Impact of Development Tools on New Product Development Performance

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Abstract

We empirically examine the direct and indirect impact of a wide range of popular new product development tools on product development performance with a large multi-industry, multi-country dataset.

Keywords: Management of Technology, Internal Co-ordination Capability, External Collaboration Capability.

Introduction

A staggering number of development tools have emerged in the literature. Firms are increasingly using these development tools for improving each and every activities throughout the entire new product development process including, market research, concept development, engineering design, prototype building, teamwork, parts management, portfolio management, project management, and general administration. However, a series of benchmarking studies conducted by Product Development Management Association (PDMA) indicate that, although "a great variety of tools are being used more often," and the "best" firms are using more development tools more often than the "rest", the overall success rate of NPD projects has stubbornly stuck at around 60% (58% - 61%) during the past 25 years (Markham and Lee, 2013). This disconnect between the development tool usage and NPD outcome suggests that the development tools may impact certain intermediate outcome variables rather than just NPD project outcome directly (Tan and Vonderembse, 2006).

Literature suggests that successful execution of NPD projects not only requires internal integration among various functions within a firm, but also requires external integration with the suppliers and customers (Koufteros et al., 2005). We, therefore, examine the role of internal coordination capability (Luo et al, 2010) and the external collaboration capability (Mishra and Shah, 2009) as the two possible intervening variables for explaining this paradox.

Literature Review

Three streams of literature are relevant to this study: (1) literature on internal integration among various functions within a firm, (2) literature on external integration with suppliers and customers,

and (3) literature on development tools. A comprehensive review of this extensive body of literature is beyond the scope of this paper.

The literature on internal integration is mature and extensive. The general proposition of this body of literature is that increased functional integration leads to improvement in NPD performance (Fitzsimmons et al., 1991). An excellent review of this literature, popularly known as integrated product development (IPD), provided by Gerwin and Burrowman (2000).

The literature on external collaboration is relatively new, but grown very rapidly in the recent past. The general argument of this body of literature is that firms can gain significant competitive advantage in NPD by leveraging the resources of their suppliers and customers through collaborative product development. Please see Mishra and Shah (2009) for a good review of this literature.

Several scholars have suggested that rapid proliferation of development tools based on digital technology should improve NPD performance (Nambisan, 2003). Increased use of development tools not only should make the current NPD practices more efficient and effective, but also will provide new ways of performing the development activities that was not possible in the past (Thomke, 1998). However, empirical evidence regarding the adoption and use of development tools and their outcomes is scarce and the results are contradictory at times. Several studies report that development tools such as CAD/CAE can improve the speed of product development (Thomke, 1998). Other research has found that adoption and use of development tool does not improve speed-to-market, NPD cost, speed, or flexibility (Kessler and Chakrabarti, 1999; Barczak, et al., 2007). This disconnect between development tool usage and NPD outcome have led some scholars to suggest that (1) IT tools may impact certain intermediate outcome variables rather than just NPD project performance (Tan and Vonderembse 2006; Bardhan et al., 2007; Peng et al., 2014), and (2) the extent to which IT tools should be used is contingent upon project characteristics (Citrin et al., 2007). While several recent papers have examined the effect of environmental contingency (Heim et al., 2012; Peng et al., 2014). Only recently, Peng et. al., (2014) presented empirical evidence that increased use of development tools lead to improvement in a firm's collaborative capability. However, this research did not recognize the distinction between the internal co-ordination and external collaboration capability. Instead, they combined both constructs into a single measure. Moreover, they did not examine the impact of the effects of collaboration on NPD outcome.

Theoretical Foundation

The OIPT asserts that the information processing requirement of a task needs to be matched with the information processing capability of an organization to achieve a given level of performance. Any mismatch between information processing requirement and the information processing capability leads to reduction in performance. The information processing requirement can be matched with information processing capability either (1) by reducing information processing requirement or (2) by increasing information processing capability. The information processing requirement is defined by the complexity and the uncertainty levels of the task, and the information processing capabilities can be achieved through the design of appropriate structural mechanisms and adopting the right set of tools (Galbraith, 1974).

Direct effect of Development tools on NPD outcome: New product development (NPD) is a process through which firms attempt to combine their technological and market *knowledge* into an artifact that addresses the needs of their customers for the first time often in a prototype form.

Therefore, the information processing requirements of a NPD project are defined by the complexity and uncertainty of the technological and market specific information necessary to arrive at a solution to the product development problem.

A wide variety of development tools have been reported in the literature that can be adopted to develop the capability needed for processing this information. These means for improving information processing capability include information organizing frameworks, design philosophies and rules of thumb, and software tools for performing detailed design tasks, communicating, collaborating, collecting information, and managing timelines and resources (Heim et al., 2013). In this study, we examine a representative sample of fifty different popular development tools. Following the general practice (Markham and Lee 2013), we organize these development tools into six general categories based on the similarities in their application purpose: market research tools, market testing tools, engineering design tools, specialized software tools, team support tools, and social media.

We propose that the adoption and use of these development tools will improve the information processing capability by improving the efficiency and effectiveness of the collection, storage, retrieval, analysis, distribution and presentation of both market related and technical information necessary for development of a product. For example, the market research tools, such as focus groups, voice of the customer, customer site visits, ethnography, lead user analysis etc., can improve understanding of the market need at the "the fuzzy front end". Market research tools such as concept engineering, concept testing, trade-off analysis etc. can be used to arrive at a better product concept and, thus, providing a better starting point for product development. Similarly, alpha testing, beta testing, gamma testing, pre-test market, pilot product release and other market testing tools can be used to test a product concept early in the development process to avoid costly mistakes and refine the final design before its release.

The engineering design tools such as design for manufacturing (DFM), failure mode and effect analysis (FMEA), rapid prototyping systems (RPT), performance modeling and simulation systems (PM&SS) etc. are expected to improve NPD outcome through improvement in the quality of the technical design. For example, use of DFM tools improves manufacturability and reduces cost of production. Use of FMEA can improve the reliability of the product design. Use of RPT systems can improve design quality by uncovering design problem early in the design process through frequent trial and errors often with better, cheaper, and quicker prototypes created with 3D printing tools. Similarly, PM&SS can provide detail information on the product performance through computer modeling at a fraction of the cost of building and testing an actual physical prototype.

The specialized software tools are specifically developed to facilitate specific product development activities. For example, remote collaborative design systems is used to improve collaboration among team members located at remote locations. Product data management systems are used to manage all data related to new and old products throughout their lifecycle. Product portfolio management software are used keep balance and manage the entire NPD program.

The team support tools are the general purpose software tools used by the NPD teams to support team activity, but not specifically designed for product development, such as video conferencing, dedicated project intranet, dedicated project space, and groupware. The social media refers to generic Internet based software platforms such as Twitter, YouTube, Facebook, Fliker, and MySpace etc.

Several scholars have also argued that these development tools can enhance the knowledge base available to an NPD team, automate tasks for idea generation and concept testing, and

improve team coordination, communication, and cooperation (Dewitt and Jones, 2001). These benefits may increase developer productivity, leading to cost and time reductions and higher product quality (Ozer 2003). Accordingly, we summarize our arguments with the following set of hypotheses:

Hypothesis 1: *Development tools usage will be positively associated with NPD outcome, specifically:*

H1a: *Market research tools usage will be positively associated with NPD outcome.*
H1b: *Market testing tools usage will be positively associated with NPD outcome*
H1c: *Engineering design tools usage will be positively associated with NPD outcome.*
H1d: *Specialized software tools usage will be positively associated with NPD outcome.*
H1e: *General purpose software tools usage will be positively associated with NPD outcome.*
H1f: *Social media usage will be positively associated with NPD outcome.*

Role of Internal Co-ordination Capability (ICC): Modern products are complex systems with many interrelated parts and components that must work together to perform their intended function. To facilitate problem solving, complex product development projects are usually divided into smaller manageable tasks and distributed among participants (individuals, functional groups, and firms) who have distinctive skills and expertise to complete the assigned tasks. However, these smaller tasks have to be eventually integrated to arrive at an overall solution to the original design problem (Simon, 1969). This interdependency of problem solving created by task decomposition is a major co-ordination challenge in managing NPD projects.

However, there are many barriers to smooth internal coordination: various business functions are specialized in different tasks with different goals, responsibilities, reward systems, routines, and culture. Therefore, in addition to processing the technological and market specific information necessary for developing the new product, firms need to process additional information to facilitate coordination across various functions within the firm for the execution of the development project. Typically, firms attempt to overcome these barriers through various formal and informal structural mechanisms including accumulating mutual understanding among functions and using techniques such as liaison personnel, formal and informal groups, project or permanent cross-functional teams, and matrix organizations created through participation of key stake holders including engineering, marketing and manufacturing in the NPD process (Fitzsimmons et. al., 1991). Firms' ability to deploy such structural mechanisms is defined as the internal coordination capability (ICC) in the literature (Luo et. al., 2010). Internal coordination capability acts as an adhesive that coordinates the various business functions. In this sense, we posit that a higher level of ICC will lead to better integration of the skills and knowledge from various business functions and better integration will lead to better NPD outcome.

Moreover, adoption and use of development tools can improve the ICC of an organization in two different ways. On the one hand, they can improve the efficiency and effectiveness of the existing formal and informal structural mechanism by providing new ways of connecting and communicating across various functions. On the other hand, sharing new information generated by these tools and practices that would not be possible without them. Thus, these tools and practices can be used to break down the functional walls and build bridges across functional silos. We summarize our arguments with the following set of hypotheses:

Hypothesis 2: *Internal Coordination Capability (ICC) will be positively associated with NPD outcome.*

Hypothesis 3: *development tools usage will be positively associated with ICC, specifically:*

H3a: *Market research tools usage will be positively associated with ICC.*
H3b: *Market testing tools usage will be positively associated with ICC*
H3c: *Engineering design tools usage will be positively associated with ICC.*
H3d: *Specialized software tools usage will be positively associated with ICC.*
H3e: *Team support software tools usage will be positively associated ICC.*
H3f: Social media usage *will be positively associated with ICC.*

Role of External Collaboration Capability (ECC): In addition to improving problem solving efficiency through internal coordination (as explained in the previous section), firms can also gain competitive advantage by leveraging heterogeneous capabilities of the suppliers and customers through external collaboration (Dyer and Singh 1998). Firms are increasingly collaborating with their suppliers and customers to leverage their technological and market knowledge for improving their product development performance. Some of the benefits of such external collaboration reported in the literature include a higher return on R&D investment, lower development costs, faster NPD, reduced risk, and access to new product development capabilities of suppliers.

Although sharing capabilities, resources and costs with partners is an attractive option, involving external partners in the product development process adds transaction costs due to increased integration challenges and risks (Williamson, 1979). According to OIPT, it is possible to minimize these negative impacts by moving away from a transactional relationships and of cultivating a collaborative relationships with their suppliers and customers through design and deployment of structural mechanisms such as joint teambuilding and training; sharing risks, reward and performance contracts; enlisting top management support and involvement etc. Following the literature (Mishra and Shah, 2009), we define a firm's ability to design and deploy these structural mechanisms as the external collaboration capability. Therefore, firms more effective in deploying these structural mechanisms will be able to gain more from their collaborative activities. We propose that development tools and practices will enhance a firm ability to deploy these structural mechanism and hence improve ECC. Several scholars have suggested that use of development tools can improve collaboration (Boutellier et al., 1998; Hameri and Nihtila, 1997). A survey of product development projects found that higher performing teams tend to use collaboration and communication technology to a greater extent than lower performing teams (McDonough, Khan and Griffin, 1999). Recently, Peng et. al., (2014) presented empirical evidence that increased use of development tools lead to improvement in a firm's collaborative capability with suppliers and customers. We summarize our arguments with the following set of hypotheses:

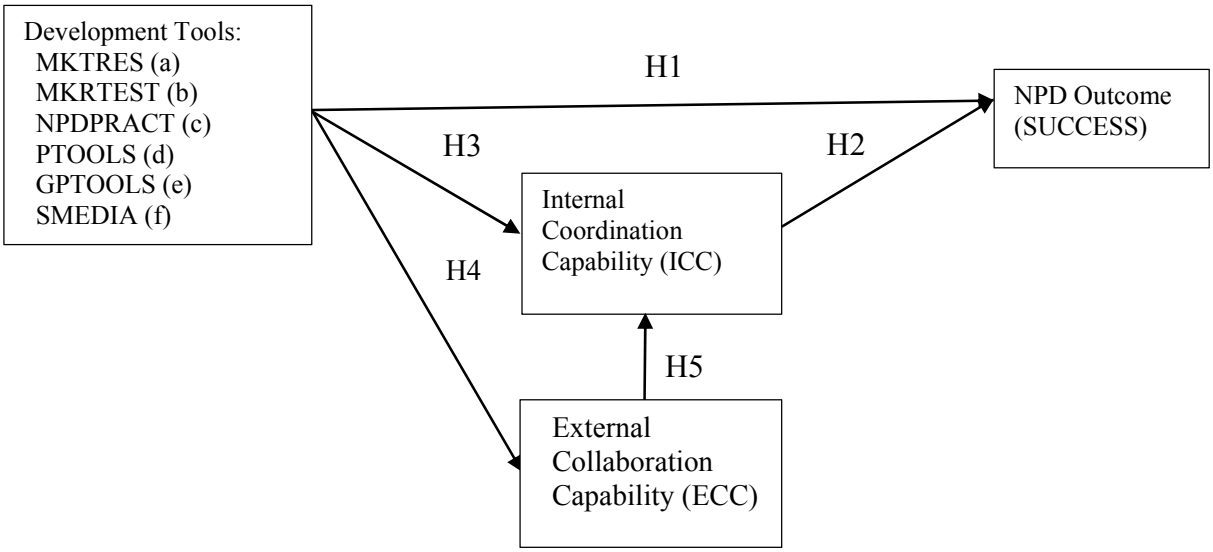
Hypothesis 4: *development tools usage will be positively associated with ECC, specifically:*

H4a: *Market research tools usage will be positively associated with ECC.*
H4b: *Market testing tools usage will be positively associated with ECC*
H4c: *Engineering design tools usage will be positively associated with ECC.*
H4d: *Specialized software tools usage will be positively associated with ECC.*
H4e: *Team support software tools usage will be positively associated ECC.*
H4f: Social media usage *will be positively associated with ECC.*

Although we expect that adoption and use of development tools and practices to improve a firm's ECC, it is important to recognize that involving external partners in the product development process creates increased coordination costs and integration challenges. This is because the efficiency and effectiveness of joint problem solving activities is affected by the weakest link in the supply chain. Therefore, to work effectively with their suppliers and customers, original equipment manufacturers (OEM) must have effective internal integration across various functions within the firm. Scholars have suggested that in inter-firm collaboration, firms' internal activities are directly influenced by their external partners' activities, which inevitably introduce additional uncertainty and complexity into the participating firms' internal coordination and decision making (Pfeffer and Salancik, 1978). Takeishi (2001) pointed out how component design quality by a supplier is affected by internal coordination within engineering departments and coordination between engineering and purchasing. It has been reported in the literature that performance effect of external collaboration with supplier is affected by a firm's ability to co-ordinate internally (Koufteros et al., 2005; Luo et al., 2010). Therefore, we propose that effects of external integration will be mediated by internal integration and there will be a positive association between a firm's external collaboration capability and internal collaboration capability. We summarize our arguments with the following hypothesis:

Hypothesis 5: *External Collaboration Capability (ECC) is positively associated with Internal Co-ordination Capability (ICC).*

Figure 1: Hypothesized Model



Research Methodology

Data: This study utilized data from the 2012 Comparative Performance Assessment Study (CPAS) conducted by Product Development Management Association (PDMA). Please see Markham and Lee (2013) for a detail description of the dataset and the complete collection procedure.

Measures: The unit of analysis for this study is a business unit within an individual company. All items, except for items used for measuring NPD outcome, are measured on a 5-point Likert scale with one as the lowest and five as the highest possible score. The two items used for measuring NPD outcome was measured on a 7-point Likert scale. We examined each factors for content validity and found that questionnaire items related to development tools are clearly separated into six different categories based on their application: (1) market research tools used early stage in the development process (MKTRES), (2) market testing tools used late stage in the development process (POSTMKT), (3) engineering design tools (NPDPRACT), (4) specialized software tools for managing NPD process (SPTOOLS), (5) general purpose software tools for supporting team process (GPTOOLS) and (6) social media (SMEDIA). We, therefore, define six separate constructs to represent the set of development tools in this study. Similarly, questionnaire items related to internal and external collaborations were defined as (1) internal coordination capability (ICC) and (2) external collaboration capability (ECC). The measure for NPD outcome (SUCCESS) was constructed with two items related to the overall success of the NPD program for the business unit. Finally, all measures were tested for convergent validity, discriminant validity, reliability and average variance extracted, and are found to meet or exceed the minimum acceptable standard specified in the literature (Carmines and Zeller, 1979; Hair et al., 1987).

Results

Analysis: We use the following set of Ordinary Least Square (OLS) regression equations to test the proposed paths in the framework.

$$SUCCESS = a_1*ICC + c_1*MKTRES + d_1*MKTEST + f_1*NPDPRACT + g_1*SPTOOLS + h_1*GPTOOLS + i_1*SMEDIA + e_1 \quad (1)$$

$$ICC = b_2*ECC + c_2*MKTRES + d_2*MKTEST + f_2*NPDPRACT + g_2*SPTOOLS + h_2*GPTOOLS + i_2*SMEDIA + e_2 \quad (2)$$

$$ECC = c_3*MKTRES + d_3*MKTEST + f_3*NPDPRACT + g_3*SPTOOLS + h_3*GPTOOLS + i_3*SMEDIA + e_3 \quad (3)$$

The main results of the analysis are presented in Table 1. Beginning with Model 1, we observe that this model is statistically significant and explains 17% variations in the NPD outcome (SUCCESS). While ICC is statistically significant in the model (a_1=0.51, $p<0.0001$), none of the six variables representing development are statistically significant in this model. Therefore, H1 is not supported, but H2 is supported. Next, Model 2 is also statistically significant explains nearly 28% variations in ICC. We observe that ECC (b_2 = 0.39, $p<0.0001$), MKTRES (c_2=0.20, $p<0.0074$), NPDPRACT (f_2 = 0.12, $p<0.0240$) and GPTOOLS (h_2=0.12, $p<0.056$) are statistically significant in this model. Therefore, hypotheses H5 is supported, but hypothesis H3 is only partially supported, i.e., H3a, and H3c are strongly supported, but support for H3e is weak. Finally, Model 3 is also statistically significant and explains 35% of the variation in ECC. We observe that MKTRES (c_2=0.21, $p<0.0002$), MKTEST (d_2 = 0.14, $p<0.0006$), SPTOOLS (g_2=0.12, $p<0.0265$) and SMEDIA (i_3=0.13 ($p<0.0123$) are statistically significant in this model. Therefore, hypothesis H4 is only partially supported, i.e., H4a, H4b, H4d, and H4f are supported, but H5c and H5e are not supported. We also, tested Model C as a competing model to explore the possibility of any direct effect of ECC on SUCCESS. However, this model was no better than Model 1. Therefore, in summary H2 and H4 are supported, H3 and H4 are partially supported, and H1 is not supported.

Table 1: Results

	SUCCESS		ICC	ECC
Independent Variables	Model 1	Model C	Model 2	Model 3
Intercept	2.97c	2.88c	1.28c	1.08c
Internal Co-ordination Capability (ICC)	0.51c	0.48c		
External Collaboration Capability (ECC)		0.13	0.39c	
Market Research Tools (MKTRES)	0.04	0.02	0.19c	0.21c
Market Testing Tools MKTEST	0.03	0.02	0.01	0.14c
Engineering design Tools (NPDPRACT)	0.14	0.14	0.12b	0.01
Specialized Software Tools (SPTOOLS)	0.22	0.20	-0.07	0.11b
General Team Support Tools (GPTOOLS)	0.17	0.17	0.12a	0.06
Social Media (SMEDIA)	-0.15	-0.17	-0.12	0.13b
N	332	332	332	332
F	9.81c	8.65c	17.99c	28.66c
R^2	0.17	0.18	0.28	0.35
Adj. R^2	0.16	0.16	0.26	0.33

Statistically significant at a= $p<0.1$, b=$p<0.05$, and c= $p<0.01$

Discussion: First, results from Model 1 suggest that adoption and use of none of the six types of development tools, examined in this study, have any direct impact on the NPD outcome (SUCCSESS), and only the internal coordination capability (ICC) have a positive impact on NPD outcome. Next, the results from Model 2 suggests that the adoption and use of market research tools (MKTRES), engineering design tools/methodologies (NPDPRACT), as well as, firms' external collaboration capability (ECC) have strong positive impact on the internal co-ordination capability (ICC). However, adoption and use of general purpose software tools (GPTOOLS) only have a weak positive impact on ICC. This findings are also in congruence with the prior literature (Peng et. al, 2014). Finally, Model 3a suggests that the adoption and use of market research tools (MKTRES), market testing tools, special purpose software tools (SPTOOLS) and social media (SMEDIA) have a positive impact on external collaboration capability (ECC). This findings are also in congruence with the prior literature (Peng et. al, 2014).

Taken together, the results from the three models suggests that although (1) none of the six types of development tools have any direct impact on the NPD outcome (SUCCESS) as measured by the overall success of the NPD program, all of them have indirect positive impact on NPD outcome. That is (1) adoption and use of market research tools (MKTRES), engineering design tools (NPDPRACT), and general purpose software tools, as well as a firm's external collaboration capability (ECC) have a direct positive impact on its internal co-ordination capability (ICC). Therefore, these three development tools have an indirect effect impact on NPD outcome through ICC. Moreover, adoption and use of (4) market research tools (MKTRES), market testing tools (MKTEST), special purpose software tools (SPTOOLS) and use of social media (SMEDIA) have a direct positive impact on a firm's external collaboration capability (ECC). Therefore, these four tools have an indirect effect on NPD outcome through ECC and ICC.

The theoretical implications of these findings are several. First, this study provides a theoretically grounded explanation for the lack of connection between development tools usage and NPD outcome with the identification of two new intervening variables: internal co-coordination capability and external collaboration capability. Next, the study also enriches the literature with empirical evidence of the indirect effect of development tools on NPD outcome. Thus, these findings can be used to provide empirical support to the PDMA findings that consistently report that "best" performing firms use "more development tools more often" (Markham and Lee 2013). Finally, this study joins the large body of literature that failed to find any evidence of the direct impact of development tools on NPD outcome. Although, lack of evidence is not an evidence of absence, it raises serious questions about such a possibility. Therefore, scholars must continue to search for the evidence of the direct effect of development tools with new data and/or methodology to find a definitive answer to this question.

The results also have several implications for the managers interested in improving their NPD program outcome. First, the absence of any direct impact of any of types of development tools suggests that managers need to pause and refocus their attention from piecemeal investment in development tools for any short term improvement in NPD outcome. Instead, they should adopt a strategic approach to investment in development tools with primary focus on improving their internal coordination capability (ICC) and external collaborative capability (ECC). Next, the results also suggests that between ICC and ECC, managers should be focusing their improvement effort on ICC first. Thus providing a way to prioritize their investment in development tools, if necessary. Finally, the findings also provide guidelines for choosing the right set of development tools/methodologies depending on whether managers are interested in improving the internal coordination capability (ICC) or external collaboration capability (ECC).

Conclusion

Development tools represent significant opportunities for gaining and sustaining competitive advantage through improving the efficiency and effectiveness of new product development. Yet, the literature has been predominantly conceptual and case based with few empirical studies producing inconclusive evidence. This study indicates that none of the development tools examined in the study have any direct impact on NPD outcome. They affect NPD outcome indirectly by improving the internal coordination capability and/or external collaboration capability of the firms.

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