Drivers of thoroughness of NPD tool use in small high-tech firms

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**Abstract:** This paper explores how thoroughly practitioners in small high-tech firms use tools in support of new product development (NPD) activities, and what drives the variation in thoroughness. We present a mixed-methods study starting with a survey of 99 firms covering 76 tools across 12 functional perspectives on NPD, which shows wide variability in reported thoroughness of use. We investigate what drives this variability via case studies of five additional small high-tech firms based on in-depth interviews with 17 key managers. We find that the principal drivers are institutional pressures that prioritise either rigorous process or pressure from targets, and a disposition within the NPD team that privileges either tool-based or ad-hoc approaches. Based on these drivers and responses, we provide contingency-based advice as to how high-tech firms in different contexts can get the best results from using NPD tools.

**Keywords:** New Product Development (NPD); tool usage; thoroughness of use; high-tech; small firms

**Introduction**

A body of empirical research supports the notion that utilizing appropriate tools and techniques can assist firms to achieve better performance in launching new products (Cooper & Edgett 2008; Maylor 2001; 1995; Nijssen & Lieshout 1995; Yeh, Yang & Pai 2008). To define NPD tools, we apply the definition of de Waal & Knott (2010) that views NPD tools as “any structured aids, managerial or technical in nature, that are used for structuring or influencing the management and effective execution of the NPD process and associated activities”. A number of authors have identified the need for tool studies to move beyond whether or not a firm uses a given tool and to consider the extent of tool usage (de Grosbois, Kumar & Kumar 2012; Kemerer 1989). In some of the only research on the issue to date, (Cooper & Kleinschmidt 1987) highlighted the thoroughness to which developers, project teams and managers implement NPD tools as an important driver of successful innovation. For successful implementation of management tools in general, Rigby (2001) suggested implementation to be approached as a major rather than a limited effort. Despite this, research has yet to establish an understanding of why thoroughness of use varies between firms and between different NPD tools (Chai & Xin 2006); why tools are used in an unfocused manner (Mahajan & Wind 1992); and why tools are often used at superficial levels (Chai & Xin 2006). It is therefore unclear what interventions might increase the levels of thoroughness, and whether these would in turn improve innovation outcomes. This problem is especially acute in the context of small high-technology firms in which conflicting demands act on very limited resources (Akgün, Lynn & Byrne 2004; Christofol, Delamarre & Samier 2009).

 In this study we attempt to address some of these issues, in particular the factors that drive variability in thoroughness of tool use among practitioners in small firms. Our research questions are 1) How prevalent is the variability in thoroughness of tool use; and 2) what drives this variability? First, we review the literature on how innovation in small high technology firms differs from innovation in larger firms, how small firms use NPD tools, and what insights exist into the thoroughness of use of NPD tools in firms, large or small. Following this, we present survey and case study findings that allow us to analyse contextual and cultural drivers, motivations and behaviours behind different levels of thoroughness in tool use.

**Literature Review**

***Innovation differences between small and large firms***

Studies of NPD processes have typically drawn on firms employing full time equivalent staff in the thousands (Akgün, Lynn & Byrne 2004; Mahajan & Wind 1992). Yet, a number of authors suggest that NPD processes in small firms differ significantly from those in large firms (Ledwith & O'Dwyer 2008; Pullen et al. 2009).

A first major point of difference between small and large is the degree of formality to which firms approach business processes. Compared to large firms, small firms are less likely to implement formally recognized innovation systems (Hoffman et al. 1998). Specifically, several studies confirm that both product innovation processes and strategy in small firms tend to be informal (Felekoglu, Maier & Moultrie 2013; Hoffman et al. 1998; Roper 1997). But how prevalent are these differences? NPD process studies between 2004 and 2012 among American firms (Markham & Lee 2013) show that despite an apparent slight downward trend over this period, over 70% of the large firms used formal, cross-functional processes, as opposed to corresponding figures below 40% for small firms. Similar levels of formality are apparent for large firms in Sweden (Rundquist & Chibba 2004) and Malaysia (Al Shalabi & Rundquist 2009). The question arises whether small firm informality will negatively impact firm performance. It appears there are two opposing schools of thought regarding this. The first suggests that as small firms often conduct product innovation in an ad hoc manner (Millward & Lewis 2005), their product innovation processes tend to suffer through a lack of structure (Fornasiero & Sorlini 2010; Jones, Hall & Bilalis 2001) This results in the so-called “innovation management gap” (Wang & Costello 2009, p. 88) of which the characteristics include insufficient planning, inadequate resources, inattention to design requirements, and ultimately failure to realize the benefits of innovation. An opposing view derives from studies that point to beneficial aspects of informality such as better shared understanding of new knowledge and improvisation capability (Vera et al. 2014) and enabling 'hyper-agility', which are important considerations for delivering results in a dynamic and unpredictable world (Marion, Dunlap & Friar 2012). Thus, the literature paints a picture whereby certain aspects of informality hold back product innovation in small firms, while other aspects of informality potentially enhance firm performance.

Small firms are furthermore characterized by limited technical resources and absence of specialist functional departments, forcing members of small-firm product innovation teams to play multiple roles and perform multiple functions (Marion, Friar & Simpson 2012). Factors that often cause delays in product development include poor definition of product requirements, technological uncertainties, and poor management (Owens 2007). Similarly, small manufacturing firms are prone to failing to undertake effective competitor analysis; not measuring product development performance; engaging manufacturing personnel too late in the development process; placing too much emphasis on technology issues (at the expense of marketing and other management issues); and maintaining ‘do-it-yourself’ and ‘just go do it’ cultures (Millward & Lewis 2005). In their own case study research, Millward and Lewis (2005) identified three additional managerial issues that impinge on small-firm innovation: (1) the influence of a dominant owner/manager; (2) a focus on time and cost ahead of other key factors; and (3) the failure to understand the importance of product design. In the next section, we expand on how these observed differences are likely to impact tool application in small firms.

***How small firms use NPD tools***

The many differences in approach to NPD that prevail between small and large firms point to an expectation that small firms’ use of innovation tools will differ from that in large firms (as set out too by Berends, Jelinek, Reymen and Stultiëns (2014)) and have different performance outcomes. Despite this, very little research has focused specifically on how SMEs adopt and use tools. The only small-firm study we found looks at learning states and absorptive capacity for tool adoption during new venture development (de Waal & Knott 2012). There remains a lack of evidence in respect of how small firms really use NPD tools.

More specifically, can we expect small firms, with their informal approach, to apply tools less thoroughly than large firms do? It is difficult, based on existing evidence, to advise them about the issue. The only relevant insight we could find was by Baird et al. (1994), who found that greater formality in planning processes, in general, led to significant increases in the levels of thoroughness to which activities were carried out. Our expectation nevertheless is that the limitations we identified in small high-technology firms would inhibit the way practitioners in these firms use NPD tools and cause them to use tools at lower levels of thoroughness. This makes small firms a good subject of study to understand the drivers of non-thorough vs thorough use of tools. Our aim in this paper is to provide the necessary empirical evidence about thoroughness of use in small firms. As a precursor to this, below we define and explore more fully the concept of thoroughness of use of tools.

***Thoroughness of tool use***

In some of the only research on the issue to date, Cooper & Kleinschmidt (1987) found that the thoroughness to which large-firm developers, project teams and managers implement NPD tools is an important driver of successful innovation. Yet, research indicates slow uptake of tools by firms around the world and more often than not, poor utilisation of tools (Chai & Xin 2006; Nijssen & Frambach 2000; Yeh, Yang & Pai 2008). This apparent contradiction makes it imperative to understand how thoroughness of use varies by category or function of tool and to understand fully the reasons behind non-thorough or superficial use of tools.

Authors variously use the terms extent of use of a tool (Kemerer 1989), the depth and rigour to which a tool is applied (Bamford & Greatbanks 2005), and thoroughness of use of a tool (Chai & Xin 2006; Graner & Misler-Behr 2013). In his study of management tools Rigby (2001) distinguishes between users using each tool "in a major effort, not a limited initiative (go deep, not broad)". In this paper, we adopt the term thoroughness of use. Nijssen and Lieshout (1995) reported that little was known in this area. Since that time, a handful of studies among large firms have sought to establish the levels of thoroughness of different tools in use (Chai & Xin 2006; de Grosbois, Kumar & Kumar 2012; Nijssen & Lieshout 1995; Peng, Heim & Mallick 2012; Swink, Talluri & Pandejpong 2006). These studies, however, only considered small selections of tools from engineering, marketing and information management perspectives. This leaves unaddressed the question of how thoroughness might vary across the multiple disciplines inherent in effective NPD, for example across product strategy, finance, creativity, risk management, manufacturing, and decision-making perspectives.

Yeh et al. (2008) proposed that because many useful tools and techniques are not utilized effectively, it could negatively impact on both overall product innovation performance and on individual performance. But what exactly is considered inappropriate and ineffective use of tools? Do these concepts relate to using tools superficially, or could it be possible to use tools in a less thorough manner yet be effective at the same time? Our review of past literature reveals some, but limited reasons why practitioners don’t use tools to their fullest potential. Seen from the broadest possible perspective, Thomke (2006) warns that tools, no matter how advanced, do not automatically confer benefits such as leading to huge leaps in performance, reducing costs and somehow fostering innovation. He continues saying that “people, processes and tools are jointly responsible for innovation and development. In fact, when incorrectly integrated into an organisation, new tools can actually inhibit performance, increase costs and cause innovation to founder”. Thomke's conviction is that tools are only as effective as the people and organisations using them.

Rigby (2001) found that users blamed ‘the speed of the new economy’ in making them believe they did not have time for implementing [management] tools thoroughly. Other reasons could be due to skill limitations on the part of users, limiting their ability to obtain the greatest potential benefit from tools, especially when they have limited time available for training (Kemerer 1989). Kemerer also argued that most tools are likely to have features that the average user does not use (the so-called 80/20 rule may apply). Other factors potentially contributing to superficial use of tools include R&D engineers lacking proficiency in the use of tools, or not knowing which tools are appropriate at each stage of the process (Yeh, Yang & Pai 2008); unsupportive organisational cultures (Feldman & Page 1984); not developing the right conditions and capabilities for tools to work (Brady et al. 1997); as a source of inspiration without utilising them fully (Knott 2008); and limited faith of managers in the usefulness of these tools (Verhage, Waalewijn & van Weele 1981).

Scholars have analysed the way practitioners use tools from a theoretical perspective as well as empirically. A key conceptual issue is that when carrying out activities, practitioners draw from the pool of practices and apply them to specific, concrete situations (Seidl 2007). In doing so, they inevitably adapt the practices they draw on, both because of the context-specific interpretation of the abstract practice (Orlikowski 2000) - 'practice-in-use' - and because they may intentionally use practices in ways different from their original intended purpose (Jarzabkowski 2004; Jarzabkowski & Kaplan 2015). Hence, 'practice-in-use' is often associated with artful performance, synthesis, improvisation, and adaptation. Lozeau, et al. (2002) found that, in the broader context of management tools, the reconstruction of tools by users, or 'corruption of tools' as they refer to it, is commonplace. Other authors view this practice more positively. Jarzabkowski and Wilson (2006) actually recommended users to draw on their experience and inventiveness to adapt existing tools and implement locally tailored solutions. Ulrich and Eppinger (2012) similarly argued that despite their structured nature, tools are not intended to be applied blindly and recommended teams to adapt and modify tools to meet their own needs and to reflect their institutional environments. Seen in these contexts, could one argue that pragmatic users make similar judgement calls when deciding on the degree of thoroughness to which tools are used in practice? In doing so, are they extending the principle of bricolage (Levi-Strauss 1966) - the art of making use of whatever is at hand - to doing so in the most economical (efficient/superficial) way?

To date no studies have fully investigated the reasons for superficial or less thorough use either for NPD tools or for management tools in general. This leaves us with a very limited understanding of how and why levels of thoroughness vary, and a need to probe what drives this variability for NPD tools.

**Exploratory study**

To address our first research question, we carried out an exploratory quantitative study to quantify across a sample of firms the magnitude of any differences in the levels of thoroughness to which practitioners use tools. We also wanted to establish how much the level of reported thoroughness might differ according to the aspect of NPD addressed by a given tool. We did this by means of an invitation-only online questionnaire to a sampling frame of 566 high-technology firms that we compiled from a database of New Zealand firms that met the criteria of employing less than 100 full-time staff. Our contact strategy had three phases that started with mailed letters of invitation, each with a unique survey access password, to the Chief Executive Officers of all 566 NPD firms in the database, requesting them to have the survey completed by the most appropriate person in the organization. We followed this up with two email reminders within a couple of days of each other to those firms that had not yet responded, to complete the online survey. This resulted in a response rate of 21.4%, but we ended with a final sample of 99 firms after cleaning the dataset and eliminating the outliers.

Using the four-stage, multi-perspective NPD process framework of de Waal & Knott (2010), we compiled a list of 76 established tools from the literature in a way to represent the 12 perspectives of the framework (Table 1). We believe that although the selected tools differ widely in level of abstraction and discipline base, they comply with the tool definition that we adopted and collectively represent a broad scope of innovation activity areas or perspectives as summarised in Table 1. This breadth was important to us as it extends beyond the usual focus on technical (Cooper, Edgett & Kleinschmidt 2004c) or ‘state-of-the-product’ (Ulrich & Eppinger 2012) and marketing related tools. We did not set out to include all existing innovation tools, but to cover a full set of categories of tool function in the context of small-firm innovation. Only project team members, such as NPD Project Manager, Team Leader, or CEO/Director were eligible to partake in the survey. Participants were asked to rate the thoroughness to which they used tools using a perceptual measure based on a 5-point Likert-type scale where 1 = not thorough and 5 = very thorough for each individual tool (the independent variables) (Chai & Xin 2006). For instances where a tool was not used, the option ‘Not Applicable’ was provided. We sought to minimize potential bias by requesting ratings for a specific project launched within the previous three years. Prior to administering the survey, we followed the four sequential stages of the pre-testing process (Dillman 2000) which included a pilot survey. Steps that ensured content validity of the questionnaire included verification and contribution by experts, and the provision of clickable pop-up operational definitions (Page & Meyer 2000) of key concepts, conveniently placed on the web pages.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NPD Process Stage | 1 | 2 | 3 | 4 | NPD Process Stage | 1 | 2 | 3 | 4 |
| Design for Six Sigma | P1 |  |  | x |  | Porters Five Forces  | P6 |  | x |  |  |
| Design for X (DfX) |  |  | x |  | PESTE Analysis  |  | x |  |  |
| Gamma Prototype |  |  |  | x | Portfolio Analysis  |  | x |  |  |
| Value Analysis/Value Engineering  |  |  | x |  | Scenario Planning  |  | x |  |  |
| Quality Function Deployment  |  |  | x |  | Intellectual Property Protection  |  | x | x | x |
| Design of Experiments |  |  | x |  | Competitor Analysis  | x |  |  |  |
| Computer Aided Engineering  |  |  | x |  | Financial Analysis  | P7 |  | x |  |  |
| Rapid Prototyping  |  | x |  |  | Cashflow Forecast  |  | x |  |  |
| Beta Prototype  |  |  | x |  | Sales Forecast  |  | x |  |  |
| Collaborative Product Development  | x | x | x | x | Synectics  | P8 | x |  |  |  |
| Alpha Prototype  |  | x |  |  | TRIZ  | x |  |  |  |
| Computer Aided Design |  | x | x |  | Delphi Method  | x |  |  |  |
| Design Mock-up  |  | x |  |  | Morphological Analysis  |  | x |  |  |
| Diffusion Models  | P2 | x | x |  |  | Roadmapping  | x |  |  |  |
| Discrete Choice  |  | x |  |  | Product Life Cycle  | x |  |  |  |
| Conjoint Analysis  |  | x |  |  | Focus Group  | x | x |  |  |
| Ethnography  |  | x |  |  | Brainstorming  | x | x |  |  |
| Lead User  |  | x | x |  | Configuration Management System  | P9 |  |  | x | x |
| Voice-of-the-Customer  | x | x | x | x | Engineering Document Mngnt System  |  |  | x | x |
| Beta-testing  |  |  | x |  | Project Intranet  |  |  | x | x |
| Limited Roll-out (Test Marketing)  |  |  | x | x | Knowledge Management  | x | x | x | x |
| In-market Testing  |  |  |  | x | Change Control System  |  |  | x | x |
| Needs Analysis  | x | x |  |  | Tele/Video-conferencing  | P10 | x | x |  |  |
| Concept Testing  | x |  |  |  | Teambuilding  |  | x |  |  |
| Total Quality Management | P3 |  |  |  | x | Cross-functional Teams  |  | x | x |  |
| Concept Statement  | x |  |  |  | Workflow  |  |  | x | x |
| Feasibility Study  |  | x |  |  | Design Review Meetings  |  | x | x | x |
| Business Case  |  | x |  |  | Malcolm Baldrige Awards Framework  | P11 |  |  | x | x |
| Marketing Plan  |  |  |  | x | Expert Systems  | x |  |  |  |
| Project Management  |  |  | x | x | Post-Launch Review  |  |  |  | x |
| Computer Integrated Manufacturing  | P4 |  |  |  | x | Post-Project Review  |  |  |  | x |
| Statistical Process Control  |  |  |  | x | Benchmarking  | x | x |  |  |
| Computer Aided Manufacturing  |  |  |  | x | Customer Satisfaction Tracking  |  |  |  | x |
| Process Flow Diagram  |  |  |  | x | Real Options Theory  | P12 |  | x |  |  |
| Fault Tree Analysis  | P5 | x |  |  |  | Selection Criteria & Screening  | x | x | x |  |
| Market/Computer Prediction Models  |  | x |  |  | Decision Screens  |  | x |  |  |
| Risk Assessment Matrix  |  | x |  |  | Stage-gates  | x | x | x | x |
| Failure Mode Effects Analysis  |  |  | x |  | Checklists  |  | x | x |  |
| **NPD PROCESS STAGES**1: Concept Generation 2: Concept Development & Validation 3: Product Development & Testing 4: Commercialization & Review |
| **PERSPECTIVES**P1: Engineering & Design P2: Market & Market Research P3: General Management P4: ManufacturingP5: Risk Management P6: Product Strategy P7: Project Finance P8: Creativity and Problem Solving P9: Information Management P10: Team Support P11: Learning & Review P12: Decision Support |

Table . Tool Selection Rationale

We summarize the data from our exploratory survey data in Figure 1. This shows wide variability in reported thoroughness of use across most of the twelve categories of tool in our study. There do not appear to be any systematic differences in thoroughness by perspective. Although the degree of variability in the data varies between the categories, this is in part due to different numbers of tools surveyed in each category. Despite this, it is apparent that variable and often low levels of reported thoroughness apply similarly across most or all classes of innovation tool. In terms of individual tools, we found that average reported levels of thoroughness varied from as little as 1.33 on the 1-5 scale for ‘Malcolm Baldrige Awards Framework (MBAF)’ to 4.19 for ‘beta prototype’. Very few tools resulted in reported thoroughness levels of 4 or above, even though our survey included tools such as ‘Prototyping’, ‘NPV/IRR’, ‘CAD/CAM’ and ‘Project Management’ that are sufficiently highly regarded that previous studies (Tidd & Bodley 2002; Yeh, Yang & Pai 2008) found them used by over 75% of firms. In terms of other contextual factors, we found that none of the following – firm maturity (age), firm size, team size, innovation type or process formality – show significant correlation in our data with thoroughness of use.



**Note: For each tool category the bottom and top tool are shown to the left and right of the horizontal bars, respectively**

Figure 1. Mean thoroughness ranges of tools within tool categories

The implication of these results is that practitioners believe they seldom use NPD tools to their full potential, and often use them quite superficially. Although the thoroughness figures are self-attributed, they come from individuals who have a strong influence over tool adoption and use. For this reason, the apparent prevalence of lack of thoroughness in tool usage, and the wide variability in thoroughness, are worth investigating further. We do this through qualitative research addressing our second research question: what drives the variability we see in thoroughness of tool use?

**Main study: qualitative cases**

***Qualitative methodology***

In our main study, we adopted qualitative case study methodology using multiple cases. We studied five small high-technology firms in New Zealand that did not form part of the exploratory study, and within each of these collected data relating to thoroughness of tool usage in a specific NPD project. This number of firms falls within the range of 4-10 cases recommended by Eisenhardt (1989) to allow for effective cross-case analysis without reaching diminishing returns. In selecting the participating firms, we employed purposive sampling (also as advocated by Eisenhardt (1989)) to explore causal phenomena as they relate to firm, project, and team characteristics. This approach is appropriate given the lack of strong supporting theory that applies directly to our research question (Rahim & Baksh 2003).

Within our overarching scope of small high-tech firms, we selected case study firms with contrasting team characteristics, firm sizes, and ownership contexts as set out in Table 2. Numbers of staff employed by the firms were 10-50 for firms B, C and D, while firm A employed slightly fewer. While the latter may strictly be a micro firm in some taxonomies, we also included in our study firm E, which allows for comparison with a larger firm context while still remaining much smaller than many firms included in NPD studies.

Team and ownership characteristics varied across our selected firms as set out in Table 2. Firms A and D had been purposely formed to take a product idea to market. Firm C was tasked to develop and launch a new product, but since it was a subsidiary of a long-established parent company, it was strongly influenced by existing, established management practices. While firm B had been in business for a number of years when they undertook the product development we studied, it was their first complete NPD project, and hence the company was inexperienced in product development. The larger firm E is an established firm with many years of product development experience and provides for comparison with the others.

***Data collection***

Our main source of data was semi-structured interviews conducted with members of the product development teams, which we recorded and transcribed for subsequent analysis. We interviewed 17 practitioners across the five firms about their experiences in specific development projects during the roughly one to three-year duration of the projects. Because of this, we were able to observe how practitioners went about using tools to meet their project needs and contextualise the factors that influenced their behaviour. We probed participants to recall and reflect on circumstances and sequences of events regarding their use of innovation tools during the period of the chosen project. Specific questions we asked concerning thoroughness of use included:

* The online tool survey [completed by the project manager, not as part of the exploratory study] indicates that the project team used certain tools more thoroughly than others. From your point of view, what amount or depth of use does this refer to?(How do you interpret “thoroughness”?).
* Why have you used some tools less thoroughly than others?
* Did you get *good or bad*results for the tools you used *thoroughly*? Please elaborate.
* Did you get *good or bad*results for the tools you used *superficially*? Please elaborate.

At the end of each interview, we progressed to reflective discussion of continued developments after the conclusion of the project under review and during the initiation of subsequent projects. Where necessary, we carried out repeat interviews to gather additional data to verify key observations.

As Table 2 sets out, in the four firms A-D, we interviewed three prominent team members who we selected to cover the breadth of discipline perspectives represented in the project. Three interviews were sufficient for these firms because of the small team size and the fact that each individual had multiple responsibilities during project execution. In firm E, we conducted five interviews because the core development team was significantly larger than for the first four companies. The interview data gave us an overview of the participants’ experiences and behaviour with regard to the level of thoroughness of tool use in their product development activity.

For triangulation purposes, we complemented the interviews with other sources of data as illustrated in Figure 2. In each firm, we first asked the project manager to complete both the online tool survey and a structured questionnaire collecting basic factual information about the company, product, and project. After each interview, we administered a questionnaire customised to include all tools used in the project. In this questionnaire, we asked participants to give a thoroughness rating for each of the tools they had personally used, and collected relevant demographic data.



Figure 2. Main study data collection process

***Analysis method***

Our analysis combined inductive and deductive reasoning iteratively, as described by Dewey (1910) as the ‘double movement of reflective thought’, and by Ragin (1994) as a process of ‘retroduction’. Hence, our analysis followed two main phases. After transcribing the interview recordings, we first drew on the transcripts to generate inductively the themes, rationales and influences participants expressed related to thoroughness of use of tools. The second phase followed a deductive form, relating the inductively generated themes to individual and team behaviours, the business context, and outcomes. The first phase was largely a within-case exercise, while the latter extended the analysis to cross-case comparison, challenge and reconciliation.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Firm A*** | ***Firm B*** | ***Firm C*** | ***Firm D*** | ***Firm E*** |
| **Respondents** |
| A1: Project Manager/SupervisorA2: Marketing ManagerA3: Engineering Manager | B1: Engineering Administrator/Project ManagerB2: Manufacturing ManagerB3: Managing Director | C1: Project ManagerC2: Marketing ManagerC3: Software Team Leader | D1: Project ManagerD2: Operations ManagerD3: Chief Executive Officer / Market Research | E1: Project ManagerE2: Hardware Project ManagerE3: Mechanical Design EngineerE4: Software Project LeaderE5: Product Manager |
| **Team** |
| University friends /graduates; inexperienced team members | One 100% dedicated member; novice engineering graduate; rest of team experienced in manufacturing; first product innovation project | Team very experienced in product innovation; all part of new spinoff firm; great collaboration with suppliers and mother company | Start-up; members have different levels of product innovation experience; involved long research phase; poor communication among members | Members very experienced in product innovation; access to great firm resources and functional support; Well-functioning team |
| **Core development team / Total involved within firm** |
| 4 / 6 | 4 / 6 | 12 / 12 | 4 / 12 | 35 / 90 |
| **Project** |
| Electronic computersecurity device | Print media wrappingmachine | Medical appliance | Gas fire heater | Portable 2-wayCommunications radio |
| **Development time (months)** |
| 24 | 12 | 16 | 20 | 24 |
| **Development cost** |
| > $100k | $60-70k | > $100k | > $100k | $14 million |
| **Firm** |
| Independent small firm; initially single product and batch manufacturing | Recent high tech venture by manufacturing firm | Spin-off from existing high-tech business | Independent small high tech firm | Established high-tech business |
| FTE Staff: 6-9 | FTE Staff: 10-19 | FTE Staff: 20-29 | FTE Staff: 40-49 | FTE Staff: 600+ |
| 1-5 years in business | 6-10 years in business | 10 to 15 years in business | 6-10 years in business | More than 40 years in business |
| **Export % of total sales** |
| > 50% | 11-30% | > 50% | 1-10% | > 50% |

Table2. Case characteristics

We combined the two techniques of pattern matching and cross-case synthesis for analysing the data. Yin (2003) defined pattern matching as “a comparison of empirically based patterns with patterns predicted prior to data collection” and cross-case synthesis as “an aggregation of findings across a series of individual studies, for example, creating word tables that display the data from the individual cases according to some uniform framework.” Thus our analysis was informed by the prior findings about tool use set out in our literature review, which we matched with observed patterns emerging from cross-case analyses that we summarised in word tables, as well as from newly emerging patterns. In the results section that follows, we have tried to convey the original context of the data by using quotations from interviews to ‘tell the stories’ and illustrate our points.

***Results and analysis***

*Analysis of reported thoroughness levels*

As a first step in the analysis, we drew on the online tool survey completed by the project managers (separately from the exploratory study) to dissect the proportions of different levels of reported thoroughness of tool use for each of the five companies, as shown in Figure 3. This highlights that managers reported using only a minority of tools at the highest-rated levels of thoroughness (15- 30% for the most thorough and 35-65% including both 4 and 5 ratings). This is consistent with our findings in the exploratory study, and hence shows that the tendency to use tools less than fully applies to our case companies as well as to those in our survey. At the same time, managers reported using few tools at a very superficial level (between 0% and 12% of tools rated at thoroughness level 1).



Figure 3: Reported thoroughness of tool use in each firm

Circumstances in the five companies differ in important ways, as do the number of tools each reports adopting. For this reason, and the use of self-ratings, we can draw limited inferences from Figure 3 about differences between individual companies. Nevertheless, it is noticeable that firm C reports using more tools very thoroughly than the other firms, and fewer superficially. The most likely explanation for this is that as a medical device company, this business felt strong external compliance pressure, which most likely drove them to take implementation of tools and methods more seriously (and to portray this stance in the questionnaire responses). Other differences in the figures, for example the relatively high reported thoroughness figures in start-up firm A, are best interpreted in conjunction with our qualitative case data, which we analyse in the sections that follow.

*Within-case analysis: thoroughness drivers by firm*

To investigate the drivers of this variability in thoroughness of tool use, we extracted from the transcripts all references we could find that related to thorough or less thorough use of innovation tools. Table 3 summarises the key points for each of the five companies. In the table, what we describe as ‘thorough use of tools’ is a relative term that does not necessarily imply reported thoroughness levels close to 100%, as our quantitative data demonstrates.

The larger, well-established firm E forms a good starting point for comparison. Despite strongly institutionalised processes and a professional ethic, time constraints still resulted in failure to fully implement some tools, notable post-project review. As the project manager (E1) indicated, “I just simply didn’t have the bandwidth to do it. I promised the team members that I would collate the data, but I failed to do it”. Pressure to move on to the next project drove pragmatic short-term thinking, overriding knowledge as to longer term benefits. We also noted that strongly institutionalised thinking could generate cynicism about newly adopted tools and approaches.

|  |  |  |
| --- | --- | --- |
| **Firm** | **Thorough** | **Less thorough** |
| A | If the person who introduced the tool had lots of ‘clout’;Because the project manager insisted on it; External pressure to comply with certain tool use procedures; If there would be possible repercussions if not used thoroughly. | Heavy workload – insufficient time; Haphazard fashion in which tools were introduced – not everybody bought into a tool equally; Some people were more resistant to change than others (ingrained ad-hoc culture);Lack of team maturity and discipline (new graduates). |
| B | Some tools are integrated into strong quality culture; Staff adhere to company’s 5 principles in everything they do. | Only used tool until problem is solved; The nature of the task or problem at hand did not justify more thorough use; Small team size – members must multi-task, rely on a very few people to get the job done; PM must wear many different hats; Immense time pressures and constraints – looming deadlines; Some tools not perceived to provide billable output (despite adding value in a different sense). |
| C | Industry regulatory and compliance factors. | Severe time pressures; Individuals fulfill multiple roles; It is because we don’t have experts in all areas. |
| D | Certain tools like EDMS etc. – we need to rigidly stick to the form that we’ve decided, so they are pretty much policed and enforced with regards to how they are implemented; Some tools are perceived to be able to provide more benefits than others; Specific training provided for some thoroughly-used tools. | Some tools are perceived not to be of much value; Users not at a level of development where they can use tools effectively; Current levels of use are already reaping considerable rewards; Poor exposure of people to development tools; Some tools are also more relevant than others; Inability of small firms to provide good opportunities for staff development in tool use. |
| E | Pressure and expectation from the core team; strong organizational culture that demands quality workmanship; Some tools are extensively used because we know they work and they are part of our stage-gate process; Some tools such as CAD are so inseparably integrated with activities and crucial to success; in-depth training provided for some tools; Tool user groups encourage best-practice tool use; From a theoretical point of view it’s always best to get the most out of a tool. | Negative attitudes among individual team members liken some tools to fads - for many years we were quite successful without doing any of that, so why do we do this?; Some tools are perceived to have little value; time constraints; Extracting from a tool just the right level of information which is required by a particular situation; It is being pragmatic in using tools to a level that they provide sufficient value; some situations justify shortcuts being taken on tools; trade-off situations with other priorities. |

Table 3: Reasons given in interviews for using tools thoroughly or less thoroughly

Firm C operated as a separate business within a mother company, but employed an experienced team. Perhaps as a result of its creation as a new entity, we did not see cynicism about new methods. The most prominent driver to use tools thoroughly was regulation within the medical sector, rather than the firm-level influence we saw in firm E. This regulation in turn drove a strong internal compliance culture, but this was tempered by the very small team size. This obligated team members to take on multiple roles including some outside their main area of expertise, and hence the use of some tools they were familiar with only in part. This, combined with time pressures, forced a pragmatic approach: “we don’t have experts in customer satisfaction tracking or anything like that … although we’re not experts in these tools we know intuitively how to use them, to a certain degree” (participant C2).

Similar requirements to multi-task and operate beyond individuals’ core expertise existed in firm B where the product development team operated as a small unit within the same building as the main manufacturing and engineering services business. As a result, the strong manufacturing process and quality control culture within the main business influenced the development team, while also detracting from its autonomy over resources, as key individuals retained responsibilities within the main business. There was no established product development process as such. Practical coping became the dominant mode of operation: “because we don’t do that much product development, we don’t have much set in the way of how we develop the product. We just go for it in the Kiwi way” (participant B1). ‘The Kiwi way’ in this context refers to a form of bricolage, reflecting lack of resources and support.

As an independent venture, firm A was not subject to any institutional orientation towards using innovation tools. Conversely, team members enjoyed the informality. An ad-hoc culture seemed ingrained, as too did followership of the founder (the current project manager). This individual was familiar with a specific range of tools focused mainly on engineering and design, and as a result the firm was “a lot more dynamic in the choice of tools” in areas such as market research, process, and planning (participant A3). The other independent firm in our study, firm D, had tried to compensate for similar ad-hoc tendencies by including a team member with large-firm experience. This was not fully effective, as “the people didn’t have any avenue to get exposed to all the [tools]” and “if you haven’t been exposed to those tools then …. the more you know the more you realise [how] little you do know” (participant D2).

*Cross-case analysis: individual, team and contextual drivers*

To probe further the drivers of these different attitudes and behaviours towards thoroughness of tool use, we next classified the different drivers implied by the statements we extracted from interviews. Figure 4 gives a summary of the emergent themes (which are the headings in bold text), with a selection of representative quotations for each theme. In this summary, we have structured the themes and drivers into those we interpret as related to external pressures (or arguably logical response to circumstances) and those we interpret as related to individual and team disposition.



*Figure 4. Analysis of drivers of tool use in small firms*

In terms of external and organizational drivers, Figure 4 shows a number of instances of stipulations from the project manager, the firm, or an external body to follow defined processes that include full use of certain tools. These entities could exert powerful pressure, and sometimes provided training in the use of specific tools. Such judgements could be driven in part by situations where significant capital outlays are required to adopt a tool or where industry-compliance factors exist. Some tools had become integrated into standard processes, such as an engineering document management system (EDMS) into a firm’s stage-gate process, and hence had become inseparably integrated with the development activity. For example, in firm E, the NPD process dictated the use of tools such as ‘business case’, ‘ROI analysis’, ‘design reviews and approvals’, and ‘voice-of-the-customer’ at defined stages.

We also saw drivers relating to short-term pressures, limited resources, and responses that focused sharply on the most pertinent and immediate needs. These pressures push practitioners to use tools less thoroughly. Product development teams felt pressured to complete a multitude of activities within ever-looming deadlines. Because of this, they made trade-offs such as attempting to save development time by eliminating aspects of a process or tool to which they ascribed lower importance. In these circumstances, they might use a tool only as completely as needed to solve the immediate problem, and not be able to justify fuller use - “we focus on solving immediate problems, nothing more, nothing less” (participant C1); “we hurriedly draw on aspects of tools” (participant A1). Such judgements could be driven in part by the desire to act as effectively and efficiently as possible in situations characterised by limited resources.

Notwithstanding strong external pressures, individuals and teams were not necessarily content with, or wholly influenced by, external drivers to use tools thoroughly or otherwise: “But don’t get me wrong, often I wish we could do it more thoroughly because I think we should be resourcing ourselves better so that we can do some of these things more thoroughly. So it’s not as if I am satisfied with the degree to which we use all these tools” (participant B2). Some individuals felt it was the right thing to do to always get the most out of a tool: “And I realized that sometimes, ..., if you actually used the tool more thoroughly we would get more value” (participant E1). Others chose to belong to tool user groups set up to encourage good practice. At times, a strong culture drove thorough implementation of certain tools. For example, in firm E: “some tools are extensively used because we know they work and they are part of our stage-gate process”, “but only a few critical tools are mandatory, for example the ‘issue management system’, ‘stage gates’ and ‘project management’”. In cases such as this, the prevailing culture among NPD practitioners supports using tools to the best of their ability, without requiring external drivers.

In other cases, we saw how the disposition of individuals and team led to less thorough or even ad-hoc use of NPD tools. Some individuals felt a disregard for some tools, perceiving them as not useful, or as fads – “for many years we were quite successful without doing any of that, so why do we do this now?” (participant E1). In the absence of team pressure and when left to their own discretion, other individuals approached tool adoption and use in a casual way – “we don’t really apply tools in a rigid way; we throw away the tool book” (participant B1); “[some tools are] often not used to their full potential as nobody demands it” (participant A1) or “poorly implemented” (participant D3). This tendency applied particularly to tools perceived to be non-intuitive to use and requiring too much training, like the issue management system in use by firm E: “you have to choose the shortcuts that are the least pain” (participant E2). Indeed, we find 14 references to ‘intuitive’ tool use in our transcripts, for example: “[the way we apply tools] is far more intuitive, absolutely” (participant C1); “although we’re not experts in these tools we know how to intuitively use them, to a certain degree” (participant C2); “I manage to pull things together in my head and intuitively know what is the right way to move forward” (participant D3).

*Synthesis: modes of tool use*

In the cross-case analysis above, it is apparent that the two types of driver of NPD tool use interact to produce different outcomes with respect to how a project team uses tools. By examining the two types, the outcomes in each of our case study companies, and drawing on extant literature, we propose that the range of possibilities can be succinctly represented by the four ‘modes of tool use’ set out in Figure 5. In this, the Organizational Context axis describes the two main types of context in which the teams operated. The context exerted different levels of two opposing pressures: one to adopt systematic processes, and the other to deliver to immediate targets and deadlines. These pressures arose from management processes within the firm, which in turn reflected sector and customer needs. The Team Disposition axis sets out the two main types of team culture we saw. ‘Tool culture’ inclines towards thorough tool use, and ‘Ad-hoc culture’ inclines towards ingenuity and individualism.



*Figure 5: Modes of tool use in an NPD team*

In *emerging mode*, the team has an entrepreneurial character. Time and resources are tight, and team members multi-task and often operate outside their core expertise (Marion, Friar & Simpson 2012). Pragmatism, bricolage (Levi-Strauss 1966) and satisficing prevail. Firm A fits this quadrant most closely. The preference for ad-hoc methods we noted in this team reflects founder influences, as set out by Millward and Lewis (2005).

In *growing mode*, the firm has developed beyond emerging mode and begun to adopt formalized NPD processes, as noted by (de Waal & Knott 2012). As yet, formalized processes are not embedded in the NPD team culture, which instead retains a preference for ad-hoc methods (Feldman & Page 1984). Firm D most closely fits this quadrant, noting especially the tensions between the individual with large-firm experience and the remainder of the team.

In *exploiting mode,* the NPD process has reached a mature state and is well-ordered, stable, efficient and effective within the firm’s established operating technological and market paradigm. This mode relates to firms organized to ‘exploit’ existing innovations and product platforms (March 1991). In our data, firm C most closely fits this quadrant, as despite being a new venture, it was a spin-off from a large established firm with a sophisticated NPD process, hence its team embodied a prior culture of quality and efficiency-oriented methods (Beckman 2006). Additionally, medical sector regulation drove the nascent firm to adopt stringent processes from foundation.

In *exploring mode*, due to a changing competitive environment, the firm’s existing income streams are being compromised. Teams are experienced and systems in place, but new pressures of time and scope force short-cutting. This mode refers to firms organized to ‘explore’ new innovations (March 1991), and hence the associated challenges associated with adaptability, experimentation, and risk taking. Firm B most closely fits this quadrant, as the team found itself newly forced into an inventive, practical coping mode.

Based on this logic, we can see a tendency towards clockwise movement around Figure 5 towards *exploring mode*. We would expect firms that fail to make timely transitions such as this to perform less well. Firm E illustrates movement from an entrenched *exploiting mode.* Pressure on its existing product paradigm led to a push towards more radical innovation and experimentation, and hence the characteristics of *exploring mode*. Progression from *exploring mode* to *emerging mode* will occur less often, as we can expect individuals moving to spinoff ventures or leaving to found new independent ventures to adopt behaviors from their prior experience (Beckman 2006).

**Discussion and contribution**

As this paper is the first to attempt full analysis of what drives variability in thoroughness of NPD tool use, we position our contribution in several different literatures and associated theoretical domains.

*Innovation tool uptake for NPD performance*

Existing literature in this area focuses on surveying patterns of tool adoption, finding popular tools, and assessing the merits of particular tools for improving NPD performance (Cooper & Edgett 2008; Maylor 2001; 1995; Nijssen & Lieshout 1995; Yeh, Yang & Pai 2008). This work is significantly undermined if the tools are being used to a variable and often very partial extent. Our exploratory study quantifies the degree to which this is indeed the case. As we report (Figure 3), our survey findings indicate that, based on the perceptions of users, tools are almost never used to their full potential, seldom used at higher rated thoroughness, and often knowingly used at superficial levels. We also find (Figure 1) that these characteristics hold for tools across all functional areas of NPD. Hence, we can only fully understand the relationship between NPD tool adoption and performance if we take into account the level of thoroughness of tool adoption.

Our case study findings provide a starting point for more nuanced study of the relationship between NPD tool adoption and performance by articulating the contextual drivers behind variable thoroughness of adoption. Practitioners in the small firms in our study often lacked the requisite knowledge to make optimal use of tools and lacked the time and resources to rectify this. This was caused by a combination of having to play multiple roles (Marion, Friar & Simpson 2012) and feeling forced to respond to time and cost pressure ahead of other factors (Millward & Lewis 2005). Investing more time in using tools involved immediate trade-offs with core activities that had short-term impact. Thus, although using tools more thoroughly has been found to be a productive way to improve innovation performance (Nijssen & Lieshout 1995), for these firms in the short term, using tools partially or less thoroughly was a rational choice. As we set out in our modes of tool use, as these firms develop, their performance likely still depends on adopting more complete and in-depth use of tools.

*NPD tools, process and practice*

Our findings apply existing theory about the motivations and drivers to use tools to the NPD domain, and add some nuances. We found the presence or absence of institutional and external standards-based pressure (Jarzabkowski 2004) influenced not only tool adoption decisions, but also decisions about thoroughness or otherwise of adoption. Notably, this was evident in firm C, which operated in the medical sector, and in firm E as institutional pressure. Target-based pressure as set out in our *emerging* and *exploring* modes tended to act in opposition to standards-based pressure, leading to less thorough use of tools. We also found social conformity (Jarzabkowski 2004) as a notable influence on thoroughness level, for example strong company-level cultural influence to use tools thoroughly, and strong team cultures that tended to encourage or discourage thoroughness. Tool use as a means of communication (Langley 1989) did not feature explicitly in our data, possibly because of the very small size of most of our firms and teams.

Our findings in all teams, but especially those of a more ad-hoc disposition, relate to the phenomenon of bricolage (Levi-Strauss 1966) in adapting tools for use. Many individuals were happy to proceed in an unsupported way, relying on ingenuity. While some of the literature we reviewed partly legitimises this approach (Jarzabkowski & Wilson 2006), what we observed differed from this literature in that the team’s need for ingenuity was not driven by unique circumstances, but instead by lack of knowledge and resources, including time. This in turn has implications for the design and communication of NPD tools, in that practitioners in pressure-driven *emerging* and *exploring* modes especially valued the possibility of picking up simple versions of tools intuitively.

The phenomena we observed in our cases that were part of larger firms relate to the different means by which firms achieve ambidexterity between the conflicting demands of innovation activities aimed at developing new products (exploration) and those that maintain income flows from existing categories of product (exploitation) (March 1991). In the firms that adopted a spatial separation of the two (Gibson & Birkinshaw 2004), the mode of tool use depended on prior team experience allied with level of support from the parent company. In firm B, which adopted a contextual design involving individual employees dividing their time between existing and new businesses, the context added pressure to the team, with consequential impact on mode of tool use.

*Limitations and potential for further work*

Although we have adopted multiple complementary methods in this study and taken care to follow rigorous methodological protocols, limitations inevitably remain. Crucially, because our study focused on small firms, our findings relating to thoroughness of NPD tool use do not necessarily apply equally to larger firms. Differences may exist due to larger team sizes, greater geographical dispersal, more institutionalised processes, easier access to specialists, and less severe resource constraints. Despite these differences, the literature we reviewed leads us to expect that non-thorough tool application will still be prevalent in larger firms. Finally, in this paper we were not able to set out the impact of thoroughness of tool use on NPD performance.

**Practical implications**

By providing insights into the reasons why innovation tools are sometimes used thoroughly and sometimes not, we anticipate that this work will help provide more nuanced advice to practitioners about tool adoption and implementation. The findings do not overturn the notion that using tools to sufficient depth or thoroughness is important if those tools are to improve innovation performance. However, they show how lack of time, skills and processes in small firms can undermine the causal relationship. Based on our findings for different types of small firm, we suggest a contingency approach to addressing these inhibiting effects. For a novice start-up firm, ensuring team diversity that mixes youth and experience should help avoid institutionalising an ad-hoc culture. In start-ups with experience, it is crucial that individuals appointed to support disciplined processes have visible top management support, especially if ad-hoc attitudes are otherwise entrenched. For larger, established firms with strong well-designed processes, our advice would be to resist the temptation to undermine these processes in response to immediate financial or delivery pressures. When these firms establish spin-offs positioned outside of the main business, the business could usefully provide support in respect of tasks and tools that lie beyond the specialist knowledge of venture team members, since these individuals will be required to cover a broader set of tasks than before. This support could take the form of training, or networking events aimed at fostering communities of practice (Brown & Duguid 1991). When firms run spinoff ventures internally, the same issues apply, but in addition the firms will need to manage the ‘explore versus exploit’ paradox (March 1991) in the relationship between the spinoff and the core business. The essence of all this advice is to ensure that the product development practitioners in small high-tech firms have the requisite skills and motivation to obtain full potential from in-depth application of selected tools.

**Conclusions**

Our findings go beyond established research into whether or not firms use particular NPD tools, by considering the thoroughness of tool usage. First, we established in an exploratory study using survey data that non-thorough use of tools is commonplace in small high-tech firms and occurs across all tool discipline areas relevant to NPD. Our finding that small high-tech firms use tools to a variable and often very partial extent undermines work that focuses on surveying patterns of tool adoption, finding popular tools, and assessing the merits of particular tools.

Our case study looking at five carefully-chosen small high-tech firms delved into the reasons for variable levels of thoroughness of tool application. The principal drivers were the external contextual emphasis, which prioritised either rigorous process or high-pressure targets, and the internal team cultural preference, which prioritised either tools or ad-hoc methods. These drivers led to four modes of tool use, each with distinct characteristics: emerging, growing, exploiting and exploring. Our findings articulate how these drivers and responses vary across our case study firms, and hence provide rich explanation for why NPD practitioners use tools at varying levels of thoroughness.

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