Best Practices in New Product Development: Adoption Rates, Adoption Patterns, and Impact

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Abstract

Firms are experimenting with numerous different best practices in order to improve the timeliness and effectiveness of their new product development (NPD) process. This paper examines how widely adopted certain best practices are, if the adoptions show any pattern in terms of being simultaneously adopted within organizations, and what impact these best practices have on NPD performance. The main assumption of this study is that widely diffused best practices will lead to greater NPD effectiveness and more successful products. We developed an inventory of best practices related to NPD, and an empirical survey was administered to 39 companies. Our results indicate that best practices associated with enhancing the human resources involved in NPD, and improving the fuzzy front end of NPD appear to be getting little attention to date, despite a strong call for such attention in the management literature. Best practices associated with the strategic implementation of NPD (project selection, goals, technological leadership, product strategy, and customer involvement) are on average all more widely adopted than best practices associated with controlling the execution of NPD (process control, metrics, documentation, change control). In linking best practices with impact, our results indicate product success depends on developing strong product concepts and ensuring organizational focus on those concepts through project selection. Concurrency in project activities enhances both product and project success. Project success also depends on controlling the NPD process via project management, and ensuring team

cohesion with group rewards. Sharing lessons-learned between projects can positively influence cycle time improvement in the NPD process. Results are moderate in strength, and survey reliability and validity are adequate.

1. Introduction

Many of the improvements that organizations have implemented in response to trying to improve their new product development (NPD) process fall into the realm of what are often called *best practices*. In general, a practice is a tactic or method chosen to perform a particular task, and/or to meet a particular objective. For example, "project team membership" is a practice that defines how resources are organized for projects. A best practice is public knowledge (Matusik and Hill, 1998), and is a tactic or method that has been shown through real-life implementation to be successful; a "cross-functional development team" would be an example of a best practice. Various research studies and management writers have identified a large number of NPD best practices (e.g. Cooper, 1993; Dixon, 1990; Paulk, et al. 1993). A special subcategory of NPD best practices have been normatively identified and categorized within the Software Engineering Institute's (SEI) Capability Maturity Model (CMM) (Paulk, et al. 1993). The emphasis of CMM is on process management of the development process.

Best practices diffuse both within an organization, and between organizations. Diffusion within an organization refers to the rate of adoption of a best practice across multiple project teams, multiple design programs, and multiple organizational units. It is not uncommon, especially in large organizations, to see a variety of best practices being implemented with great success, but only within certain pockets of the organization. Diffusion within the organization is closely associated with the organization's learning capabilities (Kodama, 1995). Diffusion between organizations refers to the rate of adoption across multiple firms, within a particular industry and across all relevant organizational types. Diffusion between organizations is in large part effected by the characteristics of the best practice (Rogers, 1995).

An organization with limited capital and personnel resources that can be devoted to improvement efforts must determine which best practices are most important to implement. The objective of this paper is to determine which best practices are being widely implemented, whether there are clusters of best practices that are being simultaneously implemented within organizations, and what the impact is of best practices on NPD product and project success. We examine adoption and diffusion within the organization indirectly by sampling development "programs" rather than individual projects. We measure the adoption of best practices across organizations, and their impact on performance via a cross-sectional survey. Even though there are numerous studies on NPD best practices, this study seeks to add value in three ways. First, most studies of NPD best practices focus at the level of the individual project; our study is one of the few to focus at the program level of the organization. Second, there have been no studies (outside SEI) concerning best practices associated with maturity, especially in the context of product (as opposed to software) development processes. This study is the first empirical study to see if the concept of maturity has any general meaning outside of the world of software development. Finally, our study seeks to identify patterns of best practice adoption within the organization. A review of previous research findings is presented, followed by our research propositions. We then describe our research method, and show subsequent empirical results. Results are discussed and thoughts on future research are given.

2. Literature Review and Research Propositions

Numerous descriptive, predictive, and prescriptive NPD studies exist. Descriptive studies typically outline the steps involved in NPD, either as a sequential or concurrent process (e.g. Cooper, 1993). Predictive studies have attempted to identify NPD "success factors". Evidence supporting the importance of these best practices varies in its strength. Some best practices have been identified as being "best" via rigorous empirical studies, while others have been identified in case studies and single-company descriptions; and some have simply been declared "best" by experts in a prescriptive manner. Brown and Eisenhardt (1995) summarized the vast NPD best practices literature and found that here is strong evidence that senior management support and control, internal and external team communication, and team composition have positive effects on NPD process performance. Second, there is weak evidence that supplier involvement and concurrency of activities have positive effects on NPD process performance. Finally, there is weak evidence that NPD process performance, product fit (with market and firm competencies), and market condition (large and growing) have positive effects on firm financial performance.

2.1 Previous Best Practice Studies

Here is a summary of findings from some of the more recent NPD best practices studies:

- Eisenhardt and Tabrizi (1995) found in a study of the computer industry that firms using an "experiential strategy of multiple design iterations, extensive testing, frequent project milestones, a powerful project leader, and a multifunctional team" (p. 84) accelerated development; while firms using "the compression strategy of supplier involvement, use of computer-aided design, and overlapping development steps describes fast pace only for mature industry segments".
- Calantone, Vickery, and Droge (1995) found in looking within a single industry (office and residential furniture) that customization, new product introduction, design innovation, product development cycle time, product technological innovation, product improvement, new product development, and original product development had positive impact on firm ROI, market share, and return on sales.

- Ettlie (1995) found those firms integrating product and process design via engineering job rotation and mobility have higher sales per employee.
- Nobeoka and Cusumano (1995) found in a study of the automotive industry that knowledge transfer between projects was best performed through "rapid design transfer", whereby "a new project begins to transfer a core design from a base project before the base project has completed its design engineering" (p. 399).
- Hauptman and Hirji (1996) found in a global study that cross-functional cooperation, in the way of two-way communication, overlapping problem solving, decision-making readiness, and readiness to share ambiguous information had a positive impact on project success.
- Zirger and Hartley (1996) found that "fast developers had teams that were cross functional, dedicated, included fast time to market as a development goal, and overlapped development activities more than slow developers" (p.143).
- Song, Souder, and Dyer (1997) found that marketing proficiency, product quality, process skills, project management skills, and alignment of skills and needs had a positive effect on product performance.
- Ettlie (1997) found that "new product success was significantly associated with market need understanding which incorporates information… from integrated design into new product development" (p. 33).
- Griffin (1997) found that cross-functional teaming was more important, in terms of reducing development cycle time, when product designs were more novel; and that a structured, formal development process helps reduce development cycle time more when developing complex products.

2.2 Categorization of Best Practices

In this study approximately 800 "practices" were identified through an exhaustive search of the research literature. This was honed down to 200 "best practices" (based on efficacy, overlap and redundancy), and the heads of engineering in five partnering companies reviewed a pilot survey, in order to check for face validity and completeness. For example, considering the issue of *customer needs analysis*, the best practice that was identified was *needs are solicited and fed back to customer for verification*.

In order to develop a more meaningful sense of what the set of best practices meant collectively, they were classified into categories. The first thing we noticed was that a large number of best practices represented activities that were performed in various stages of the development process. For example, the use of computer aided design (CAD) was an activity primarily useful during the stage of detailed design. A logical and accepted process model of NPD depicting these stages is Cooper's stage gate model of the NPD process (Cooper, 1993). Thus, a number of best practices were put into the following categories (see Figure 1, and Table 1):

- Customer Requirements: How potential customer requirements are identified, defined and changed.
- Product Strategy: How new product development is aligned with internal constraints and with external factors like regulations and competition.
- Concept Generation: How candidate concepts for new products are generated or acquired.
- Concept Selection: How candidate product concepts are screened and concepts selected for further development.

- Concept Design: how the selected concept is designed at a high level.
- Detail Design & Redesign: How product details, materials, dimensions are specified.
- Manufacturing and Launch Preparations: How manufacturing processes are developed and channels to get the product to the customer are established.
- Product Improvement and Disposal: How product defects are identified, improvements made, and how products are disposed of at the end of life.

--insert Figure 1--

--insert Table 1--

2.3 Best Practice Research Propositions

Surprisingly few studies exist that examine the impact of best practices within these different stages of the NPD process; some areas are more heavily covered than others are. The first five categories (Customer Requirements, Product Strategy, Concept Generation, Concept Selection, and Concept Design) have to do with the "fuzzy front end". There is a sense in practice that while these activities are very important, industry is perhaps not doing all it could to manage these up-front activities effectively (Khurana and Rosenthal, 1997).

Balanchandra (1997) summarizes a number of different studies that support the importance of best practices within Customer Requirements; these "factors" fall under the labels of: market analysis, meeting customer needs, client acceptance, understanding the market, and problem definition. The importance of Customer Requirements was validated by Bacon et al. (1994), who found that a clear understanding of user needs and explicit description of product concept and definition were keys to NPD success. Requirements definition and control is a key element within the ISO 9001 Quality Systems Standard. We therefore propose:

P1: Best practices in Customer Requirements will positively affect NPD process and product outcomes.

The importance of best practices within Concept Generation, Concept Selection, and Concept Design is more poorly documented. While there is much written on how to generate and select concepts, there is far less research concerning the impact of such methods. Cooper (1993) documents that in his studies that Concept Selection was notoriously weak in practice. Khurana and Rosenthal (1997) developed a number of case studies and found that while companies had a moderate degree of implementation concerning product concepts, they had low degrees of implementation concerning product definition, value chain considerations, and front-end project definition and planning. It is commonly thought that most of a product's quality, cost, and performance is decided during conceptual design, and the very little influence comes from the details of the design (Hauser and Clausing, 1988).

P2: Best practices in Concept Generation will positively affect NPD process and product outcomes.

P3: Best practices in Concept Selection will positively affect NPD process and product outcomes.

P4: Best practices in Concept Design will positively affect NPD process and product outcomes.

The importance of best practices in Product Strategy has been fairly well documented. Cooper's original studies found that the product, the customer, and firm competencies must be aligned (Cooper, 1979), and that formalization of strategy can have positive benefits (Cooper, 1975). Balachandra and Friar's review (1997) of best practices identifies a number of studies highlighting the importance of technology being tied to business strategy. In another meta-analysis of existing NPD best practices literature, Brown and Eisenhardt (1995) found that there was weak evidence that product fit (with market and firm competencies) had positive effects on firm financial performance. Song, Souder, and Dyer (1997) found that alignment of skills and needs had a positive effect on product performance.

P5: Best practices in Product Strategy will positively affect NPD process and product outcomes.

A number of studies have focused on how best practices in Detail Design can impact NPD effectiveness. Most of these studies have focused on the use of Computer Aided Design (CAD) tools (for example, see discussion in Eisenhardt and Tabrizi (1995)). Our best practice list here revolved around more basic issues however, such as customer and supplier involvement, formalized decision-making, and change control (also an important element of the ISO 9001 standard).

While there is a trend to involve suppliers more in the product development process, the jury is still out as to whether such involvement is actually beneficial. A number of studies (DeMeyer and Van Hooland, 1990; PDR, 1996) found a beneficial effect. In a study of Mitsubishi Electronics, Funk (1993) found that an especially effective practice was the temporary transfer of supplier personnel to the OEM firm. Brown and Eisenhardt (1997) found that computer firms form strategic alliances with vendors in order to effectively "probe the future", enhancing their ability to stay up-to-date with technological and market trends in areas outside of their core competencies. Some research shows however that supplier involvement can actually increase development time (Eisenhardt and Tabrizi, 1995; Zirger and Hartley, 1996).

Leonard-Barton (1995) highlights a number of cases where customer involvement in design had beneficial effect. Her studies demonstrate that involving customers directly in the design process can help establish buy-in, it helps generate knowledge of the user's environment so that product usage can be better understood, and it is an effective and realistic way to test prototype products. Cusumano and Shelby (1995) report on Microsoft's use of internal employees as customers, and their subsequent involvement in development.

P6: Best practices in Detail Design and Redesign will positively affect NPD process and product outcomes.

Perhaps one of the most researched areas of NPD best practices is Manufacturing and Marketing preparations; in this general category we would include: concurrent product and process design, field testing of the product, and preparation of the marketing channels. Concurrency has been proven many times over to have a positive impact on NPD performance (e.g. see Eisenhardt and Tabrizi (1995), Ettlie (1995), Ettlie (1997), Hauptman and Hirji (1996), Zirger and Hartley (1996)). Cooper (1993) highlights the fact that in his studies marketing planning and preparation is often the weakest link in NPD.

P7: Best practices in Manufacturing and Marketing Launch Preparations will positively affect NPD process and product outcomes.

Finally, a number of studies have advocated "design for disassembly" or "design for disposal", but no formal studies have indicated the impact of these activities on NPD performance (Handfield et al., 1997).

P8: Best practices in Product Improvement and Disposal will positively affect NPD process and product outcomes.

Empirical evidence supporting the effect of "maturity" deserves separate attention, as this particular concept has not been well researched. The Software Engineering Institute's (SEI) process Capability Maturity Model (CMM) (Paulk et al., 1993) is used by the U.S. Department of Defense to evaluate the capabilities of software suppliers. It loosely has roots to Crosby's Quality Management Maturity Grid (Crosby, 1979). The model has granularity, in terms of five levels of process maturity (initial, repeatable, defined, managed and optimizing), and thus represents a way to gauge/predict NPD performance on an ordinal scale. However, it has been used almost exclusively in the software-engineering environment. The capability maturity model is descriptive and normative, and defines the key practices that characterize and differentiate each successive level of process maturity. Thus, it provides a method for assessing firms' capabilities to produce quality software. The CMM defines maturity as "the extent to which a specific process is explicitly defined, managed, measured, controlled, and effective" (Paulk et al., 1993, sec. 1.2).

The CMM's maturity levels are defined as:

• Level 1 - *initial* - The process is characterized as ad hoc, and occasionally even chaotic. Few processes are defined, and success depends on individual effort.

• Level 2 - *repeatable* - Basic project management processes are established to track cost, schedule, and functionality. The necessary process discipline is in place to repeat earlier successes on similar projects.

• Level 3 - *defined* - The process for both management and engineering activities is documented, standardized and integrated into a standardized process for the organization. All projects use an approved, tailored version of the organization's standard process. Activites are well integrated.

• Level 4 - *managed* - Detailed measures of the process and product quality are collected. Both the process and products are quantitatively understood and controlled.

• Level 5 - *optimizing* - Continuous process improvement is enabled by quantitative feedback from the process and from piloting innovative ideas and technologies.

SEI-CMM is operationalized in the following manner. The maturity level is indicative of process capability, and contains key process areas. For example, Level 2 (repeatable) is indicative of a disciplined process, and contains key process areas such as software project planning, requirements management, and software project tracking and oversight. A key process area achieves goals, and is organized by common features. Common features include (a) commitment to perform, (b) ability to perform, (c) activities performed, (d) measurement and analysis, and (e) verifying implementation. Each common feature contains key practices that describe activities to be undertaken. For example, a key practice addressing implementation of software project planning is "estimates for the size of the software work products are derived according to a documented procedure" (Paulk et al., 1993, sec. 3.3).

Upon examination of these key practices within SEI CMM we categorized the best practices into four categories--goals, metrics, project management, and organizational structure. Additionally, a more general category of “maturity” was used to capture more general best practices that did not fall into the specific realm of these four (for instance, issues having to do with change control, process documentation, and organizational learning in general).

The effect of these collective best practices embodied in SEI CMM has only been studied in the context of software engineering. From 1987 to 1994, a total of 379 organizations have been formally assessed by SEI; upon initial assessment, the distribution of maturity was 73% initial, 16% repeatable, 10% defined, 0.6% managed, and 0.3% optimizing (Hayes & Zubrow, 1995). It has been found that project management--project planning, tracking, and oversight specifically--is the key differentiator between level one and level two performers (Goldenson and Hersleb, 1995). Organizations took on average 25 months to move from one level of maturity to the next (Hayes & Zubrow, 1995).

In performing software NPD improvement, the median value of return on investment has been 500 percent, from an annual investment of $245,000 (Hayes & Zurbow, 1995). CMM maturity level has been found to be positively correlated with ability to meet schedule and financial targets, product quality, staff productivity, staff morale, and customer satisfaction (Goldenson and Hersleb, 1995). An organizational study of 176 software engineering groups showed that maturity level was positively correlated to reduced employee turnover and absenteeism, reduced software defects after release, decreased cost of poor quality, improved competitive position, decreased cycle time, decreased development cost, and decreased schedule and cost overruns. The study also found that while about 20 months were required to move from Level 1 to Level 2, fewer months were required for each subsequent step (Williams, 1997).

In summary, previous research findings support the effectiveness of numerous best practices, and these practices appear to reflect both the activities engaged in NPD, the project management and organizational structure supporting NPD, and the maturity of the NPD process (see Figure 1). We therefore put forth the following propositions.

P9: Best practices in goals will positively affect NPD process and product outcomes.

P10: Best practices in metrics will positively affect NPD process and product outcomes.

P11: Best practices in project management will positively affect NPD process and product outcomes.

P12: Best practices in organizational context will positively affect NPD process and product outcomes.

P13: Best practices in maturity will positively affect NPD process and product outcomes.

Best practices are not always effective in every domain they are implemented. For example, Gupta et al. (1987) found that the need for integration between marketing and R&D increased as a function of aggressiveness of strategy for NPD and the perceived uncertainty of the environment. Olson et al. (1995) found that the participativeness of the design team was contextually linked to the relative level of product newness. The Boston Consulting Group (1993) found that not all best practices were differentiators of performance. In general, across different problem areas, it is being discovered that a "best practice" in one context can be ineffective in another--domain matters (Ernst & Young, 1992). Issues such as domain type, uncertainty, complexity, and restrictiveness (Van de Ven, 1980) may play a role in determining whether a best practice is effective. We therefore put forth the following propositions:

P14: The impact of best practices (as identified in P1-P13) may be contingent upon industry type, customer type, or market volatility.

The next section describes how these propositions were operationalized and tested.

3. Research Method

Product and process performance was measured using perceptual scales (many of the items were adapted from scales developed by Olson et al., 1995). While this introduces some error in measuring performance, the problems of comparing actual performance data across very different industries necessitates the use of a relative rather than absolute scale.

Standard survey analysis was performed (DeVellis, 1991). Pilot testing narrowed the number of best practices down to 98; therefore the survey consisted of 98 items on best practices (including maturity) 16 items on NPD performance, and several demographic questions. Respondents were asked to focus on the program rather than project level. Roughly this meant that a response of “0” meant that the best practice was not used anywhere in the organization, and a response of “5” meant that the best practice was used on all development projects (within a time frame of the last two years). One item was discarded because less than 50% of the respondents correctly completed the item and another because of a printing problem.

A population of organizations was constructed using personal contacts from the researchers, with equal representation from the commercial and industrial sectors. Requests for participation were also posted in various electronic forums. A total of 39 organizational respondents were generated, from an original mailing of 250, for a response rate of 16%. Six of the 39 firms had revenues in the range of $1-10 million; 10 had revenues in the range of $10-100 million; and 23 had revenues over $100 million. Thirty of the 39 considered themselves to be in the top one-third of the market, in terms of market share. Two-thirds of the firms had one at least one quality award (state, national, supplier) for their quality performance. Two-thirds of the firms were ISO 9000 certified, and an equal amount considered themselves to be in markets that could be described as "volatile and growing". No formal analysis of non-respondents was performed;

informal analysis of non-respondent demographics demonstrated no difference with the respondents. Each survey was completed (typically) by a single individual, most often the VP or Director of Engineering or Marketing.

Single respondent problems exist (DeVellis, 1991). In order to formally test whether the singular responses would have an influence on subsequent data analysis, two organizations were asked to have five individuals complete the survey. Analysis of variance was then performed, and it showed that the variation of (average) scores between organizations was significantly greater than the variation between respondents in a single organization.

4. Adoption Rates and Patterns

Figure 2 shows a histogram of the 98 best practices in terms of their overall adoption rate across all organizations within the sample. For example, only 3 best practices had an average adoption rate of less than 1.0 (0=no adoption, 5=full adoption within the organization). For discussion purposes we have highlighted both ends of the distribution in Table 2: those best practices with an average adoption rate of less than 1.0 and those with an average adoption rate of over 3.5. One can see that multiple channels for customer requirement identification are being extensively used, product and process specifications are typically documented, and project activities are typically planned with some notion of concurrency. Conversely, we can see that organizations have not widely adopted product reuse strategies, external facilitators for teams, or unconstrained examination of product concepts.

--insert Figure 2--

--insert Table 2--

Table 3 shows the rate of adoption of best practices bundled according to the original categories. The data shows that reported NPD performance, in terms product success, process success, and process improvement was about average (2.5 on a 5 point scale), and that overall adoption of all the best practices was about 48% (2.41 on a 5 point scale, where 5 means 100% adoption). Averaged across all firms, the rate of adoption across the different best practice categories does not vary that much (40-60% adoption). Best practices within the categories of product strategy, detailed design, and goals achieved an adoption rate of about 58%, while best practices within the categories of product disposal, concept generation, concept screening, and concept design achieved an adoption rate of about 36%. This matches evidence presented in other studies, especially that firms were not doing well in the "fuzzy front end". At the level of the individual organization, however, wide differences exist. In any particular best practice category one can find adoption rates for at least one firm as low as nil and as high as 90%.

--insert Table 3--

In order to better understand how organizations clustered or bundled the adoption (or non-adoption) of multiple best practices simultaneously, the items corresponding to a best practice category were treated as a psychometric measurement scale, and scale reliability and factor analysis were used. Not enough data was present to perform factor analysis on all the items simultaneously, so the initial categories were used as a priori "constructs" or bundlings, and subsequent analysis sought to confirm whether these sets of best practices indeed covaried in a strong manner. Factor analysis and Cronbach's alpha were used iteratively to determine reasonable bundlings. Factor analysis (with a varimax rotation) was used to confirm the unidimensionality of the initial bundling. Items were eliminated, and in some cases categories combined, in order to increase reliability and unidimensionality. In determining significant loadings from factor analysis, an absolute cut-off value of 0.40 was used, although the data shows that almost all loadings were quite a bit higher than that. In the case of one category—organizational context—items were disbursed into other categories through a process of trial and error. Three different researchers participated in the analysis so as to ensure that such changes had face validity. Cronbach's alpha was calculated as a measure of scale reliability. All of the alpha's were above 0.60, which is considered minimal for a new scale; 10 of the 14 were above 0.70, which is considered good (DeVellis, 1991).

Please note that there was no a priori assumption that the "category scales" we put together would indeed hold together as unidimensional, theoretical constructs. Each category (e.g. detailed design) consisted of an inventory of different best practices that happened to be coincident in the phase of NPD in which they are typically implemented. For example, the category of *detailed design* consisted of the best practices *of suppliers are selected based on a formal supplier certification program* and *materials are selected based on formal engineering analysis* (amongst others). If such an inventory for a single category exhibits the characteristics of a unidimensional and reliable scale, then it may imply that organizations are indeed implementing sets or collections of best practices related to one another by their place in the NPD life cycle. On the other hand, new categories (constructs) that emerge indicate different ways in which organizations are bundling the implementation of best practices.

A summary of the final bundlings (constructs) is shown in Table 4. Scale reliability is shown in parentheses next to the construct title, and factor loadings for each individual item are shown in parentheses next to the item. NPD performance outcomes broke out into three scales, product success, project success, continuous quality improvement, and a single item, cycle time improvement. Maturity and project management were broken into three constructs, documentation, change control, and process management, and several items originally in that category were added to the goals and metrics constructs. Concept generation, selection, and screening collapsed into a single construct, concept design, and the category of product strategy was broken into two constructs, product strategy and project selection. Finally, three additional constructs--customer involvement, technological leadership, and human resource development--emerged from the analysis.

--insert Table 4--

Analysis of these new categories shows that firms in general do not implement bundles of best practices according to their place within the stage-gate process; the one exception to this was conceptual design. Rather, firms appear to bundle (and adopt) best practices together according to their role in either strategically supporting the development process (technological leadership, human resource development), determining the specific opportunity to engage with (product strategy, project selection), involving the customer throughout the process (customer involvement), and overall organizational control of NPD activities (documentation, change control, goals, metrics, and process control).

Table 5 shows the rate of adoption of best practices bundled according to the new categories (constructs). An interesting pattern emerges from analysis of the construct (best practice) areas ranked by adoption rate. First, best practices associated with enhancing the human resources involved in NPD, and improving the fuzzy front end of NPD appear to be getting little attention to date, despite a strong call for such attention in the management literature (e.g. Cooper, 1993; Khurana and Rosenthal, 1995; Leonard-Barton, 1995). Second, there appears to be a natural clustering (although not statistically significant per se) of best practices associated with the strategic implementation of NPD versus the control of NPD. Best practices associated with the strategic implementation of NPD (project selection, goals, technological leadership, product strategy, and customer involvement) are on average all more widely adopted than best practices associated with controlling the execution of NPD (process control, metrics, documentation, change control). In this study firms have shown more interest in adopting best practices associated with the "big picture" of NPD versus best practices associated with the detailed execution of NPD. Of course part of this may be the result of a sampling issue—strategically oriented best practices may have more wide spread relevance than tactically oriented best practices.

--insert Table 5--

Finally, correlation analysis was performed to see if any of the demographic factors—firm size, market volatility, market type—had any effect on adoption rates across any of the categories. No contingencies were found.

5. Best Practices and NPD Performance

In order to examine whether specific best practices (rather than bundles of best practices) had any effect on specific NPD outcomes, correlation analysis was used. What is shown in Table 6 are those individual best practices that had significant correlation with at least three individual outcome-related (performance) items. While one needs to be cautious because of spurious results and single-item measurement problems, the results nevertheless can be interpreted in a broad manner. Collectively, the individual best practices seem to highlight the importance of NPD planning and project management.

--insert Table 6--

Standard linear regression was used to determine the importance of best practice categories and possible contingencies with demographic variables. In order to better capture some of the variance in the model, four different "single item" variables (individual best practices that were significantly correlated with outcome performance, as identified in Table 6, but did not get bundled into a larger category of best practices) were also included in the modeling. Forward regression was used, and both the parameter associated with the best practice category as well as the model itself had to have a significance level less than 0.05. Results are recorded in Table 7. The percent of variance explained by the models, r^2-corrected, ranged from nil to 54%.

--insert Table 7--

No factors were significant in predicting continuous quality improvement. This is perhaps because of a mismatch in question type. While the best practice items, and the items associated with performance focus on some relative level over a fixed period of time, the items associated with continuous quality improvement were focused on changes in relative levels over a fixed period of time. Another possible explanation is that organizational leadership, which was not explicitly addressed in the survey, drives this outcome.

The best practice categories of project selection, process control, and conceptual design, coupled with the individual best practice of concurrency in project activities predicted product success with an r^2-corrected of 24%. Interestingly the relationship between process control and product success was negative. The positive effect of concurrency in project activities on product success is only slightly surprising; while Eisenhart and Brown (1995) found that many studies found support for concurrency and process success, this result goes one step further to link it to product success. The positive relationship with conceptual design implies that best practices associated with the initial product concept are important in influencing market success. The positive relationship with project selection implies those firms that do better at screening out poor ideas will tend to have better outcomes at the other end of the process. Collectively these two findings suggest that product success is in part a function of coming up with good product concepts and ensuring that one does not spend organizational effort on poor product concepts. The negative relationship between process control and product success is more difficult to explain. This may be a spurious relationship; or it may indicate that firms implementing process control coincidentally, in this study, also happen to be less creative in their product designs.

The best practice category of process control, coupled with the individual best practices of concurrency in project activities and group rewards predicted project success with an r^2-corrected of 54%. The finding that best practices associated with process control (which could have also been labeled "project management") positively influence project success further validates the empirical studies based on the SEI CMM that highlight the positive effect of process maturity on project success, and that process maturity is in large part a function of project management activities. The positive relationship between concurrency and project success validates Brown and Eisenhardt's (1995) findings, while the importance of team cohesion is highlighted by the positive relationship with group rewards.

Finally, the individual best practice of "Lessons Learned" (project post-mortems) predicted cycle time improvement with an r^2-corrected of 10%. This form of performance feedback and learning has proven to have some success.

The results can be summarized as follows:

Product success depends on developing strong product concepts and ensuring organizational focus on those concepts through project selection. Concurrency in project activities enhances both product and project success. Project success also depends on controlling the NPD process via project management, and ensuring team cohesion with group rewards. Sharing lessons-learned between projects can positively influence cycle time improvement in the NPD process.

6. Summary

A survey of 39 organizations demonstrated that organizations are implementing NPD best practices in varying frequency, that certain best practices are being bundled together and implemented simultaneously, and that certain best practices appear to positively influence the outcomes of the NPD process. It would appear that there might be a mismatch between the best practices that firms are implementing, and those best practices that would give them the most leverage in terms of product and process success. Leonard-Barton (1995) and others have advocated the need to develop the human resources involved in NPD; many of the NPD successes and failures at Microsoft, for example, can be attributed to the human resource practices being followed (Cusumano and Shelby, 1995). Yet industry does not appear to be making much headway in implementing best practices that will enhance the NPD workforce. Likewise, numerous studies (Khurana and Rosenthal, 1997) including this one have highlighted the importance of doing better at the "fuzzy front end" of the development process, and yet best practices in this area are not widely adopted. Similarly, this study showed that while firms have focused most of their energy towards adopting best practices associated with the strategic implementation of NPD (project selection, goals, technological leadership, product strategy, and customer involvement), these areas are not as significant in influencing NPD performance as best practices associated with controlling the execution of NPD (process control, metrics, documentation, change control).

Several caveats accompany the results here. The statistical analysis shows that the reliability of the constructs is good, and the regression results have adequate r^2 values to conclude that the effects observed are real. There are several shortcomings in the measurement system however. First, because only single respondents were used, bias in the results exists. Secondly, because outcomes are measured perceptually, not only is there error in the judgement process, but "aspirations" tend to reduce the variance of the numbers reported. Namely, low performers will tend to have low aspirations and over-score themselves; and high performers will tend to have high aspirations and under-judge themselves. This leads to a set of responses all around "3.0", which makes it very difficult subsequently to determine significant effects. Finally, the sample size (n=39) is relatively small, although it was large enough to enable a demonstration of statistical significance in both the models and their parameters.

Methodologically, future work should address the multiple respondent issues, project – level data collection and analysis, and a larger sample size. It would appear that more value would be gained by focusing research efforts at the level of the individual firm—why do they bundle together best practices in particular ways and implement them simultaneously, how do they determine which best practices to implement, and how do they gain synergies through such simultaneous implmentation?

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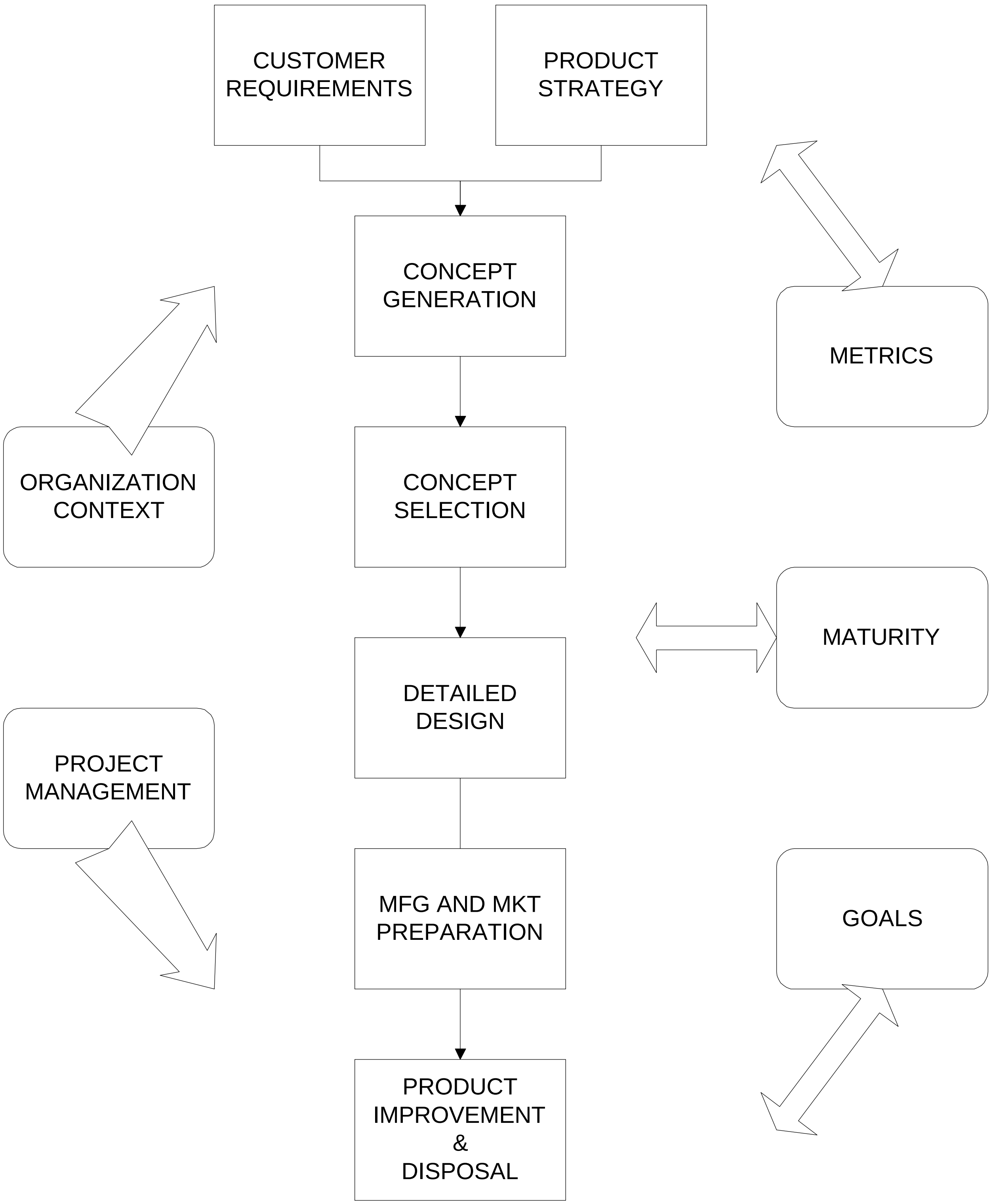

Figure 1 A Structural Model of NPD Best Practices

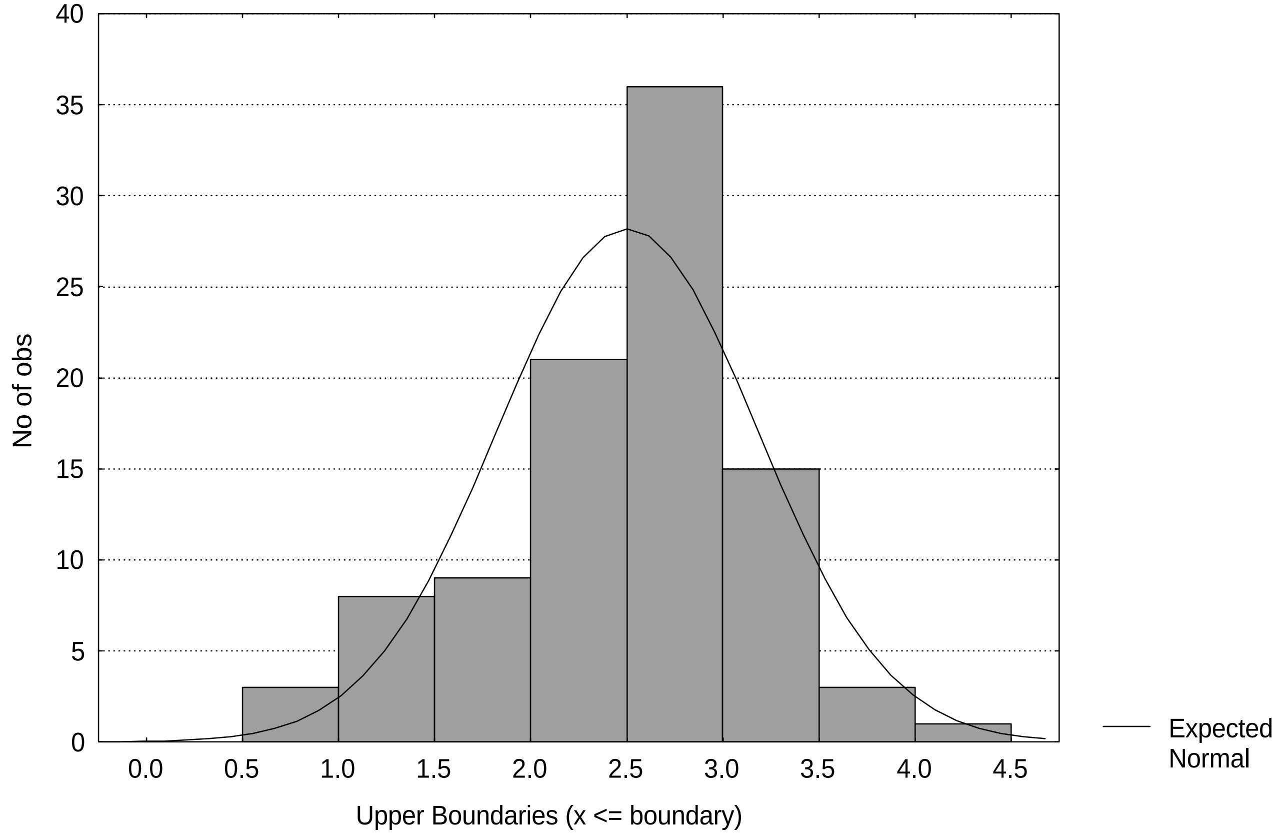

Figure 2 Histogram Depicting the Average Adoption Rate of 98 Different Best Practices (Adoption Rate averaged across 39 firms; 5=fully adopted)

Table 1 Best Practices in New Product Development

Customer Requirements: How potential customers requirements are identified, defined and changed.

- Customer needs are identified via multiple sources of information.
- Product requirements are solicited, consolidated & fed back to potential customers.
- Product requirements are documented and subject to formal change control.
- Product requirements are allowed to change only during the early stages of design.
- Decisions on changes to product requirements are based on assessment of multiple predefined criteria.
- During requirements definition, potential customers are involved continuously and interactively.
- Demographic changes in our marketplace are continuously investigated and forecasted.

Product Strategy: How new product development is aligned with internal constraints and with external factors like regulations and competition.

- Projects are initiated through a process involving multiple functional areas.
- Projects are terminated through a formal decision making process.
- Project priorities are updated periodically through a systematic process.
- Project funding is primarily based on potential business contribution to the company.
- New opportunities are most often put through a formal process to determine priorities.
- Company constraints are incorporated into established division "Design Rules".
- Product strategy is used by departments to collectively align priorities with other departments.
- Development projects are categorized and matched with appropriate existing NPD processes.
- NPD plans are most influenced by informed planning activities (e.g. SWOT, forecasting...).
- Regulatory compliance is handled through design guidelines that anticipate compliance challenges.
- Market research is used as input into design decision making.
- NPD plans are most influenced by analyses of overall value to potential customers.

Concept Generation: How candidate concepts for new products are generated or acquired.

- New product concepts are generated jointly by employees, customers and suppliers.
- New product concepts are based on anticipated industry technological capabilities.
- New product concepts are explored in an unconstrained manner.

Concept Selection: How candidate product concepts are screened and concepts selected for further development.

- Concepts are selected using multiple, explicit criteria.
- Concept selection is based on simultaneous evaluation of multiple concepts.
- Concept selection occurs after manufacturability issues have been addressed.
- Agreement on concept selection is in the form of explicit (documented) buy in from all departments.

Concept Design: how the selected concept is designed at a high level.

- Concepts are designed to optimize product performance through its life cycle.
- Technological risks are managed by completing essential inventions before development.
- Risk analysis is performed to proactively determine project priorities.
- Concepts are documented and are subject to formal change control.

Detail Design & Redesign: How product details, materials, dimensions are specified.

- Product performance is verified by testing of prototypes by customers.
- Detail design decisions are made by employees with input from customers and suppliers.
- Suppliers are selected based on a formal supplier certification program.
- Materials are selected based on formal engineering analysis.
- Target specifications are set to minimize problems over the entire product life cycle.
- Documentation describes the product and its production processes.
- Formal Change Control begins at the concept stage.

Table 1, continued

Manufacturing and Launch Preparations: How manufacturing processes are developed and channels to get the product to the customer are established.

- Production processes are developed using off-line pilot production lines.
- Transition to production occurs through early product and process integration.
- Product launch plan is based on forecast of market demand.
- Products are launched when service, sales and distribution channels are ready.
- Product performance is evaluated through field-testing.
- Market receptivity is evaluated by key customer feedback prior to launch.
- The decision to launch is automatic, once all the preparations are complete.

Product Improvement and Disposal: How product defects are identified, improvements made, and how products are disposed of at the end of life.

- Product improvements/redesigns occur because improvement ideas from customers are solicited.
- At the end of product useful life it can be returned and/or reused in other products.

Goals: The quantified objectives of performance for the new product development system and its products.

- Project goals are supported by documented resource commitments.
- Project objectives include economic, market and product outcomes.
- Project objectives emphasize delighting customers.
- Program (a collection of projects) goals are primarily economic criteria based.

Metrics: The quantified measures of performance for the new product development system and its products.

- We track financial investments in individual projects.
- We track project schedule slippage on a continuous basis.
- We track lead times for specific project steps.
- Program metrics includes the number and type of design projects at various stages.
- We track the number of changes (of any type) in each project phase.
- We compare our project performance with the best in class.
- Metrics are used to improve the NPD process.

Project Management: How project participants are organized and situated to perform competent work on projects.

- Accountability for managing a project is shared by everyone involved in the project.
- Project responsibilities are determined jointly by project members.
- Project planning emphasizes prevention of problems in projects.
- Project management activities emphasize proactively limiting schedule slippage.
- Project members are organized around product families.
- Suppliers and/or Customers (for OEM's) assign their people to participate in projects.
- Project activities show considerable overlap and collaboration.
- Project members communicate freely and continuously.
- Project members are physically/virtually colocated for the project duration.
- Group achievements and individual achievements are equally important.
- Teams facilitation is provided through an external facilitator.
- Teamwork training is required of team members.

Table 1, continued

Organizational Context: The supporting systems that enable competent work on projects.

- Senior managers focus on defining a general new product strategy.
- Senior managers review projects on a relatively continuous basis.
- Senior managers convey that good NPD processes are essential to gain competitive advantage.
- The technical strategy of the company is defined and known throughout the organization.
- Technologies are proactively developed to gain competitive advantage.
- Technological changes in the industry are actively driven by our R&D efforts.
- Performance evaluations are based on peer reviews.
- Rewards are based on both individual and group achievements.
- Employees build their project skills through interaction with mentors and facilitators.
- Career development programs include external assignments.
- A single product database is the source of data for several disciplines and tool sets.
- The "Information Systems" department is directed to provide a competitive advantage.
- Computer based tools like CAD/CAM are used widely by everyone involved.
- Information Systems are operated and maintained jointly by IS people and users.
- Individuals can get appropriate training easily, as and when required.
- External communications are maintained by all employees, with suppliers and industry groups.

Maturity: The extent to which a process has knowledge of itself and takes action on that knowledge.

- New products are developed using processes that are explicitly documented.
- Improving the NPD process is the responsibility of all project teams.
- Improvement of the NPD process occurs through "Lessons Learned" disseminated across projects.
- Process learning occurs through exchange of process data and analyses of other projects.
- We want to establish a goal-driven, structured and monitored NPD process.
- We try to prevent problems from occurring.
- We try to control the development process through data on intermediate steps from multiple projects.
- Development process outcomes agree well with predicted expectations.
- Development process goals include anticipating product life cycle challenges.
- Process metrics are aligned with management goals for the NPD process.
- Development process metrics are quantitative.
- We have been collecting process data for a while.

Table 2 Most Widely and Least Widely Adopted Best Practices

Best Practice	*Adoption Score**
<u>Most Widely Adopted</u>	
We try to prevent problems from occurring.	4.01
Customer needs are identified via multiple sources of information.	3.71
Project activities show considerable overlap and collaboration.	3.71
Documentation describes the product and its production processes.	3.56
Project funding is primarily based on potential business contribution.	3.50
<u>Least Widely Adopted</u>	
At the end of useful life products can be returned or reused.	0.99
Team facilitation is provided through an external facilitator.	0.94
New product concepts are explored in an unconstrained manner.	0.78

* Adoption Score ranges from 0 to 5. Each individual organization stated the degree of adoption within the firm, where 0 corresponded to no adoption and 5 to across-the-board adoption. The numbers shown above represent the average of these responses across the 39 participating organizations.

Table 3 Summary Adoption Scores for Original Best Practices Categories (1-5 scale, 5=100% diffused)

	Average	Low	High
Outcomes			
Product Success	2.58	1.50	3.75
Process Success	2.58	1.50	3.75
Process Improvement	2.72	1.00	3.75
Best Practices			
Product Disposal	1.82	0.00	4.50
Concept Design	1.90	0.00	3.50
Concept Generation	1.95	0.00	4.67
Concept Selection	2.29	0.50	4.50
Project Management	2.35	0.92	3.42
Customer Requirements	2.45	0.71	4.43
Metrics	2.45	0.43	3.86
Organizational Context	2.48	0.87	3.80
Manufacturing Preparations	2.58	0.86	3.86
Maturity	2.68	0.46	4.15
Detailed Design	2.72	0.67	4.67
Product Strategy	2.81	1.00	4.08
Goals	2.90	0.00	4.50
Average Score—Best Practices	2.41	1.23	3.45

Table 4 Final Constructs and Associated Reliability
(factor loadings shown in parentheses with the item;
Cronbach alpha shown in parenthesis with the construct)

Continuous Quality Improvement (.73)

R6 Our new products were introduced before the competition (.75)
R12 We improved the quality of our new products (.86)
R13 We improved the success rate of our new products (.68)

Product Success (.67)

R1 Our new products meet profitability targets (.76)
R2 Our new products capture significant market share (.55)
R3 Our new products generate significant revenue growth (.60)
R4 Our new products provide unique benefits to our customers (.73)

Project Success (.79)

R9 Our projects were on schedule (.89)
R10 Our projects were within budget (.87)
V93 Project outcomes agree well with predicted expectations (.82)

Cycle Time Improvement

R11 We reduced our NPD cycle time

Customer Involvement (.72)

V2 Product requirements are solicited consolidated & fedback to potential customers (.64)
V6 During requirements definition, potential customers are involved continuously and interactively (.77)
V19 NPD plans are most influenced by analyses of overall value to potential customers (.55)
V20 New product concepts are generated jointly by employees, customers and suppliers (.44)
V31 Product performance is verified by testing of prototypes by customers (.61)
V43 Market receptivity is evaluated by key customer feedback prior to launch (.68)
V45 Product improvements/redesigns occur because improvement ideas from customers are solicited (.58)

Project Selection (.76)

V8 Projects are initiated through a process involving multiple functional areas (.77)
V10 Project priorities are updated periodically through a systematic process (.70)
V12 New opportunities are most often put through a formal process to determine priorities (.77)
V16 NPD plans are most influenced by informed planning activities (e.g. SWOT, forecasting...) (.80)

Product Strategy (.74)

V14 Product strategy is used by departments to collectively align priorities with other departments (.85)

V17 Regulatory compliance is handled through design guidelines that anticipate compliance challenges (.70)
V18 Market research is used as input into design decision making (.72)
V73 The technical strategy of the company is defined and known throughout the organization (.75)

Concept Design (.71)
V21 New product concepts are based on anticipated industry technological capabilities (.64)
V22 New product concepts are explored in an unconstrained manner (.58)
V23 Concepts are selected using multiple, explicit criteria (.56)
V24 Concept selection is based on simultaneous evaluation of multiple concepts (.70)
V25 Concept selection occurs after manufacturability issues have been addressed (.67)
V27 Concepts are designed to optimize product performance through its life cycle (.70)

Tech Leadership (r=.60)
V74 Technologies are proactively developed to gain competitive advantage
V75 Technological changes in the industry are actively driven by our R&D efforts

Documentation (.76)
V3 Product requirements are documented and subject to formal change control (.76)
V26 Agreement on concept selection is in the form of explicit (documented) buy in from all departments (.69)
V29 Risk analysis is performed to proactively determine project priorities (.61)
V30 Concepts are documented and are subject to formal change control (.86)

Change Control (.65)
V4 Product requirements are allowed to change only during the early stages of design. (.80)
V5 Decisions on changes to product requirements are based on assessment of multiple predefined criteria. (.56)
V37 Formal Change Control begins at the concept stage. (.73)
V55 We track the number of changes (of any type) in each project phase. (.70)

Goals (.66)
V47 Project goals are supported by documented resource commitments (.73)
V48 Project objectives include economic, market and product outcomes (.76)
V50 Program (a collection of projects) goals are primarily economic criteria based (.82)

Metrics (.70)
V96 Process metrics are aligned with management goals for the NPD process (.68)
V97 Development process metrics are quantitative (.91)
V98 We have been collecting process data for a while (.79)

Process Control (.87)
V33 Suppliers are selected based on a formal supplier certification program (.80)
V36 Documentation describes the product and its production processes (.65)
V39 Transition to production occurs through early product and process integration (.56)

V52 We track project schedule slippage on a continuous basis (.66)
V57 Metrics are used to improve the NPD process (.77)
V60 Project planning emphasizes prevention of problems in projects (.64)
V61 Project management activities emphasize proactively limiting schedule slippage (.79)
V86 New products are developed using processes that are explicitly documented (.66)
V89 Process learning occurs through exchange of process data and analyses of other projects (.64)
V92 We try to control the development process through data on intermediate steps from multiple projects (.58)

Human Resource Development (.72)
V69 Teamwork training is required of team members (.84)
V79 Career development programs include external assignments (.83)
V95 Development process goals emphasize building up new development competencies (.75)

Table 5 Summary Adoption Scores for New Best Practices Categories (1-5 scale, 5=100% diffused)

	Average	Low	High
Outcomes			
Product Success	3.60	2.50	4.75
Project Success	2.94	1.00	4.33
Continuous Quality Improvement	3.50	1.67	4.67
Cycle Time Improvement	3.63	2.00	5.00
Best Practices			
Human Resource Development	1.72	0.00	4.33
Concept Design	1.96	0.00	4.16
Change Control	1.98	0.00	5.00
Documentation	2.18	0.00	5.00
Metrics	2.40	0.00	5.00
Process Control	2.67	0.00	4.30
Customer Involvement	2.67	0.86	4.57
Product Strategy	2.70	0.00	5.00
Technological Leadership	2.79	0.00	5.00
Goals	3.05	0.00	5.00
Project Selection	3.16	0.00	5.00

Table 6

More Performance Items*

V1	on.
V8	
V16	NPD plans are most influenced by informed planning activities.
	NPD plans are most influenced by analyses of overall value to customers.
V57	rove the NPD process.
V61	
V64	Project activities show considerable overlap and collaboration.
	Project members communicate freely and continuously.
V67	d individual achievements are equally important.
V88	
	across projects.
V92	
	from multiple projects.

* a correlation of .30 or above was statistically significant at p<0.05

Table 7 Results from Regression Analysis

Product Success (adjusted r^2=0.24)

Factor	Beta	p-value
Project selection	0.32	0.05
Process control	-0.41	0.02
Conceptual design	0.44	0.01
Project concurrency	0.34	0.04

Project Success (adjusted r^2=0.54)

Factor	Beta	p-value
Process control	0.44	0.00
Team Awards	0.28	0.02
Project concurrency	0.33	0.01

Product Success (adjusted r^2=0.10)

Factor	Beta	p-value
Disseminate lessons learned	0.36	0.025