple products, it can increase rapidly along with the magnitude of the project and becomes the central challenge when developing highly complex goods (e.g., aeroengines) (Nightingale, 2000). However, simultaneously complex projects generate greater market performance than their simpler counterparts (Ahmad,

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Mallick, & Schroeder, 2013), which can explain why they are so interesting for many companies.

To understand the complexity of NPD projects, existing studies have analysed the properties of the system involved in NPD projects (Dooley & Van de Ven, 1999; McCarthy, Tsinopoulos, Allen, & Rose-Anderssen, 2006; Mihm, Loch, & Huchzermeier, 2003), outlined how to design NPD processes to handle complexity (Chao, Lichtendahl, & Grushka-Cockayne, 2014; Iansiti & MacCormack, 1997) and unravelled practices that individuals and companies use to manage complexity (Chapman & Hyland, 2004; Dunne & Dougherty, 2016; Griffin, 1997a). Yet, prior research has not been able to put forward an approach that would capture the causal complexity (e.g., Misangyi et al., 2017) inherent in the NPD processes. That is, how can one product development activity be dependent on the presence or absence of other activities, how may different kinds of NDP processes lead to the same outcome, and why may specific kinds of activities have a positive effect in one process but no effect in other processes? In this paper, we address these questions by presenting a mechanism-based approach to NPD processes.

Mechanism explanations are a form of middle-range theories (Hedström & Swedberg, 1998) that focus on explaining how and through what kind of a process an outcome is produced (Bechtel & Abrahamsen, 2005; Bunge, 2004; Pajunen, 2008). Previously, this approach has been used to explain how the complex interplay of activities gives rise to organisational decline and turnaround processes (Pajunen, 2005, 2008), and recently it has been suggested as a potential way to shed light on the complexity of innovation processes (Hedström & Wennberg, 2017; Perkmann & Phillips, 2017). Our interest lies in elaborating this approach in the context of the NPD process. Specifically, we address the question of how mechanism-based theorising can enable us to better understand the causal complexity of NPD processes.

To illustrate and elaborate the suggested approach, we present an in-depth, historical analysis of the Finnish meteorological instrument company Vaisala and their central NPD projects during the 1970s. By building on a constant comparison of cases (Eisenhardt, 1989), we first identify central NPD practices and then use qualitative comparative analysis (Ragin, 1987) to identify how these practices are configured together to actualise ideation, evaluation and commercialisation mechanisms. Finally, we analyse how the identified mechanisms concatenate together to explain NPD projects and the NPD process in different forms. Based on these findings, we suggest that the mechanism-based approach provides a novel way to explain the causal complexity of NPD processes with regard to conjunctural causation (i.e., how the effect of an activity is dependent on other activities) and equifinality (i.e., how multiple activity configurations and their sequences can lead to a similar outcome).

The rest of this paper is organised as follows. First, we review existing literature on the complexity of NPD processes. Then, we explain the mechanism-based approach as a potential way to capture the causal complexity of NPD processes. Thereafter, we present our field study, which examines the organisational mechanisms driving Vaisala's NPD process. Finally, we discuss our findings and present concluding remarks.

Complexity of NPD processes

Companies are under constant pressure to develop new products. However, the complexity of NPD makes the outcomes, costs and schedules of this activity uncertain (Griffin, 1997a; Kim & Wilemon, 2007; Nightingale, 2000). Prior research has emphasised two interrelated sources of complexity. First, complexity often emerges from the size of the NPD project where it relates to the number of technologies, components or functions being developed (Chapman & Hyland, 2004; Griffin, 1997a; Kim & Wilemon, 2003; Nightingale, 2000) and to the number of organisations or business functions that are involved in the project (Dougherty, 2017; Kim & Wilemon, 2003). Second, complexity stems from the nature of the development activities, such as the number of different development tasks and their interdependence (Ahmad et al., 2013; Chapman & Hyland, 2004; Dooley & Van de Ven, 1999; McCarthy et al., 2006), as well as the novelty of these tasks (Chao et al., 2014; Maggitti, Smith, & Katila, 2013; Tatikonda & Rosenthal, 2000).

Earlier research has also provided suggestions on how the complexity of NPD processes could be managed. Studies taking a systems perspective consider that complexity is generated by the size and interdependence of the components of the system involved in NPD projects (Dooley & Van de Ven, 1999; McCarthy et al., 2006; Mihm et al., 2003). Consequently, complexity is suggested to be manageable by cutting interdependencies between problem-solving activities (Mihm et al., 2003) or by favouring complementary rather than conflicting dependencies (Oyama, Learmonth, & Chao, 2015).

Researchers have also considered how to design an NPD process to manage complexity. In particular, proponents of both linear and concurrent NPD processes have laid out evidence on how different process models can help manage complexity. On the one hand, studies focusing on linear NPD processes such as the Stage-Gate have pinpointed at which stages of the process complexity occurs (Cooper, 2008) and how these processes could be adapted to account for the degree of complexity (e.g., Chao et al., 2014; Salerno, de Vasconcelos Gomes, da Silva, Bagno, & Freitas, 2015). On the other hand, studies examining concurrent product development processes, where activities are executed partially or completely in parallel, have suggested that complex processes have to be broken down into smaller components where problem-solving occurs (Iansiti & MacCormack, 1997; Nightingale, 2000; Van de Ven, 2017). Recent studies have also suggested that complexity could be managed by combining elements from both of these process types to generate hybrid processes that have overall structure but simultaneously accommodate iteration cycles that can help in managing complexity (Cooper, 2016; Sommer, Hedegaard, Dukovska-Popovska, & Steger-Jensen, 2015).

Prior research has also examined practices that individuals and companies use to manage complexity. For instance, Griffin (1997a) found that project complexity increases cycle time and that formal NPD process can reduce this time but not negate complexity. In a similar vein, better communication and cooperation across involved parties (Chapman & Hyland, 2004; Chaudhuri & Boer, 2016; Kim & Wilemon, 2007), use of cross-functional teams (Ahmad et al., 2013) and application of project planning and control tools (Chapman & Hyland, 2004; Kim & Wilemon, 2003) have been suggested as ways to manage complexity. Furthermore, on the individual level, the use of digital science (Dougherty & Dunne, 2012) and abductive reasoning (Dunne & Dougherty, 2016) have been suggested as ways to manage complexity.

Overall, we have a fairly good understanding of what complexity is on the aggregate level and what companies and individuals can do to manage it. However, what has been left to a lesser focus is examinations of the causal complexity that arises from NPD activities, their non-linear relationships and how they come to co-constitute NPD processes. Against this backdrop, we next present a mechanism-based approach as a potential way to understand the causal complexity of NPD projects that arise from development activities and their productive interrelationships.

Mechanism-based explanations

The mechanism-based approach seeks to provide explanatory understanding (Bunge, 2004; Hedström & Ylikoski, 2010; Kaidesoja, 2013) of how and through what kind of a process an outcome is brought about (Hedström & Wennberg, 2017; Pajunen, 2008). In this paper, we build on the philosophical literature on mechanisms (e.g., Bechtel & Abrahamsen, 2005; Glennan, 2002; Machamer, Darden, & Craver, 2000) and a related conceptualisation of organisational mechanisms (Pajunen, 2008). According to Pajunen (2008, p. 1451), mechanisms that drive organisational processes have four basic characteristics:

> First, mechanisms consist of component parts and their activities/interactions. Second, they produce something. Third, this productive activity depends essentially on the hierarchical (part–whole) structure of mechanisms. Fourth, mechanism explanations are representations or models of mechanisms that, if accurate, describe relevant characteristics of the mechanisms operating in organizational processes.

Next, we elaborate how this conceptualisation enables capturing the processual and causally complex nature of NPD.

First, the component parts of mechanisms are the entities that perform product development activities. These entities are individuals or groups of individuals that are capable of performing activities both individually and collectively (Gross, 2009; Hedström & Ylikoski, 2010; Kaidesoja, 2013). Thus, the first step in building a mechanism explanation is the identification of what entities partake in NPD processes and what activities they conduct during these processes.

A typical feature of product development is that the effect of an activity is dependent on the effects of other activities (cf. Machamer et al., 2000). Thus, we argue that the causally productive body of the mechanism can be considered as the configuration of interdependent activities. This stems from the notion that a mechanism explanation should explain how its components interact to produce a mechanism (Kaidesoja, 2013). Therefore, the second essential part of building a mechanism explanation of specific NPD processes is to identify how the activities of entities are configured together to generate outcomes. This configuration should capture the causally complex interaction of activities producing the outcome we are interested in explaining.

However, according to the idea of a hierarchical (part–whole) structure of mechanisms, this joint effect of the interactions of activities remains conceptually unintelligible if we do not understand the activity of the mechanisms as a whole, that is, a conceptualisation of what the mechanism does at a more abstract level. As argued in prior theorisations related to mechanism explanations (e.g., Glennan, 2002; Machamer et al., 2000; Pajunen, 2008), without an understanding of the higher-level activity of the mechanism as a whole, the causally productive account of activities remains unintelligible, whereas the activity level configurations are essential for understanding the higher-level activity of the mechanism in its context. Consequently, because both levels are necessary for a conceptually intelligible explanation, we cannot simply reduce the explanatory power of mechanisms to their constitutive components.

Importantly, this part-whole structure enables comparisons of how the same mechanism works in different cases and contexts. Namely, by addressing an additional aspect of causal complexity, we argue that it is possible for different kinds of product development activity configurations to lead to the same outcome. In a similar vein, Gross (2009) noted that mechanisms are composed of bundles of activities that both individuals and groups assemble together to address problems in various ways. In order to empirically capture this equifinality related to NPD processes, we build on the methodological opportunities provided by qualitative comparative analysis (QCA) (see Ragin, 1987).

Since the higher-level activity of a mechanism may not be directly observed, mechanism explanations are always epistemic activities that involve representing and reasoning (inductively and deductively) about mechanisms. This also means that the explanation of mechanisms is a discovery process that proceeds from the initial sketches towards more comprehensive models of mechanisms (Bechtel & Abrahamsen, 2005; Glennan, 2005). Altogether, by following this explanatory approach, we are able to pay attention to both abstract theorisation and inherent causal complexity of the processes. We suggest that this leads us closer to the systematic mid-range theories that have direct managerial relevance.

Methodology

Our empirical study can be understood as a historical case study that uses comparative historical analysis as a basis for theorising about mechanisms (Kipping & Üsdiken, 2014; Pajunen, 2005; Vaara & Lamberg, 2016). We selected the Finnish Vaisala Corp. as our research site. Vaisala is one of the leading manufacturers of meteorological measurement instruments in the world, and we focus our study on the period ranging from 1969 to 1981, when the company expanded from a small producer of radiosondes used in weather balloons to making automatic weather stations, weather satellite equipment and thin film technology. During this period, the company grew their turnover from 1.20 million USD to 12.96 million USD and expanded from a single product line to three product lines. The substantial focus that Vaisala put on NPD and the rich array of NPD activities that were used to realise this growth make the research site relevant for showcasing the mechanism-based approach.

During the period of inquiry, Vaisala's NPD department grew from 21 to 69 persons, and the average investment in product development was 16.3% of turnover. Despite large growth, the structure of the department remained largely the same. The NPD department was organised as a project organisation where NPD projects were managed by project managers who assigned NPD staff to projects based on needed man-months.

The project magnitude oscillated between three man-months for the smallest incremental project, to close to 90 man-months for the larger system projects (covering only the work done by Vaisala staff). The NPD projects were supervised by a group of top executives that was called the 'new product group' and consisted of the CEO and the product development, marketing and commercial directors of the company. This group effectively led the NPD activities of Vaisala since they made all crucial decisions related to the NPD projects.

Instead of relying on retrospective interviews that are prone to errors and can be coloured by knowledge of the outcome of the events (Golden, 1992), we used archival data, which enabled us to trace NPD projects as they unfolded. In doing so, the Vaisala archives were our primary source of data, and we collected 2617 pages of material to understand the NPD activities of Vaisala during multiple periods of archival work. This included the annual reports of the NPD department, weekly meeting memos of the new product group, research program documentation and NPD project documentation. This material was supplemented by company histories and book chapters related to the company. The annual reports of the NPD department and the weekly meeting memos of the new product group were identified as the central documentation related to NPD activities. In effect, the annual reports of the NPD department gave us an overview of NPD activities, while the new product group meeting memos enabled us to understand what actions and decisions were made on a weekly basis. This evidence was also subjected to source criticism, which is customary in historical research (Golder, 2000). The central documentation used in our analyses was considered reliable since it was produced for company internal use with limited distribution, it formed consistent time series that indicated little editing of data, and many of the activities could be corroborated across multiple sources.

We proceeded in successive stages to analyse our data and to develop a mechanism-based explanation of how the NPD process functioned. We first wrote a historical narrative of the company and its NPD activities during the period of analysis. This enabled us to pinpoint 15 central NPD projects (see Table 1). Subsequently, we wrote individual narratives of each of the projects to understand how they were carried through (Eisenhardt, 1989).

Next, following the idea that mechanisms should produce something (Hedström & Wennberg, 2017; Pajunen, 2008), we identified three central intermediate outcomes shared by the studied projects. These outcomes were the following: (1) the completion of initial product concept or technology, (2) managers' decision regarding commercialisation of the product, and (3) the final outcome of the whole project. Thereafter, we compared these to prior NPD process frameworks (e.g., Barczak, Griffin, & Kahn, 2009; Cooper, 2008; Hansen & Birkinshaw, 2007), in order to examine how earlier research had explained these steps. We also compared them to how the company's managers conceived the key steps of their NPD process. As a result, we suggest that there exists three mechanisms – *ideation, evaluation* and *commercialisation* – producing these three outcomes. That is, at the abstract level, the mechanism of ideation, when actualised via the interaction of entities' activities, produces the initial concept or technology. The mechanism of evaluation, in turn, produces either a positive or a negative decision regarding commercialisation. Thus, the quality of the outcome is, again, causally

Table 1. Studied NPD projects.

Project	Product launch	Description
ELSA	February 1971	Automatic antenna for receiving signals from weather satellites that was developed in collaboration with Helsinki University of Technology.
RS restructuring	March 1972	Radiosonde aimed at correcting all known errors left in the previously developed radiosonde product.
RS 21 and RS 24 radiosondes	March 1972	Radiosondes developed to match customers' requests for radiosondes that would function with other manufacturers ground equipment.
Electronic microscope	The project was terminated in January 1973	Electronic microscope based on an existing prototype that the company had in internal use.
CK 12 aviation radiophone	The project was terminated in September 1973	Backup air traffic control system that was developed for the Finnish air force to update the previous aviation radiophone.
HUMICAP	February 1974	Thin-film humidity measurement sensor developed in collaboration with VTT Technical Research Centre of Finland.
CORA	March 1975	Automatic upper-air measurement system that functioned in the global OMEGA radio navigation network.
Kemi lighthouse	June 1975	First automatic weather station that Vaisala developed. The final product was realised in collaboration with American Sierra Corporation.
New sonde batteries	July 1975	In-house developed batteries that decreased unit cost and increased the reliability of battery supply.
METOX	September 1975	Automatic switch to the METOX radiotheodolite that increased reliability.
HATTARA	February 1976	First airport weather station that Vaisala developed. It was developed in collaboration with Finnish Meteorological institute.
MIDAS	September 1976	Weather station developed as part of a COST 30 project involving both public research institutions and customers.
Personal dust sampling pump	The project was terminated in November 1976	Sampling pump developed in collaboration with University of Tampere to measure air quality in mining, founding and stone processing.
SODAR	Fall 1979	Weather radar for airports developed in collaboration with University of Oulu.
NASTA	August 1980	Radiosonde that would be used as the standard radiosonde the company would sell in the 1980s.

dependent on how the activities are configured. Finally, the mechanism of commercialisation produces, in the positive case, a product that is launched in the market.

After this, we turned to examine how these mechanisms were actualised at the level of entities partaking in the NPD projects. We identified four distinct groups of actors that had a role in how products were developed. These were the following: (1) Vaisala's NPD department, which conducted development work; (2) Vaisala's new product group, which was a group of top managers who directed NPD activities; (3) external collaborators who took part in the NPD projects; and (4) customers and institutional developers involved in some of the projects. These different actors had different roles, and they conducted different activities during NPD projects. For instance, while ideation was primarily done by Vaisala's NPD department, these ideas were evaluated by the new product group during the evaluation stage.

Next, we chronologically coded the activities of these actors by using annual reports of the NPD department and the weekly meeting memos of the new product group as the primary sources. This amounted to an initial list of 618 instances that depicted discrete activities done in the confines of the studied projects. Thereafter, we used within- and cross-case analyses (Eisenhardt, 1989) to identify recurring NPD activities across the suggested mechanisms. Simultaneously, we compared these activities to the existing research on NPD practices to seek agreement. This step yielded 15 different recurring NPD activities (5 for each of the mechanisms) with 406 instances of data associated with them. In doing so, a single activity, such as the development of a prototype, could be constituted of multiple instances of data from different sources. Table 2 presents these recurring activities, their theoretical grounding and the number of instances of data associated with each of the recurring activities.

To explain how NPD activities were configured together to causally activate the mechanisms, we used crisp-set qualitative comparative analysis (QCA) (Ragin, 1987; Rihoux & De Meur, 2009). QCA has been suggested as a suitable method for studying mechanisms because it enables uncovering how combinations of variables lead to outcomes (Pajunen, 2005). In practice, the presence and absence of recurring activities in each of the NPD process stages were first coded into truth tables (Ragin, 1987) and then analysed for necessity and sufficiency. Then, the Boolean minimisation procedure of the Tosmana program (Cronqvist, 2011) was applied to the truth tables. This allowed the identification of minimised causal configurations of recurring activities regarding each mechanism.

The minimised configurations were further analysed in dialogue with the NPD cases. This allowed each NPD project to be assigned to a specific configuration in each of the mechanisms and for some of the configurations to be excluded because of a lack of fit with the project characteristics. Where suitable, the minimised configurations were further reduced by combining them, which is a suggested procedure for making combinations of central conditions more visible (Rihoux & De Meur, 2009; Schneider & Wagemann, 2012). This analytical step enabled us to return to the cases with the minimised configurations and examine how the clusters of causal factors enabled the completion of each of the outcomes. These procedures are in line with the inductive use of QCA, where the minimised configurations incite the opportunity to reanalyse cases (Yamasaki & Rihoux, 2009), and with the idea that in-depth analysis of underlying processes must be worked out by the researcher through dialogue between the cases and configurations (De Meur, Rihoux, & Yamasaki, 2009). Together, via these analyses, we are able to pay attention to both the abstract theorisation (i.e., the higher-level activity of the mechanism) and the inherent causal complexity of the NPD projects (i.e., the causally productive account of NPD activities).

Findings

Ideation mechanism

Different combinations of the five recurring activities were present in each of the 15 projects that led to the actualisation of the ideation mechanism. These activities were first coded into a truth table, and because all of the projects were later evaluated by the managers, the outcome condition for all of the cases were coded as success. At this

Table 2. Recurring NPD activities.

Ideation				Evaluation				Commercialisation			
Recurring activity	Corresponding theory	Example from data	# of data instances	Recurring activity	Corresponding theory	Example from data	# of data instances	Recurring activity	Corresponding theory	Example from data	# of data instances
Further development of existing product	Generating product improvements and product line extensions (Barczak et al., 2009; Griffin, 1997b)	Decided in January to initiate improvement of RS with regards to all known shortcoming left in RS 16. (NPD annual report 1969–1970)	17	*Product evaluation*	Product characteristics and technical feasibility are key to product success (Cooper, Edgett, & Kleinschmidt, 2004)	Test results were so positive that the product was decided to be commercialised immediately. (NPD annual report 1969–1970)	36	*Product launch*	Orchestrating launch is critical for success (di Benedetto, 1999)	The systems was operational [at customers premises] in June 1975. (NPD annual report 1975–1976)	58
Execution of pre-study	Using pre-development activities to guide projects (Cooper et al., 2004)	Analysis was conducted through a literature review consisting of over 100 articles on the topic. (NPD annual report 1971–1972)	45	*Competition evaluation*	Understanding competition is crucial for product success (Cooper et al., 2004)	Volume is big enough so that big boys such as Pleassey, Phillips and Siemens are interested. (New product group meeting memo 14.12.1973)	11	*Acquiring a patent*	Codifying and protecting knowledge assets (Rosenkopf & Nerkar, 2001)	Initial decision to patent HUMICAP in USA, W-Germany, United Kingdom, France, Japan, Switzerland, Brazil, Finland. (New product group meeting memo 12.9.1973)	6
Collaborating with a third party	Establishing collaborative partnerships to access knowledge (Barczak et al., 2009)	Study on airport weather stations in collaboration with Finnish Meteorological Institute (NPD annual report 1973–1974)	21	*Market evaluation*	Alignment with customer needs is crucial for product success (Cooper et al., 2004; Kahn et al., 2006)	Market development outside USA has been slower than expected. (New product group meeting memo 30.1.1979)	29	*Further development of the product*	Generating product improvements (Barczak et al., 2009; Griffin, 1997b)	The sold systems generated a need to develop the systems further and therefore the following components were renewed […] (NPD annual report 1978–1979)	77
Initiating a project to match customer need	Using market knowledge to guide projects (Cooper et al., 2004; Griffin, 1997b; Kahn et al., 2006)	Requested the final user to be actively involved in the project (New product group meeting memo 3.10.1973)	7	*Product policy evaluation*	Aligning project with strategy (Kahn et al., 2006)	Fits badly to our existing network of agents. Maintenance has to be organised separately. (New product group meeting memo 29.12.1972)	25	*Investment in production equipment*	Making long-term investments to support innovation (Barczak et al., 2009)	Production equipment requires roughly 100.000 FIM investments. (New product group meeting memo 24.8.1972)	9

(*Continued*)

Table 2. (Continued).

Ideation				Evaluation				Commercialisation			
Recurring activity	Corresponding theory	Example from data	# of data instances	Recurring activity	Corresponding theory	Example from data	# of data instances	Recurring activity	Corresponding theory	Example from data	# of data instances
Development of a prototype	Demonstrating feasibility (Clark & Wheelwright, 1993)	During the period, functional prototype was being built, including mechanical parts (NPD annual report 1974–1975)	23	*Risk evaluation*	Risk assessment enables mitigating high mortality rates of new products (Barczak et al., 2009; Griffin, 1997b)	Pros: ready prototype, does not cannibalise, we can get public funding for the project, new growth market. (New product group meeting memo 29.12.1972)	30	*Adding product to evaluation benchmark portfolio*	NPD portfolio management (Barczak et al., 2009; Kahn et al., 2006)	Wind measurements with Vaisala equipment will be based on the OMEGA/LORAN C network (NPD annual report 1971–1972)	12

point, we did not find any necessary or sufficient conditions. Subsequently, we carried out the Boolean minimisation procedure, assigned projects to configurations and further reduced the configurations by combining them. Table 3 presents the final configurations, the projects assigned to them, a depiction of the common characteristics between the projects and theoretical explanations of the configurations that actualise the mechanism.

The first activity configuration (E*c*s) depicts projects where an existing product provided the grounds for ideation and the project primarily focused on engineering a new version of it. For instance, the RS restructuring project was initiated to improve the previously developed radiosonde RS 16. This characterisation corresponds with Vaisala's plan to incrementally develop existing products, such as radiosondes, that were assigned to this configuration. Altogether, this configuration of activities was causally productive in actualising the ideation mechanism (i.e., it explains how the ideation mechanism works in these projects). Since these activities primarily relate to local search, we suggest that in these cases, the ideation mechanism is activated through *local search* activities.

The second activity configuration (S*n*(e+c)) reflects initiatives that used a pre-study to generate a product idea for which there was not yet a clear customer need. This configuration depicts the search for new technologies that would enable expansion into new product areas, which is in line with Vaisala's plan to extend into new product areas during the decade. The development of the CORA system reflects this well since the initial product idea was a result of a study on the potential ways to measure upper air winds. These activities mainly relate to technological exploration, and therefore, we consider that in these cases, the ideation mechanism works through the bundle of activities focusing on *technology exploration*.

The third configuration (C*P*e*(n+S)) reflects collaborative NPD projects in which the goal was to jointly develop a prototype that was not based on an existing product. This converges with Vaisala's goal to increase collaboration with external parties to gain access to new knowledge. These activities mainly relate to collaborative development, and therefore, we suggest that in these cases, the ideation mechanism works through the configuration of activities focusing on *collaborative exploration*.

Table 3. Boolean minimisation of ideation configurations.

Configurations	Projects assigned to configuration	Common characteristic(s) between projects	Theoretical explanation of the configuration
E*c*s	RS restructuring, RS 21 and RS 24, CK 12 Aviation radiophone, Electronic Microscope	Further development of an existing product	Local search
S*n*(e+c)	New Sonde Batteries, HATTARA, Kemi lighthouse, CORA, NASTA	Pre-study based project where customer need did not already exist	Technology exploration
C*P*e*(n+S)	ELSA, Personal Dust Sampling Pump, METOX, SODAR, MIDAS, HUMICAP	Collaboration with a third party combined with the creation of a prototype	Collaborative exploration

Capital letter = condition present; Lowercase letter = condition absent; * = denotes logical and; + = denotes logical or; E = Further development of existing product; C = Initiating a collaboration with a third party; S = execution of a pre-study; N = initiating a project to match existing customer needs; P = development of a prototype

These three modes of operation for the ideation mechanism also resonate with existing theory, particularly with regard to the different ways to conduct organisational search (e.g., March, 1991). Specifically, local search could be understood as enhancing current technological knowledge through refinement (March, 1991), whereas technology exploration builds on technological boundary spanning and collaborative exploration relies on organisational boundary spanning (Rosenkopf & Nerkar, 2001).

Evaluation mechanism

Because none of the projects were discontinued during ideation, all projects were analysed in this stage. Since the outcome of the mechanisms could be either a decision to commercialise the product or to discontinue the project, we analysed both of these ways to actualise the mechanism. Again, the projects were coded into a truth table, and the decision to commercialise the product was coded as the outcome condition. Both negative evaluations and forfeited evaluations were coded as the absence of an activity since it was possible that the new product group could either forfeit from evaluating a project with regard to certain dimensions or reach a negative outcome in an evaluation, and neither of these could be considered as supporting the decision to launch a product. Next, the projects were analysed for necessity and sufficiency, which indicated product evaluation as being a necessary but not sufficient condition for the decision to commercialise a product. After this, the Boolean minimisation process was carried out, and subsequently, projects were assigned to configurations (see Table 4). As one configuration led to project termination, it was compared to the successful configurations to check for consistency.

The first configuration (P*M*L) reflects the selection of products for commercialisation in existing markets where the products fill technical requirements and follow the product policy of serving existing customers. For instance, the METOX and HATTARA systems were evaluated as continuing development in their respective areas where potential customers were already known. Building on

Table 4. Boolean minimisation of evaluation configurations.

Configurations	Projects assigned to configuration	Common characteristic(s) between projects	Outcome	Theoretical explanation of the configuration
P*M*L	RS restructuring, RS 21 and RS 24, METOX, HUMICAP, Kemi lighthouse, MIDAS, NASTA, HATTARA	Policy coherent offering to perceived markets	Commercialisation	Existing market evaluation
P*c*M*R	ELSA, CORA, SODAR	Products to new markets with risk mitigation	Commercialisation	New market evaluation
P*C*L*r	New Sonde Batteries	Policy coherent internal strategic initiatives	Commercialisation	Internal initiative evaluation
p*c*m*l	CK 12 aviation radiophone, Personal Dust Sampling Pump, Electronic microscope	Failure in all areas related to the offering	Project termination	Project termination

Capital letter = condition present; Lowercase letter = condition absent; * = denotes logical and; + = denotes logical or; P = product evaluation; C = competition evaluation; M = market evaluation; L = product policy evaluation; R = risk evaluation these considerations, we suggest that the evaluation mechanism works through the configuration of activities related to *existing market evaluation*.

The second configuration (P*c*M*R) can be understood as the selection of projects for commercialisation in new markets where the product is technically feasible and responds to a customer need, but where there is either a high level of competition or a lack of understanding of the competition, which is dampened by a positive risk evaluation. For instance, when the decision to commercialise SODAR was made, it was noted that competitors were ahead of Vaisala in this product area, but the external funding acquired for the project would make the product launch a low-risk initiative. Therefore, we suggest that in these cases, the evaluation mechanism works through the configuration of activities related to *new market evaluation*.

The third configuration (P*C*L*r) explains only one project that led to a commercialisation decision, so it is beneficial to analyse the configuration in conjunction with the project with which it is associated to account for its uniqueness (Woodside & Baxter, 2013). When analysing these together, it can be noted that the configuration depicts the comparison of an internally developed battery to third party products in order to determine which product is more suitable for the company where the firm-internal nature of the project is used to circumvent the need for risk evaluation. Keeping these notions in mind, we suggest that the evaluation mechanism in this case works through the activity configuration focused on *internal initiative evaluation*.

The fourth configuration (p*c*m*l) is the only configuration that led to a decision to discontinue the project. It represents the realisation of failure in product ideation because the product was deemed a failure in all four areas. Thus, this indicates that the evaluation mechanism produces *project termination* if none of the activities are performed successfully.

These configurations show how Vaisala's new product group fulfilled their task of systematically evaluating new product ideas and how the evaluation mechanism can function. Theoretically, they reflect ideas of NPD portfolio management, where the aim is to have a balanced variety of different kinds of projects (e.g., Barczak et al., 2009; Kahn, Barczak, & Moss, 2006). Each configuration positions the developed product idea in the product portfolio as either serving existing markets, enabling the expansion into new markets, increasing internal efficiency or being discarded due to suboptimal performance prospects.

Commercialisation mechanism

A total of 12 projects were commercialised. These projects were first coded into a truth table, and all projects were coded as leading to success. Then, the projects were analysed for necessity and sufficiency, which (unsurprisingly) revealed that a product launch is both a necessary and sufficient condition for commercialisation. Subsequently, the Boolean minimisation procedure was carried out and cases were assigned to configurations based on case-specific knowledge (see Table 5).

The first configuration (L*p*n) represents a product launch with no effects beyond the addition of one new offering to the offering portfolio. Therefore, we suggest that successful commercialisation is in this case produced through the component level activity that is purely focused on *product launch*.

The second configuration (L*e*F*p) can be understood as launching a standalone product that is thereafter further developed. For instance, the new radiosonde batteries that were commercialised for internal use were further developed, but they did not

Table 5. Boolean minimisation of commercialisation configurations.

Configurations	Projects assigned to configuration	Common characteristic(s) between projects	Theoretical explanation of the configuration
L*p*n	RS restructuring, RS 21 and RS 24, SODAR	New products that resulted only in product launch	Product launch
L*e*F*p	New sonde batteries, MIDAS	Standalone products that were launched and further developed	Standalone product launch and redevelopment
L*E*n	ELSA, METOX, Kemi lighthouse, HATTARA	New products that affected future development	Future evaluation altering product launch
L*E*F*P	HUMICAP, NASTA, CORA	Patented products that were sedimented to the offering portfolio	Trajectory altering product launch

Capital letter = condition present; Lowercase letter = condition absent; * = denotes logical and; + = denotes logical or; L = product launch; E = product added to evaluation benchmark portfolio; F = further development of the product; P = acquiring a patent; N = investment in production equipment

affect the development of other offerings. The absence of effects on the evaluation of new products and patenting indicates the lack of a broader effect on the company. Based on this, we suggest that a successful commercialisation mechanism can also be produced through an activity configuration characterised by *standalone product launch and redevelopment*.

The third configuration (L*E*n) represents launching new products that affect how future products will be evaluated because they occupy a distinct position in the product portfolio. For instance, the two automatic weather stations assigned to this configuration (Kemi lighthouse and HATTARA) were used after launch as products against which new weather stations would be benchmarked. Therefore, we suggest, in these cases, that the commercialisation mechanism works through activities related to *future evaluation altering product launch*.

Finally, the fourth configuration (L*E*F*P) reflects products that had a trajectory through their further development, but they also influenced what types of products would be developed in the future and what types of intellectual property the company held. The associated projects constitute turning points for the company. For instance, launching HUMICAP generated a new product line, and launching CORA opened the measurement system market for the company. Therefore, we suggest that the commercialisation mechanism can also be activated through *trajectory altering product launch* activities.

The different ways in which the commercialisation mechanism functions show the diversity of innovation process outcomes (e.g., Kim & Chung, 2017) and how innovation projects can lead to substantial amounts of adaptation and change in the focal organisation (Van de Ven, Polley, Garud, & Venkataraman, 2008). In doing so, further development of the new product affects future ideation activities and technological knowledge in that specific area (Rosenkopf & Nerkar, 2001). When the product launch is combined with an alteration of how future products are evaluated, the company updates its product evaluation process to reflects its current product portfolio (Barczak et al., 2009; Kahn et al., 2006). Finally, trajectory alteration broadly affects how the company will develop products in the future.

Understanding the NPD process through mechanisms

Explaining how the NPD process functions through mechanisms necessitates examining how different activity configurations realise the ideation, evaluation and commercialisation mechanisms and how these configurations concatenate together to explain NPD projects (see Pajunen, 2005 for comparison). This enables understanding different paths through which the NPD process can be actualised (see Figure 1).

When examining the NPD process through the found mechanisms and the configurations that actualise them, we find that the process does not follow unitary paths and

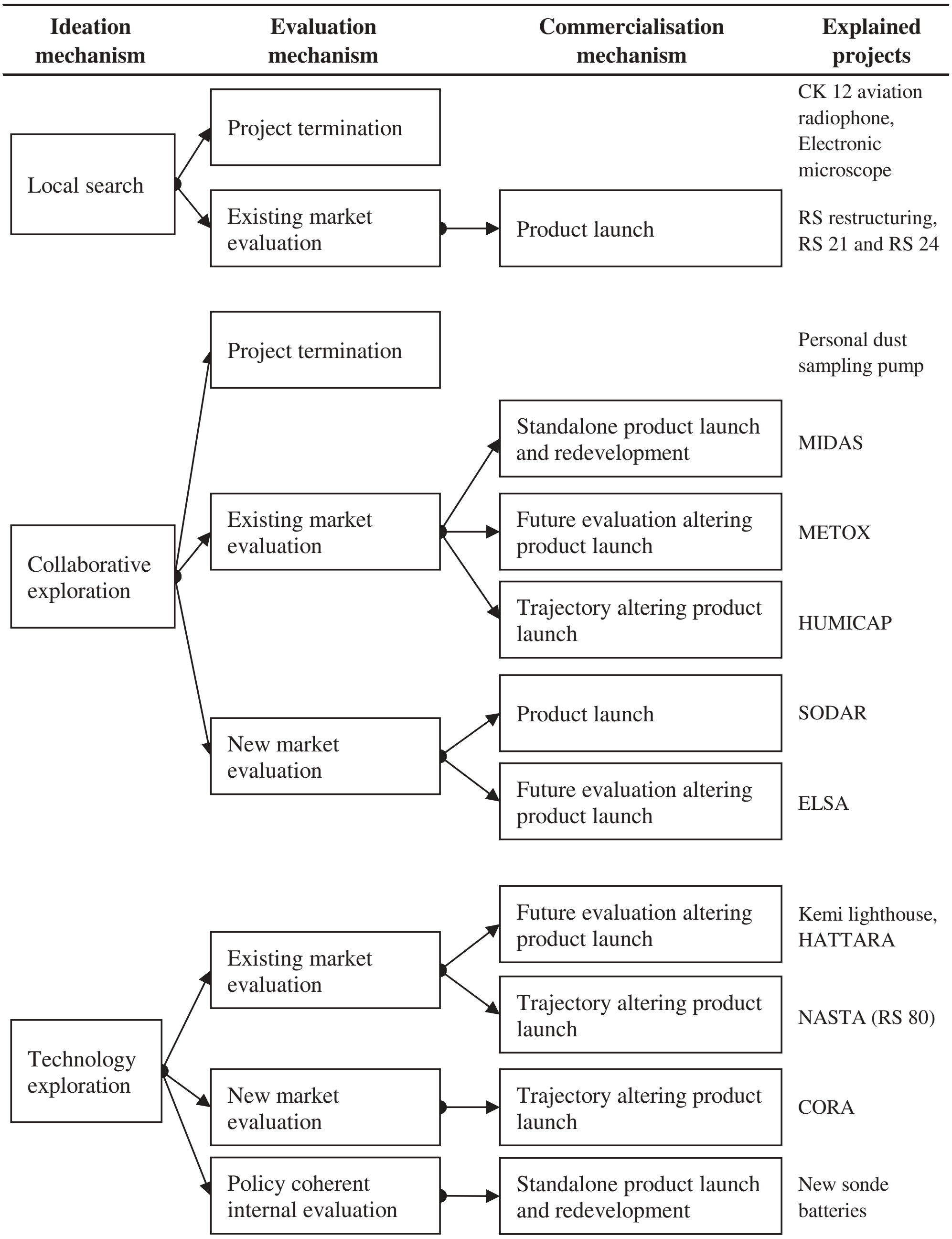

Figure 1. Configuration paths actualising the NPD process.

exhibits substantial variation. This is in line with the idea that NPD processes are rarely linear (Van de Ven et al., 2008). However, we can see tendencies in the way in which different activity configurations concatenate together when they are used to explain NPD projects. Local search led either to project termination during evaluation or to product launch during commercialisation. In doing so, these projects provided continuity by serving existing markets, but easily lacked sufficient customer benefits to warrant product launch. When Vaisala conducted collaborative exploration, the projects led to all potential outcomes, including project termination. Therein the collaborating party had a key role in the probability of project success, and the variation in collaborative projects shows that the focal company did not have full control over this type of process and its outcomes. Technology exploration, in turn, always had a lasting effect on the company since none of the projects were terminated or resulted only in a product launch. Therefore, technology exploration always had an effect on future product development, either by feeding the ideation process with new possibilities or by changing the way in which products were evaluated. These findings reveal how the actualisation of a mechanism in a certain way can have a tendency to cause certain future actions that can reveal potential paths through which the NPD process can be realised.

When the ideation and evaluation mechanisms are compared with each other, we can see interesting dynamics between them. The ideation mechanism is primarily technology-oriented because none of the configurations contain customer-related activities, while the evaluation mechanism is more geared towards customer needs. This shows how to link customers and technologies together (Danneels, 2002) by orienting different process stages to different functions. Simultaneously, this dynamic explains how decentralised external search (García-Granero, Vega-Jurado, & Alegre, 2014) and technology exploration (March, 1991) can be aligned with the offering portfolio of a company through centralised project evaluation. Both of these findings show how Vaisala partitioned their divergent and convergent activities (Van de Ven, 2017; Van de Ven et al., 2008) to different parts of the NPD process and how these two types of activities were related to each other to enable both the exploration of new ideas and their alignment with the organisation.

Discussion and conclusions

This study shows how NPD processes function through mechanisms that are constituted of activity configurations. By revealing different mechanisms and activity configurations that realise them, the mechanism-based approach enables reconstructing NPD processes and explaining how they generate outcomes (Hedström & Wennberg, 2017; Pajunen, 2008). In doing so, the mechanism-based explanations provide an appropriate approach to capturing the causal complexity related to NPD processes. Next, we elaborate why this is the case.

On the activity level, the mechanism-based approach directs the researcher to focus on how activities are configured together and how these configurations actualise mechanisms (Pajunen, 2008). This enables accounting for *conjunctural causation* (Schneider & Wagemann, 2012), which refers to the idea that the effect of a single activity is determined by the specific combination of activities of which it is a part. In doing so, NPD activities are analysed as part of a configuration where a single activity can have a differential effect, depending on other activities in that configuration.

The suggested approach also shows how each of the mechanisms can be actualised through multiple activity configurations. Our field study demonstrated this by showing, for example, how different configurations of evaluation activities came to co-constitute the four ways in which Vaisala evaluated projects. We can consider that the configurations depict bundles of activities that enable problems to be addressed in different ways (Gross, 2009) and in doing so depict different ways in which a mechanism can function. Accordingly, this shows how mechanism-based explanations can account for another critical aspect of causal complexity, that is, *equifinality*, which refers to the idea that there can be multiple causal paths to an outcome.

Furthermore, on the process level, mechanism-based explanations can depict how processes become realised through mechanism sequences, where each mechanism can be actualised through different activity configurations. This explains the dynamic processes which mechanisms give rise to (Hedström & Wennberg, 2017), such as different ways in which an NPD process can be completed. This also accounts for equifinality on the process level since an NPD process can be completed through a combination of different ideation, evaluation and outcome activities. Simultaneously, however, the analysis of activity configurations can reveal interrelationships between how activity configurations function together to actualise processes, for instance, how local search could only lead to a product launch in our empirical analysis.

Altogether, building on these insights, we suggest that the mechanisms-based approach provides a novel and important way to develop understanding of the causal complexity of NPD processes. It complements existing ways of analysing complexity on the level of NPD activities since prior research has primarily focused on uncovering activities to manage complexity (Chapman & Hyland, 2004; Kim & Wilemon, 2007), rather than how activities generate complexity and how this complexity can be understood. Similarly, the mechanism-based approach complements the study of linear and concurrent NPD processes that have tried to pinpoint when complexity occurs (Cooper, 2008; Salerno et al., 2015) by trying to explain how complexity functions within these processes.

The mechanism-based approach also shares similarities with existing ways to understand complexity in the context of NPD processes, especially with regard to system-oriented studies that focus on interdependencies and how they create complexity (McCarthy et al., 2006; Mihm et al., 2003). However, the system-oriented studies aim to explain how complexity emerges and functions in different kinds of systems, while the mechanism-based approach tries to explain complexity on the level of NPD activities and activity configurations. Thus, while similar in approach, these two ways of studying complexity have a different focus.

Implications for practice

While the focus of our study is methodological, we perceive that our analysis provides two primary implications for practice. First, our study foregrounds the benefits of understanding how recurring NPD activities function together in order to untangle activity level complexity. Even a rudimentary understanding of these interrelationships could help managers to plan what NPD activities should be conducted together to reap the full benefit from them. This could help in re-engineering NPD processes to be more effective.

Second, since the configurations depict bundles of activities that enable addressing problems in different ways, it is likely that managers are able to understand and categorise how they conduct certain NPD process events and stages. Mapping how these activity bundles follow each other could enable optimising NPD processes and changing them to produce desired outcomes. In essence, this is what Vaisala managers did when they decided to increase collaboration and focus on technology exploration when they needed to move beyond their current market.

Limitations and further research

While our study provides initial insights to the benefits of mechanism-based inquiry, we perceive that there are a number of ways to strengthen the approach and employ it to study different kinds of NPD processes. Indeed, the proposed mechanism-based approach constitutes only one potential way to study NPD process mechanisms, and we further focused our study on causal complexity. Thus, we encourage further studies to examine different ways in which mechanism-based theorising could be used to study NPD processes and further elaborate on the kind of knowledge this approach provides. We perceive that the mechanism-based approach can itself still be developed further.

While our empirical study provides initial insights on the causal complexity of NPD processes, there are multiple avenues for further study. First, the mechanism-based approach could be applied to the analysis of different kinds of entities and different levels of analysis. For instance, this could entail focusing on mechanisms that undergird individual and group level problem-solving activities during NPD processes. Second, the mechanism-based approach could also be used to examine different kinds of NPD processes. This could entail examining, for instance, mechanisms that underlie processes that integrate customers more tightly to the process or use different digital tools to expedite processes. We hope that the ideas presented in this study provide encouragement for such studies.

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