**NPD tools, thoroughness and performance in small firms**

ABSTRACT

*This paper draws on survey data to clarify whether small high-technology firms benefit most from adopting greater numbers of new product development (NPD) tools to support NPD projects, or from using tools more thoroughly. This is an important issue given that small firms adopt NPD tools despite facing acute resource limitations and using informal processes. Prior studies of the performance impact of NPD tools have focused on large firms, and very few have assessed the performance impact of using NPD tools to higher levels of thoroughness. The paper covers tools across functional/technical and management/marketing aspects of NPD, and measures performance in process, product and market. We found that increasing the number of tools adopted did not measurably improve performance, in contrast to prior findings in larger firms. Instead, we found that firms obtained meaningfully improved NPD performance from using tools at higher average levels of thoroughness. Higher average thoroughness produced statistically significant performance benefits across seven of our nine performance measures. Our findings imply that small firms should emphasize selective but thorough and well-designed implementation of NPD tools.*

 ***Keywords:*** New Product Development, NPD, Tools, Thoroughness, Performance, Small high-technology firms

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Introduction

Successful innovation management is in part determined by the effective use of methods, techniques and tools for New Product Development (NPD), yet despite their importance this field is "fertile for further research" (Teza, Buchele, de Souza, & Dandolini, 2016). A small 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; Markham & Lee, 2013; Maylor, 2001; McQuater, Scurr, Dale, & Hillman, 1995; Nijssen & Lieshout, 1995; Yeh, Yang, & Pai, 2008). This in turn is essential if firms are to extract value from their technological resources. For this paper, we define NPD tools as “structured aids, managerial or technical in nature, used for structuring or influencing the management and effective execution of the NPD process and associated activities” (de Waal & Knott, 2010), thus including techniques and methods. Tools can enhance performance in new product development (NPD) projects by improving both the product and the efficiency of the process through which it was created (Maylor, 2001). Improvements in product performance are important as this enables products to outperform competitive products in the marketplace, while process improvements typically help firms in matters such as beating others to market, launching on time and not exceeding projected development costs (Montoya-Weiss & Calantone, 1994).

Although there is an existing literature on NPD tools and performance, it predominantly draws from larger high-technology firms typically employing several hundred or thousand full-time equivalent staff. As far as we can determine, no NPD tool research has focused on firms with annual turnover below NZ$5 million or employing 100 or fewer staff. This leaves unknown the extent to which the relationships identified in large firms are valid for small firms (Thia, Chai, Bauly, & Xin, 2005). This leaves open the possibility that in some circumstances, adoption of tools and practices could actually inhibit NPD performance in the small-firm context, especially since evidence exists of occasional negative impact from tool adoption in large firms (Ahmad, Mallick, & Schroeder, 2012; Crawford, 1992; Meyer & Utterback, 1995; Olson, Walker, & Ruekert, 1995). Furthermore, when Small and Medium Sized Enterprises (SMEs) are unable to generate a return on their resource investments on innovation because of some operating deficiency, their existence and development can be threatened (Rosenbusch, Brinckmann, & Bausch, 2011).

In their meta-analysis of innovation in SMEs, Rosenbusch et al. (2011) concluded that a systematic analysis of the innovation–performance relationship in SMEs is non-existent. The lack of studies on NPD tools and performance in small firms represents a significant omission given the importance of small firms for employment, innovation and social and economic growth in both developed and developing countries. Small high technology firms, in particular, make a major contribution to industrial innovation and technological change (Akgün, Lynn, & Byrne, 2004). Conducting our study in New Zealand provided us with a population of firms characterized by small size in terms of both turnover and staff employed. Within this population, we targeted high technology engineering/manufacturing firms that produce sellable physical units.

Our research question for the present study is the extent to which the number of tools a small firm adopts, and the thoroughness of adoption, impacts NPD performance. We address this question using survey data covering tools across functional/technical and management/marketing aspects of NPD, and measuring performance across process, product and market. First, we review the existing literature on NPD processes, tools and performance in small high-technology firms.

NPD in Small High-technology Firms

Despite the fact that SMEs make up more than 97% of all businesses in New Zealand where we conducted this study, research on NPD practices of these companies is scant (Metikurke & Shekar, 2011), not only in New Zealand, but worldwide. Before focusing on NPD tools and performance, we first look at how NPD in small high technology firms differs from NPD in larger firms. There is broad consensus that significant differences exist (Ledwith & O'Dwyer, 2008; Pullen, de Weerd-Nederhof, Groen, Song, & Fisscher, 2009) and that small firms are subject to the "liability of smallness" (Grando & Belvedere, 2006) because of their limited access to financial and other resources. In their literature review of small-firm innovation in the UK, Hoffman et al. (1998) found it often hypothesized that small firms differ from large firms in their relative lack of formally recognized innovation and greater use of external linkages in innovation. Because of this reliance on external resources or knowledge, small firms are more likely to employ collaboration as a mechanism (Sawang & Matthews, 2010). Indeed, Nieto and Santamaria (2010) found that technological collaboration is a critical factor for small firms to improve innovativeness. This reflects small firms’ limited technical resources and absence of specialist functional departments, which in turn force members of small-firm NPD teams to play multiple roles and perform multiple functions (T. Marion, Friar, & Simpson, 2012). Such teams primarily develop market and user assumptions ‘inside the core team’, excluding potential users and customers from the design process. In general, marketing-related activities in NPD are undertaken less frequently and are less well executed than technical activities (Huang, Soutar, & Brown, 2002).

NPD processes in small firms tend to be informal (Hoffman et al., 1998; Roper, 1997). Indeed, in a comparison with larger firms de Waal and Knott (2016) found that small high-technology firms, due to resource limitations and competing priorities, generally operate without formalised NPD processes. They found this correlates with such firms adopting fewer NPD tools overall, and fewer complex tools, but similar numbers to larger firms for simple tools. Similarly, small firms also tend to follow an informal approach to their NPD strategy (Lindman, 2002). This is despite empirical evidence that NPD strategy leads to better small firm performance (Terziovski, 2010). Because small firms often conduct NPD in an ad hoc manner (Millward & Lewis, 2005), their product innovation process tends to suffer through a lack of structure (Fornasiero & Sorlini, 2010; Jones, Hall, & Bilalis, 2001, September). Wang and Costello (2009, p. 88) referred to this as an “innovation management gap” that often exists in small firms: insufficient planning, inadequate resources, inattention to design requirements, and ultimately failure to realize the benefits of innovation. Factors that often cause delays in NPD include poor definition of product requirements, technological uncertainties, and poor management (Owens, 2007). Similarly, small manufacturing firms are prone to avoiding formal documented processes; failing to undertake effective competitor analysis; not measuring NPD 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 NPD: (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.

Some studies point to beneficial aspects of the informality of small-firm NPD. Vera et al. (2014) found that irrespective of the size of firm, NPD teams working in the context of ‘minimal structure’ (goal clarity combined with autonomy) exhibit better shared understanding of new knowledge and improvisation capability; the ‘minimum structure’ conditions are more likely to be prevalent among team members in small firms. Marion et al. (2012) articulated how smaller firms succeed through goal-driven rapid development of technology and "instinctive exploration of market potential rather than quantitative analysis". This 'hyper-agility' arises from small omni-functional teams operating without functional boundaries that are guided less by processes and methods that would be typical for larger firms.

Thus, the literature vividly characterises small-firm NPD as far more informal, emergent and unstructured than is typical for large-firm NPD. Process and strategy studies among larger American firms (M. Adams, 2004) show that the majority (in excess of 80%) have formal NPD processes in place and that 74% of large firms are guided by formalized NPD strategy for 80% of their projects. Similar levels of formality are apparent for large firms in Sweden (Rundquist & Chibba, 2004) and Malaysia (Al Shalabi & Rundquist, 2009). This contrast points to an expectation that small firms’ use of NPD tools will differ from that in large firms and have different performance outcomes. Despite this, very little research has focused specifically on the differences in tool adoption and use between SMEs and larger firms. The only such study looks at learning states and absorptive capacity for tool adoption during new venture development (de Waal & Knott, 2012). There remains a lack of evidence of the performance impact of NPD tool adoption in small firms. Limitations in small high-technology firms might inhibit the performance benefits that otherwise accrue from adopting NPD tools. This makes it difficult, based on existing evidence, to advise such firms about tool adoption. Our aim in this paper is to provide the necessary empirical evidence about performance outcomes.

Tool use terminology

Nijssen and Frambach (2000) referred to the number of tools adopted by a firm as tool diffusion within the firm. As our unit of research is an NPD project, in this research we study the impact of number of tools used in the project on NPD performance. Equally important is the intensity of tool use, which implies both the frequency of use (not considered in this study) as well as the depth of use relative to the tool’s specifications (Graner & Mißler-Behr, 2013). Depth of use has also been referred to as the degree of thoroughness to which practitioners use a given NPD tool within a project (de Waal & Knott, 2010). In this study use the term thoroughness of use to mean the depth and rigour to which the tool is applied, the resources and time devoted to it, and the extent to which the project uses all relevant components of the tool.

Below, we derive our main hypotheses for the study by considering the potential impact of the number of tools used and the thoroughness of use.

***Impact of Number of Tools Used on NPD Performance***

A number of scholars have sought to understand whether using more NPD tools results in better NPD performance. By comparing NPD projects in two similar large firms, Benders and Vermeulen (2002) in their article ‘Too many tools? On problem solving in NPD projects’ highlighted the potential for markedly contrasting outcomes from tool adoption.

Larger scale studies provide evidence that in general, adoption of NPD tools has a positive impact on product success, at least in larger firms (Barczak, Griffin, & Kahn, 2009; Fernandes, Vieira, Medeiros, & Natal Jorge, 2009; González & Palacios, 2002). Looking more specifically at the number of tools adopted to support NPD projects, Graner and Mißler-Behr (2013) investigated what factors would lead to greater adoption. They found that the design of the NPD process (in first place) and the degree of top management support (in second place) had significant influence on the number of tools used (as well as intensity of use). Adoption of a larger number of tools in support of an NPD project ought to lead to higher performance, especially given the proven associations between some individual tools and performance (Jose, Ignacio, & Angel, 2018; Yeh et al., 2008).

Yet to date the extant literature is unable to confirm or disprove a relationship between number of tools used and NPD performance, especially for small firms. As Teza et al. (2016)identified, there is overall a scarcity of research related to the themes of diffusion and adoption of NPD tools. Maylor’s (2001) is the only study we could find that investigated the impact of tool diffusion (number of tools used) on NPD performance. His study looked at 21 mainly engineering and design tools among 46 large manufacturing companies. The results indicated only limited support for the notion that adopting more tools will result in improved performance, for example in the areas of time to market, product cost, and product quality. In the present study, we extend Maylor’s (2001) work to the domain of small high-technology firms and to a broader scope of tools covering management/marketing as well as functional/technical NPD tasks. In order to clarify the impact of adopting tools in small firms, we define the hypothesis:

H1: A higher number of tools adopted within projects is associated with improved NPD performance.

We consider in our literature review, analysis and discussion the nuances around this basic hypothesis, such as the potential for resource limitations to inhibit the relationship in small firms.

***Impact of Thoroughness of Use on NPD Performance***

Scholars studying the use of tools in management and strategy have found that the relationship between tool use and outcomes depends as much on their interpretation and execution as on the merits of the tools themselves (Jarzabkowski, 2004; Jarzabkowski & Kaplan, 2015; Jarzabkowski & Wilson, 2006; Lozeau, Langley, & Denis, 2002; Seidl, 2007; Wright, Paroutis, & Blettner, 2013). Similarly, for NPD-related activities, evidence suggests that mere devotion of resources is not sufficient and that proper management and utilization of those resources is needed for firms to innovate successfully (Brady et al., 1997). Hence, with respect to NPD tools, two questions arise: How thoroughly do practitioners apply tools (de Waal & Knott, 2010), and what is the impact of thoroughness of use on NPD performance (de Waal & Knott, 2013). As we indicate below, both questions remain largely unanswered. The research of Chai and Xin (2006) was the only attempt at answering the first question, albeit only for eight tools in their survey. They indeed found thoroughness ratings varied between 3 and 4 on a 5-point Likert-type scale (5 representing a very high degree of thoroughness).We found only two studies that in any way address the second question, both focusing on IT tools and providing limited insights. Marion et al. (2016) limited their research to collaborative IT tools and found that the best-performing projects used all of these tools more intensively than poorer-performing projects in terms of both frequency and thoroughness of use. Mauerhoefer et al. (2017) chose to use the term 'effectiveness of tool usage' with the emphasis on 'frequency of use' (one of the two components of intensity of tool usage) and found it (for IT tools) is positively associated with NPD performance. From a very limited empirical base we conclude that, irrespective of firm size, little is known about the variability that exists in the thoroughness of tool application and also how this impacts NPD performance.

Given what the literature tells us about NPD in small firms, they are likely to be especially prone to using tools superficially (the opposite of thoroughly), for instance if they lack the relevant expertise, time, and buy-in to use formal methods. In order to test the relationship between thoroughness of tool use and NPD performance in small firms, we define the hypothesis:

H2: Higher levels of thoroughness in tool usage are associated with improved NPD performance.

Research Design and Methodology

***Survey Design and Measures***

We obtained our data from an invitation-only online questionnaire that we administered among high-technology firms, which asked respondents to provide data on a specific NPD project completed within the previous three years. We developed this questionnaire from the relevant literatures on product development, marketing and technology management. As noted in our review, small high-technology firms often focus on state-of-the-product aspects of NPD at the expense of market-related issues and sound processes. Similarly, while research in this field has done much to stress the value of tool application and use (M. Adams, 2004; Araujo, Benedetto-Neto, Campello, Segre, & Wright, 1996; Chai & Xin, 2006; Mahajan & Wind, 1992; Maylor, 2001; Nijssen & Frambach, 1998, 2000; Nijssen & Lieshout, 1995; Thia et al., 2005; Tidd & Bodley, 2002; Yeh et al., 2008), most of the tools studied belong to the domains of design and engineering. For this paper, therefore, we selected a set of twenty widely used tools covering both functional/technical and management/marketing tasks (Table 1) that we felt should be applicable to small high-tech firms. Although this list is far from comprehensive, it is sufficient given the objectives of this paper.

**Table 1. NPD Tools used in this study**

|  |  |  |
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| **T#** | **Tool name** | **Summary definition** |
| 1 | Brainstorming | It involves the rapid pooling of all and any ideas that a group of people can come up with before any discussion or judgement takes place. Every idea is recorded no matter how bizarre or irrational [6] |
| 2 | Business Case | The results of the market, technical and financial analyses, or up-front homework. Ideally defined just prior to the "go to development" decision (gate), the case defines the product and project, including the project justification and the action or business plan [1] |
| 3 | Collaborative Product Development | When two firms work together to develop and commercialize a specialized product [1] |
| 4 | Concept Testing | The process by which a concept statement is presented to consumers for their reactions [1] |
| 5 | Configuration Management | The process of managing a product’s requirements and design documentation as it evolves and changes over its lifecycle (from requirements definition through production, operation, support and disposal) and assuring that the resulting products and processes conform to this documentation [2] |
| 6 | Design of Experiment | A methodology to desensitize a new product's performance characteristics to variation in critical product and process design parameters [2] |
| 7 | Customer Satisfaction Tracking | A method for tracking some customer satisfaction index or indices over the lifecycle of a product [7] |
| 8 | Design Mock-up | A scale or full-size model of a design or device, used for demonstration, design evaluation, promotion, and other purposes [3] |
| 9 | Electronic Document Management System | A software program that manages the creation, storage and control of NPD documents electronically [2] |
| 10 | Failure Mode Effects Analysis | This is a tool for exploring potential problems ahead of implementation of new products, processes, services [6] |
| 11 | Feasibility Studies | The process of analysing the likely success of a project or a new product [1] |
| 12 | Focus Groups | Meetings with a group of customers, users, or potential users of a product to explore their needs and obtain their feedback on product ideas and concepts [2] |
| 13 | In-Market Testing | A small-scale implementation of a specific marketing approach where the researcher is controlling all the variables except the one being tested [5] |
| 14 | Intellectual Property Protection | Information, including proprietary knowledge, technical competencies, and design information, which provides commercially exploitable competitive benefit to an organization [1] |
| 15 | Lead User | Those users who are the most advanced users of the product, customers who are pushing the product to its limits, or customers who are adapting an existing product(s) to new uses. Lead users are a good source of information on needs for a new type of product [3] |
| 16 | Needs Analysis | A quick way to gather or confirm basic user requirements used throughout the product development process [4] |
| 17 | Project Management | Project management is a framework for a range of tools for helping plan and implement development and change projects. A range of tools exist, including: Gantt charts (bar charts), Activity charts, Flow charts, Milestone charts [6] |
| 18 | Prototype | A physical model of the new product concept. Depending upon the purpose, prototypes may be non-working, functionally working, or both functionally and aesthetically complete [1] |
| 19 | Risk Management | The process of identifying, measuring, and mitigating the business risk in a product development project [1] |
| 20 | Value Analysis | The act or process by which tangible product features or intangible service attributes are bundled, combined or packaged with other features and attributes to create a competitive advantage, reposition a product or increase sales [1] |

 [1] (PDMA, 2017) [2] (DRM-Associates, 2017) [3] (Filmswork-Studio, 2017)
[4] (Baxter & Courage, 2005) [5] (Nykiel, 2007) [6] (Tidd & Bessant, 2017)
[7] (Keiningham, Aksoy, Cooil, Peterson, & Vavra, 2006)

For our dependent variables, we sought a broad and representative set of performance measures. In part this is because literature tells us that different NPD tools contribute in different performance areas (González & Palacios, 2002; Yeh et al., 2008), although data limitations made it impractical for us to test performance effects of individual tools. More crucially, a number of different performance areas are potentially of interest to firms (R. Adams, Bessant, & Phelps, 2006; Griffin, 1997b; Kleinschmidt, 1994), including launched on time (Huang, Soutar, & Brown, 2004), product performance, profitability (Ledwith & O'Dwyer, 2009; Mallick & Schroeder, 2005) and degree of collaborating with partners (Parida, Westerberg, & Frishammar, 2012; Vera et al., 2014). One key distinction made in the literature on improving NPD performance is the need to address both the product and the process (Chiesa, Coughlan, & Voss, 1996; Maylor, 2001). Process efficiency refers to the new product development process from inception through to commercialization, and includes characteristics such as development costs and time to market. Product performance refers to the technical attributes of the product, such as meeting performance and quality specifications. These two performance criteria do not fully cover the success or otherwise of the commercialized product, such as sales volumes and market perception. We therefore also sought measures covering a third area, innovation efficacy (Alegre, Lapiedra, & Chiva, 2006) or innovation market performance (Montoya-Weiss & Calantone, 1994). This area includes measures such as product profitability and market perception. Within these three broad areas of performance, we surveyed the NPD literature for previously used measures (Griffin, 1993, 1997a; Griffin & Page, 1996; Kleinschmidt, 1994; Nijssen & Frambach, 2000; Nijssen & Lieshout, 1995; Ulrich & Eppinger, 2008; Yeh et al., 2008). We selected nine measures (Table 3) that occur frequently in these studies and together cover the three major NPD performance areas.

The survey used perceptual measures based on 5-point Likert-type statements (e.g. 1 = poor performance; 5 = excellent performance) for each of these nine dependent variables, as the use of third-party measures was not practical. For instances where a tool was not used, we provided the option ‘Not Applicable’. While Ketokivi and Schroeder (2004) proposed that both the reliability and validity of perceptual measures are satisfactory, ignoring informant bias can substantively distort results. To minimise potential for common method bias, we incorporated the recommendations of Conway and Lance (2010) and Chang et al. (2010) into our survey design. We requested ratings for a specific project launched within the previous three years and used nine separate measures of project performance (as set out above) rather than relying on a single measure. The survey rubric assured respondents of anonymity and that there were no right or wrong answers. Survey items were largely fact-based, such as having used a named tool in the identified project. As we set out later in this section, we ensured construct validity by means that included pre-testing and clickable pop-up tool definitions. Importantly, our measures for thoroughness and number of tools derive from the tool-focused part of the survey, separate from and with no easily discernible link to the part of the survey measuring performance. Following the recommendation of Conway and Lance (2010), we did not perform post-hoc statistical tests for method bias.

For the independent variables, we used categorical measures of whether the firm had used a given tool. For tools the firm had used, we asked follow-up questions relating to each individual tool, of which one question asked about the level of thoroughness (1 = not thorough; 5 = very thorough). In this study, we treat our 5-point Likert scale of our dependent variables as interval scales, hence we are able to use standard multiple-regression techniques. Figure 1 schematically depicts the two hypotheses in relation to the different types of variables that formed part of this study.

To determine which control variables to include for the study, we first drew on the work of Rosenbusch et al. (2011), who found that innovation performance depends on contextual factors such as the age of the firm (included as a demographic question in the survey) and the type of innovation or project strategy (see Figure 2). As our study’s focus is on small high-tech firms ranging from very small (5 employees or fewer) to 100+, we also include firm size in terms of equivalent full-time staff members and NPD team size (1 to 5, to 31+) as control variables. Finally, based on our review of the literature which found that SMEs do not innovate in formally recognized ways (Hoffman et al., 1998), often lack structure (Maravelakis, Bilalis, Antoniadis, Jones, & Moustakis, 2006), and conduct NPD in an ad hoc manner (Millward & Lewis, 2005), we also control for NPD process type. We measured NPD process type using the four categories: No process; Informal process; Formal & Sequential; Formal & Cross-Functional (Griffin, 1997b).



**Figure 1. Hypothesized relationship between constructs and NPD Performance**

## 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 (including each of the tools in the survey), conveniently placed on the web pages. Following Graetz et al. (2006), we addressed external validity of our findings by drawing on concepts that are commonly used in the extant literature, defining them with as little ambiguity as possible, and ensuring a sufficiently large data set.

***Sample***

Our sample frame consisted of 566 New Zealand high-technology firms that are engaged in NPD activity, with the emphasis on engineered, discrete, physical products and software (excluding process-intensive and primary sector products). As far as we were able, we included all firms in New Zealand that met the defined criteria. Past comparisons of New Zealand with American SMEs found, for the former, flatter organizational structures and greater blurring of cross-functional roles, and greater emphasis on oral learning (Souder, Buisson, & Garrett, 1997), while more specifically for NPD, firms tend to follow 'niche strategies' and use informal processes to execute them (Gawith, Grigg, Shekar, & Anderson, 2008). A prevailing perception among NPD teams is process being restrictive and a form of management control more suited to larger companies (Metikurke & Shekar, 2011). Our contact strategy resulted in a response rate of 21.4% (112 completely filled-out responses), after accounting for 43 cases of undelivered mail. This is an acceptable response rate given a relatively lengthy questionnaire. We excluded thirteen responses that contained crucial missing values or were otherwise unusable, resulting in a completed sample of 99 firms, which is sufficient to be representative of the population for a sampling error of ±10%.

The issue of self-selection is inherent in constructing a sample in this manner as participation is always voluntary, and hence non-response error can threaten external validity (Miller & Smith, 1983). We addressed this problem by following two of the protocols proposed by Lindner, Murphy, and Briers (2001): (1) the comparison of early to late respondents, and (2) using ‘days to respond’ as a regression variable. Using Armstrong and Overton’s (1977) method for the first protocol, we found no statistically significant differences in number of tools reported between early and late respondents, and infer based on this method that the non-response error is negligible. For the second protocol, we coded ‘days to respond’ as a continuous variable and calculated regression equations against the two variables ‘number of tools used’ and ‘mean performance’. As both these variables yielded insignificant results (variable 1: F = .556; Sig. = .458; variable 2: F = .002; Sig. = .966), we deduced that non-respondents do not differ from respondents. Both protocols suggest that the non-response error does not pose a serious threat to the external validity of this study. However, a conservative interpretation would be that our findings reflect the upper quartile for the level of engagement with NPD tools by New Zealand high-technology firms.

Figure 2 provides a breakdown of the sample’s 99 projects in terms of project strategy, showing a balance between low and higher-risk types of innovation. The sample represents 40% consumer and 60% industrial NPD projects. The breakdown of type of business is 46% manufacturing firms and 27% technology start-ups, with the remainder as “other” (government research agencies, engineering firms, consulting firms, etc.). Based on those who gave an industry (SIC category) for the firm, the breakdown is software technology (30.9%), hardware and equipment (22.0%), industrial (16.1%), energy and power (10.3%), household and personal products (5.9%), consumer durables (5.9%), food, beverage & tobacco (4.4%), aerospace & defence (1.5%), pharmaceutical & biotechnology (1.5%), and automobiles & components (1.5%).



Figure 2. Sample Characteristics *—* Number of Projects vs Innovation Type and Risk

Data on project team size and firm size in our completed sample confirm that both are substantially smaller than for prior NPD tool research. None of the projects under study employed more than twenty full-time staff. One third of the firms employ five or fewer full-time staff in total, while 65% employ between 1 and 19 full-time staff and hence represent small-to-medium size (SME) enterprises as defined in the New Zealand context. Only 9% employ more than 100 people, and of these none exceed the Unites States definition of an SME (Mazzarol, 2012), which is for fewer than 500 employees. In terms of annual turnover, 76% of the sample firms fall in the less than NZ$5 million category. Only two firms have annual revenues of more than NZ$50 million, with perhaps one firm marginally exceeding the European Union limit (Mazzarol, 2012) for medium-sized firms of €50 million.

Ideally, we wanted NPD project managers to complete the survey, but found instead that the firm’s CEO or one of its directors completed 59% of the surveys. Since the sample firms are so small, these people are very hands-on as is evident from their indicated broad scope of responsibilities for the projects under consideration: Technical/R&D: 74%; Marketing: 46%; Market research: 39%; Finance: 44%; Manufacturing: 30%; Quality assurance: 41%. In these settings, we can view the CEO or director who completed the survey as the project manager. People designated as project managers, process managers, or somebody familiar with a particular project, completed the remaining questionnaires.

Data Analysis and Results

As a first step in our analysis, we set out descriptive statistics for the tools in our study as set out in Table 2. From this, we can see that at least 19 firms used each tool, and much larger numbers (up to 77) used most. We can also see that there was wide variability in the level of thoroughness to which respondents reported they used each tool.

**Table 2. NPD Tools: Frequency and Thoroughness of Use**

|  |  |  |  |
| --- | --- | --- | --- |
| **Tool #** | **Tool name** | **Frequency of use** | **Thoroughness of use\*** |
|  |  |  | **Mean** | **Std Dev** |
| T1 | Brainstorming | 77 | 3.87 | 0.97 |
| T2 | Business Case | 56 | 3.64 | 1.07 |
| T3 | Collaborative Product Development | 52 | 3.40 | 1.29 |
| T4 | Concept Testing | 46 | 3.83 | 1.20 |
| T5 | Configuration Management System | 19 | 3.42 | 1.31 |
| T6 | Design of Experiment | 32 | 3.19 | 1.42 |
| T7 | Customer Satisfaction Tracking | 45 | 3.40 | 1.12 |
| T8 | Design Mock-up | 68 | 3.71 | 1.27 |
| T9 | Electronic Document Management System | 28 | 3.50 | 1.29 |
| T10 | Failure Mode and Effects Analysis | 19 | 2.63 | 1.17 |
| T11 | Feasibility Study | 52 | 3.48 | 1.06 |
| T12 | Focus Groups | 27 | 3.33 | 1.36 |
| T13 | In-Market Testing | 45 | 3.91 | 0.85 |
| T14 | Intellectual Property Protection | 63 | 3.90 | 1.17 |
| T15 | Lead User | 27 | 3.30 | 1.33 |
| T16 | Needs Analysis | 45 | 3.78 | 1.02 |
| T17 | Project Management | 69 | 3.45 | 1.15 |
| T18 | Prototype | 58 | 4.21 | 0.87 |
| T19 | Risk Management | 19 | 2.63 | 1.17 |
| T20 | Value Analysis | 21 | 3.10 | 1.48 |

\*1: low; 5: high

Given that our hypotheses investigate the performance impact of the number of tools used and the thoroughness of tool use, we next ran a regression to check whether the number of tools influenced thoroughness of use. The result showed almost no correlation, and no statistical significance.

***Impact of Number of Tools Used on NPD Performance***

To evaluate H1, we first plotted the relationship graphically as shown in Figure 3. This depicts a lack of measurable effect on the average of our nine performance measures from tool diffusion (the number of tools used on a project). To confirm the descriptive result, we tested for H1 by carrying out regression analyses with the independent variable tool diffusion (the number of tools used on a project) against performance, using each of our nine performance measures PM1-PM9 individually, and using the performance averages for process, product and market (as itemised in Table 3). The analysis did not support H1 for any of these measures of performance, as none of the regressions produced statistically significant results.



**Figure 3. Performance versus Number of Tools Used on a Project**

To eliminate the possibility that this failure to find a performance impact might be caused by some reported tool usage being too superficial to make an impact, we repeated the exercise using a narrower definition of tool use including only reported thoroughness levels from 3 to 5. In doing so, we still found a lack of clear differences in performance according to number of tools used. Finally, we repeated the exercise using the total of all thoroughness figures for each project, in order to capture total effort expended on tools including thoroughness as well as number of tools. Again, the regression result was not statistically significant and showed a negligible coefficient.

***Impact of Thoroughness of Tool Use and Control Variables on NPD Performance***

In this section, we evaluate H2 by testing the relationship between the level of thoroughness to which a tool is used and the resulting NPD project performance. To do this, we first created a variable Average Level of Thoroughness (ALT) representing the average level of thoroughness of tool use across all instances where that tool was adopted in a project. This variable isolates thoroughness of tool use from the number of tools used. Having done this, mindful of recommendations made by Schwab, Abrahamson, Starbuck and Fidler (2011) to set out practical impacts and not rely solely on hypothesis testing, we first drew a scatterplot and regression line showing average performance against ALT for the 20 tools in the study (Figure 4). The graph shows a clear relationship between thoroughness of use and performance outcome, amounting to over 20% of our performance scale between the most and least thorough reported usage.



Figure 4. Average Performance versus Average Level of Thoroughness

In quantitative terms, the regression shown in Figure 4 is statistically significant (p=0.00) with a coefficient of 0.35 and adjusted R Square of 12.85%. We also re-ran this test excluding the data point in the bottom left, and still found statistical significance at p=0.00, with a coefficient of 0.30 and adjusted R Square of 8.83%. To investigate further, we refined this result by performing stepwise regressions including each of our five control variables. We ran these regressions against each of our performance measures PM1-PM9 individually, as well as against the average of all nine. The findings are shown in Table 3.

Table 3 indicates that for the average of PM1-PM9, none of the control variables test significant, and hence none is included in the stepwise regression. Tests for individual performance measures show that average level of thoroughness (ALT) tests significant for seven of the nine measures. Team size explains additional variance in the case of PM4 (performance specifications) and PM7 (customer satisfaction). In these cases, Model 1 including only ALT shows an adjusted R Square of 7.68% and 16.7% respectively, indicating a larger influence than team size. The coefficients for team size are negative, suggesting that complex projects that have larger teams are more likely to run into challenges with performance specification and customer satisfaction. Firm age explains additional variance in the case of PM9 (revenue goals), but again Model 1 including only ALT shows an adjusted R Square of 9.36%. The coefficient for firm age is positive, indicating that managers in older firms are more likely to have given higher ratings for revenue goals. This is to be expected – though again ALT explained more of the variance.

**Table 3. Regression results: Thoroughness (ALT) and Control Variables vs NPD Performance**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **ALT** | **Firm Size** | **Process Type** | **Project Type** | **Firm Age** | **Team Size** | **Model****Adj R2** |
| **Average of PM1 – PM9** | .001\*\* |  |  |  |  |  | 9.72% |
| **Process Performance** |  |  |  |  |  |  |  |
| PM1 Launched on time |  |  | .083\*  |  |  |  | 2.48% |
| PM2 Adherence to budget |  | .021\*\* | .023\*\* |  |  |  | 3.37% |
| PM3 External collaboration | .001\*\* |  |  |  |  |  | 13.09% |
| **Product Performance** |  |  |  |  |  |  |  |
| PM4 Performance specs | .003\*\* |  |  |  |  | .069\* | 10.18% |
| PM5 Quality specifications | .000\*\* |  |  |  |  |  | 13.56% |
| PM6 Serviceability | .006\*\* |  |  |  |  |  | 7.92% |
| **Market Performance** |  |  |  |  |  |  |  |
| PM7 Customer satisfaction | .000\*\* |  |  |  |  | .093\* | 18.55% |
| PM8 Profit goals | .014\*\* |  |  |  |  |  | 6.71% |
| PM9 Revenue goals | .001\*\* |  |  |  | .016\*\* |  | 15.15% |

Significant p values shown: \*p < .10; \*\*p < .05 ALT = Average Thoroughness

ALT does not test significant for PM1 or PM2, and hence is not included in the regression models for these performance measures. In the case of PM1 (launched on time), this may indicate that time-based performance benefits from using NPD tools thoroughly are inhibited by the additional resources devoted to them. A similar effect could account for the result we see for PM2 Adherence to Budget. Instead, the analysis shows that NPD Process type tests as significant for PM1 and PM2. As we set out earlier, this variable indicates the sophistication level of projects’ governing processes. Hence, it is logical that it significantly correlates with two of the three process performance measures. The coefficients are positive in each case. However, the adjusted R Square values are lower than those shown for ALT and PM2-PM9. Figures for Variance Inflation Factor (VIF) for the above were all between 1.00 and 1.03, indicating very little collinearity between the predictors.

In conclusion, we find strong support for the existence of a relationship between thoroughness of tool use (as represented by ALT) and NPD project performance, hence we accept H2.

Discussion and Implications

The most striking aspect of our findings is that we found good support for our hypothesis that using NPD tools more thoroughly should lead to better outcomes, but no support for our hypothesis that using a larger number of tools improves outcomes.

Our finding of no significant performance differences according to number of tools adopted contrasts with that of Maylor’s (2001) study, which found differences in some performance areas. Maylor’s finding was for a narrower set of performance measures that included only engineering tools. Despite this, our contrasting finding is likely due to the smaller firm sizes in our sample. Small firms have limited capacity or resources to use a larger number of tools without adversely affecting other NPD tasks (de Waal & Knott, 2012), whereas this limitation should apply less often in larger firms with more resources. One adverse effect of using a larger number of tools could be on the level of thoroughness of use. However, this relationship did not meaningfully apply to the firms in our study, as we found no significant differences in thoroughness of tool use according to number of tools a firm used. Perhaps most surprising was our finding that the total of all thoroughness figures for each project, indicating the total effort expended on tools for the project (including thoroughness as well as number) still produced no correlation with performance. Our interpretation of this result is that using a greater number of tools at any given level of thoroughness does not improve performance.

For the relationship between thorough use of tools and performance, we found that when firms use tools at the highest levels of thoroughness, they obtain better NPD performance than they do from modest use of the same number of tools. By isolating the effect of thoroughness from the effect of number of tools, we found statistically significant correlations supporting this performance benefit across seven of the nine NPD performance measures in our study. In qualitative terms, the difference in performance was meaningful at over 20% of our scale for performance averaged across nine measures.

Thoroughness of tool use had a far greater influence on NPD performance than our control variables NPD process type, NPD project type, firm age and size, and team size. The control variable that had the clearest influence was NPD process type, which represents the extent to which the firm has implemented a formal NPD process. This correlated significantly with performance measures related to timeliness and efficiency, which is in line with prior studies (Akgün et al., 2004; Millson & Wilemon, 2006; Salomo, Weise, & Gemünden, 2007), and with expectations given that from our nine performance measures, these relate most closely to NPD process. However, we found thoroughness of tool use accounted for a greater proportion of the variance in NPD performance across seven of the nine NPD performance measures in our study.

Given this finding, the question of how thoroughly firms implement different NPD tools deserves more attention than it has received until now. Despite the performance improvement we found when firms used tools more thoroughly, we also observed high variability in reported levels of thoroughness (as highlighted in Table 2 and Figure 4). Future work could usefully investigate drivers of this variability. Given that we only studied twenty selected tools, future work could also usefully probe to what extent our findings hold across all tools or for individual tools or specific types of tool. Additionally, we acknowledge that our concept of ‘thoroughness’ incorporates multiple elements including depth, rigour, resources allocated, frequency of use, and usage of the tools’ different components. By investigating these elements separately, future work may provide more nuanced guidance as to which aspects of ‘thoroughness’ would most improve NPD performance.

Although we have studied small high-technology firms, our findings are novel in the broader context of NPD, including in larger firms. Very little prior work has studied the impact of using NPD tools to higher levels of thoroughness, nor have prior studies covered as broad a set of NPD tool types or performance measures. However, our findings do not necessarily apply in full to the large-firm context, as this is typically different in important respects including larger team sizes, easier access to specialists, less severe resource constraints, and higher levels of formality in NPD processes. Further studies could therefore usefully establish to what extent our findings apply to large high-technology firms.

In the small-firm context, our findings demonstrate that firms benefit most from systematic and well-resourced but selective and carefully designed use of NPD tools. In contrast, our literature review found that small firms are prone to using tools superficially. The best way for them to improve NPD performance is by selecting the right tools for their circumstances, implementing them thoroughly, and integrating them into an effective NPD process.

Conclusions

In this paper, we set out to clarify whether small high-technology firms benefit most from adopting greater numbers of new product development (NPD) tools to support NPD projects, or from using tools more thoroughly. Previous studies of the impact of using NPD tools have been in large firms with annual turnover above NZ$5 million or employing many more than 100 people, and very few have assessed the impact of using tools to higher levels of thoroughness.

The key implication of our results is that NPD practitioners in small high-technology firms are more likely to improve performance in product, process or market aspects of NPD by using tools more thoroughly than by adopting an increased number of tools. From our survey results, we draw the inference that for small firms, using a larger total number of tools does not improve performance by any measure. In contrast, from the same survey we infer that using the same number of tools more thoroughly correlates significantly and to a meaningful extent with improved NPD performance across a broad set of measures. We conclude that small firms should use tools selectively and proportionately to their available resources. They benefit most from thorough and carefully designed use of the right tools.

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