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The cumulative power of incremental innovation and the role of project sequence management

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Abstract

In innovation and project management studies incremental development projects are perceived as theoreticlly and organisationally uninteresting. By means of a longitudinal study of product improvement projects at an automobile firm, this paper challenges such views and shows how the cumulative impact of the studied sequence resulted in a competitive repositioning of the company's product portfolio during a financially difficult period. Project managers achieved this by transcending the separation between exploration and exploitation projects; they not only adhered to time, cost and quality goals but also tried out new ways of testing and experimenting with controversial technical ideas. The paper analyzes the intensive inter project learning that generated these ambidextrous capabilities and emphasizes that practices at the project-level need to be buttressed by expanded management learning and capability development also at the sequence level.

Keywords: Incremental innovation; Project sequence; Exploration; Exploitation; Multi-project management; Ambidextrous; Longitudinal, inter project learning, resistance to change

1. Introduction

Project studies and innovation research often come together in empirical investigations of similar objects. This relatedness is seldom acknowledged: “though both disciplines refer to the same concepts – projects and innovation – until recently there was very little mutual recognition and cross-referencing” (Davies et al., 2018, p. 966). Project management has historically privileged rationalistic, planning-oriented perspectives associated with exploitation projects (Mahmoud-Jouini et al., 2016), whereas classical innovation studies focus on open-ended processes, serendipity and organic forms of management (Burns and Stalker, 1961; Van de Ven et al., 2008). Increasingly, however, project researchers are studying various types of radical, explorative projects where the focus is on knowledge creation and learning (Loch et al., 2006; Lenfle, 2008). In this way they are entering a terrain, which was previously the privilege of innovation studies (Utterback, 1996; Christensen, 1997).

However, both innovation and project management studies have shown little interest in exploring new ways of managing incremental innovation projects, despite the fact that projects targeting gradual improvements of established products are crucial to sustain firm revenues and long-term success. Moreover, studies of multi-project management, such as portfolio and program management, tend to focus on composition, allocation and balancing of projects at a given point in time (Dawidson, 2006) whereas a deeper understanding of the role of incremental innovation projects requires longitudinal analyses of a sequence of projects and their collective impact over time. Against this background, this paper will investigate an eight-year sequence of incremental development projects in an organization. The purpose is dual: (1) to identify the cumulative impact on product performance of such a sequence, (2) to contribute to project theory by analyzing the management

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practices developed to overcome internal resistance and to cope with the uncertainties of organizational transience.

The paper is based on a study of twelve projects at an automotive company in the 2007–2015 period. Vehicle development projects typically involve the integration of changes in multiple soft- and hardware components, and are characterized by emergent properties, which means that repeated testing is needed to safeguard critical performance parameters. This context generates a need for tight control and coordination, but also creates discretionary space for experienced managers. Step by step, the studied stream of projects reduced the greenhouse gas emissions of the company's existing models, a crucial achievement in a financially difficult period. The technological limits of the firm's existing vehicle models were impossible to determine ex ante. When a project succeeded in meeting highly demanding goals, participants tended to perceive this to be the end of the road - until the next project started, and new reduction possibilities had to be detected and realized. The paper analyzes the intensive inter-project learning, including both technical solutions and managerial practices, which evolved during this process.

Theoretically, the study challenges the conventional separation of exploitation and exploration projects, where the former type is associated with planned development in a well-known terrain, and the latter with (re-)search in uncertain areas where strict planning is not possible (Lenfle, 2008). The importance of managing both types of projects has been recognized by management scholars for a long time; more recently project management students have also emphasized the need for such an ambidexterity (Eriksson, 2013; Turner et al., 2013b). So far, however, there are few studies of ambidextrous management practices at the project level. The paper addresses this gap by demonstrating how management in a project sequence learned to combine explorative and experimental practices and in this way transcended the exploitation – exploration dichotomy in innovation and project management studies.

The paper is organized as follows. The next section provides an overview of the relevant literature. Section 3 focuses on the research method and the data collection process. Section 4 provides detailed information about the twelve selected projects. Section 5 introduces two concepts from the project lineage-literature, generative concept and meta-rules, to interpret the management of these projects. Next, the learning processes during the project sequence are analyzed. The Discussion section reflects on the value of longitudinal approaches for understanding the dynamics in a project sequence, the development of ambidextrous management capabilities and the transient character of organizational positions. The Conclusion highlights the cumulative impact of the incremental project sequence, summarizes the paper's contributions to project theory and suggests directions for further studies.

2. Studies of project lineage management and incremental innovation

According to standard industrial life cycle-models, technological innovations take place in periods of discontinuities, so-called eras of ferment which are characterized by radical change, followed by prolonged periods of incremental change and social equilibrium (Abernathy and Utterback, 1975; Anderson and Tushman, 1990; Magnusson and Berggren, 2011). From a firm perspective, the world is more complex, and irrespective of the industrial era, radical innovation projects need to be followed by incremental improvement projects in order to make the product innovation a commercial success. Moreover, if a product requires a long time to be developed and is used for an even longer time (in the case of the auto industry normally amounting to five plus fifteen years) new technologies diffuse slowly across a firm's product range (Schäfer et al., 2006). This means that firms depend on incremental projects to maintain the market value of their existing products long after they have launched new technological generations.

In project management studies, incremental projects, often referred to as exploitation projects, tend to be associated with rationalistic views of project management. In these projects, technical and market requisites are supposed to be well-known, and clearly defined project goals can be accomplished in a specified period of time within the budget and quality requirements (Lenfle, 2008). Exploitation projects are contrasted with explorative, research or pre-development projects, in which much of the technology and the market are unknown, and “neither the goals nor the means to attain them can be defined at the beginning” (Lenfle, 2014, p. 921). Exploration projects are conceived as experimental learning processes, which demand a particular set of management practices (Loch et al., 2006,) and the advice is to manage them as experiments (Thomke, 2003). Studies of such projects often challenge established project management rules by highlighting unconventional approaches, e.g. skunk work methods of autonomous decision-making, colocation and physical separation (Bommer et al., 2002; Brown and Scott, 2011; McCurdy, 2013).

Firm level studies suggest that organizations have to manage both exploitation and exploration projects, which requires the development of ambidextrous capabilities and forms of organizing. In the general management literature, structural arrangements and temporal separation (Tushman et al., 2010; Turner et al., 2013a) are distinguished from leadership and culture-approaches, referred to as contextual ambidexterity, where “stretch, discipline, support, and trust” need to be combined at the business unit level (Raisch and Birkinshaw, 2008, p. 391). A study of the management of research and development projects (Mirow et al., 2008) identified problems in both the structural and contextual approaches, such as the low priority and support for research projects within units responsible for both research and development. An increasing interest in ambidextrous capabilities at the project management level has inspired several conceptual and literature-based studies (Eriksson, 2013, Leybourne and Sainter, 2012). As observed by Turner et al. (2013b), however, there has been limited research into the mechanisms or project practices which could support ambidexterity. Unfortunately, their suggestion to use an intellectual capital approach to investigate how managers mobilize human, organizational and social capital to enable ambidexterity at the operational level seems difficult to apply in the project management context. Further studies of ambidextrous management at the project level are needed, and as emphasized by Davies et al. (2018), studies informed by a practice perspective will also create bridges between innovation and project management research.

A related body of literature has developed a barriers-approach for analyzing failures in innovation projects, suggesting the need for distinctive roles such as promotors, champions or technological gatekeepers to support such projects. This literature is limited to describing the success factors for radical innovation projects (Gemünden et al., 2007). Recently, however, scholars have started to pay more attention to the dynamics of incremental innovation, arguing that the "neglected period /of incremental change/ in technological life cycles can be quite interesting" (Lee and Berente, 2013, p. 1469). These scholars criticize previous conceptions of incremental change as "theoretically and socially uninteresting. …/and as/ smooth, orderly, and driven by technological considerations" (Dokko et al., 2012, p. 682). Informed by these insights, the current paper suggests that both innovation and project management students would benefit from closer investigations of incremental development projects, i.e. projects that focus on the gradual improvement of one or several performance parameters in a given product, but which do not change the basic technology or architecture.

A change of analytical lens from single-project to project-sequence raises the question of how to conceptualize project ensembles. In a critique of the emphasis on planning, calculation and control in conventional multi-project managing studies, Midler (2013) and Maniak and Midler (2014) propose project lineage management as a fruitful framework for analyzing emergent project sequences, applying this concept to studies of sequences where a top management initiated vanguard project is followed by projects that extend the original ideas. Conventional forms of multi-project management, using portfolio or program approaches for example, could be conceived as 'horizontal' or cross-sectional means to achieve a proper mix and balance of competing projects in terms of long- and short-term orientation, market segments and product categories (Dawidson, 2006). Project lineage management on the other hand suggests a 'vertically' oriented framework to analyze the dynamics of projects over time. Thus the two frameworks complement rather than exclude each other.

In this paper the focus is on the 'vertical', longitudinal dimension, encouraged by the suggestion to study "the trajectory, the flow of projects" (Söderlund et al., 2014, p. 1089). In contrast to Maniak and Midler (2014), the empirical case consists of a series of incremental development projects that neither required any initial break-through project nor top management visions. Nevertheless, two core ideas in the project lineage management framework inspires the empirical analysis: the importance of a generative or guiding concept to frame the project sequence and its selection process; and the significance of meta-rules or sequence-specific management practices to maintain project integrity and overcome innovation barriers related to intra-organizational resistance, frozen knowledge and process rigidities. The cumulative impact of incremental projects pursued in a rapidly paced sequence is a key theme. Another theme is the evolution of project management practices across the studied sequence. By capturing this learning process the paper contributes to the field of inter-project learning, which according to Hartmann and Dorée (2015) has been marked by slow progress. Moreover, the sequence approach makes it possible to shed light on the transience of the projects´ organizational position and degrees of autonomy (cf. McCurdy, 2013), and the need for management capabilities at the sequence level to cope with this organizational precariousness.

3. Method and data

Project management practices develop in a context shaped by industry characteristics and product constraints. The management of vehicle projects, which constitute the empirical subject of this paper, requires the balancing of dozens of different performance parameters, which includes difficult trade-off decisions (MacDuffie and Fujimoto, 2010). The complexity of the product and its required performance means that a single project has strictly limited possibilities to influence these parameters. Even when one subsystem is completely changed, the impact on the product level is diluted by the presence of all the other subsystems. Automobiles often figure in the innovation and project literatures to illustrate the importance of integration and the slowness of overall change, even when firms make major efforts to launch new technologies. This can be illustrated by the case of Toyota Prius, which was a radical innovation project in an incrementally oriented industry. After four years of intensive development, the original hybrid-electric Prius was launched in 1997. Then the company needed several consecutive improvement projects to establish the hybrid powertrain on the market (Magnusson and Berggren, 2001, 2011). This example underlines the importance of studying sequences of development projects in complex product industries.

The paper is based on a longitudinal study of the so-called CO_2-projects conducted at Volvo Cars between 2007 and 2015. In total, 30 projects were realized by the same core management group during this period. Almost all of them focused on reducing the greenhouse gas emissions of the company's existing models. During the first years, the improved model versions were named DRIVe-cars, short for" Drive environmentally". Twelve of the projects, based on diesel powered models for the European market, have been selected for this study (see also Berggren and Magnusson, 2012). Other CO_2-projects involving the same key managers but not included here dealt with flexi-fuel or gasoline powered models, or models for non-EU markets. All of them were characterized by a fast-paced project rhythm, targeted specific markets or customer segments and often succeeded in having a strong sales impact. In 2015, the last year of the empirical study, the company entered a new phase with the launch of products built on novel vehicle platforms and more powerful powertrains prepared for electrification.

The longitudinal research design involved lengthy real-time, as well as retrospective and reflective interviews with key actors over a seven-year period (2010–2016). Recurrent interviews with the chief engineer and the program coordinator of the selected projects were complemented by interviews with the head of their department, functional specialists, and the chairman of the engineers´ union and the vice president of R&D at Volvo Cars. The conversations constituted expert interviews in a dual sense: the interviewees were selected based on their expertise in the studied area and met interviewers/researchers with an intimate knowledge of the product development complexities in the automotive industry, based on decades of prior research. In the empirical sections below, extensive interview quotes reflect the observations and reflections of the key interviewees.

The real-time interviews usually involved the chief engineer and his team. These interviews had the advantage of "proximity in time" (Leonard-Barton, 1990) but by their very nature focused on the current project/−s and did not allow for any systematic reflection regarding the emerging sequence and its specific management practices. Most of the interviews revolved around five simple questions: What projects are you working on right now? Why these projects? What targets are you chasing? Are you introducing any new solutions, e.g. new component technology and if so, please describe them? Which are the key issues/hurdles?

By contrast, the retrospective interviews focused on the progression of the project sequence from the start in 2007/2008 to the end of the study period in 2015. A key role was played by the program coordinator who retired from the company in late 2014 and was employed by the research team to collect data on the twelve projects. In this way, the researchers acquired detailed project information on time, cost, performance and other variables which are normally very hard to access for outsiders. This data constituted the point of departure for several rounds of intensive retrospective interviews in 2014 and 2015, structured by a set of questions regarding accomplishments, management practices and inter project learning (see Appendix 1).

A third type of semi-structured interviews had an exclusive reflective and evaluative character. These interviews involved the project leaders (Chief engineer and program coordinator), their manager and the company's vice president of R&D. In these interviews, we sought to analyze the specific reasons for the success of the DRIVe projects; their overall contribution to the firm; the relevance of their management practices for other type of automotive projects; as well as the limits of these practices, i.e. for which type of projects they would not be feasible.

Data on the 'hard' accomplishments of the studied projects, the emissions performance and the sales of the revised models, were collected by the project coordinator and verified by the researchers with functional specialists and publically available industry reports. The study of 'soft' issues, such as management practices to overcome hurdles and resistance based on deeply held design rules, required tactics akin to the experiential learning approach in management training (Berggren and Söderlund, 2008), i.e. in-depth conversations with key managers, focused on critical project experiences.

This type of data is open to interpretation. We followed the advice in Leonard-Barton (1990) and were careful to be two researchers in all the retrospective and reflective interviews performed in 2014–2015. After each round of fieldwork, we wrote independent interview reports, and compared our observations and findings. Concise texts were developed on important themes, such as "the specificities of the CO_2 projects" and "management means for gaining organizational acceptance", and the texts were then checked elaborated in follow-up sessions with managers and executives. The conversations mostly enfolded in a climate of trust and openness. However, similar to other studies of product development projects (cf. Midler, 2013), it was agreed that the disclosed cost information did not enter any published reports.

A list of interviewees and dates is provided in Table 1. In addition to interviews, the study used internal documents regarding the cost, time, technical content and performance of the twelve projects. Reports from external sources were used for validation of the environmental impact.

The study uses CO_2-emissions as a key outcome variable, which is a variable closely related to fuel efficiency. Emissions and efficiency are reported according to the European driving cycle NEDC, which was the basis for type approvals in the relevant period. Several studies have pointed to the gap between the NEDC figures and emissions in real drive (T&E, 2015; Tietge et al., 2015). As a consequence, the EU is replacing NEDC with the more realistic Worldwide Harmonized Light-Duty Vehicles Test Procedure, WLTP (EU, 2017). A detailed analysis (not reported in this paper) of the technical changes implemented by the projects suggests that some changes aimed at satisfying the artificial conditions of the type approval test more than reducing real consumption. Other changes such as the electronic grill shutter, which is particularly effective in reducing emissions in colder countries, had an impact on the road but almost none in the NEDC test. The net result (i.e. emissions reductions in real drive) of the two types of technical changes is difficult to assess. In the period of study, premium makers in Europe were continuously announcing improvements in both efficiency and power. Realistic tests tend to make dual improvements harder to achieve and may force

Table 1
Overview of interviews.

Interviewee/position	Date of interview
Chief engineer	April 21st, 2010; Oct. 21st, 2010; Oct. 3rd, 2013; Dec. 19th, 2014; April 15th, 2015; June 22nd, 2015; Sept. 1st, 2016.
Head of technical project managers	Sept. 1st, 2016
Powertrain specialists	Oct. 21st, 2010
Sales manager	Oct. 5th, 2010
Program coordinator	Oct. 21st; 2010; Dec. 19th - Dec 20th, 2014; April 21st – April 22nd, 2015
VP of R&D	June 22nd, 2015

car makers to choose. If the WLTP test cycle had been in place during the studied period, it would probably have been easier for the projects to achieve organizational acceptance, and the meta-rules discussed below would have been even more powerful.

4. A sequence of incremental vehicle projects

Automotive R&D is made up of several layers, starting with pre-development (research) of new systems and components (T&E, 2012). This is followed by the development of new platforms which are planned to last for a decade or more; then on the basis of these platforms new vehicle models are developed; and finally these models are regularly revised and updated, so-called facelifts. Whereas new technologies may take decades to reach maturity, the development time of a new model tends to be four years. The average time for revising and updating an existing model varies across companies; at Volvo it has been around two years.

The projects studied here began with very limited resources in a period of crisis where new platforms and models were far from realization. Thus the project managers focused on improving existing models as quickly as possible. After a few rounds, they had developed a cycle of around 12 months to deliver the results, i.e. half the company's standard time for model revisions. A group of 12–15 managers providing competence in all the relevant areas worked full time, while the participation of technical specialists and sub-project members varied according to the task at hand. Table 2 below presents key aspects of the 12 projects and their impact on reducing CO_2-emissions.

The first projects in this sequence were initiated in 2007 and started to deliver in 2008, i.e. in the midst of the crisis, when GM and Chrysler went almost bankrupt. Volvo Cars and its corporate owner, Ford Motor Company, were both in serious economic troubles, and Ford started to sell out its premier automotive group. This created a management vacuum at the top until Volvo was acquired by Geely in China in 2010 (Logan, 2015). In addition to financial and ownership-related problems, Volvo's product planning identified a significant gap between the predicted CO_2-emissions of its cars and the expected EU requirements. To address this gap, a dedicated unit was formed with a budget intended to span several years. Internally the unit was referred to as the CO_2-program, and this label is used below. However, it was never a program in the conventional multi-project management sense of a coordinated ensemble of complementary projects designed to achieve a specific corporate purpose. Instead, it created a permeable umbrella for an emerging series of fast-paced projects which were allowed to focus on one particular target.

The urgency of the situation, the deep financial crisis and Volvo's lack of fuel efficient models in the pipeline, created a

Table 2
Twelve selected “CO -projects” 2007–2015.

Launch year	Models	Key technical changes	Interview comments regarding company-internal discussions	Reduced emissions in g CO /km
2008	C30, S40, V50	Recalibration of engine control, improved aerodynamics, adjusted gear ratios	First Volvo project focused on one sharp goal. “A lot of resistance!”	From 132/129 g to 115/119 g = ‘Environmental car’ in Sweden
2009	C30, S40, V50	Start-stop supported by a compact motorcycle battery + smart battery charging	“Ford impressed, copied and paid for our solution”	From 115 g to 104 g.
2009	S80, V70	Small engines in large cars – 1.6 l instead of 2.5 l	“Opponents argued that his car is not drivable. Early test drives killed the BS…”	From 150 g + to 129 g
2009	S80, V70	More advanced smart battery charging, Low friction tires	First large ‘environmental’ cars “Difficult discussion re stability and braking range of new tires”	From 129 g to 119 g
2009	C30	Optimization of fuel pre-injection systems	Tradeoff: “More engine noise!”	From 104 g to 99 g.
2010	S40, V50	Improved tires. LED-lights – “diamond in the dark”	“Very hard to reach the goal – end of the road?”	From 104 g to 99 g.
2011	C30, New V40	Reengineering of energy-wasting accessories	“We trimmed everything”	From 99 g till 94 g.
2012	S60,V60, S80, V70	Automatic drive co-developed with supplier; Start-stop in drive at 5 km/h (SID 5)	SID 5 controversial: “An internal war”. Solution: backup power supply to secure safe handling	119 g. “Crucial for several market segments, and hugely successful”
2012	S60, V70, S80.	Upgrading of the large 5-cylinder engines: start-stop, SID5, etc.	“All these powerful cars now became environmental cars in Sweden”	136 hp. engines: 114 g 163 and 215 hp. engines: 119 g.
2013	V40	Top grill shutter to improve engine compartment temperature and battery efficiency	“End of the road – we cannot do more”	From 94 g to 88 g.
2014	V40	Both old 1.6 l and new 2.0 l engines. Optimization of fuel injection system critical	“The new engine too big for us, plus the challenge of optimizing two engines simultaneously”	From 88 g to 85 g.
2015	V 40	Lower grill shutter to further improve engine compartment temperature; Reduced weight, smaller fuel tank.	“Added cost for tooling provoked resistance – Dutch incentives critical to finalize the project.”	From 85 g to 82 g.

Sources: “Technical content CO_2-programs”, 2013; “Current status DRIVe Volvo Cars 2013”; interviews with project coordinator, Dec. 19th - Dec 20th, 2014; April 21st –April 22nd, 2015. “hp” stands for horsepower.

window of opportunity for novel initiatives and a well-known chief engineer started to implement unconventional project practices under the protective umbrella of the CO_2-program's special organizational arrangement. During the eight year-period studied, these projects resulted in the launch of low emission versions across the company's product portfolio and cumulatively reduced emissions per model by 25–40%. Frugal versions of the compact V40-model lowered their CO_2-emissions from 129 g/km in 2007 to 82 g/km in 2015.

The revised model versions were developed and diffused rapidly. Several variants, for example the V70 automatic, enjoyed very strong sales in their targeted market. In 2010, during the aftermath of the financial crisis, 40% of Volvo's European sales consisted of low emission DRIVe models. Taken together, the incremental low-budget projects resulted in a competitive repositioning of the company in the EU market, from being one of the worst performers in terms of greenhouse emissions to one of the best in its segment (T&E, 2015). This transition significantly increased the company's sales of its existing models during a difficult period, and provided breathing space for the development of entirely new models. In a retrospective interview in June 2015, The Vice President of R&D emphasized: "*We would not have existed if we hadn't had these environmental cars.*" How, then was it possible to realize this series of fast-paced projects so successfully? To answer this question, it is necessary to analyze key elements of their management practices.

5. Management practices: A generative concept and four meta-rules

5.1. The generative concept

A basis for the emerging project sequence was the early articulation of a generative concept based on three principles: Build on existing products; focus on one sharp goal and deliver improvements in every project; stick to a fast-paced rhythm to exploit temporary incentive regimes and keep costs low.

Vehicle development projects normally have to balance a multitude of conflicting performance parameters or vehicle properties, such as attractive design, competitive cost, convenience, speed, safety, driving experience, noise, functionality, reliability and fuel efficiency. At Volvo Cars, 25 of these vehicle properties had designated organizational stakeholders with a responsibility to monitor new development projects. The generative concept of the CO_2-projects with its sharp focus on one sharp goal (emissions and efficiency) implied tradeoffs with several properties, such as acceleration, vibration and noise, but not with safety and overall quality. Thus the projects overrode objections from the marketing department and limited top speed to 190 km/h instead of the usual 210 to 220 km/h. By doing so they also reduced the weight of the brake system. Many in the R&D organization perceived the focus on one property as a radically new and non-attractive approach:

"*Several departments argued that the idea of selling stripped down cars with feeble engines was a basket case. They could not understand our scenario which predicted that lower emissions were a necessity. But top management saw the need for change, and the value of fast projects with less demand for engineer hours."* (Project coordinator, 2014). Importantly, the local sales organizations in Europe saw the benefit for their customers of projects which delivered fuel-efficient cars much faster than the corporate planning process.

Every project guided by this key concept worked with an ambitious goal, tight deadlines, and a high risk of failure: *"There is always a tough time pressure, and no guarantee that we will reach our targets. Only a few weeks before the official approval test do we know if we have succeeded. So many activities run in parallel, development and testing; concept development and industrialization (preparation for production). All kinds of problems may emerge, disturbing noise, vibrations, engine irregularities, and so on. Moreover, there is always the risk that other projects may have a negative impact on us. Cost-reduction projects, for example, may decide to cancel a component which adds cost but is important for us to reach our emissions target. One example is the electronic grill shutter which disappeared in such a way, forcing us to fight to get it back."* (Project coordinator, 2015).

At the same time, the first principle of the guiding concept, to build on existing products, limited corporate risks. In this sense the projects differed from new model or platform projects which may be business-critical for a small company. Moreover, the incrementalism of the projects made them easy to introduce in the manufacturing process. In theory, production launch could be postponed, although this flexibility was very seldom used. "*So far we have never failed to achieve the objectives / once the formal project has started/, and often we are less expensive than the budget. We have simply not had any time to use the allocated resources. Many projects have recovered their costs within one year's sales. But every day we are coming closer to a failure."* (Project coordinator, 2014).

5.2. The four meta-rules

The generative concept with its three elements - build on existing products; focus on one sharp goal; and exploit short-term incentive regimes - was supported by an evolving set of "meta-rules", which will be reviewed under four headlines.

(1) Create business value by targeting specific markets.

The very first DRIVe-project reached an important market goal by launching models which were classified as "environmental cars" in Sweden. This provided a boost to sales, since buyers could enjoy significant purchasing subsidies. Subsequent projects targeted other national incentives, for example the subsidies associated with being classified as a "low-emitting car" in Belgium. The targeting of specific and temporary incentives emerged as a general practice in the studied project sequence. Later, the Dutch incentives for low-emitting vehicles became increasingly important (cf. T&E, 2014), and provided a strong business case for the last three projects shown in Table 2. Other projects focused on requirements to qualify as preferred taxi vehicles or company cars in various countries.

To get formal executive approval, the capacity of the project managers to define goals based on specific market incentives was critical. This capacity relied on a flow of information from the expanding network around the program's chief engineer, which provided detailed data on customer requirements, government subsidies and changes in tax regimes. All this information helped project managers to build the business case and to achieve a wider organizational acceptance of the proposed projects.

(2) Compress the project process and the decision-making format.

To launch the improved model versions on the target market in time, the projects had to abandon the sequential stage-gate process for product development introduced by Ford, Volvo's previous owner. A compact process with parallel build and test loops was implemented, supported by a standardized decision making rhythm with weekly management meetings for all types of decisions. Whereas product engineers in other programs often had to wait for decisions from several levels of hierarchy, the CO_2-projects could move forward at a brisk pace. According to interviewed project managers, the work process department at the R&D organization was highly skeptical to the fast-paced approach practiced in the CO_2-program and doubted its capacity to safeguard appropriate quality. In the beginning, the approach was just tolerated by upper management but when the program started to deliver successful results it became explicitly accepted. As noted by the new Vice President of R&D (2015):

"*Volvo was a small company stuck in processes. We need to go back to the product, make the engineers the most important in the company and unleash their energy!*"

(3) Walk the consumption walk and test rough and ready prototypes early

After a few projects, the CO_2-program had established a standard process. This started with a feasibility test in existing vehicles before a formal project launch. After project approval, the next step was to do the "consumption walk". Here, the project coordinator and the system analysts scrutinized all areas which could contribute towards reaching the specified emissions goal within the allocated time. A preliminary value, measured as fractions of CO_2 -reduction, was attached to each area. This was followed by a phase focused on developing and testing each proposition as soon as possible; first in theoretical models, then in rough and ready prototypes, i.e. real cars equipped with prototype software. Although the projects dealt with limited changes, managers learned that repeated tests were indispensable. Many factors might influence the final result or have negative side effects on other properties.

"We update the consumption walk regularly…. It's about the sum of contributions in so many areas. Oftentimes each of them only affects a few tenths of a gram CO_2. For us, one gram is a big thing! At the update, we might find that the project needs another 0.4-gram reduction to reach the goal, and then we have to systematically review everything again. Each project normally starts with 20 different areas, some of them deliver less than expected, other are positive surprises. At the end we might end up with twelve areas that deliver enough to satisfy the goal, and we throw out the remaining eight" (Project coordinator, 2014).

For projects with safety implications such as the installment of start-stop functionality or the introduction of small engines in the company's large models, realistic crash tests early on were particularly important:

"We need to do the crash tests early, already in late autumn (to deliver a final product in late spring). Simulation models are good, but lack precision, and we need time for redesign after the first crash tests, and to do the test again. Fortunately, we have highly experienced crash analysts and they know what to do." (Project coordinator, 2014).

(4) Attract the commitment of every involved engineer and think beyond projects.

"We needed to replace a previous 'fear of failure'- culture with a can-do attitude, where engineers are free to try out new approaches without risking humiliating criticism" (Technical projects director, 2016).

Creativity was important but had to be guided by a common focus: *"When we involved tire engineers they had to refocus from optimal grip in 220 km/h to optimized rolling resistance at normal speeds and transmissions specialists had to change from maximum acceleration to minimum losses."* (Chief engineer, 2014). Moreover, all engineers, many of whom were involved for only a fraction of their time, had to understand the importance of attention to detail: "*We are chasing tenths of a gram in emissions*" (Project coordinator, 2015). To avoid micro-management, project managers cultivated a mindset of individual responsibility and commitment throughout the projects, and sought to reinfuse this into every new participant.

Normally, infrastructure investments are a concern for the line organization, and projects are careful not to become involved. The importance of the fine details and every minor contribution to emissions reductions made it necessary for the projects in the sequence to devote resources to fine-tuning the R&D infrastructure, to make measurements more precise, to train test-drivers, calibrate laboratory instruments, etc. "*If we don't do this, nobody will*!" (Chief engineer, 2014). This going-beyond the usual project approach needed special commitment, but was supported by the fast-paced flow, where managers and engineers learned that they would soon need the equipment and infrastructure again. In this way, the project sequence permeated several boundaries, between subsequent projects as well as between projects and the surrounding organization.

5.3. Resistance and techno-organizational learning

On a number of occasions, the seemingly simple technical changes suggested by the projects encountered fierce internal opposition, in particular if they were related to packaging, pricing, demand for new suppliers or deviations from standard rules for vehicle design and component combinations.

When project managers started to design the first Volvos with a start-stop system they soon discovered that the heavy support battery suggested by the original R&D plans would make it very hard for the project to reach its emissions target.

"So we challenged the electrical engineers: ′think radical, dare to try something new′! Then someone suggested that a small motorcycle battery of the AGM-type (Absorbent Glass Mat) might be enough. We assembled all the components in a simple test rig, uploaded a rough prototype of the necessary software and ran it together with the guys from advanced engineering. Next the electrical specialists did the math and concluded that a small battery would do the job." (Project coordinator, 2015).

Another hurdle in this project concerned the location of the support battery. The project leaders suggested locating it behind the front bumper, but were severely criticized by functional specialists who cited problems of dust, corrosion and crash risks.

"*During six months the small extra battery travelled around in the engine compartment, until finally, after several tests, the battery ended up behind the front bumper, the originally suggested place."* (Project coordinator, 2015) Then, however, the Volvo purchasing system had no established suppliers of this type of battery. *"So we started by purchasing the motorcycle batteries via unofficial channels."* (Project coordinator, 2015).

Pricing issues constituted another barrier, especially when a component needed to reduce emissions increased the basic price of a model without any offsetting government incentives. Thus the introduction of LED-lamps initially met with strong resistance, since the tooling cost for this 1-g CO_2-reduction (not even registered in the official NEDC tests) would directly affect the price of the car. The marketing department doubted that buyers would pay for such a negligible improvement. The project managers circumvented this barrier with two actions. First, they approached the styling department, but not with a standard presentation. Instead they placed a vehicle prototype with LED-lights in a dark room outside the department's offices.

"*When the head of styling spotted the prototypes with these 'diamonds in the dark', he was immediately convinced"* (Chief engineer, 2013). Then the project advised the financial controller to treat LED-lights as an option that was not included in the basic price, and this was accepted.

"The LED-options became very popular because of their ′ cool look′, not because of the little increase in fuel efficiency" (Chief engineer, 2013),

Existing design rules, based on deeply held convictions of engineering possibilities, constituted another type of barrier. A very controversial proposal was the initiative to install the small 1.6-l engine in the company's large cars, which were normally equipped with 2.0 or 2.5 l engines. Opponents perceived this as unrealistic, arguing that such a small engine would make the car impossible to drive. The project managers reminded their opponents that the same power had sufficed to move similar cars twenty years ago, so the physics should not be a problem. Then they installed the small engine in a large car and invited an executive to go for a test drive. The diesel engine's strong torque at low speed convinced the executive of the feasibility of the configuration. The project could continue.

"This was the first time we built a demo car in a pre-study and invited top managers to test. Later we used this device many times. It is often not enough to show the calculations, it's hard to make people change their opinion just after seeing some numbers. But with a demo car and real test drives, the bullshit dies" (Chief engineer, 2014).

A similar issue emerged when project groups planned to include engine stop at low speed, so-called SID5, in the stop-start system. "*There was almost a war with the specialists in chassis dynamics who worried that this could lead to shutdowns of the servo system and sudden loss of steering control. So we did various trial runs, where we walked by the vehicles in normal pedestrian speed (5 km/h) to demonstrate the low speed involved – at 7 km/h a driver is still able to handle the steering wheel manually, without servo assist – and finally we got acceptance from the chassis guys*." (Project coordinator, 2015).

The examples illustrate that incremental innovations in a complex product are far from trivial. Almost every change might have real or imagined side effects, which need to be tested and negotiated. Taken together, the examples also show the power of the sequence approach in terms of technological and management learning. In the beginning, the project teams could pick low-hanging technology fruits, which previous vehicle projects had not exploited. Step by step, their knowledge of technological possibilities increased in an evolutionary inter-project learning process involving identification, testing, variation and retention (cf. Lindkvist, 2008).

At the same time, new reduction goals tended to imply a need for increased engineering and managerial efforts. A first sense of reaching the end of the line emerged as soon as in 2009 when the 99 g vehicles were launched. If the project sequence had ended here, this level would have been conceived as the technological limit of this vehicle architecture. However, subsequent projects continued to move the frontier. In 2013 the 88 g car was launched, and a second sense of reaching the end of the line emerged among project participants. Again, subsequent efforts proved this feeling to be premature. In 2015, the chief engineer was still optimistic about the possibilities of further incremental improvements.

A key part of the learning process involved understanding the barriers related to organizationally embedded knowledge and finding ways to surmount them - in spite of limited bargaining power, small budgets and non-critical projects. As illustrated above, project managers developed a range of ways to challenge engineering specialists, to try out unconventional ideas, to illustrate the limited risks involved in their solutions and to convince executives of the feasibility of their proposals. They also learned how to proceed pragmatically in small steps and adapt the scale of the proposed change to the level of the resistance without losing the overall direction. An example was the introduction of start-stop functionality at low speed drive, discussed above. This was limited to 5 km/h in the first project, in a second project it was limited to 7 km/h, and in an envisioned, but in 2015 not realized project, to 20 km /h. The sequential fast-paced approach facilitated a pragmatic approach; a smaller step than that originally intended could be implemented in one project, and pursued by a bigger step in a project in the following year.

6. Discussion

The preceding analysis of an eight-year sequence of incremental vehicle development projects contributes to the project management literature in several ways.

(1) The analysis illustrates that project lineage and sequence management are valid concepts beyond their previous usage in studies of radical, breakthrough projects (Maniak and Midler, 2014), and may be developed to understand dynamic and extended sequences of incremental projects. Instead of being triggered by a top management initiative, the studied CO_2-program at Volvo Cars emerged as an improvised venture, which created space for entrepreneurial middle managers to organize product development projects in novel ways. Their projects soon delivered improvements of the company's existing models, and they earned a reputation that attracted resources for new improvement projects. A distinctive project sequence evolved with a significant cumulative impact on the company's produce performance. The finding underlines the importance of longitudinal studies which may uncover processes far beyond the original project intentions (cf. Van de Ven et al., 2008).

(2) The analysis challenges the established dichotomy of exploitation versus exploration projects and highlights the need to study ambidextrous management practices at the project level. In the project and innovation literature, exploitation projects are perceived as rigidly controlled by detailed schedules and cost controls, whereas exploration projects are associated with experimental approaches unrestrained by any standard project criterion (Lenfle, 2008, 2014). In the general management literature authors have suggested that organizations need to handle exploitation and exploration separately by means of ambidextrous capabilities at the business unit level (Raisch and Birkinshaw, 2008; Tushman et al., 2010; Turner et al., 2013a). Several researchers have called for studies of ambidextrous management practices also at the project level (Eriksson, 2013; Turner et al., 2013b), but actual investigations are few and mainly limited to infrastructure projects (e.g. Liu and Leitner, 2012).

The paper adds to the project and innovation literatures by showing how practices associated with exploitation and exploration may be combined at the practice level within incremental projects. In the study, project managers designed experiments, tryouts, and tests of rough and ready prototypes, but at the same time adhered to strictly defined performance goals and delivery windows. These combinations indicate that the dichotomy exploitation versus exploration may be transcended, and suggest a need for a more fine-grained typology of project practices.

(3) Resistance to change is a classical theme in studies of management and organization behavior (OB). Resistance to change is an important theme also in the projects analyzed above. However, most of the literature is focused on resistance to organizational change and on ways for managers to cope with employee attitudes, emotions, and efforts to protect established positions (Dent and Goldberg, 1999; Bovey and Hede, 2001; Oreg, 2007). The problem studied in this paper is different; not resistance to organizational change, but resistance to technical (product-related) changes. The organizational change-literature sometimes refers to the problem of “obsolete knowledge” (Piderit, 2000), but in general, knowledge issues play a marginal role in the OB literature. By contrast, in this study knowledge issues play a key role. However, the knowledge related to resistance in this paper is not ´obsolete´ in the ordinary sense; it is better described as sedimented, or ‘frozen´ knowledge: taken-for granted design standards, engineering rules of thumbs, etc. Philosophers of science, such as Edmund Husserl (Hyder, 2003), have analyzed the historic sedimentation of science. However, the impact of sedimented knowledge on complex product projects and management means to deal with it is seldom studied. Thus the paper makes an important contribution by analyzing how novel management practices - dramatic visual displays, hands-on physical demonstrations, executive test rides, unorthodox use of nonstandard components, etc., – can effectively confront, erode or circumvent resistance based on organizationally embedded and sedimented knowledge.

(4) Several studies in the project management literature emphasize the importance of organizational context and project history (Engwall, 2003; Lakemond and Berggren, 2006). The longitudinal approach in this paper adds to this literature by capturing the dynamic nature of the organizational context, and by analyzing the sequence-related management capabilities needed to handle this dynamism. The studied projects started in a period of financial crisis, when the company urgently needed improved products. This gave project managers considerable decision latitude and the protection of a special organizational setup. After a few years, however, the special organization with its own budget was dissolved and the projects integrated in the main R&D organization in which all projects compete for resources.

The transience of the projects´ separate location and autonomy echoes observations in another longitudinal study – the ´faster, better, cheaper´- program at NASA (McCurdy, 2013). Launched in a period of severe resource constraints, the first projects within this program enjoyed a high level of autonomy and delivered a successful stream of results. The next series of projects could not maintain their integrated set-up, and NASA scrapped the initiative in favor of its conventional heavy management approach.

Unlike the non-conventional space projects, the vehicle projects studied here never formed any self-sufficient units. Their mission to incrementally improve the company's existing models implied a need for project managers to constantly engage with specialists in a shifting range of subunits inside or outside the organization. At the same time, they had to protect the generative concept and the meta-rules of the emerging sequence. This dilemma highlights the importance of a broad set of managerial capabilities: capabilities to interact and negotiate with the organization where the projects are embedded, to commit shifting groups of fractionally involved engineers to the fast-paced project targets, and to defend the sequence-distinctive project process and project specifications,

Overall, the study challenges the view that incremental innovations are by nature uninteresting, smooth, and orderly (Dokko et al., 2012). It shows the challenges involved when meddling with complex products, where changes in one component to improve performance along one parameter could have side effects on other parameters; or where sedimented knowledge in the organization generates fears that such effects will occur. To surmount these barriers, the studied project managers developed an iterative approach involving a variety of experimental and conventional practices. The results could be compared with a cornerstone in the philosophy of Wittgenstein (2009): Do not solve a problem created by frozen beliefs and convictions, dissolve it!

7. Conclusion and future studies

Several researchers have addressed the need to bring together innovation and project management studies, and there is now an increasing trend of mutual recognition between the two disciplines (Davies et al., 2018). This paper utilizes a combined approach to analyze a sequence of vehicle development projects, where one project is followed by the next in a project stream which step by step improves a company's established products. Due to a tendency to privilege breakthrough or mega-size projects, and a scarcity of longitudinal analyses, both innovation and project management studies tend to underestimate the power of sustained incrementalism. The paper shows that incremental improvement projects can be delivered at a fast-pace and result in a strong cumulative impact on a company's entire product portfolio. This cumulative power of incremental innovation is both theoretically important and socially relevant. An example of this relevance is the current EU negotiations concerning standards for greenhouse gas emissions in 2030, where the auto industry opposes the Parliament's targets, citing risks of excessive costs for each extra percentage of reduction. The study reported here, however, suggests that much more emissions reduction than conventionally expected is possible by means of stepwise and low-cost fine-tuning of existing technologies.

The paper shows that simple technical solutions may face fierce resistance and require the evolution of new management practices. The project managers in the study adhered to the criteria of time and cost, associated with exploitation projects, but combined them with experimental practices, e.g. early test rides, rough and ready prototyping, on-spot visualization and flexible technological searches, associated with exploration projects. In the discussion on ambidexterity, i.e. the capacity to manage both explorative and exploitative projects, the management literature emphasizes the benefits of separating such projects structurally or temporally. The study challenges these suggestions by showing how combinations of time-focused and experimental practices co-existed at the project level. These findings suggest that ambidextrous project practices should be studied in several types of projects engaged in complex product development.

The study also illustrates the transient character of project locations and degrees of autonomy within established organizations during the enfolding of an extended sequence. These observations suggest that ambidextrous practices at the project-level need to be buttressed by expanded management learning and capability development also at the sequence level.

The study is based on a longitudinal analysis of a single project sequence in a particular industry. To build a comprehensive understanding of project sequence management and intra-sequence learning processes, different types of sequences and contexts need to be studied by means of longitudinal research designs: studies of other types of product development projects, of process development in capital-intensive industries, as well as studies of business development projects. Hopefully such future studies will enrich our knowledge of ambidextrous project management practices, and expand the repertoire of ways to overcome resistance to change based on sedimented knowledge and taken for granted beliefs.

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Appendix 1. Agenda for retrospective interviews 2014–2015

1. Basic review of data for all 12 projects.

Project target,
Project period (from start to launch),
Project budget,
Critical challenge(−s).
Outcomes –achievement in relation to target, sales in the first year/−s; revenues/cost.

2. Analyze challenges in each project

What were the specific difficulties at the start (e.g. accommodation of a new engine)?
What hurdles/organizational resistance did the project encounter?
How did the project surmount these hurdles?
How did you gain organizational acceptance, and if needed, executive support?
Which specific efforts were most important to reach the target?

3. The project sequence as a whole

In what ways did the projects in this sequence differ from other development projects in the Volvo R&D organization?
What means did you use to pay attention to and motivate project members?
How did you organize the project process to secure rapid progress to the defined target?

- how did you arrange decision-making in the projects to achieve fast feedback to engineering suggestions, and resolve tradeoff situations?
- what kind of tests did you use, and in which tests were particularly important for project progress?

What, as a whole, were the project risks and how did you manage them?

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