PRODUCT DEVELOPMENT PRACTICES THAT MATTER

By

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This thesis is dedicated to my parents, Alpana and Rajesh Gupta
Product Development Practices that Matter

by

Nisheeth Gupta

Submitted to the Engineering Systems Division
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Masters of Management and Engineering
at the
Massachusetts Institute of Technology

Abstract

Product Development consists of activities to transforms a market opportunity and technological innovation into successful products. Several waves of improvements in technological innovation and product development have already substantially enhanced companies' ability to deliver differentiated products to markets faster, more efficiently, and with higher quality. However, the degree of success achieved has varied greatly between companies and even among units within individual companies. Determining important processes in the product development and their relationships with organizational and project performance are crucial to sustainable success in product development. Studying these relationships would give us insights into the product development dynamics. The objectives of this research are to determine important product development processes and their relationship with each other and organizational capabilities.

To achieve the objectives of this research, a step-based approach was adopted. First, understand relationship between processes and firm's actual financials such as Sales, R&D Expenditure, and COGS. Second, identify relationship between processes and self-reported performance on Financials, Operational Effectiveness, Product Performance, and Customer Satisfaction. Third, identify relationship among different performance parameters to unearth indirect impact of processes on performance. In each step, processes were studied at three levels. Processes were combined based on our classification and the way they statistically cluster. Research used Linear Regression Analysis, ANOVA Analysis, Principal Component Analysis, and Cluster Analysis. Fourth, test four hypotheses based on statistics. The work in this thesis illustrates how various product development practices may influence performance measures of organization. While we focused on companies in the Automotive, Hi-Tech and Medical-device industries, I believe that product makers of all stripes could benefit from this work.

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Acknowledgement

While this thesis bears the name of one author, it is truly the combined effort of many. Because it is impossible to acknowledge all by name, I would like to say a huge thank you to everyone who contributed to this work. Additionally, I would like to recognize the following people to whom I am especially grateful.

For the completion of thesis, I owe great debts to my research advisors Professor Warren Seering and Dr. Eric Rebentisch. They guided me through the entire research process and methodology. In the process of this work, I learned from them how to think with an open mind from all possible angles and dare to question everything. I will benefit from these lessons all my life.

To everyone at McKinsey & Co. who made this project not only possible, but also a lot of fun! With special thanks to Michael Gordon, Chris Musso, Christie Barrett, Ben Mathews, Jochen Linck, and Rekha Ranganathan.

I also want to extend my thanks to all my friends and colleagues who give me much encouragement and advice during my work. Thanks for helping me learn so many other things which made the past two years more than an academic journey, but a portion of a life’s journey.

To my family, especially my parents, for everything.
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1 Introduction and Overview

In this chapter, I introduce this study of product development that has a goal to understand the relationship among an array of product development and management practices and market outcomes. The research includes organizations from around the world in a variety of business sectors.

Section 1.1 provides the motivation behind the study. Section 1.2 defines product development in detail. Section 1.3 outlines the role of this thesis in the on-going dialogue, section 1.4 discusses the hypothesis and section 1.5 introduces each of the eight chapters.

1.1 Motivation

The link between Product Development (PD) performance and PD practices is an ongoing pursuit for the academic and business communities. The challenges of the 21st Century business environment force a poignant question: “What are the key levers that have direct impact on product development performance?” Having experienced practical challenges in two large firms before coming to MIT, I did feel the need of new form of analysis to make robust, appropriate and effective product development functions. One that will allow companies to identify exactly which levers will achieve maximum impact on product development performance. My personal interest and an opportunity to advance the understanding of product development motivated me to be a part of this research.

1.2 Definition of Product Development

Product development is a creative and interdisciplinary activity that transforms a market opportunity and technological innovation into successful products. Product development is not only a major activity in the lift of a product-oriented enterprise, but also essential to the economic success of such organization. Product development processes are organized in a way that required participation by virtually all the major functions within the organization such as strategic planning, marketing, product design, manufacturing and financial planning and budgeting. It also involves interactions with stakeholders such as customers and suppliers that are outside of the organization.

Ulrich and Eppinger (2004) define product development as a process that starts with product planning and ends with production ramp-up, as shown in
According to Ulrich et al. (2004), product planning involves an assessment of the strategy, technology and marketing objectives of the company producing the product. The concept development phase involves identification of technical possibilities and market needs, creation of product concepts, and evaluation of those concepts against the market needs. The architecture is created during the system design phase, and competing objectives are reconciled and early prototypes created for industrial designers. This phase is followed by the detail design phase where the parts’ specifications, such as weight, mass, and materials, are specified. Detail design is followed by testing and refinement of prototypes and pre-production versions of the product. In the production ramp-up phase, the product is produced as ready for market but with the intention of fine-tuning the production system and training the workforce.

1.3 How thesis fits in dialogue

The product concept, along with its product strategy, and the firm’s business situation is assumed to affect the choice of development process such as concurrent engineering (Pawar and Riedel, 1994), customer involvement (Souder et al., 1997), supplier involvement (Cusumano and Taeishi, 1991), heavyweight manager (Clark and Fujimoto, 1990), senior management support (Cooper and Kleinschmidt, 1987), and stage-gate reviews (Cooper and Kleinschmidt, 1990). These process choices may affect overall project performance directly, or indirectly, through process performance. Product development literature has focused on the relationship between product development process and outcomes (Koufteros et al., 1998; Terwiesh and Loch, 1999), but not on process performance. Thus, the product development literature implicitly assumes only a direct path from process choices to overall project performance. Process performance is a key missing link (Ahmad Syamil et al., 2004).
In this dissertation I will try to identify key product development process through statistical analysis between process performance and project performance as well as corporate performance. I will also test a set of hypothesis and mini-hypothesis based on statistical analysis.

We will consider product development process performance in 4 categories: strategy, smart product design & development, smooth integration across value chain, and superior capabilities.

### 1.4 Hypothesis

Below is the list of hypothesis and corresponding mini-hypothesis that we will test in our research.

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Mini Hypothesis</th>
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<tbody>
<tr>
<td>Product development pays.</td>
<td>(1)Companies with strong PD practices grow faster than those with average or weak practices</td>
</tr>
<tr>
<td>High performers grow faster, especially organic growth and</td>
<td>(2)Companies with strong PD practices launch products with higher product margins than those with average or weak practices</td>
</tr>
<tr>
<td>generate healthier product margins and spend less on R&amp;D</td>
<td>(3)Companies with strong PD practices spend less on R&amp;D than those with average or weak practices</td>
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<tr>
<td>Companies with continuous improvement systems in PD execution and product quality practices realize lower costs levels (i.e. unit costs)</td>
<td>(1)Companies with continuous improvement systems in PD execution practices realize lower R&amp;D cost levels than those w/o such systems</td>
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<tr>
<td></td>
<td>(2)Companies with continuous improvement systems in product quality practices realize lower unit cost levels than those w/o such systems</td>
</tr>
<tr>
<td>Companies that use customer and competitive inputs into PD accomplish product launches with better price-</td>
<td>(1)Companies with strong customer insight practices accomplish product launches with better price-value satisfaction than companies that do not take customer insights into account</td>
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value satisfaction and higher product volumes and revenues

| People development practices such as recruiting and maintaining high levels of PD talent impact all major performance results | (1) People with strong people development practices (such as hiring and developing talent) spend less in R&D than those with avg. or weak practices
| (2) People with strong people development practices (such as hiring and developing talent) launch products with lower unit costs than those with avg. or weak practices |

| Customer insights are critical to determining which projects to kill or accelerate therefore optimizes portfolio management practices | Customer insights are critical to determining which projects to kill or accelerate therefore optimizes portfolio management practices |

1.5 **Description of thesis document**

The dissertation is organized into seven chapters sandwiched between an introduction and a conclusion.

Chapter 2 discusses literature analysis and review. Literature is reviewed from both academic and commercial sources. This chapter also provides overview of literature analysis from lenses of hypothesis.

Chapter 3 provides an understanding of research design and database characteristics. It also discusses data collection methodology. It also discusses how respondents were identified.

Chapter 4 jumps into details of data handling. It discusses nature of variable, scale of variables, steps involved in data cleaning, and information on statistical tests.

Chapter 5 presents and discusses statistical analysis results based on actual financials of the firms.

Chapter 6 covers discussion on various statistical analysis based on self-assessed performance.

Chapter 7 proves or disproves hypothesis based on analysis presented in chapter 5 and 6.

Finally, Chapter 8 summarizes the entire study, and suggests areas for further research.
1.6 References


2 Literature Analysis

The objective of literature review is to capture the essence of past research work in product development. A total of 14 papers specific to hypothesis have been reviewed in depth in this research. Reviewed papers are both from academic and commercial source.

2.1 Methodology of Literature Analysis

Each paper was searched and reviewed in a methodological manner. Table below discusses steps of literature analysis.

<table>
<thead>
<tr>
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<th>Output</th>
<th>Time</th>
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<tr>
<td>• Search &amp; fetch relevant paper</td>
<td>• List of ~ 0-12 papers to read</td>
<td>~5 Hours</td>
</tr>
<tr>
<td>• In depth analysis of identified papers</td>
<td>• List of insights in PD</td>
<td>~8 to 10 Hours</td>
</tr>
<tr>
<td>• Collective analysis of insights</td>
<td>• List of insights that we might be able to refute</td>
<td>~1 Hour</td>
</tr>
<tr>
<td></td>
<td>• Identify gaps in insights</td>
<td></td>
</tr>
<tr>
<td>• Verify that no one else has refuted insight or</td>
<td>• Confirm literature analysis gaps or possibility to</td>
<td>~2 Hours</td>
</tr>
<tr>
<td>addressed identified gaps</td>
<td>• possibility to refute an insight</td>
<td></td>
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<td>~14 to 21 Hours</td>
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2.2 Journals referred

Papers from both academic and commercial sources were studied. Below is the partial list of journals we referred to in our literature analysis.

Academic Journals

- Journal of Marketing
- Journal of Accounting Research
- Marketing Science
- Journal of Service Research
- Strategic Management Research
Bain & Company Newsletter
IEEE

Commercial Articles

- Accenture
- American Productivity & Quality Center
- Boston Consulting Group
- Booz Allen
- Deloitte
- Management Roundtable
- NIST
- PRTM
- UK Dept. for Business, Enterprise & Regulatory Reform (DTI)
- Bain & Company Newsletter

2.3 Framework of information capturing

For each paper we gathered the following information:

- Paper Title
- Author
- Yr. of Publication
- Insights
- Issue Addressed
- Academic/Commercial
- Research Methodology
- Number of Data points
- Industry examined
- Variables in database
- Data Collection Method
- Robustness of Research

Captured information of 14 papers is given in Appendix A.
2.4 Literature Review

Discussion on 10 of the 14 literature paper reviewed is presented below.

2.4.1 ‘Smart Spenders: The Global Innovation 1000’ (By Booz Allen Hamilton)

This report was published in year 2006 by Booz Allen Hamilton. Their research was focused to understand high leverage innovators: Companies who spend less than competitors on R&D, yet outpace their industries by a wide margin. This research considered 1000 companies (top publicly traded R&D spenders) from 10 industries. They obtained key financial metrics for these 1000 companies under consideration from year 2001 to 2005. This research considers variables such as R&D/Sales, Company size, sales growth, gross profit, operating profit, enterprise profit, market capitalization, total shareholder return. Researcher surveyed only financial statements and omitted privately held firms. Comparison between industries was made by indexing R&D spend & financial metrics levels for each company against the median level for that industry.

This research concluded that,

- Less than 10 percent of companies are high-leverage innovators, but overall companies are getting better at getting more for their R&D spend.
- No significant relationship exists between R&D spending and the primary measures of corporate performance, although there is a positive correlation between R&D/sales (intensity) to gross margins.
- Common attributes between high leverage innovators: all build distinctive capabilities in ideation, project selection, development, or commercialization.

2.4.2 ‘2004 R&D Benchmarking Report’ (By DTI-UK)

This report was published in 2004. This research explores relationship between R&D intensity and performance measures such as sales growth and market capitalization to sales. To this effect, research covered 700 UK & 700 international firms from 5 sectors: pharma & health, electronics & IT, engineering & chemicals, low intensity (food producers, support services, etc), very low intensity (oil & gas, utilities). Primary data was taken directly from the latest audited annual accounts of the companies listed using a standard methodology. In this research only primary data from the latest audited annual accounts of the companies was considered, and no data was
taken from secondary or unpublished sources. It included both listed and private companies, and foreign-owned UK companies.

Research concluded the following:

- Sales growth rises with R&D intensity (R&D/sales) for a wide range of R&D performing sectors
- Higher R&D intensity associated with higher share price growth in high R&D intensity sectors
- 74% of companies with higher wealth creation efficiency have investment intensity (R&D or capital) above average

2.4.3 ‘How R&D affects sales growth, productivity and profitability’ (By Graham K. Morbey and Robert M. Reithner)

Graham K. Morbey and Robert M. Reithner published this paper in 1990. Focus of their research was to understand influence of R&D on future sales and profitability. They analyzed 727 companies from 19 industries. The data was provided by S&P Compustat services. Their research took into account acquisitions and divestitures. In their research methodology they used non-parametric rank order statistics, Avg. R&D parameters (1983-86) expenditure & performance parameters for yr 1987.

Their research concluded the following:

- Strong relation between R&D Intensity and subsequent growth in sales.
- No direct relationship between R&D intensity and growth margin.
- Strong relation between R&D expenditure per employee and subsequent company productivity, measured as sales per employee.
- To ensure profitability from increased sales, management must promote and maintain high levels of employee productivity in all sections within their company
2.4.4 ‘R&D Effective index: A metric for product development performance’ (By Michael E. McGrath, Michael N. Romeri)

Michael E. McGrath and Michael N. Romeri published this paper in 1994. Focus of their research was to come up with a metric to measure effectiveness of product development effort. They analyzed 45 companies from different industries within electronics industry. Mr. McGrath was working in PRTM and used his clients information. Their research took into account new product Revenue %, Profit % from new product, Investment in R&D % to calculate R&D Effectiveness Index.

Their research concluded the following:

- Comparing R&D/Sales of 2 firms is effective only if strategies and opportunities are similar and their PD processes are equally effective.
- Companies with more effective R&D outperformed the average in growth and profitability.
- Companies with high R&D effectiveness grew twice as fast as the average.
- High performers spend less on R&D and got more out of it. They wasted less on product that did not come to market. They met their original project goals more often.

2.4.5 ‘Competencies, Innovation and Profitability of Firms’ (by Ada Leiponen)

Ada Leiponen published this paper in 2000. Focus of their research was to investigate impact of competencies on economic performance. They analyzed 209 Finnish manufacturing firms. Authors view profitability as function of competency, innovation, few firm and industry specific characteristic. They used generalized method of moments (GMM). Survey data was from the period of 1989-91, and financial data from period 1985-93. Authors considered parameters such as Profitability - net profit margin, and Competency - level of education. They took Innovation as an indirect output measure of product/process innovation or both.
Their research concluded the following:

- Competence (Educational Measure) is positively associated with profitability.
- Process innovation is tightly coupled with profitability.
- Product innovation has adverse effect on profit margin -- small firms MAY be constrained by limited resources and therefore cannot carry out both types of innovation (product & process) simultaneously.

2.4.6 ‘Competitive Positioning and Innovative efforts in SMEs’ (By Lefebvre et. Al.)

Lefebvre published this paper in 2005. Focus of their research was to understand relationship between competitive positioning and innovative efforts as measured by R&D Expenditures, process innovation, and the use of patent databases. They analyzed 445 SMEs from various industries. Firms were selected from government master file of manufacturing firms operating actively in Quebec, Canada. Questionaire were sent to CEO of firms. 12% responded.

Authors use Hierarchical Factor Analysis on independent variable to classify data points into best, niche, and worst. Later, authors calculated mean financial performance parameters to understand these groups. This research considers product price, product cost, product quality, product image, product diversity, quality of customer service, frequency of introducing new products, R&D/Sales, innovation score for product technologies (weighted avg. of score given by panel of 40 experts), number of patents, and use of patent information.

Their research concludes, firms hold a stronger competitive position in terms of cost, quality, and diversity generally make greater efforts with regard to innovation.

2.4.7 ‘Productivity Gains from implementation of employee training program’ (By Bartel et.al.)

Bartel published this paper in 1994. Focus of their research was to understand how labor productivity, measured at the level of the business unit, is affected by the implementation of formal employee training programs. They analyzed 495 Compustat II business lines from various industries. Authors observed variables such as Presence/absence of training, yr in which training is given, age of business unit, % of employees unionized, number of policies, type of policies, %
of people undergone training. Their methodology was to observe relationship between training and wages as evidence of relationship between training and productivity.

2.4.8 ‘The impact of human resource management practices on turnover, productivity, and corporate financial performance’ (By Huselid)

Huselid published this paper in 1995. Focus of their research is to understand impact of HRM policies and practices on firm performance. They analyzed 968 firms from various industries. They mailed questionnaire to HR department of 3452 firms to collect firm level data on company performance. 28% firms responded. Author collected information on parameters such as Employee turnover, Sales/Employee, Employee outcome, market based and accounting based measure of company performance.

Author came up with 2 factors using Principal Component Analysis. He verified 2 factor formations using external information - human resources mentioned as important in Disclosure, number of people in HR department.

Author concluded that high performance practices impact employee turnover, and on per employee basis, sales, market value and profit. Overall, HRM can create a source of sustained competitive advantage, esp. when aligned with firm's competitive strategy. The author also observed that, productivity is negatively correlated with R&D Intensity (log of R&D/Sales)-- (Corr = -0.01). Author also observed that high performance practices have an impact of 40% on employee turnover.

2.4.9 Product Development Mastery: A Key Contributor to High Performance’ (By Accenture)

This report was published in 2008 by Accenture. Their research focuses to understand relationship between superior product development capabilities and financial performance (market cap growth, product margins, productivity). Research draws insights from client work with distinctive product development players. Very little explanation is given on methodology. Report does not disclose number of data points.
Accenture’s result concluded that,

- Relationship exists between product development mastery and superior financial performance.
- Strong PD performance results in market cap CAGR premium of 7 to 26% above industry average.
- Faster product time to market (as much as 30 to 50 percent faster than average)
- Higher revenue and margin from new products (as much as 10 percent higher for each)
- As much as 50 percent greater productivity in the product development function

2.4.10 ‘The Effect Human Resource Management Practices on Productivity: A study of steel finishing lines’ (By Ichniowski)

Ichniowski published his research in 1997. His research focuses on identification of complementary in HRM practices and impact of HRM practices on employee productivity in steel industry. In this research 2910 observations on productivity from 36 steel production lines owned by 17 companies are studied. Data is collected by personal visit to sites. Interviews of 1-3 days with HR Manager, labor relation manager, operations manager, superintendent, line workers, union representatives were carried out. In this research information was also collected from personnel files, manuals, bargaining agreement.

Research concludes that firms realize gain in productivity by adopting clusters of complementary practices and benefit little from making ‘marginal’ changes in any one practice.

2.5 Meta Analysis of Literature from lenses of Hypothesis

We now map key takeaways from 14 research papers and come up with meta-analysis for hypothesis under consideration.
2.5.1 Companies with strong PD practices spend less on R&D than those with average or weak practices

![Diagram showing relationships between PD Practices and "Growth" indicators.]

Gaps in Literature

- R&D/Sales not normalized by industry avg. as in our database
- Linked some growth or competitive indicator with function of R&D rather than with PD practices in general.
2.5.2 **Companies with continuous improvement systems in PD execution practices realize lower R&D cost levels than those w/o such systems**

Figure 2-3: Academic Literature Analysis on 'Companies with continuous improvement systems in PD execution practices realize lower R&D cost levels than those w/o such systems'
Figure 2-4: Academic Literature Analysis on 'Companies with strong PD practices spend less on R&D than those with average or weak practices'

2.5.3 **Companies with strong customer insight practices accomplish product launches with better price-value satisfaction than companies that do not take customer insights into account**

Based on [11], [12], and [13]

<table>
<thead>
<tr>
<th>Study By</th>
<th>Data</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson, Fornell, Mazranchevyl (2004)</td>
<td>&amp; 200 Fortune 500 firms in 40 industries 1% change in ACSI-&gt;avg. 1.016% during 1993-97 with American change in Tobin's q or $275m in Customer Satisfaction Index (ACSI), firm value 1-100</td>
<td>1% change in ACSI-&gt;$275m in firm value</td>
</tr>
<tr>
<td>Ittner and Larcker (1998)</td>
<td>120 firms and ACSI index</td>
<td>1 unit increase in ACSI-&gt;$240m increase in market value</td>
</tr>
<tr>
<td>Gruca &amp; Rego (2005)</td>
<td>ACSI and Compustat Data from 1 point increase in ACSI- $55m 1994-2002 for 105 firms in 23 industries and 4% reduction in variability</td>
<td>1 point increase in ACSI-&gt;$55m increase in cash flow in next year and 4% reduction in variability</td>
</tr>
</tbody>
</table>

Based on [14]
<table>
<thead>
<tr>
<th>Study By</th>
<th>Data</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson &amp; 125 firms and Swedish firms</td>
<td>1% increase in satisfaction -&gt; 2.37%</td>
<td></td>
</tr>
<tr>
<td>Mittal (2000)</td>
<td>customer satisfaction increase in ROI; 1% drop in satisfaction -&gt; barometer (SCSB)</td>
<td>5.08% drop in ROI</td>
</tr>
<tr>
<td>Nayyar (1995)</td>
<td>106 firms from 68 industries for 1981-91 average cumulative abnormal return (CAR); Decrease in customer service -&gt; 0.46%</td>
<td></td>
</tr>
</tbody>
</table>

2.5.4 Potential conflicts, challenges and... Opportunities?

It is observed through literature analysis that research generally focuses on a very specific set of levers in product development. None of the literature analyzed looked deep into different sets of levers that affect product development. This could be attributed to multiple reasons such as 1.) No defined framework that covers all levers of Product Development 2.) It is not clear how to define a holistic framework 3.) Capturing information on vast number of levers is a logistics problem that can derail such a research effort.

Our research team believes that to allow companies to build robust, appropriate and effective product development functions, a new form of analysis and insight is required. One that will allow companies to identify exactly which levers will achieve maximum impact on cost, quality and time to market.
2.6 References


3 Research Design & Database Characteristics

Our research team believes that companies must take a holistic look at all their practices across all functions critical to product development and at all levels in the organization. They must then prioritize changes from the most immediate needs to those that would take them to leading edge product development practice. In this chapter we will look at various elements of the framework used in this research. We will discuss types of industries and projects selected to participate in our research. At the end of this chapter we discuss characteristic of database on which statistical analysis is carried out.

3.1 Framework

![Research Framework Diagram]

Figure 3-1: Research Framework
Our PD framework considers 4 PD elements or categories:

- Smart Product
- Smooth Integration
- Enterprise level PD strategy deployment
- Competence & Capabilities

### 3.1.1 Categories & Dimensions

Each category is broken down into various PD dimensions as shown below. Due to proprietary nature of framework some of the dimensions have been removed.

**Smart Product**

- Align product to strategy
- Align on strategic priorities
- ...

**Enterprise level PD strategy deployment**

- Product Development Environment
- Portfolio management
- ...

**Smooth Integration**

- Project planning and organization
- Product development execution
- ...

**Competence & Capabilities**

- Capability management
- ...

In total we covered 140+ PD practices spread over various dimensions. A sample list of some of these PD practices is given in Appendix B.

3.1.2 Self Assessment Performance Parameters

Self assessed performance is evaluated on 17 outcome dimensions. These dimensions cover 4 broad performance categories namely,

- Financial Performance
- Customer Satisfaction
- Operational Effectiveness
- Product Performance

Participants grade their project on a scale of 0 to 5 on each of these dimensions.

Table 3-1: Project Performance Parameters

<table>
<thead>
<tr>
<th>Performance dimension</th>
<th>Outcome dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial performance</td>
<td>NPV/IRR</td>
</tr>
<tr>
<td></td>
<td>Product revenues</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Customer satisfaction</td>
<td>Satisfaction with function and performance</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Product performance</td>
<td>Performance vs. specification</td>
</tr>
<tr>
<td></td>
<td>Product quality</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
</tbody>
</table>
3.1.3 Actual financials parameters

For each firm in database we gathered actual financials for year 2003-07.

- Revenue
- EBIT
- EBITDA
- COGS
- R&D

3.2 Data collection methodology

We approached leadership of firms in three specific sectors,

- Auto & Assembly
- High-Tech
- Medical Devices

Leaderships were explained PD survey framework, research approach, sample report that they would get as feedback, and time frame & resources requirement.

Once a firm is ready to participate we asked leadership of firm to identify ~3 or more completed, broad, strategic projects with typical performance and issues of PD. We also asked that one project of each of the following types to participate:

- Continuous improvement
- Incremental Innovation
- New Platform

It was made sure that participating projects were completed not more than a year ago at the time of participation.

3.3 Identification of respondents

Once projects were identified, senior leaders in Product Development, Operations, and Marketing were identified to do telephonic interview and to fill internet based survey. Interviews with selected project team members and functional leaders were also carried out.
3.4 Software Packages used
Survey was internet based. At the back end, server used to save all entries. We can get this raw database in excel sheet format. This raw database was cleaned before feeding it to statistical software. We exclusively used SPSS 16.0 for this research. A small tutorial on various steps that I carried out in SPSS is in Appendix E. This tutorial is not complete.

3.5 Database characteristics
Below we discuss characteristics of database studied in this research. Characteristics presented are

- Industries break up analysis
- Project type break up analysis
- Professional characteristics of people who participated in the survey

3.5.1 Industries
Table 3-2: Types of industries in database

<table>
<thead>
<tr>
<th>BU sector</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid ANA</td>
<td>10</td>
<td>12.0</td>
<td>12.0</td>
<td>12.0</td>
</tr>
<tr>
<td>High Tech</td>
<td>49</td>
<td>59.0</td>
<td>59.0</td>
<td>71.1</td>
</tr>
<tr>
<td>MED</td>
<td>18</td>
<td>21.7</td>
<td>21.7</td>
<td>92.8</td>
</tr>
<tr>
<td>Others</td>
<td>6</td>
<td>7.2</td>
<td>7.2</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>83</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

3.5.2 Project
Table 3-3: Types of projects in database

<table>
<thead>
<tr>
<th>Project description</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td>6</td>
<td>7.2</td>
<td>7.2</td>
<td>7.2</td>
</tr>
<tr>
<td>Continuous improvement</td>
<td>5</td>
<td>6.0</td>
<td>6.0</td>
<td>13.3</td>
</tr>
<tr>
<td>General</td>
<td>11</td>
<td>13.3</td>
<td>13.3</td>
<td>26.5</td>
</tr>
<tr>
<td>Incremental innovation</td>
<td>37</td>
<td>44.6</td>
<td>44.6</td>
<td>71.1</td>
</tr>
<tr>
<td>New Platform</td>
<td>24</td>
<td>28.9</td>
<td>28.9</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>83</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
3.5.3 People role/experience

Number of people participated in online survey: 294

Table 3-4: Characteristics of people who participated in online survey

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years on the project</td>
<td>2.1</td>
</tr>
<tr>
<td>Years with the company</td>
<td>9.5</td>
</tr>
<tr>
<td>How many product development project teams have you been on?</td>
<td>~6</td>
</tr>
<tr>
<td>Years of PD experience from other jobs in previous companies</td>
<td>1.1</td>
</tr>
</tbody>
</table>
4 Data Handling

Objective of this chapter is to present key theory material and provide set of steps carried out in our statistical analysis.

4.1 Nature of variables

In our research we handled three data types. Below we will discuss the definition of each of these data types.

4.1.1 Categorical data type

Definition: A set of data is said to be categorical if the values or observations belonging to it can be sorted according to category. Each value is chosen from a set of non-overlapping categories.

4.1.2 Interval data type

Definition: An interval scale is a scale of measurement where the distance between any two adjacents units of measurement (or 'intervals') is the same but the zero point is arbitrary. Scores on an interval scale can be added and subtracted but can not be meaningfully multiplied or divided.

In our research PD practice variables are interval measures, which in a very strict interpretation could be considered categorical, but in practice it is customary to treat them as interval and therefore it is acceptable to take an average or use other operations that involve division.

4.1.3 Ordinal data type

Definition: A set of data is said to be ordinal if the values / observations belonging to it can be ranked (put in order) or have a rating scale attached. You can count and order, but not measure, ordinal data. The distinction between neighboring points on the scale is not necessarily always the same.

In our research, the self-assessed performance measures are ordinal variables.

4.1.4 Continuous data type

Definition: A set of data is said to be continuous if the values / observations belonging to it may take on any value within a finite or infinite interval.
In our research, CATPCA algorithm is used to identify components from self-assessed performance parameter. This procedure transforms the number (distances) into continuous numbers, at which point it is possible to perform virtually any mathematical operation on them.

**4.2 Scale of variables**

**4.2.1 Scale of Dependent variable**
Self-assessed performance measures are dependent variables. Scale is 0 to 5. Below is brief explanation of each level.

**Level 0:** No knowledge of whether this metric is used or not

**Level 1:** Below forecast despite corrective actions being taken

**Level 2:** Below forecast established in the business plan at the time of funding

**Level 3:** Fulfilled forecast established in the business plan at the time of funding

**Level 4:** Exceed forecast communicated in the business plan at the time of funding

**Level 5:** Surpassed forecast communicated in the business plan at the time of funding. Set benchmark in industry.

**4.2.2 Scale of Independent variable**
PD practices are dependent variables and are measured on a scale of 1 to 6.

**Level 1:** Strong disagree

**Level 6:** Strongly agree
4.3 Statistical Tests used

4.3.1 CATPCA
The CATPCA procedure quantifies categorical variables using optimal scaling, resulting in optimal principal components for the transformed variables. The variables can be given mixed optimal scaling levels and no distributional assumptions about the variables are made.

In CATPCA, dimensions correspond to components (that is, an analysis with two dimensions results in two components), and object scores correspond to component scores.

4.3.2 ANOVA
The One-Way ANOVA procedure produces a one-way analysis of variance for a quantitative dependent variable by a single factor (independent) variable. Analysis of variance is used to test the hypothesis that several means are equal. This technique is an extension of the two-sample \( t \) test.

In addition to determining that differences exist among the means, you may want to know which means differ. There are two types of tests for comparing means: a priori contrasts and post hoc tests. Contrasts are tests set up before running the experiment, and post hoc tests are run after the experiment has been conducted. You can also test for trends across categories.

4.3.3 Bivariate Correlation
Correlation is a bivariate analysis that measures the strengths of association between two variables. In statistics, the value of the correlation coefficient varies between \( +1 \) and \( -1 \). When the value of the correlation coefficient lies around \( \pm 1 \), then it is said to be a perfect degree of association between the two variables. As the value goes towards \( 0 \), the relationship between the two variables will be weaker. Usually, in statistics, we measure three types of correlation: Pearson correlation, Kendall rank correlation and Spearman correlation.

4.3.3.1 Pearson r correlation
Pearson \( r \) correlation is widely used in statistics to measure the degree of the relationship between the linear related variables. For the Pearson \( r \) correlation, both variables should be
normally distributed. For example, in the stock market, if we want to measure how two commodities are related to each other, Pearson r correlation is used to measure the degree of relationship between the two commodities. The following formula is used to calculate the Pearson r correlation:

The formula for Pearson's correlation takes on many forms. A commonly used formula is shown below.

**Equation 1: Pearson Correlation**

\[
r = \frac{\sum XY - \sum X \sum Y}{\sqrt{\left(\sum X^2 - \frac{\left(\sum X\right)^2}{N}\right)\left(\sum Y^2 - \frac{\left(\sum Y\right)^2}{N}\right)}}
\]

Where:

- \(r\) = Pearson r correlation coefficient
- \(N\) = number of value in each data set
- \(\sum xy\) = sum of the products of paired scores
- \(\sum x\) = sum of x scores
- \(\sum y\) = sum of y scores
- \(\sum x^2\) = sum of squared x scores
- \(\sum y^2\) = sum of squared y scores

4.3.3.2 **Spearman rank correlation**

Spearman rank correlation is a non parametric test that is used to measure the degree of association between the two variables. It was developed by Spearman, thus it is called the Spearman rank correlation. Spearman rank correlation test does not assume any assumptions about the distribution. Spearman rank correlation test is used when the Pearson test gives misleading results.
The following formula is used to calculate the Spearman rank correlation

Equation 2: Spearman Rank Correlation

\[
\rho = 1 - \frac{6\sum d_i^2}{n(n^2 - 1)}
\]

Where:

- \(\rho\) = Spearman rank correlation
- \(d_i\) = the difference between the ranks of corresponding values Xi and Yi
- \(n\) = number of value in each data set

4.3.4 Independent T-test

The T Test procedure compares the means of two groups or (one-sample) compares the means of a group with a constant.

4.3.5 Identification of High-Mid-Low performers based on performance score

Initially, for each self-assessed performance parameter, we computed average score \& SD based on scores of all projects.

- Projects (or data points) 1SD above average are High performers
- Projects (or data points) within +1/-1 SD around average are in Mid performers
- Projects (or data points) 1 SD below average are Low performers

However, this strategy has couple of issues as our database is not huge.

- Boundary between High-Mid and Mid-Low moves as new data points are added
- Data points which are high performers in one data set could turn to be mid/low performer as more data points are added
We devised an approach based on absolute score of project rather than a project’s distance from mean.

- Projects (or data points) with score 4 and above are High performers
- Projects (or data points) with score 3 are Mid performers
- Projects (or data points) with score 2 and below are Low performers

4.4 Steps before running Statistical Analysis

Certain steps need to be carried out on database before we run correlation, ANOVA, CATPCA, cluster analysis or any other analysis. Below are the steps carried out in serial order which we followed before carrying out any statistical analysis.

4.4.1 Combining of respondents information at project level

Generally, from each participating project multiple people filled out the survey. We obtained project level score by computing straight average of response of participants to a given question.

4.4.2 Cleaning of Performance score

We took average of performance score provided by multiple participants for same project. However, while taking the average of project performance scores, we obtained non-integer numbers on multiple occasions. As project performance variables are ordinal in nature they cannot be non-integer. To resolve the issue we considered role and seniority of participants to identify a person who got best knowledge of project performance. In most of the participating projects, project manager participated and thus identification of person who got a good overview of project was easy. We assigned the selected person’s score to project level to resolve the issue.

4.4.3 Calculation of Dimension variables

For each project, dimension level scores are computed by taking average of score computed for questions within a dimension.

4.4.4 Calculation of Categories variables

For each project, category level scores are computed by taking average of score computed for dimensions within a category.
4.5 Statistical Analysis Approach

Analysis was carried out in two broad steps.

1. Actual Financials based analysis
2. Self Assessed Performance based analysis

In actual financials based analysis only Pearson correlation was used. However, in Self-assessed Project Performance analysis 4 different types of analysis were carried out. Namely,

- Pearson and Spearman Correlation
- Analysis of Variance (ANOVA)
- Principal Component Analysis
- Cluster Analysis

Information on how each analysis is carried out is presented in next 2 chapters.
5 Actual Financials based Analysis

We have EBITDA/Revenue, Sales CAGR, and R&D/Sales at the firm level for certain data points. As data points are from different industries, we cannot carry out further analysis on all data points taken together. As numbers of data points in our database with actual financials are few, it did not make sense to carry out analysis at each industry level. Therefore, we followed the procedure discussed below to normalize the actual financials by their corresponding industry averages.

Relevant firms from Forbes 500 firms were classified into 3 industries under consideration in this research. For each industry, average of EBITDA/Revenue (Yr. 2007), Revenue CAGR, and R&D/Sales (Yr. 2007) was calculated. These values were used for normalizing EBITDA/Revenue, Revenue CAGR, and R&D/Sales in our database so that we can carry out different statistical analysis tests on data points from various industries together.

5.1 Correlation between Actual Financials and PD Practices

A straight average of scores on a set of questions in each dimension was computed for each data point. Although we know that component analysis is more preferred to straight average, we carried out straight average as number of data points with actual financials are few. Once, score at dimension level was computed for all data points, Pearson correlation was carried out between dimension scores and Actual Financials. The results are shown below.

Reliably correlated: P value <= 0.01

Medium Reliability: 0.01 < P Value <= 0.05

Mildly Reliable: 0.05 < P Value <= 0.1
### Table 5-1: Correlation between Actual Financials and PD Dimensions

<table>
<thead>
<tr>
<th>McKinsey data only</th>
<th>Reliably correlated</th>
<th>Medium reliability</th>
<th>Mildly reliable</th>
<th>Unreliable</th>
</tr>
</thead>
<tbody>
<tr>
<td>EBITDA_REVE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NUE_2007_NR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>revenueCAGR_</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RNRM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RnD_Sales2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NRM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product development environment</th>
<th>Pearson Correlation</th>
<th>.303</th>
<th>-.066</th>
<th>-.654</th>
</tr>
</thead>
<tbody>
<tr>
<td>practices scores mean</td>
<td>Sig. (2-tailed)</td>
<td>.366</td>
<td>.842</td>
<td>.040</td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Portfolio management practices scores mean</th>
<th>Pearson Correlation</th>
<th>.320</th>
<th>.037</th>
<th>-.483</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>Sig. (2-tailed)</td>
<td>.337</td>
<td>.909</td>
<td>.157</td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technology development practices scores mean</th>
<th>Pearson Correlation</th>
<th>.278</th>
<th>.106</th>
<th>-.125</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>Sig. (2-tailed)</td>
<td>.408</td>
<td>.744</td>
<td>.730</td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Development of enterprise capabilities practices scores mean</th>
<th>Pearson Correlation</th>
<th>.004</th>
<th>.126</th>
<th>-.281</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>Sig. (2-tailed)</td>
<td>.690</td>
<td>.697</td>
<td>.466</td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Align to product strategy practices scores mean</th>
<th>Pearson Correlation</th>
<th>.211</th>
<th>.169</th>
<th>-.859</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>Sig. (2-tailed)</td>
<td>.533</td>
<td>.599</td>
<td>.001</td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Customer insights practices scores mean</th>
<th>Pearson Correlation</th>
<th>.119</th>
<th>.026</th>
<th>-.404</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>Sig. (2-tailed)</td>
<td>.727</td>
<td>.936</td>
<td>.247</td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>12</td>
<td>10</td>
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<table>
<thead>
<tr>
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<td>.652</td>
<td>.052</td>
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<table>
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<th>-.470</th>
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<td>.991</td>
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<th>Defining the product architecture practices scores mean</th>
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<th>-.546</th>
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<table>
<thead>
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<th>Pearson Correlation</th>
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<th>.126</th>
<th>-.676</th>
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<td>Sig. (2-tailed)</td>
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<td>.032</td>
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<table>
<thead>
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<th>Architecture and Modularity practices scores mean</th>
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<th>-.310</th>
<th>-.117</th>
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<td>mean</td>
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<td>.327</td>
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<table>
<thead>
<tr>
<th>Product quality practices scores mean</th>
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<th>-.540</th>
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<tbody>
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<td>mean</td>
<td>Sig. (2-tailed)</td>
<td>.142</td>
<td>.287</td>
<td>.107</td>
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<tr>
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<td>10</td>
<td></td>
</tr>
<tr>
<td>Project planning and organization practices scores mean</td>
<td>Pearson Correlation</td>
<td>EBITDA_REVENUE NUE_2007_NR M</td>
<td>revenueCAGR_ NRM</td>
<td>RnD_Sales2007 _NRM</td>
</tr>
<tr>
<td>-------------------------------------------------------</td>
<td>---------------------</td>
<td>-----------------------------</td>
<td>----------------</td>
<td>-----------------</td>
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<tr>
<td>N</td>
<td>11</td>
<td>12</td>
<td>10</td>
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</tr>
<tr>
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<td>-0.352</td>
<td>1.138</td>
<td>0.004</td>
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<td>N</td>
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</tr>
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<td></td>
</tr>
<tr>
<td>Configuration &amp; Change Management practices scores mean</td>
<td>Pearson Correlation</td>
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<td>0.361</td>
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</tr>
<tr>
<td>N</td>
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<td>10</td>
<td></td>
</tr>
<tr>
<td>Ramp up management practices scores mean</td>
<td>Pearson Correlation</td>
<td>0.339</td>
<td>0.284</td>
<td>-0.536</td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
<tr>
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<td>Pearson Correlation</td>
<td>0.428</td>
<td>0.181</td>
<td>-0.834</td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Capability management practices scores mean</td>
<td>Pearson Correlation</td>
<td>0.050</td>
<td>0.354</td>
<td>-0.243</td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Knowledge systems practices scores mean</td>
<td>Pearson Correlation</td>
<td>0.411</td>
<td>0.274</td>
<td>-0.143</td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Mindsets practices scores mean</td>
<td>Pearson Correlation</td>
<td>0.299</td>
<td>-0.036</td>
<td>-0.608</td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

Multiple correlations in above table are strong with very good p-value, but results cannot be relied upon as numbers of data points are few. Having highlighted that, we will discuss statistical analysis results that are interesting.

It was observed that all significant correlations with R&D/Sales are negative indicating that being good at certain PD practices would drive R&D/Sales ratio low. We ran regression between mean practice score of 143 questions and R&D/Sales to understand relationship between them.
Figure 5-1: Regression between R&D/Sales and overall PD practice score

![Graph showing regression between R&D/Sales and overall PD practice score]

<table>
<thead>
<tr>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>McKinsey Client</td>
</tr>
<tr>
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</tr>
<tr>
<td>Residual</td>
</tr>
<tr>
<td>Total</td>
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<tr>
<td>yes</td>
</tr>
<tr>
<td>Residual</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

The independent variable is Mean Practices Scores (all).

Although ANOVA result in Figure 5-1 says that chance of such a relation to happen at random is 6%, regression is based on just handful of data points. Also if two data points in top left are removed, it can heavily impact regression results. Given that both these data points (VIOLET and RED) belong to Hi-Tech industry, it may make more sense to look at regression for data points that are very close in their products & services offerings. It also looks possible to fit non-linear regression on these data points.

As we could not get more data points with actual financial information, conclusions have been drawn based on current database that we have. Due diligence needs to be carried out to get clear understanding of this relationship.
5.2 Correlation between Actual Financials and Self Assessed Project Performance Parameters

Categorical Principal Component Analysis (CATPCA) was utilized to combine 17 Self-assessed outcome measures into five components. Two components were generated for 6 parameters under financial performance dimension. For remaining dimensions only one component/dimension was created. These 17 measures were also combined into one factor name Overall Self Assessed Performance.

Table 5-2: Correlation between Actual Financials and Self-Assessed Outcome Measures

| Overall Self-Assessment statistic | Groupings of Self-Assessed criteria | EBITDA | REVEN | E_2007 | NRM | AGR_NUM | Rnd_Sales2007_1 | NRM | FM |
|----------------------------------|------------------------------------|--------|-------|--------|-----|--------|-----------------|-----|----|---|
| CATPCA performance (all score (1 dimension--all outcome variables) | Pearson Correlation | .165 | .016 | - .506 | N | 19 | 20 | 18 |
| | Sig. (2-tailed) | .50 | .93 | .03 | |
| SG&A, Dollar Market, and unit cost | Pearson Correlation | .111 | .164 | - .162 | N | 19 | 20 | 18 |
| | Sig. (2-tailed) | .85 | .46 | .52 | |
| Project NPV, Product Revenue, Prodi | Pearson Correlation | - .30 | .246 | - .13 | N | 19 | 20 | 18 |
| | Volume | .20 | .29 | .60 | |
| Satisfaction | Pearson Correlation | .19 | .023 | - .34 | N | 19 | 20 | 18 |
| | Sig. (2-tailed) | .44 | .27 | .19 | |
| Operation Effectiveness | Pearson Correlation | - .10 | .04 | - .53 | N | 19 | 20 | 18 |
| | Sig. (2-tailed) | .64 | .56 | .02 | |
| Product and Process Quality | Pearson Correlation | - .11 | .204 | - .45 | N | 19 | 20 | 18 |
| | Sig. (2-tailed) | .83 | .38 | .05 | |

Table 5-2 shows relationship between project level performance and overall firm’s actual financial performance. Again as number of data points are few it is difficult to strongly rely on these results. Having said that, we observe a relationship exists between project performance and firm’s actual financial performance. We also see that ‘operational effectiveness’ and ‘product & process quality’ have negative and significant correlation with R&D/Sales.
5.3 Correlation between Actual Financials and PD Practices at Question Level

Correlations were carried out between PD practices questions and Actual financials. Later, on the basis of context of questions, these questions were combined and regression was computed.

Figure 5-2: Regression between R&D/Sales and 'Rigorous testing with effective feedback; Risk Analysis; Multiple Contingency plans'

![Graph showing regression between R&D/Sales and 'Rigorous testing with effective feedback; Risk Analysis; Multiple Contingency plans']

Pearson Correlation = -0.925 (Significance = 0)

Figure 5-3: Regression between Revenue(CAGR) and Product Offering Strategy

![Graph showing regression between Revenue(CAGR) and Product Offering Strategy]

Pearson Correlation = 0.606 (Significance = 0.028)

Figure 5-4: Regression between R&D/Sales and 'Firm strategy and definition of project scope and scale'

![Graph showing regression between R&D/Sales and 'Firm strategy and definition of project scope and scale']

Pearson Correlation = -0.712 (Significance = 0.014)
Figure 5-5: Regression between R&D/Sales and 'Active Leadership & working environment'

![Graph showing the regression between R&D/Sales and 'Active Leadership & working environment'.]

Pearson Correlation = -0.723 (Significance = 0.012)

Figure 5-6: Regression between R&D/Sales and 'Good understanding of sources of delay and resolution of issues'

![Graph showing the regression between R&D/Sales and 'Good understanding of sources of delay and resolution of issues'.]

Pearson Correlation = -0.561 (Significance = 0.072)

Figure 5-7: Regression between R&D/Sales and 'Team's understanding of customer values'

![Graph showing the regression between R&D/Sales and 'Team's understanding of customer values'.]

Pearson Correlation = -0.796 (Significance = 0.003)
Figure 5-8: Regression between EBITDA/Sales and Formal make-buy decision processes on technologies

Pearson Correlation = 0.649 (Significance = 0.0)

Figure 5-9: Regression between R&D/Sales and Involvement of downstream partners

Pearson Correlation = -0.775 (Significance = 0.005)

Figure 5-10: Regression between R&D/Sales and involvement of suppliers in concept design

Pearson Correlation = -0.582 (Significance = 0.1)
Figure 5-11: Regression between R&D/Sales and continuous improvement using customer feedback

Figure 5-12: Regression between R&D/Sales and brainstorming of possible architectures

Pearson Correlation = -0.717 (Significance = 0.02)  
Pearson Correlation = -0.619 (Significance = 0.042)

Figure 5-13: Regression between R&D/Sales and PD Execution

Pearson Correlation = -0.563 (Significance = 0.071)

Note that regression in Figure 5-1 to Figure 5-13 are based on handful of data points. If data points in top left are removed, it can heavily impact regression results. It is also possible to fit non-linear regression as well.
As we could not get more data points with actual financial information, conclusions have been
drawn based on current database that we have. Due diligence needs to be carried out to get clear
understanding of relationship between PD practices and financial performance of firm.

In Figure 5-2 we observe that firms that have low R&D/Sales are good at up-front planning i.e.
they consider impacting factors, identify trigger points up front, and put risk mitigation strategies
in place. Later, rigorous testing with effective feedback enables them to identify, quantify and
manage project, product, technology and process risks throughout the project. Overall, it
indicates that upfront planning is important.

Based on Figure 5-2 and Figure 5-3, Revenue CAGR based High performers have a well planned
product offering strategy that would go a long way in changing competitive landscape over
extended period of time. They optimize value of PD portfolio by measuring throughput
performance of projects. Firm’s strategy and quantified requirements of target market segment
help in defining project scope and scale. Overall, it indicates that quantified understanding of
target market and well planned product offering strategy are critical.

Based on

Figure 5-5 firms with low R&D/Sales have characteristics of active leaders, friendly PD
environment, commitment to work, and proper staffing to maximize knowledge and expertise.
They also foster a culture where continuous innovation is stressed. This shows that high
performers expect disruption and are ready for it.

Figure 5-6 and Figure 5-7 indicates that firms with low R&D/Sales are good at execution in all
phases of PD and thus have good products on time rather than a breakthrough product behind
schedule. The research also indicates that best talent is appointed to lead project teams, cross-
functional teams have a clear understanding of work and protocols and project decisions are
based on clear understanding of customer values. Overall, excellent product development
execution is critical in driving R&D/Sales low.

Figure 5-8 indicates that the way a company reacts to changes in technology will determine its
performance. EBITDA/Sales based high performers are good at assessing disruptive
technologies, and they have a formal procedure to decide which technologies will power current and future products in their portfolio.

Figure 5-9 and Figure 5-10 suggests that firms where innovation is collaborative i.e. it is open and not tightly controlled have low R&D/Sales. High performers (based on R&D/Sales) involve PD manufacturing personnel, downstream partners and suppliers from early phase of product development.

Based on Figure 5-11 and Figure 5-12 we conclude that firms which integrate customer feedback in product design and pay strong attention to product architecture have low R&D/Sales. Flexibility in system’s design helps these firms to tailor the product to customer needs.
6 Self-Assessed Project Performance based Analysis

We observed in Table 5-2 that project performance is linked with firm’s actual financial performance. Now, we would use project performance as our dependent variable and carry out analysis to determine key PD practices at project level.

6.1 Correlation between 24 PD Practices dimension and Overall Self-Assessed Project Performance

Categorical Principal Component Analysis (CATPCA) was utilized to combine 17 Self-assessed outcome measures into one component named Overall Self Assessed Performance.

A straight average of scores on a set of questions in each dimension was computed for each data point. We also carried out component analysis and it will be discussed later. Once, score at dimension level was computed for all data points, Spearman correlation was carried out between dimension scores and Actual Financials as actual financials are ordinal in nature.
Table 6-1: Correlation between Self-Assessed outcome measure and PD Dimensions

<table>
<thead>
<tr>
<th>Self Assessed Performance</th>
<th>Pearson Correlation</th>
<th>Sig. (2-tailed)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product development environment practices scores mean</td>
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<td>.081</td>
<td>40</td>
</tr>
<tr>
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<td>Technology development practices scores mean</td>
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<td>.142</td>
<td>40</td>
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<tr>
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<td>40</td>
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<tr>
<td>Align to product strategy practices scores mean</td>
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<td>40</td>
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<td>Architecture and Modularity practices scores mean</td>
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<td>40</td>
</tr>
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<td>Sig. (2-tailed)</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>---------------------</td>
<td>------</td>
<td>----------------</td>
</tr>
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<td>PD execution practices scores mean</td>
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<td>Sig. (2-tailed)</td>
</tr>
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<td>Sig. (2-tailed)</td>
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<td>Sig. (2-tailed)</td>
</tr>
<tr>
<td>Performance management practices scores mean</td>
<td>Pearson Correlation</td>
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<td>Sig. (2-tailed)</td>
</tr>
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<td>Configuration &amp; Change Management practices scores mean</td>
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<td>Sig. (2-tailed)</td>
</tr>
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<td>Sig. (2-tailed)</td>
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<td>Sig. (2-tailed)</td>
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<td>Pearson Correlation</td>
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<td>Sig. (2-tailed)</td>
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<td>Knowledge systems practices scores mean</td>
<td>Pearson Correlation</td>
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<td>Sig. (2-tailed)</td>
</tr>
<tr>
<td>Mindsets practices scores mean</td>
<td>Pearson Correlation</td>
<td>.272</td>
<td>Sig. (2-tailed)</td>
</tr>
</tbody>
</table>

In above table we observe that multiple PD dimensions are significantly correlated with overall project performance indicating that PD pays. In further discussion we will go to next level of analysis in terms of which specific PD dimensions impact which specific outcome measure.

6.2 Correlation between 24 PD Practices Dimensions and 17 Self Assessed Performance Measures

Spearman correlation was carried out between 24 PD Practices dimensions and 17 Self assessed performance measures. Scores at dimension level for each data point was determined as discussed earlier.
| Table 6-2: Correlation between Self-Assessed Outcome Performance and PD Dimensions |
|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
|                           | Project IRR and NPV       | Product revenues          | Product volumes           | Product's dollar market share | Product unit costs        | Product SG&A cost         | Satisfaction with product function and performance | Satisfaction with price for value | Time to market              | Adherence to budget        | Project team morale        | Supplier/Partner Delivery |
| Product development environment | 0.03 | 0.23 | 0.10 | 0.07 | 0.03 | 0.12 | -0.01 | -0.02 | 0.30 | 0.31 | 0.21 | 0.36 | 0.36 | 0.36 | 0.19 | 0.20 | 0.04 | 0.09 |
| Portfolio management       | -0.11 | 0.02 | -0.07 | 0.05 | -0.13 | 0.02 | 0.09 | 0.12 | 0.12 | -0.02 | 0.10 | 0.17 | 0.16 | 0.10 | 0.24 | 0.33 | -0.06 |
| Technology development     | 0.03 | 0.04 | -0.06 | -0.01 | 0.03 | 0.05 | -0.10 | 0.07 | 0.28 | 0.20 | 0.20 | 0.29 | 0.11 | 0.19 | 0.16 | 0.23 | 0.12 |
| Development of enterprise capabilities | 0.06 | 0.01 | -0.10 | -0.14 | -0.03 | 0.08 | -0.12 | 0.23 | 0.31 | 0.26 | 0.32 | 0.31 | 0.16 | 0.08 | 0.04 | 0.32 | 0.24 |
| Align to product strategy  | 0.05 | 0.12 | -0.03 | 0.09 | 0.06 | 0.23 | 0.02 | 0.10 | 0.29 | 0.28 | 0.22 | 0.15 | 0.14 | 0.26 | 0.18 | 0.26 | 0.18 |
| Customer insights          | 0.00 | -0.08 | -0.02 | 0.01 | 0.22 | 0.15 | 0.08 | 0.04 | 0.19 | 0.17 | 0.13 | 0.29 | 0.11 | 0.04 | 0.11 | 0.19 | 0.21 |
| Idea generation             | 0.01 | 0.04 | -0.05 | 0.15 | 0.27 | 0.01 | -0.10 | 0.27 | 0.00 | 0.05 | 0.37 | 0.06 | 0.07 | 0.07 | 0.16 | 0.18 | -0.02 |
| Concept development         | 0.14 | 0.17 | 0.05 | 0.09 | 0.03 | 0.22 | 0.00 | 0.20 | 0.28 | 0.22 | 0.36 | 0.22 | 0.08 | 0.16 | 0.01 | 0.29 | 0.06 |
| Defining the product architecture | 0.03 | 0.11 | 0.05 | 0.12 | 0.10 | 0.07 | 0.14 | 0.10 | 0.10 | 0.04 | 0.17 | 0.05 | 0.17 | 0.09 | 0.05 | 0.21 | 0.13 |
| Managing product cost       | 0.08 | 0.13 | 0.14 | 0.07 | 0.07 | 0.11 | -0.08 | 0.01 | 0.25 | 0.09 | 0.17 | 0.32 | 0.09 | 0.02 | 0.12 | 0.09 | 0.10 |
| Architecture and Modularity | 0.13 | 0.08 | 0.01 | 0.07 | 0.08 | -0.13 | 0.13 | -0.13 | 0.13 | 0.17 | 0.17 | 0.24 | 0.11 | 0.18 | 0.05 | 0.15 | 0.08 |
| Product quality             | 0.02 | 0.12 | 0.05 | 0.09 | 0.17 | 0.05 | 0.13 | 0.13 | 0.06 | 0.17 | 0.15 | 0.13 | 0.15 | 0.06 | 0.08 | 0.11 |
| Project planning and organization | 0.11 | 0.14 | 0.06 | 0.05 | 0.14 | 0.12 | -0.04 | 0.01 | 0.26 | 0.35 | 0.23 | 0.33 | 0.23 | 0.31 | 0.06 | 0.03 |
| PD execution                | 0.15 | 0.16 | 0.21 | 0.03 | 0.15 | 0.14 | -0.08 | 0.04 | 0.32 | 0.27 | 0.23 | 0.37 | 0.30 | 0.36 | 0.13 | 0.25 | 0.12 |
| Supplier development        | 0.11 | 0.10 | 0.00 | 0.07 | 0.09 | 0.05 | 0.07 | 0.19 | 0.09 | 0.15 | 0.36 | 0.14 | 0.14 | 0.18 | 0.23 | 0.09 | 0.07 |
| PDM                        | 0.01 | 0.07 | 0.09 | 0.01 | 0.04 | 0.16 | 0.08 | 0.10 | 0.03 | 0.14 | 0.10 | 0.28 | 0.15 | 0.07 | 0.22 | 0.08 | 0.07 |
| Performance management      | -0.09 | -0.05 | -0.07 | -0.10 | 0.01 | 0.06 | 0.13 | 0.31 | 0.18 | 0.39 | 0.32 | 0.18 | 0.30 | 0.04 | 0.33 | 0.17 |
| Configuration & Change Management | 0.01 | 0.06 | 0.06 | 0.12 | 0.17 | 0.01 | 0.04 | -0.06 | 0.10 | 0.10 | 0.36 | 0.11 | 0.06 | 0.12 | 0.01 | 0.15 | 0.15 |
| Ramp up management          | 0.31 | 0.10 | 0.20 | 0.20 | 0.03 | 0.15 | 0.03 | 0.05 | 0.44 | 0.42 | 0.13 | 0.37 | 0.10 | 0.18 | 0.12 | 0.21 | 0.35 |
| Risk management             | 0.04 | 0.13 | 0.07 | 0.15 | -0.09 | 0.10 | 0.01 | 0.20 | 0.26 | 0.25 | 0.32 | 0.25 | 0.22 | 0.14 | 0.02 | 0.19 | 0.18 |
| Capability management       | 0.16 | -0.03 | -0.07 | -0.70 | 0.14 | -1.14 | 0.01 | 0.32 | 0.34 | 0.40 | 0.38 | 0.19 | -0.28 | 0.08 | 0.22 | 0.31 |
| Knowledge systems           | 0.08 | 0.21 | 0.03 | 0.05 | -0.07 | 0.01 | -0.21 | 0.12 | 0.19 | 0.23 | 0.25 | 0.30 | 0.07 | 0.22 | 0.02 | 0.22 | 0.07 |
| Mindsets                   | 0.12 | 0.09 | 0.13 | -0.01 | 0.09 | 0.26 | -0.10 | 0.11 | 0.16 | 0.17 | 0.26 | 0.16 | 0.11 | 0.08 | 0.04 | 0.11 | 0.06 |
Based on above table,

- Financially-oriented metrics show no direct relationship to practices
- Some questions linked to these metrics may be masked within a practice
- Financial outcomes may be indirectly linked to other performance metrics

We also found that multiple outcome measures from Operational Effectiveness and Product & Process quality have significant correlation with PD practices.

6.3 Correlation between 4 Categories and 17 Self Assessed Performance Measures

As discussed in Chapter “Research Design and Database Characteristics” each category is divided into dimensions that are further divided into processes. For each project simple average is taken of process scores to calculate dimension level score. Further simple average of dimension score is taken to arrive at category level score. Below is correlation between categories and 17 self assessed performance measures.
Table 6-3: Correlation between Self-assessed performance measures and PD Categories

Zooming out to the 4 categories level, we still see no linkages to the first-tier metrics i.e. financial metrics.

We also observe that,

- Performance metrics that are directly linked to multiple categories are: Time-to-market, Adherence to Budget, Project Team morale and Supplier/Partner delivery performance
- Some information is lost in zooming out to this level, so we need to also zoom into the question level
6.4 ANOVA Analysis of each Self Assessed Performance Measure

For each performance metric, each project was categorized based on performance into 3 bins: Low, Mid, High. We used ANOVA analysis to look for questions that show significant difference between performance bins. We considered any question leading to significant difference between High-to-Mid AND High-to-Low to be a differentiating question. A sample of relevant questions identified in ANOVA analysis are shaded in gray in correlation analysis presented in Appendix C.

Below are the observations made based only on ANOVA Analysis:

Financial metrics

- Incentives for project teams
- Stable development which requires limited required rework
- Minimizing the number of new processes, both from internal and suppliers, reduces project SG&A cost

Second-tier metrics

- Developing and promoting project leadership along established processes
- Scoping projects (including technology and required attributes) from the start
- Strong project planning and organization, including a strong project leader that can resolve conflicts/ delays

6.5 Correlation between PD Practices Questions and Self Assessed Performance

Spearman Correlation was carried between PD Practices questions and 17 self assessed performance measures. For each 17 self assessed performance measure we identified questions with correlation’s p-value less than 0.05. Relevant questions to each self-assessed performance measure identified through ANOVA analysis are shaded in gray in Appendix C.

For each outcome measure we identified significantly (p-value < 0.05) correlated PD Practices with that outcome measure. Based on correlation analysis, Performance measure that showed correlation with PD practices are discuss below,
NPV & IRR
- Facilitate communication & Knowledge sharing
- Clear understanding of what technologies are critical
- Minimize handoffs disruptions across functional boundaries
- Business plan address full lifecycle costs and impacts

Time to Market
- Measure and track skill proficiency levels
- Development of leadership to meet strategy
- Clear view of scope and scale
- Minimize handoffs disruptions across functional boundaries
- Verify manufacturability, reliability, quality under real world before full scale launch
- Clear understanding of quality and timing of deliverables
- Accurate duration prediction of individual tasks
- Verification of Supplier quality and other commitments
- Facilitate communication & Knowledge sharing
- Avoid resource conflicts
- Standard work for PD and business processes
- Usage of widely-accepted standards for interface
- Minimize disruption & overloading of staffing
- Manage critical skills explicitly to assure that they are provided

Adherence to Budget
- Use of widely-accepted standards for interface definitions
- Clear view of scope and scale
- Minimize handoffs disruptions across functional boundaries
- Minimize disruption & overloading of staffing
- Verify manufacturability, reliability, quality under real world before full scale launch
- Quantified understanding of potential sources of delays
- Clear understanding of what technologies are critical
- Facilitate communication & Knowledge sharing
- Early system testing
• Clear understanding of quality and timing of deliverables
• Quick resolution of issues
• Critical skills management

Supplier/Partner Performance
• Explicit management of critical skills to assure they are provided
• Minimize handoffs disruptions across functional boundaries
• Continuous improvement of PD task processes
• Tightly manage software and physical interfaces
• Verification of Supplier quality and other commitments
• Explore all elements of value chain to identify cost reduction opportunities
• Availability of all necessary data to trade off product performance with cost, TTM and risk
• Work packages to drive autonomous working
• Suppliers contribute to concept design
• Quantified understanding of competitor’s offering
• Minimize staffing disruption
• Transparency in risk management
• Clear understanding of cost targets
• Early selection and involvement of suppliers

Supplier/Partner Innovation
• Facilitate communication & Knowledge Sharing
• Quantified understanding of competition’s product offering
• Quick resolution of issues
• Customer’s field data drive continuous improvement activities
• Improve PD task processes
• Work packages to drive autonomous working

Supplier/Partner Risk
• Clear understanding of critical technologies
• Minimize staffing disruption
• Status Checks
• Accurate prediction of individual tasks
• Minimize handoffs disruptions across functional boundaries
• Early system testing
• Quick resolution of issues
• Early selection and involvement of suppliers
• Suppliers share joint performance targets

**Product Quality**
• Play leading role in the definition of industry standards
• Gather customer insight data from all sources in the value chain
• Rigorous analysis of market trends
• Reuse of product architecture, modules, interfaces, and work package design
• Verification of Supplier quality and other commitments
• Verify manufacturability, reliability, quality under real world before full scale launch
• Clear software strategy

**Process Quality**
• Leadership to meet strategy
• Track skill proficiency
• Staffing practices to minimize overloading and multitasking

### 6.6 Mapping of Correlation & ANOVA Analysis

Results of ANOVA analysis and Correlation at dimension level were superimposed to understand key PD practices dimensions. By superimposing we identified dimensions that came out relevant both in correlation and ANOVA analysis.
Table 6-4: Overlapped results of Correlation and ANOVA Analysis

<table>
<thead>
<tr>
<th>Correlation</th>
<th>ANOVA</th>
<th>Correlation &amp; ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project IRR and NPV</td>
<td>Product revenues</td>
<td>Product's dollar market share</td>
</tr>
<tr>
<td>Product volumes</td>
<td>Product unit costs</td>
<td>Product SG&amp;A cost</td>
</tr>
<tr>
<td>Satisfaction with product function</td>
<td>Performance and performance</td>
<td>Satisfaction with price for value</td>
</tr>
<tr>
<td>Time to market</td>
<td>Adherence to budget</td>
<td>Supplier/Partner delivery</td>
</tr>
<tr>
<td>Supplier/Partner Innovation</td>
<td>Supplier/Partner Risk</td>
<td>Performance vs. specification</td>
</tr>
<tr>
<td>Product quality</td>
<td>Process quality (validation)</td>
<td></td>
</tr>
</tbody>
</table>

Product development environment
Portfolio management
Technology development
Development of enterprise capabilities
Align to product strategy
Customer insights
Idea generation
Concept development
Defining the product architecture
Managing product cost
Architecture and Modularity
Product quality
Project planning and organization
PD execution
Supplier development
PDM
Performance management
Configuration & Change Management
Ramp up management
Risk management
Capability management
Knowledge systems
Mindsets

Key PD Practices to various outcome measures based on Correlation & ANOVA are listed below:

**Time to Market**

- Development of Enterprise Capabilities
- Align product to strategy

**Adherence to Budget**

- Align product to strategy
• Project planning and organization

• Risk Management

• Capability Management

Supplier/Partner Performance

• PD Execution

• Mindsets

Supplier/Partner Risk

• Project planning and organization

6.7 Correlation between PD dimensions identified using component analysis and Self-Assessed Performance Measures

Component analysis was carried out using Principal Component Analysis techniques. Weights assigned to questions in identified components helped in interpretation of that component and in assignment of suitable name to that component. Components analysis is shown in Appendix D.
Table 6-5: Correlation between Components and Outcome Measure

<table>
<thead>
<tr>
<th>Component Description</th>
<th>Table Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Development Environment</td>
<td></td>
</tr>
<tr>
<td>Strategy to cannibalize existing product offerings</td>
<td>-0.07</td>
</tr>
<tr>
<td>Portfolio management</td>
<td>-0.10</td>
</tr>
<tr>
<td>Technology development</td>
<td>0.05</td>
</tr>
<tr>
<td>Development of Enterprise Capabilities</td>
<td>0.09</td>
</tr>
<tr>
<td>Align product to strategy</td>
<td>0.04</td>
</tr>
<tr>
<td>Rigorous tracking of customer insights</td>
<td>0.10</td>
</tr>
<tr>
<td>Validate product attributes/specs with users</td>
<td>-0.15</td>
</tr>
<tr>
<td>Idea generation</td>
<td>-0.04</td>
</tr>
<tr>
<td>Concept development</td>
<td>0.22</td>
</tr>
<tr>
<td>Defining the product architecture (product system design)</td>
<td>-0.02</td>
</tr>
<tr>
<td>Rigorous product costing process and targets</td>
<td>0.15</td>
</tr>
<tr>
<td>Invest in product cost reduction</td>
<td>0.06</td>
</tr>
<tr>
<td>Push towards architecture roadmap &amp; reuse of subsysyms</td>
<td>0.11</td>
</tr>
<tr>
<td>Rigorous interface management</td>
<td>0.09</td>
</tr>
<tr>
<td>Invest in and develop insights and capabilities for quality</td>
<td>0.09</td>
</tr>
<tr>
<td>Measure and track quality outcomes</td>
<td>0.00</td>
</tr>
<tr>
<td>Plan and pace schedule to well-understood process</td>
<td>0.26</td>
</tr>
<tr>
<td>Team and managers not empowered beyond team</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>Table Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project IRR and NPV</td>
<td></td>
</tr>
<tr>
<td>Product revenues</td>
<td></td>
</tr>
<tr>
<td>Product volumes</td>
<td></td>
</tr>
<tr>
<td>Product dollar market share</td>
<td></td>
</tr>
<tr>
<td>Product unit costs</td>
<td></td>
</tr>
<tr>
<td>Product S &amp; A cost</td>
<td></td>
</tr>
<tr>
<td>Satisfaction with product</td>
<td></td>
</tr>
<tr>
<td>Function and performance value</td>
<td></td>
</tr>
<tr>
<td>Satisfaction with price for value</td>
<td></td>
</tr>
<tr>
<td>Time to market</td>
<td></td>
</tr>
<tr>
<td>Adherence to budget</td>
<td></td>
</tr>
<tr>
<td>Project team morale</td>
<td></td>
</tr>
<tr>
<td>Supplier/Partner Delivery</td>
<td></td>
</tr>
<tr>
<td>Supplier/Partner Performance</td>
<td></td>
</tr>
<tr>
<td>Supplier/Partner Innovation</td>
<td></td>
</tr>
<tr>
<td>Performance vs specification</td>
<td></td>
</tr>
<tr>
<td>Product quality</td>
<td></td>
</tr>
<tr>
<td>Process Quality Validation</td>
<td></td>
</tr>
</tbody>
</table>

Note: The table values are shown as correlation coefficients, with significance levels indicated by asterisks.
| Continuous improvement mindset | Well understood processes and capabilities | Rigorous selection and involvement of supplier in PD lifecycle | Active participation of suppliers in PD lifecycle | Product Data Management (PDM) | Usage of KPI and product-based milestones | R -- ineffective project reviews (alternate explanation: decision flexibility outside formal process) | Configuration & change management | Downstream capabilities/requirements validated up front | Capacity planning optimizes demands on system from product stream | Rigorous process to identify and track risks | Rigorous product testing | Capability management | Create formal knowledge management systems | Invest in boundary-spanning/integrating activities | Make complex knowledge explicit | Common vision & team; Complexity/risk are our management tasks | Project objectives are top priority |
|---------------------------------|---------------------------------|-------------------------------------------------|-------------------------------------------------|---------------------------------|---------------------------------|-------------------------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| -0.03                           | 0.03                            | -0.11                           | -0.16                           | 0.01                           | 0.06                           | -0.11                           | 0.14                           | 0.14                           | 0.05                           | 0.13                           | 318**                          | 0.21                           | 0.16                           | 0.22                           | 278**                          | -0.04                           |
| 0.22                            | 0.08                            | -0.04                           | -0.02                           | 0.25                           | 0.19                           | 0.16                           | 0.13                           | 266*                           | 0.25                           | 0.22                           | 12.44                          | 0.02                           | 0.04                           | 0.15                           | 0.15                           | 0.04                           |
| 0.12                            | 0.05                            | -0.01                           | -0.11                           | 0.07                           | -0.01                           | -0.13                           | 0.20                           | 0.09                           | 0.09                           | 0.25                           | 0.20                           | 0.04                           | 0.15                           | 0.16                           | 0.05                           | 0.13                           |
| 0.00                            | 0.07                            | -0.19                           | -0.01                           | -0.09                           | 0.08                           | 0.10                           | 0.21                           | -0.05                          | -0.01                          | 0.15                           | -0.08                          | 0.10                           | 0.10                           | 0.291*                         | 0.12                           | -0.07                          |
| 0.10                            | 0.18                            | 0.05                            | 0.11                            | -0.19                           | 0.05                           | 0.05                           | 0.09                           | 0.03                           | 0.09                           | 0.27                           | 0.06                           | 0.10                           | 0.10                           | -0.10                          | 0.01                           | 0.05                           |
| -0.09                           | -0.12                           | -0.19                           | -0.02                           | -0.14                           | 0.02                           | -0.12                           | 0.16                           | 0.23                           | 0.07                           | 272**                          | 0.20                           | 0.07                           | 0.25                           | -0.01                          | 286**                          | 0.10                           |
| -0.19                           | -0.02                           | 0.16                            | 0.17                            | -0.09                           | 0.04                           | -0.01                           | -0.06                          | 0.23                           | 0.09                           | 367**                          | 0.14                           | 0.26                           | 0.05                           | -0.24                          | 0.08                           | 0.18                           |
| 0.02                            | 0.06                            | 0.08                            | 0.12                            | -0.12                           | 0.01                           | 0.02                           | 0.07                           | 0.11                           | 0.10                           | 363**                          | 0.14                           | -0.04                          | 0.17                           | 0.03                           | 0.12                           | 0.05                           |
| 313**                           | 0.13                            | 0.17                            | 0.15                            | 0.03                           | 0.10                           | 0.00                           | 0.11                           | 362**                          | 364**                          | 0.11                           | 361**                          | 0.14                           | 0.18                           | 0.11                           | 0.23                           | 341**                          |
| 0.20                            | 0.15                            | 0.15                            | 0.21                            | -0.14                           | -0.24                          | -0.13                           | -0.19                          | 0.07                           | 0.03                           | 0.04                           | 0.16                           | 0.19                           | 0.15                           | -0.05                          | -0.17                          | 0.01                           |
| -0.09                           | 0.13                            | 0.04                            | 0.16                            | -0.270*                         | 0.09                           | 0.02                           | 0.13                           | 309**                          | 0.13                           | 360**                          | 292*                           | 0.11                           | -0.08                          | 0.00                           | 0.11                           | 0.01                           |
| 0.09                            | 0.04                            | 0.01                            | 0.02                            | 0.03                           | 0.02                           | 0.15                           | 0.19                           | -0.04                          | 0.16                           | 0.07                           | -0.02                          | 0.17                           | 293*                           | 0.19                           | -0.04                          | 0.13                           |
| 0.14                           | -0.05                           | -0.06                           | -0.05                           | 0.08                           | 0.10                           | -0.10                           | 0.04                           | 320**                          | 299*                           | 423**                          | 346**                          | 0.16                           | 257*                           | 0.05                           | 0.19                           | -323**                         |
| -0.05                           | -0.01                           | -0.14                           | -0.12                           | -0.14                           | 0.26                           | 0.04                           | -0.01                          | -0.09                           | 357**                          | 0.08                           | -0.09                          | 0.20                           | -0.05                          | 0.14                           | -0.09                          |
| -0.20                           | -0.12                           | -0.13                           | -0.24                           | -0.262*                         | -0.10                           | -0.09                           | 0.05                           | 0.10                           | 0.02                           | 0.12                           | 0.16                           | -0.07                          | -0.15                          | 0.08                           | -0.06                          | -0.07                          |
| 330**                           | 0.27                            | 0.10                            | 0.03                            | 0.13                           | 0.13                           | 0.05                           | 302**                          | 0.15                           | 290*                           | 0.03                           | 0.13                           | 0.18                           | 0.19                           | -0.02                          | 0.03                           | 0.14                           |
| -0.02                           | 0.06                            | 0.05                            | -0.01                           | -0.12                           | 0.10                           | -0.05                           | 0.15                           | 0.12                           | 0.12                           | 0.15                           | 0.11                           | 0.05                           | 0.04                           | -0.02                          | 0.16                           | -0.08                          |
| 0.14                           | -0.03                           | 0.02                            | 0.01                            | 0.04                           | 0.23                           | -0.05                           | 0.04                           | 0.15                           | 0.19                           | 321*                           | 0.17                           | 0.08                           | 0.26                           | -0.18                          | -0.08                          | 0.13                           |
Table 6-6: Mapping of Component Analysis results on Dimension Analysis

<table>
<thead>
<tr>
<th>Component Analysis</th>
<th>Dimension Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Project IR and NPV</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Product Development Environment</td>
<td>Product Development Environment</td>
</tr>
<tr>
<td>Portfolio management</td>
<td>Portfolio management</td>
</tr>
<tr>
<td>Technology development</td>
<td>Technology development</td>
</tr>
<tr>
<td>Development of Enterprise Capabilities</td>
<td>Development of Enterprise Capabilities</td>
</tr>
<tr>
<td>Align product to strategy</td>
<td>Align product to strategy</td>
</tr>
<tr>
<td>Customer insights</td>
<td>Rigorous tracking of customer insights</td>
</tr>
<tr>
<td>Idea generation</td>
<td>Idea generation</td>
</tr>
<tr>
<td>Concept development</td>
<td>Concept development</td>
</tr>
<tr>
<td>Defining the product architecture (product system design)</td>
<td>Defining the product architecture (product system design)</td>
</tr>
<tr>
<td>Managing product cost</td>
<td>Rigorous product costing process and targets</td>
</tr>
<tr>
<td>Architecture and modularity</td>
<td>Push towards architecture roadmap &amp; reuse of subsystems</td>
</tr>
<tr>
<td>Product quality</td>
<td>Invest in and develop insights and capabilities for quality</td>
</tr>
<tr>
<td>Project planning and organization</td>
<td>Plan and pace schedule to well-understood process</td>
</tr>
<tr>
<td>Project development execution</td>
<td>Well understood processes and capabilities</td>
</tr>
<tr>
<td>Supplier development</td>
<td>Rigorous selection and involvement of supplier in PD lifecycle</td>
</tr>
<tr>
<td></td>
<td>Active participation of suppliers in PD lifecycle</td>
</tr>
</tbody>
</table>
Component analysis shows which questions within a dimension club together. Spearman correlation between identified components and self-assessed performance measures show which of these components are critical.

**NPV/IRR**

- Downstream capabilities/requirements validated up front
- Make complex knowledge explicit
Product Volumes

- Well understood processes and capabilities

Product’s dollar market share

- Well understood processes and capabilities

Product’s SG&A Cost

- Rigorous tracking of customer insights

Time-to-Market

- Strategy to cannibalize existing product offerings
- Technology development
- Development of Enterprise Capabilities
- Align product to strategy
- Rigorous tracking of customer insights
- Concept development
- Rigorous product costing process and targets
- Plan and pace schedule to well-understood process
- Well understood processes and capabilities
- Downstream capabilities/requirements validated up front
- Rigorous process to identify and track risks
- Capability management

Adherence to Budget

- Strategy to cannibalize existing product offerings
- Align product to strategy
- Rigorous interface management
- Invest in and develop insights and capabilities for quality
- Team and managers not empowered beyond team
- Downstream capabilities/requirements validated up front
- Capability management
• Make complex knowledge explicit

**Supplier/Partner Delivery Performance**

• Product Development Environment
• Development of Enterprise Capabilities
• Rigorous product costing process and targets
• Team and managers not empowered beyond team
• Continuous improvement mindset
• Downstream capabilities/requirements validated up front
• Rigorous process to identify and track risks
• Capability management

**Supplier/Partner Innovation**

• Team and managers not empowered beyond team
• Well understood processes and capabilities

**Supplier/Partner Risk**

• Align product to strategy
• Team and managers not empowered beyond team
• Rigorous product testing
• Capability management

**Performance Vs Specification**

• Strategy to cannibalize existing product offerings
• Portfolio Management
• Rigorous tracking of customers insight
• Active participation of suppliers in PD lifecycle
Product Quality

- Portfolio management
- Development of Enterprise Capabilities
- Align product to strategy
- Concept development
- Plan and pace schedule to well-understood process
- Continuous improvement mindset
- Usage of KPI and product-based milestones

Process Quality

- Rigorous tracking of customer insights
- Downstream capabilities/requirements validated up front
- Capability management

Table 6-6 juxtaposes correlation results based on dimension (mean of question scores within a dimension) and Component Analysis (identification of sub-dimensions within dimension rather than straight average of question scores). It also shows that component analysis is more specific compared to our dimension level analysis i.e. we are able to point out specific processes within a dimension.

6.8 Understanding what PD practices does not matter

Straight average or component analysis of questions in a dimension causes loss of granularity. Therefore, question level analysis results were studied at dimension level to get new insights into which PD practices do not matter.
Table 6-7: Mapping of significant questions to PD Dimensions Vs Self-Assessed Outcome Measure

<table>
<thead>
<tr>
<th>Dimension</th>
<th>PD Dimension</th>
<th>Performance Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of Enterprise Capabilities</td>
<td></td>
<td>WVP &amp; NR, Product Volume, Product Dollar Market Share, Product Unit Cost, Product S&amp;D Cost</td>
</tr>
<tr>
<td>Technology development</td>
<td>1</td>
<td>1 2 4 3 2 1 2 4 2</td>
</tr>
<tr>
<td>Customer insights</td>
<td>1</td>
<td>1 2 4 3 2 1 2 4 2</td>
</tr>
<tr>
<td>Align on strategic priorities</td>
<td>1</td>
<td>1 2 4 3 2 1 2 4 2</td>
</tr>
<tr>
<td>Product Development Environment</td>
<td></td>
<td>1 2 4 3 2 1 2 4 2</td>
</tr>
<tr>
<td>Align product to strategy</td>
<td>1</td>
<td>1 2 4 3 2 1 2 4 2</td>
</tr>
<tr>
<td>Portfolio management</td>
<td>1</td>
<td>1 2 4 3 2 1 2 4 2</td>
</tr>
<tr>
<td>Idea generation</td>
<td>1</td>
<td>1 2 4 3 2 1 2 4 2</td>
</tr>
<tr>
<td>Concept development</td>
<td>1</td>
<td>1 2 4 3 2 1 2 4 2</td>
</tr>
<tr>
<td>Defining the product architecture (product system design)</td>
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<td>1 2 4 3 2 1 2 4 2</td>
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<tr>
<td>Managing product cost</td>
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<td>1 2 4 3 2 1 2 4 2</td>
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<tr>
<td>Architecture and modularity</td>
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<td>1 2 4 3 2 1 2 4 2</td>
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<td>Product quality</td>
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<td>Project planning and organization</td>
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<td>1 2 4 3 2 1 2 4 2</td>
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<td>1 2 4 3 2 1 2 4 2</td>
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<td>Supplier development</td>
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<td>Performance management</td>
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<tr>
<td>Configuration &amp; change management</td>
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<tr>
<td>Mindsets</td>
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<td>1 2 4 3 2 1 2 4 2</td>
</tr>
</tbody>
</table>

In Table significantly correlated questions were mapped to dimensions. We identified PD Dimensions from which 0% questions got correlated to a specific PD performance measure.

**Overall practices found to be least correlated to any outcome measure**

- Configuration & change management
- Defining the product architecture (product system design)
- Idea generation
- Product Data Management (PDM)
6.9 Cluster Analysis on Performance Parameter

PD Outcome measures have a complex and interdependent relationship. Hierarchical Analysis was carried out among 17 Self-assessed performance measures to understand complex relationship among them.

Table 6-8: Cluster Analysis on Self-Assessed Outcome Measure

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<thead>
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<td>Adherence to budget</td>
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<tr>
<td>Time to market</td>
<td></td>
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<tr>
<td>Supplier/Partner Delivery Performance</td>
<td></td>
<td></td>
<td>+</td>
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<tr>
<td>Process quality (validation)</td>
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<td>+</td>
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<tr>
<td>Product unit costs</td>
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<tr>
<td>Supplier/Partner Risk</td>
<td></td>
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<tr>
<td>Product SG&amp;A cost</td>
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<td></td>
<td>+</td>
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<tr>
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<td>Product volumes</td>
<td></td>
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<tr>
<td>Product’s dollar market share</td>
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<tr>
<td>Product revenues</td>
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<tr>
<td>Project team morale</td>
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<td>Satisfaction with price for value</td>
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<tr>
<td>Performance vs. specification</td>
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<tr>
<td>Satisfaction with product function and performance</td>
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</tbody>
</table>

We see the following clusters above,

Operations/Project Management

- Project IRR and NPV
- Adherence to Budget
- Time to Market
- Supplier/Partner Delivery Performance
- Process Quality
- Product Unit cost
- Supplier/Partner Risk

Dollar Stream

- Product Volume/Revenue
- Product’s Dollar Market Share
• Supplier/Partner Innovation

**Product Performance**

• Customer Satisfaction
• Performance Vs Specification
• Product Quality

IRR & NPV is an important financial measure. In above table we observe that NPV/IRR Most Closely Related to Operational/Project Management Outcomes.

Closest outcome measure to NPV/IRR is Adherence to budget by disciplined execution and project management. Next closest is Time To Market (adherence to schedule), Supplier/Partner Delivery Performance, Process Quality, which is operational effectiveness and consistent execution. Next tier which is close to NPV/IRR is Product Unit Costs, Supplier/Partner Risk i.e. Management of product cost (direct and procured).

6.10 *Inter-correlation matrix among Self-assessed Performance Parameters*

We computed inter-correlation matrix among 17 self-assessed outcome measures to understand inter-dependency and possible second order effects through PD practices levers.
Table 6-9: Inter-correlation matrix among Self-Assessed Performance Parameters

<table>
<thead>
<tr>
<th></th>
<th>Project IRR and NPV</th>
<th>Product revenues</th>
<th>Product volumes</th>
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<th>Project SG&amp;A cost</th>
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<th>Satisfaction with price for value</th>
<th>Time to market</th>
<th>Adherence to budget</th>
<th>Project team morale</th>
<th>Supplier/Partner Delivery Performance</th>
<th>Supplier/Partner Innovation</th>
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<th>Performance quality</th>
<th>Process quality (validation)</th>
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<td>Product SG&amp;A cost</td>
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</table>

It can be observed that Project NPV, Product Volume and Product cost are all linked to budget adherence, supplier performance and process quality. It is likely that any practices linked to budget, supplier or process success, may also have indirect financial implications.
7 Hypothesis Testing

7.1 Companies with strong PD practices grow faster than those with average or weak practices

As discussed in previous sections, several PD practices are seen linked to the following outcome measures,

- Time to market (Adherence to schedule)
- Adherence to Budget
- Supplier/Partner delivery performance
- Supplier/Partner Risk
- Process Quality

In chapter 6, we observed that these outcome measures influence NPV/IRR of project. As we know that NPV/IRR in turn impacts how fast a firm grows. Thus, we see an indirect link between PD practices and companies growth.

7.2 Companies with strong PD practices spend less on R&D than those with average or weak practices

Figure 5-2, Figure 5-3 to Figure 5-7, and Figure 5-9 to Figure 5-13 indicates tight linkage between PD practices and less expenditure on R&D as percentage of sales.

7.3 Companies with continuous improvement systems in PD execution practices realize lower R&D cost levels than those w/o such systems

Figure 5-13 specifically shows that a strong significant correlation exists between PD execution practices and lower R&D cost levels.
7.4 Companies with strong customer insight practices accomplish product launches with better price-value satisfaction than companies that do not take customer insights into account

None of the questions that were on customer satisfaction correlated with price-value satisfaction, and therefore it is difficult to comment on this hypothesis.

7.5 Companies with strong competitor insight practices accomplish product launches with better price-value satisfaction than companies that do not take competitor insights into account

In Self Assessed Performance based Analysis it is observed that competitor insight practices (Question #9) is significantly correlated to Self-assessed performance parameter – ‘Product Quality’. In cluster analysis section, it can be observed that performance parameter ‘Product Quality’ and ‘Price-Value satisfaction’ are in same cluster indicating that they are closely related. From these two observations we can draw the conclusion that competitor insight practices is linked with price-value satisfaction.

7.6 People with strong people development practices (such as hiring and developing talent) spend less in R&D than those with avg. or weak practices
We try to maximize staffing stability to develop deep knowledge and expertise.

Figure 7-1: Regression between R&D/Sales and Staffing to develop deep knowledge and expertise

Pearson Correlation = 0.753 (Significance = 0.007)

In it can be observed that we have a positive significant correlation between people development and R&D expenditure indicating that we disprove the above hypothesis.
8 Findings and Next Steps

Process management theory suggests that one should not only implement the correct processes, one should also monitor how well the processes are operating and, if necessary, intervene in a timely manner. Product development success measures that focus on overall project performance are known at the end of the project, too late to improve the ongoing process. To better achieve product development goals such as customer satisfaction, adherence to schedule, adherence to budget, cost reduction, timely process performance feedback should be available.

This research has presented and validated links between process performance and project performance, and it has also identified key product development practices linked closely to a performance measure.

8.1 Findings

Following are the key PD practices that came out relevant in driving R&D/Sales low.

- Rigorous testing with effective feedback
- Risk analysis and multiple contingency plans
- Firm strategy and quantified requirements of target market segment help in defining project scope and scale
- Active leadership & friendly environment
- Good understanding of sources of delay
- Regular status check at production integration level
- Quick resolution of issues
- Entire team shares a common understanding of what the customer values for making daily project decisions
- Formal make-buy decision process on new technologies
- Involvement of PD manufacturing personnel & downstream partners
- All key functions and suppliers contribute to concept design
- Continuous improvement using customer feedback
- Brainstorming of possible system architectures
- Continuous improvement of processes, tasks, and product quality

In this research we found that,

- Corporate level finance metrics are not directly related to process performance
- Adherence to budget, time to market, supplier/partner delivery performance, and process quality, which are operational effectiveness measures are closely linked with project’s financial performance. Next tier close to project’s financial performance are product unit cost and supplier/partner risk.

Following are the key PD Practices to operational effectiveness performance measures that have come out relevant.

**Adherence to Budget**

- Clear understanding of project and product details
- Quick identification and resolution of risks and uncertainties in
  - Project planning (such as resource/capacity conflict, handoffs etc.)
  - Ramp up management (such as new process technologies, manufacturability, reliability, quality, supplier quality, etc.)
- Smooth integration of processes through proper planning and coordination
- Development and management of human resources and skills
Adherence to Schedule (Time to Market)

- Smooth transition of technologies into product stream
- Clear view of project scope and scale
- Improvement of capabilities and task processes
- Development and management of human resources and skills
- Smooth integration of processes through usage of standard work procedure, proper planning and management
- Quick identification and resolution of risks and uncertainties in
  - Project planning
  - Ramp up management (such as new process technologies, manufacturability, reliability, quality, supplier quality, etc.)

Supplier/Partner Delivery Performance

- Smooth transition of technologies into product stream & formal make-buy decision process on new technologies
- Life cycle cost modeling, early benchmarking, and clear understanding of cost targets
- Development and management of human resources and skills; Avoid overloading of critical resources
- Smooth integration of processes through proper planning and coordination
- Continuous task processes improvement activities
- Suppliers integrated into PD process
• Quick identification and resolution of risks and uncertainties in ramp up management and in general
• Continually measure and assess performance

Supplier/Partner Delivery Performance

• Development and management of human resources and skills; Avoid overloading of critical resources
• Clear view of project scope and scale
• Performance tracking at project level including suppliers

8.2 Next Steps

When more data points are added in future, we can carry out advanced statistical analysis on this database such as

  o Structural equations

  o Partial correlation
## APPENDIX A – Literature Analysis

<table>
<thead>
<tr>
<th>Title</th>
<th>How R&amp;D affects sales growth, productivity and profitability</th>
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<tbody>
<tr>
<td>Author</td>
<td>Graham Morvey</td>
</tr>
<tr>
<td>Year of Publication</td>
<td>1990</td>
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</tbody>
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| Insights | • Strong relation between R&D Intensity and subsequent growth in sales.  
  • No direct relationship between R&D intensity and growth margin.  
  • Strong relation between R&D expenditure per employee and subsequent company productivity, measured as sales per employee.  
  • To ensure profitability from increased sales, management must promote and maintain high levels of employee productivity in all sections within their company |
<p>| Robustness of research | Medium |
| Issue addressed | Influence of R&amp;D on future sales and profitability |
| Academic/Commercial | Academic |
| Industry Examined | 19 Industries |
| Number of data points | 727 companies |
| Variables in Database | Profit Margin, Sales/Employee, ROA, R&amp;D/Sales, R&amp;D/Employee, R&amp;D Expenditure (All R&amp;D figures are avg. of 4 yrs) |
| Data Collection Method | Data provided by S&amp;P Compustat services |</p>
<table>
<thead>
<tr>
<th>Title</th>
<th>R&amp;D Effective index: A metric for product development performance</th>
</tr>
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<tbody>
<tr>
<td>Author</td>
<td>McGrath</td>
</tr>
<tr>
<td>Year of Publication</td>
<td>1994</td>
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</tbody>
</table>

**Insights**

- Comparing R&D/Sales of 2 firms is effective only if strategies and opportunities are similar and their PD processes are equally effective.
- Companies with more effective R&D outperformed the average in growth and profitability.
- Companies with high R&D effectiveness grew twice as fast as the average.
- High performers spend less on R&D and got more out of it. They wasted less on product that did not come to market. They met their original project goals more often.

<table>
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<td>Industry Examined</td>
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<td>Research Methodology</td>
<td>Calculated R&amp;D Effective Index.</td>
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<tr>
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<tr>
<td>Variables in Database</td>
<td>New product Revenue %, Profit % from new product, Investment in R&amp;D %</td>
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<tr>
<td>Data Collection Method</td>
<td>PRTM</td>
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<tr>
<td>Title</td>
<td>Competencies, Innovation and Profitability of Firms</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Author</td>
<td>Leiponen</td>
</tr>
<tr>
<td>Year of Publication</td>
<td>2000</td>
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</tbody>
</table>

**Insights**
- Competence (Educational Measure) is positively associated with profitability.
- Process innovation is tightly coupled with profitability.
- Product innovation has adverse effect on profit margin -- small firms MAY be constrained by limited resources and therefore cannot carry out both types of innovation (product & process) simultaneously.

**Robustness of research** Medium

**Issue addressed**
Investigates impact of competencies on economic performance

**Academic/Commercial** Academic

**Industry Examined** Finnish Manufacturing firms

**Research Methodology**

**Number of data points** 209 Companies

**Variables in Database** Product /Process innovation, Education of emp., Financial performance

**Data Collection Method** Survey
<table>
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<tr>
<th>Title</th>
<th>Competitive Positioning and Innovative efforts in SMEs</th>
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<tr>
<td>Author</td>
<td>Lefebvre</td>
</tr>
<tr>
<td>Year of Publication</td>
<td>1993</td>
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<tr>
<td>Insights</td>
<td>Firms which hold strong a stronger competitive position in terms of cost, quality, and diversity generally make greater efforts with regard to innovation</td>
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<td>Robustness of research</td>
<td>Medim</td>
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<td>Issue addressed</td>
<td>Relationship between competitive positioning and innovative efforts as measured by R&amp;D Expenditures, process innovation, an the use of patent databases</td>
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<td>Academic</td>
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<tr>
<td>Industry Examined</td>
<td>SMEs from various industries</td>
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<td>Research Methodology</td>
<td>Heirarchical Factor analysis on independent variable to classify datapoints into best, niche, worst. Later, calculated mean financial performance parameters to understand these groups.</td>
</tr>
<tr>
<td>Number of data points</td>
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<tr>
<td>Variables in Database</td>
<td>Product price, product cost, product quality, product image, product diversity, quality of customer service, frequency of introducing new products, R&amp;D/Sales, Innovation score for product technologies (weighted avg. of score given by panel of 40 experts), number of patents, use of patent information</td>
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<td>Data Collection Method</td>
<td>Firms were selected from government master file of manufacturing firms operating actively in Quebec, Canada. Questionaire were sent to CEO of firms. 12% responded.</td>
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<td>Title</td>
<td>Productivity Gains from implementation of employee training program</td>
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<tr>
<td>Author</td>
<td>Bartel</td>
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<td>High Rate of labor productivity observed after training. Effects observed on individual employee and organization level</td>
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<td>Academic</td>
</tr>
<tr>
<td>Industry Examined</td>
<td>Manufacturing in general</td>
</tr>
<tr>
<td>Research Methodology</td>
<td>Observation of relationship between training and wages as evidence of relationship between training and productivity.</td>
</tr>
<tr>
<td>Number of data points</td>
<td>495 Compustat II business lines</td>
</tr>
<tr>
<td>Variables in Database</td>
<td>Presence/absence of training, yr in which training is given, age of business unit, % of employees unionized, number of policies, type of policies, % of people undergone training</td>
</tr>
<tr>
<td>Data Collection Method</td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>The impact of human resource management practices on turnover, productivity, and corporate financial performance</td>
</tr>
<tr>
<td>-------</td>
<td>---------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Author</td>
<td>Huselid</td>
</tr>
<tr>
<td>Year of Publication</td>
<td>1995</td>
</tr>
<tr>
<td>Insights</td>
<td>High performance practices impact employee turnover, and on per employee basis, sales, market value and profit. Overall, HRM can create a source of sustained competitive advantage, esp. when aligned with firm's competitive strategy. Also observed that, Productivity is negatively correlated with R&amp;D Intensity (log of R&amp;D/Sales)-- (Corr = -0.01). Observed that high performance practices have an impact of 40% on employee turnover</td>
</tr>
<tr>
<td>Robustness of research</td>
<td>High</td>
</tr>
<tr>
<td>Issue addressed</td>
<td>Impact of HRM policies and practices on firm performance. Direct and economical impact on firm performance observed.</td>
</tr>
<tr>
<td>Academic/Commercial</td>
<td>A</td>
</tr>
<tr>
<td>Industry Examined</td>
<td>Wide range of industries</td>
</tr>
<tr>
<td>Research Methodology</td>
<td>Came up with 2 factors using PCA. Verified 2 factor formation using external information - human resources mentioned as important in Disclosure, number of ppl in HR department</td>
</tr>
<tr>
<td>Number of data points</td>
<td>968 Companies</td>
</tr>
<tr>
<td>Variables in Database</td>
<td>Employee turnover, Sales/Employee, Employee outcome, market based and accounting based measure of company performance</td>
</tr>
<tr>
<td>Data Collection Method</td>
<td>Questionnaire mailed to HR dept. of 3452 firms to collecte firm level data on company performance. Response rate 28%</td>
</tr>
<tr>
<td>Title</td>
<td>The Effect Human Resource Management Practices on Productivity: A study of steel finishing lines</td>
</tr>
<tr>
<td>-------</td>
<td>------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Author</td>
<td>Ichniowski</td>
</tr>
<tr>
<td>Year of Publication</td>
<td>1997</td>
</tr>
<tr>
<td>Insights</td>
<td>Firms realize gain in productivity by adopting clusters of complementary practices and benefit little from making 'marginal' changes in any one practice.</td>
</tr>
<tr>
<td>Robustness of research</td>
<td>High</td>
</tr>
<tr>
<td>Issue addressed</td>
<td>Complementaries exist in HRM practices. Impact of HRM practices on employee productivity</td>
</tr>
<tr>
<td>Academic/Commercial</td>
<td>Academic</td>
</tr>
<tr>
<td>Industry Examined</td>
<td>Steel industry</td>
</tr>
<tr>
<td>Research Methodology</td>
<td>Productivity = Tonnage/Month. Impact of distinctive combinations of HRM practices (7)</td>
</tr>
<tr>
<td>Number of data points</td>
<td>2910 observations on productivity from 36 steel production lines owned by 17 companies</td>
</tr>
<tr>
<td>Variables in Database</td>
<td>Tonnage/Month, 25 controls for detailed features of line. These technological control affect productivity</td>
</tr>
<tr>
<td>Data Collection Method</td>
<td>Personal visit to sites. Interview of 1-3 days with HR Manager, labour relation manager, operations manager, suprintendent, line workers, union representatives. Collected information from personnel files, manuals, bargaining agreement.</td>
</tr>
<tr>
<td>Title</td>
<td><strong>2004 R&amp;D Benchmarking Report</strong></td>
</tr>
<tr>
<td>-------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>Company</td>
<td>DTI (UK)</td>
</tr>
<tr>
<td>Year of Publication</td>
<td>2005</td>
</tr>
</tbody>
</table>
| Insights | • Sales growth rises with R&D intensity (R&D/sales) for a wide range of R&D performing sectors  
| | • Higher R&D intensity associated with higher share price growth in high R&D intensity sectors  
<p>| | • 74% of companies with higher wealth creation efficiency have investment intensity (R&amp;D or capital) above average |
| Robustness of research | High                          |
| Issue addressed | Positive relationship between R&amp;D intensity and performance measures such as sales growth and market capitalization to sales. |
| Academic/Commercial | Commercial                     |
| Industry Examined | 5 sectors: pharma &amp; health, electronics &amp; IT, engineering &amp; chemicals, low intensity (food producers, support services, etc), very low intensity (oil &amp; gas, utilities) |
| Research Methodology | Primary data from the latest audited annual accounts of the companies listed; no data is taken from secondary or unpublished sources. Includes both listed and private companies, and foreign-owned UK companies. |
| Number of data points | 700 UK &amp; 700 international |
| Variables in Database |                              |
| Data Collection Method | primary data taken directly from the latest audited annual accounts of the companies listed using a standard methodology |</p>
<table>
<thead>
<tr>
<th>Title</th>
<th>Product Development Mastery: A Key Contributor to High Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company</td>
<td>Accenture</td>
</tr>
<tr>
<td>Year of Publication</td>
<td>2008</td>
</tr>
</tbody>
</table>
| Insights | - confirms that a relationship exists between product development mastery and superior financial performance.  
- strong PD performance results in market cap CAGR premium of 7 to 26 % above industry average.  
- Faster product time to market (as much as 30 to 50 percent faster than average)  
- Higher revenue and margin from new products (as much as 10 percent higher for each)  
- As much as 50 percent greater productivity in the product development function |
<p>| Robustness of research | Unknown |
| Issue addressed | Positive relationship between superior product development capabilities and financial performance (market cap growth, product margins, productivity) |
| Academic/Commercial | Commercial |
| Industry Examined | Unknown |
| Research Methodology | Insights drawn from client work with distinctive product development players. Very little explanation of methodology. |
| Number of data points | unknown |
| Variables in Database | Unknown |
| Data Method Collection | client work |</p>
<table>
<thead>
<tr>
<th>Title</th>
<th>Smart Spenders: The Global Innovation 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company</td>
<td>Booz Allen Hamilton</td>
</tr>
<tr>
<td>Year of Publication</td>
<td>2006</td>
</tr>
</tbody>
</table>
| Insights      | - Less than 10 percent of companies are high-leverage innovators, but overall companies are getting better at getting more for their R&D spend.  
 - No significant relationship between R&D spending and the primary measures of corporate performance, although there is a positive correlation between R&D/sales (intensity) to gross margins.  
 - Common attributes between high leverage innovators: all build distinctive capabilities in ideation, project selection, development, or commercialization. |
| Robustness of research | High                                    |
| Issue addressed | High leverage innovators: companies who spend less than competitors on R&D, yet outpace their industries by a wide margin. |
| Academic/Commercial | Commercial                              |
| Industry Examined | 10 Industries                         |
| Research Methodology | Survey of financial statements, omitting privately held firms.  
Comparison between industries was made by indexing R&D spend & financial metrics levels for each company against the median level for that industry. |
<p>| Number of data points | 1000 companies (top publicly traded R&amp;D spenders) |
| Variables in Database | R&amp;D/Sales, Company size, sales growth, gross profit, operating profit, enterprise profit, market capitalization, total shareholder return |
| Data Collection Method | Obtained key financial metrics from 2001 to 2005 |</p>
<table>
<thead>
<tr>
<th>Title</th>
<th>Customer Satisfaction and shareholder value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author</td>
<td>Anderson, Eugene, Fornell, Mazvancheryl</td>
</tr>
<tr>
<td>Year of Publication</td>
<td>2004</td>
</tr>
<tr>
<td>Insights</td>
<td>1% change in ACSI-&gt;1.016% change in Tobin's Q or $275m in firm value. ACSI positively correlated with equity prices and price to book value</td>
</tr>
<tr>
<td>Robustness of research</td>
<td>High</td>
</tr>
<tr>
<td>Issue addressed</td>
<td>Builds upon work done by Ittner and Larcker</td>
</tr>
<tr>
<td>Academic/Commercial</td>
<td>Academic</td>
</tr>
<tr>
<td>Industry Examined</td>
<td>40 Industries</td>
</tr>
<tr>
<td>Research Methodology</td>
<td></td>
</tr>
<tr>
<td>Number of data points</td>
<td>200 Fortune 500 Firms</td>
</tr>
<tr>
<td>Variables in Database</td>
<td>ACSI (Yr 1994-97), Tobin's q, advertising/Sales, Market Share, concentration level of firm</td>
</tr>
<tr>
<td>Data Collection Method</td>
<td></td>
</tr>
</tbody>
</table>
Are non-financial measures leading indicators of financial performance? An analysis of customer satisfaction

Title

Are non-financial measures leading indicators of financial performance? An analysis of customer satisfaction

Author

Ittner and Larcker

Year of Publication

1998

Insights

Correlation between customer satisfaction and future accounting performance. A 10 point increase in CSI was associated with a 2% increase in retention, a 3% in revenue change. Strength of satisfaction-profitability link varies across industries as well as across firms within an industry

Robustness of research

High

Issue addressed

This paper examines three questions on the value relevance of customer satisfaction measures: (1) Are customer satisfaction measures leading indicators of accounting performance? (2) Is the economic value of customer satisfaction (fully) reflected in contemporaneous accounting book values? And (3) Does the release of customer satisfaction measures provide new or incremental information to the stock market?

Academic/Commercial

Academic

Industry Examined

Research Methodology

Number of data points

120 Firms

Variables in Database

CSI(1995), Revenue (1996), how long customer has been in business, Customer retention, Book value of Asset, Book value of Liability, Market value of equity

Data Collection Method
<table>
<thead>
<tr>
<th>Title</th>
<th>Customer satisfaction, cash flow, and shareholder value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author</td>
<td>Gruca &amp; Rego</td>
</tr>
<tr>
<td>Year of Publication</td>
<td>2005</td>
</tr>
<tr>
<td>Insights</td>
<td>1 point increase in ACSI-&gt;$55M increase in net operating cash flow in next yr and 4% reduction in variability</td>
</tr>
<tr>
<td>Robustness of research</td>
<td>High</td>
</tr>
<tr>
<td>Issue addressed</td>
<td>Relationship between customer satisfaction and future cash flows</td>
</tr>
<tr>
<td>Academic/Commercial</td>
<td>Academic</td>
</tr>
<tr>
<td>Industry Examined</td>
<td>23 Industries</td>
</tr>
<tr>
<td>Research Methodology</td>
<td></td>
</tr>
<tr>
<td>Number of data points</td>
<td>105 Fortune 500 Firms</td>
</tr>
<tr>
<td>Variables in Database</td>
<td>R&amp;D intensity, ACSI, Market share,</td>
</tr>
<tr>
<td>Data Collection Method</td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>Stock Market Reactions to customer service changes</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Author</td>
<td>Nayyar</td>
</tr>
<tr>
<td>Year of Publication</td>
<td>1995</td>
</tr>
<tr>
<td>Insights</td>
<td>Increase in customer service-&gt;0.46% average cumulative abnormal return(CAR); Decrease in customer service-&gt;-0.22% CAR</td>
</tr>
<tr>
<td>Robustness of research</td>
<td>Medium</td>
</tr>
<tr>
<td>Issue addressed</td>
<td>examine stock market reactions to reports of changes in some elements of customer service reported during 1981-91</td>
</tr>
<tr>
<td>Academic/Commercial</td>
<td>68 industries</td>
</tr>
<tr>
<td>Industry Examined</td>
<td>Relation actions that influence achievement of customer service objectives (Customer Service objectives - Risk of purchase, Purchasing cost, Ease, Personalization) with CAR</td>
</tr>
<tr>
<td>Research Methodology</td>
<td>324 customer service change news reports covering 106 firms</td>
</tr>
<tr>
<td>Number of data points</td>
<td>Cumulative Abnormal Returns (CAR)</td>
</tr>
<tr>
<td>Variables in Database</td>
<td>Several computerized data bases such as Mead's NEXIS, DIALOG's several newspaper, business, and corporate press release data bases, and Infotrac were systematically searched over the period 1981-91 to identify news reports of actions by firms that may affect customer service</td>
</tr>
<tr>
<td>Data Collection Method</td>
<td></td>
</tr>
</tbody>
</table>
## APPENDIX B – Product Development Framework

<table>
<thead>
<tr>
<th>Question No.</th>
<th>Category</th>
<th>Dimension</th>
<th>Question</th>
<th>Reversed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ENTERPRISE-LEVEL PD STRATEGY DEVELOPMENT</td>
<td>Product Development Environment</td>
<td>There are generally no significant consequences for the teams that define goals and objectives for new projects if they are inaccurate or unrealistic</td>
<td>r</td>
</tr>
<tr>
<td>2</td>
<td>ENTERPRISE-LEVEL PD STRATEGY DEVELOPMENT</td>
<td>Product Development Environment</td>
<td>Our organization’s core cultural values require that we take seriously the keeping of our commitments to deliver on promises to both to external and internal customers at all levels</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>ENTERPRISE-LEVEL PD STRATEGY DEVELOPMENT</td>
<td>Product Development Environment</td>
<td>Our enterprise-level leadership actively participates in regular reviews of the outstanding risks in the product portfolio</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>ENTERPRISE-LEVEL PD STRATEGY DEVELOPMENT</td>
<td>Product Development Environment</td>
<td>We have a deliberate strategy of cannibalizing our existing product offerings with replacement products</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>ENTERPRISE-LEVEL PD STRATEGY DEVELOPMENT</td>
<td>Product Development Environment</td>
<td>For software, we have a clear and distinct strategy, development process, and release roadmap that is integrated with our overall product development process</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>SMART PRODUCT</td>
<td>Align product to strategy</td>
<td>We assure a clear flow down from the strategic objectives of the firm (or business unit) to the project level objectives</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>SMART PRODUCT</td>
<td>Align product to strategy</td>
<td>We do not have a clear understanding of what technologies are critical to our project success</td>
<td>r</td>
</tr>
<tr>
<td>27</td>
<td>SMART PRODUCT</td>
<td>Align product to strategy</td>
<td>Our project has had a clear view of its scope and scale from the start, resulting in very stable development with a very small number of disruptive scope and scale changes.</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>SMART PRODUCT</td>
<td>Align product to strategy</td>
<td>We have a quantified understanding of the critical performance attributes required of the target market segments</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>SMART PRODUCT</td>
<td>Align on strategic priorities</td>
<td>You would extend the timeline by 10% to better match the features to customer preferences by 10%.</td>
<td></td>
</tr>
<tr>
<td>73</td>
<td>SMOOTH INTEGRATION</td>
<td>Project planning and organization</td>
<td>Project team leader has authority to expend discretionary budget to use without approvals</td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>SMOOTH INTEGRATION</td>
<td>Project planning and organization</td>
<td>Project team leader is not responsible for reviewing team members performance</td>
<td>r</td>
</tr>
<tr>
<td>75</td>
<td>SMOOTH INTEGRATION</td>
<td>Project planning and organization</td>
<td>We prominently display and frequently communicated the project plan and status to all team members</td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>SMOOTH INTEGRATION</td>
<td>Project planning and organization</td>
<td>We have periodic product integration events defined by a regular cadence or tempo to conduct status checks</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>SMOOTH INTEGRATION</td>
<td>Project planning and organization</td>
<td>We plan and coordinate all handoffs across functional boundaries to minimize disruptions (e.g., rework loops, delays, specification revisions, etc.)</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>--------------------</td>
<td>------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>116</td>
<td>SMOOTH INTEGRATION</td>
<td>Risk management</td>
<td>We explicitly identify, quantify and manage project, product, technology and process risks throughout the project.</td>
<td></td>
</tr>
<tr>
<td>117</td>
<td>SMOOTH INTEGRATION</td>
<td>Risk management</td>
<td>We explicitly identify, quantify and manage key market risks through development and launch.</td>
<td></td>
</tr>
<tr>
<td>118</td>
<td>SMOOTH INTEGRATION</td>
<td>Risk management</td>
<td>We don't have a culture of candor and transparency in identifying, tracking, and funding the retirement of risks.</td>
<td></td>
</tr>
<tr>
<td>119</td>
<td>SMOOTH INTEGRATION</td>
<td>Risk management</td>
<td>Enterprise leadership are often unaware of the status of risk.</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>SMOOTH INTEGRATION</td>
<td>Risk management</td>
<td>We fund and execute parallel contingency plans for high-risk subsystem development.</td>
<td></td>
</tr>
<tr>
<td>121</td>
<td>SMOOTH INTEGRATION</td>
<td>Risk management</td>
<td>We repeat tests after any changes that could effect the validity of previously performed tests.</td>
<td></td>
</tr>
<tr>
<td>122</td>
<td>SMOOTH INTEGRATION</td>
<td>Risk management</td>
<td>Our testing plans rarely include requirements testing and regulatory testing and lifecycle performance (e.g., quality, reliability, usability, serviceability).</td>
<td></td>
</tr>
<tr>
<td>123</td>
<td>SMOOTH INTEGRATION</td>
<td>Risk management</td>
<td>Our testing provides timely and cost-effective feedback to design on product maturity and completeness.</td>
<td></td>
</tr>
<tr>
<td>124</td>
<td>SUPERIOR COMPETENCE AND CAPABILITIES</td>
<td>Capability management</td>
<td>We track skill staffing levels to minimize the potential overloading of critical resources.</td>
<td></td>
</tr>
<tr>
<td>125</td>
<td>SUPERIOR COMPETENCE AND CAPABILITIES</td>
<td>Capability management</td>
<td>Our staffing practices minimize multitasking.</td>
<td></td>
</tr>
<tr>
<td>126</td>
<td>SUPERIOR COMPETENCE AND CAPABILITIES</td>
<td>Capability management</td>
<td>Our project staffing is often unstable during execution.</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>SUPERIOR COMPETENCE AND CAPABILITIES</td>
<td>Capability management</td>
<td>We minimize disruptions to staffing due to external demands from other projects.</td>
<td></td>
</tr>
<tr>
<td>128</td>
<td>SUPERIOR COMPETENCE AND CAPABILITIES</td>
<td>Capability management</td>
<td>We use a skills database to compose teams prior to project launch.</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX C – Correlation between Self-assessed Performances and PD Practices
<table>
<thead>
<tr>
<th>Question No.</th>
<th>Category</th>
<th>Dimension</th>
<th>Question</th>
<th>Correlation Coefficient</th>
<th>Sig. (2-tailed)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>SMART PRODUCT</td>
<td>Align product to strategy</td>
<td>We do not have a clear understanding of what technologies are critical to our project success - 1</td>
<td>0.341</td>
<td>0.017</td>
<td>49</td>
</tr>
<tr>
<td>29</td>
<td>SMART PRODUCT</td>
<td>Align on strategic priorities</td>
<td>You would extend the timeline by 10% to better match the features to customer preferences by 10%.</td>
<td>0.290</td>
<td>0.044</td>
<td>49</td>
</tr>
<tr>
<td>47</td>
<td>SMART PRODUCT</td>
<td>Concept development</td>
<td>We seldom use prototyping, simulation, and/or modelling to test product concepts with users early in the concept phase</td>
<td>0.373</td>
<td>0.008</td>
<td>49</td>
</tr>
<tr>
<td>59</td>
<td>SMART PRODUCT</td>
<td>Managing product cost</td>
<td>We use competitive and internal “best-of” benchmarking early in projects to set aggressive cost targets - 1</td>
<td>0.300</td>
<td>0.040</td>
<td>47</td>
</tr>
<tr>
<td>76</td>
<td>SMOOTH INTEGRATION</td>
<td>Project planning and organization</td>
<td>We have periodic product integration events defined by a regular cadence or tempo to conduct status checks - 1</td>
<td>0.343</td>
<td>0.017</td>
<td>48</td>
</tr>
<tr>
<td>88</td>
<td>SMOOTH INTEGRATION</td>
<td>Product development execution</td>
<td>We have difficulty demonstrating year-on-year improvements in outcomes from our continuous improvement efforts</td>
<td>0.299</td>
<td>0.039</td>
<td>48</td>
</tr>
<tr>
<td>133</td>
<td>SUPERIOR COMPETENCE AND CAPABILITIES</td>
<td>Knowledge Systems</td>
<td>We create representations of our product and process knowledge to facilitate communication and knowledge sharing</td>
<td>0.343</td>
<td>0.016</td>
<td>49</td>
</tr>
<tr>
<td>139</td>
<td>SUPERIOR COMPETENCE AND CAPABILITIES</td>
<td>Mindsets</td>
<td>We rarely share information across functional boundaries - 1</td>
<td>0.324</td>
<td>0.023</td>
<td>49</td>
</tr>
<tr>
<td>Question No</td>
<td>Category</td>
<td>Dimension</td>
<td>Question</td>
<td>Correlation Coefficient</td>
<td>Sig. (2-tailed)</td>
<td>N</td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
<td>-----------</td>
<td>---------</td>
<td>-------------------------</td>
<td>----------------</td>
<td>----</td>
</tr>
<tr>
<td>1</td>
<td>ENTERPRISE-LEVEL PD</td>
<td>Product Development Environment</td>
<td>There are generally no significant consequences for inaccurate/unrealistic goals and objectives</td>
<td>0.28</td>
<td>.019</td>
<td>69</td>
</tr>
<tr>
<td>15</td>
<td>ENTERPRISE-LEVEL PD</td>
<td>Technology development</td>
<td>Cross functional teams define, identify, and help transition new technologies into product streams - 1</td>
<td>0.35</td>
<td>.003</td>
<td>69</td>
</tr>
<tr>
<td>17</td>
<td>ENTERPRISE-LEVEL PD</td>
<td>Development of Enterprise Capabilities</td>
<td>We identify and manage critical skills across projects explicitly to assure they can be provided</td>
<td>0.24</td>
<td>.048</td>
<td>68</td>
</tr>
<tr>
<td>19</td>
<td>ENTERPRISE-LEVEL PD</td>
<td>Development of Enterprise Capabilities</td>
<td>We measure and track skill proficiency levels at the individual level - 1</td>
<td>0.41</td>
<td>.001</td>
<td>67</td>
</tr>
<tr>
<td>22</td>
<td>ENTERPRISE-LEVEL PD</td>
<td>Development of Enterprise Capabilities</td>
<td>We use a well-established process to develop a cadre of project leadership to meet our strategy</td>
<td>0.40</td>
<td>.001</td>
<td>68</td>
</tr>
<tr>
<td>23</td>
<td>ENTERPRISE-LEVEL PD</td>
<td>Development of Enterprise Capabilities</td>
<td>We have separate and well-funded efforts to develop capabilities in software management, architecture, and development</td>
<td>0.26</td>
<td>.044</td>
<td>61</td>
</tr>
<tr>
<td>27</td>
<td>SMART PRODUCT</td>
<td>Align product to strategy</td>
<td>Our project has had a clear view of its scope and scale from the start with few disruptive scope and scale changes</td>
<td>0.43</td>
<td>.000</td>
<td>69</td>
</tr>
<tr>
<td>30</td>
<td>SMART PRODUCT</td>
<td>Align on strategic priorities</td>
<td>You could allow product cost to expand by 10% to prevent the timeline from slipping by 10%</td>
<td>-0.27</td>
<td>.027</td>
<td>68</td>
</tr>
<tr>
<td>31</td>
<td>SMART PRODUCT</td>
<td>Align on strategic priorities</td>
<td>You would be satisfied to miss customer preferences by 10% in order to achieve product cost savings of 10%</td>
<td>-0.30</td>
<td>.011</td>
<td>69</td>
</tr>
<tr>
<td>48</td>
<td>SMART PRODUCT</td>
<td>Concept development</td>
<td>Concept development teams have all necessary data to trade off product performance with cost, time to market and risk</td>
<td>0.37</td>
<td>.002</td>
<td>65</td>
</tr>
<tr>
<td>55</td>
<td>SMART PRODUCT</td>
<td>Managing product cost</td>
<td>Cross-functional management teams explore all elements of the value chain to identify new cost-reduction opportunities</td>
<td>0.28</td>
<td>.019</td>
<td>69</td>
</tr>
<tr>
<td>59</td>
<td>SMART PRODUCT</td>
<td>Managing product cost</td>
<td>We use competitive and internal &quot;best-of&quot; benchmarking early in projects to set aggressive cost targets - 1</td>
<td>0.25</td>
<td>.045</td>
<td>65</td>
</tr>
<tr>
<td>60</td>
<td>SMART PRODUCT</td>
<td>Managing product cost</td>
<td>We use established cost baselines to measure impact of cost-reduction efforts, and monitor performance over time - 1</td>
<td>0.28</td>
<td>.022</td>
<td>67</td>
</tr>
<tr>
<td>61</td>
<td>SMART PRODUCT</td>
<td>Managing product cost</td>
<td>Subteams lack an understanding of cost targets by subsystems, and rarely review progress toward cost reduction goals - 1</td>
<td>0.35</td>
<td>.004</td>
<td>66</td>
</tr>
</tbody>
</table>
## Adherence to Budget

<table>
<thead>
<tr>
<th>Question No.</th>
<th>Category</th>
<th>Dimension</th>
<th>Question</th>
<th>Correlation Coefficient</th>
<th>Sig. (2-tailed)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>ENTERPRISE-LEVEL PD STRATEGY DEPLOYMENT</td>
<td>Product Development Environment</td>
<td>For software, we have a clear strategy, development process, and release roadmap integrated with our overall PD process</td>
<td>0.30</td>
<td>0.017</td>
<td>61</td>
</tr>
<tr>
<td>17</td>
<td>ENTERPRISE-LEVEL PD STRATEGY DEPLOYMENT</td>
<td>Development of Enterprise Capabilities</td>
<td>We identify and manage critical skills across projects explicitly to assure they can be provided</td>
<td>0.25</td>
<td>0.46</td>
<td>65</td>
</tr>
<tr>
<td>20</td>
<td>ENTERPRISE-LEVEL PD STRATEGY DEPLOYMENT</td>
<td>Development of Enterprise Capabilities</td>
<td>Our processes to build expertise are largely informal, relying mostly on on-the-job experiences -1</td>
<td>0.27</td>
<td>0.33</td>
<td>64</td>
</tr>
<tr>
<td>22</td>
<td>ENTERPRISE-LEVEL PD STRATEGY DEPLOYMENT</td>
<td>Development of Enterprise Capabilities</td>
<td>We use a well-established process to develop a cadre of project leadership to meet our strategy</td>
<td>0.40</td>
<td>0.001</td>
<td>65</td>
</tr>
<tr>
<td>26</td>
<td>SMART PRODUCT</td>
<td>Align product to strategy</td>
<td>We do not have a clear understanding of what technologies are critical to our project success -1</td>
<td>0.31</td>
<td>0.012</td>
<td>65</td>
</tr>
<tr>
<td>27</td>
<td>SMART PRODUCT</td>
<td>Align product to strategy</td>
<td>Our project has had a clear view of its scope and scale from the start with few disruptive scope and scale changes</td>
<td>0.32</td>
<td>0.009</td>
<td>65</td>
</tr>
<tr>
<td>31</td>
<td>SMART PRODUCT</td>
<td>Align on strategic priorities</td>
<td>You would be satisfied to miss customer preferences by 10% in order to achieve product cost savings of 10%</td>
<td>-0.30</td>
<td>0.016</td>
<td>65</td>
</tr>
<tr>
<td>61</td>
<td>SMART PRODUCT</td>
<td>Managing product cost</td>
<td>Subteams lack an understanding of cost targets by subsystems, and rarely review progress toward cost reduction goals -1</td>
<td>0.33</td>
<td>0.007</td>
<td>64</td>
</tr>
<tr>
<td>67</td>
<td>SMART PRODUCT</td>
<td>Architecture and modularity</td>
<td>We use industry or widely-accepted standards for interface definitions wherever possible -1</td>
<td>0.43</td>
<td>0.000</td>
<td>63</td>
</tr>
<tr>
<td>69</td>
<td>SMART PRODUCT</td>
<td>Product quality</td>
<td>We conduct early system testing to determine how interactions affect overall quality targets</td>
<td>0.31</td>
<td>0.015</td>
<td>62</td>
</tr>
<tr>
<td>74</td>
<td>SMOOTH INTEGRATION</td>
<td>Project planning and organization</td>
<td>Project team leader is not responsible for reviewing team members performance -1</td>
<td>0.25</td>
<td>0.042</td>
<td>65</td>
</tr>
<tr>
<td>77</td>
<td>SMOOTH INTEGRATION</td>
<td>Project planning and organization</td>
<td>We plan and coordinate all handoffs across functional boundaries to minimize disruptions</td>
<td>0.35</td>
<td>0.004</td>
<td>65</td>
</tr>
<tr>
<td>79</td>
<td>SMOOTH INTEGRATION</td>
<td>Project planning and organization</td>
<td>Boundary spanning team members have difficulty convening functional leadership to drive issue resolution</td>
<td>0.29</td>
<td>0.023</td>
<td>63</td>
</tr>
<tr>
<td>80</td>
<td>SMOOTH INTEGRATION</td>
<td>Project planning and organization</td>
<td>We have a quantified understanding of the potential sources of delays and plans to mitigate them -1</td>
<td>0.31</td>
<td>0.012</td>
<td>64</td>
</tr>
<tr>
<td>86</td>
<td>SMOOTH INTEGRATION</td>
<td>Product development execution</td>
<td>We experience significant rework cycles because work package owners don’t understand quality and timing of deliverables</td>
<td>0.29</td>
<td>0.021</td>
<td>63</td>
</tr>
</tbody>
</table>
## APPENDIX D – Component Analysis

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Question</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
<th>Factor Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Development Environment</td>
<td>There are generally no significant consequences for the teams that define goals and objectives for new projects if they are inaccurate or unrealistic</td>
<td>0.78</td>
<td>-0.03</td>
<td></td>
<td>Product Development Environment</td>
</tr>
<tr>
<td>Product Development Environment</td>
<td>Our organization’s core cultural values require that we take seriously the keeping of our commitments to deliver on promises to both to external and internal customers at all levels</td>
<td>0.88</td>
<td>0.03</td>
<td></td>
<td>Strategy to cannibalize existing product offerings</td>
</tr>
<tr>
<td>Product Development Environment</td>
<td>Our enterprise-level leadership actively participates in regular reviews of the outstanding risks in the product portfolio</td>
<td>0.75</td>
<td>0.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product Development Environment</td>
<td>We have a deliberate strategy of cannibalizing our existing product offerings with replacement products</td>
<td>-0.13</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product Development Environment</td>
<td>For software, we have a clear and distinct strategy, development process, and release roadmap that is integrated with our overall product development process</td>
<td>0.25</td>
<td>0.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portfolio management</td>
<td>We don’t always require fit with strategic direction and corporate priorities in order to obtain project funding approval</td>
<td>0.63</td>
<td></td>
<td></td>
<td>Portfolio management</td>
</tr>
<tr>
<td>Portfolio management</td>
<td>We account for balancing portfolio risk profile (from “safe” to “high uncertainty”) during project funding approval</td>
<td>0.66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portfolio management</td>
<td>We require rigorous analysis of market trends for project funding approval</td>
<td>0.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portfolio management</td>
<td>We require detailed analysis of the competitor landscape for approving project funding</td>
<td>0.86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portfolio management</td>
<td>We measure portfolio throughput performance, i.e., the average time for projects to go from commitment of capital to generating revenues</td>
<td>0.67</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portfolio management</td>
<td>We actively stall, accelerate, and cancel projects to optimize the total value of the product development portfolio</td>
<td>0.45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology development</td>
<td>We lack a clear and detailed understanding of which technologies are critical to our business’ success</td>
<td>0.76</td>
<td></td>
<td></td>
<td>Technology development</td>
</tr>
<tr>
<td>Technology development</td>
<td>13</td>
<td>We use a formal roadmap that defines the timing and sequence of the emergence of technologies needed for future product streams</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>----</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology development</td>
<td>14</td>
<td>We don't use a formal make-buy decision process to determine whether we acquire new technologies or develop them in-house</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology development</td>
<td>15</td>
<td>Cross functional teams define, identify, and help transition new technologies into product streams</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX E – SPSS Tutorial

Importing data from Excel Sheet

NOTES: Remove empty cases from Excel otherwise SPSS would crash.

The excel file that needs to be imported should be closed while being imported in SPSS.

1. Select Data from File->Open->Data


Select the excel file that need to be imported and hit Open.
NOTE: In case the SPSS gives error in opening XLS file, copy the content of XLS file by copying them in a new XLS file.

**Making Raw Data in SPSS ready**

1. **Remove columns that are not needed. Following is the list:**
   
a. RespondentUniqueKey  
b. AuthenticationKey  
c. CompletedDate  
d. BU sub-sector  
e. Date answering

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Respondent...</td>
<td>String</td>
<td>29</td>
</tr>
<tr>
<td>2</td>
<td>Authentication...</td>
<td>String</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>CompletedD...</td>
<td>Date</td>
<td>23</td>
</tr>
</tbody>
</table>

Go to Variables tab. Select variable to be deleted as shown above and delete it.

2. **Rename the variables**

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>q1</td>
<td>String</td>
<td>255</td>
</tr>
<tr>
<td>2</td>
<td>Client</td>
<td>Numeric</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>q2</td>
<td>String</td>
<td>255</td>
</tr>
<tr>
<td>4</td>
<td>q3</td>
<td>String</td>
<td>255</td>
</tr>
<tr>
<td>5</td>
<td>q4</td>
<td>String</td>
<td>255</td>
</tr>
<tr>
<td>6</td>
<td>q5_1</td>
<td>Numeric</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>q6</td>
<td>Numeric</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>Lifecycle</td>
<td>Numeric</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>q8</td>
<td>String</td>
<td>255</td>
</tr>
<tr>
<td>10</td>
<td>q9</td>
<td>Numeric</td>
<td>8</td>
</tr>
</tbody>
</table>

Performance measure questions 1 to 143 are renamed as q21.0_1 to q163.0_1  
Outcome measure questions 1 to 17 are renamed as (q164.1_1 to q180.1_1) and (q164.0_1 to q180.0_1). qxxx.0_1 is response weather the corresponding metric is used. qxxx.1_1 is response on a scale of 1 to 5.
3. Aggregate multiple responses from a project

Select q8 as the Break Variable. Add alphanumeric variables.
Set specific values as ‘First’ in the Aggregate Function for alphanumeric variables.

Select q2.1_0 to q180.1_1 and add them to Aggregated Variables. Set the specific value to Median.
4. **Cleaning Performance or Output measures data**

Representatives of a project that participated in FP survey should have same opinion on performance parameter. Therefore, their response to 17 performance questions (q164 to 180) in the survey should be same. However, representatives are not on same page (can be due to asymmetric information).

Ideally aggregated performance measures should have integer values as they are ordinal variables. Non-integer values indicate that people from same project have different views on a given output measure.

Cells with non-integer value needs to be set to an integer value.

An example of how to take this decision is show below.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Company Name</th>
<th>Project Name</th>
<th>Name</th>
<th>Current position</th>
<th>Role/position on the project</th>
<th>Years on the project</th>
<th>Years with the company</th>
<th>How many of project development projects have you been on?</th>
<th>Responded</th>
<th>Response</th>
<th>Whose response selected</th>
<th>Response selected</th>
<th>Doubt</th>
<th>Conservative</th>
</tr>
</thead>
<tbody>
<tr>
<td>164</td>
<td>Siemens Aon 5-7</td>
<td>Vinod Philip</td>
<td>Team Member</td>
<td>11</td>
<td>11</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siemens Aon 5-7</td>
<td>Sam Miller</td>
<td>Engineering Manager</td>
<td>PTS Turbo Owner</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siemens Aon 5-7</td>
<td>Mazar</td>
<td>Master Engineer</td>
<td>Master Engineer</td>
<td>5</td>
<td>31</td>
<td>11</td>
<td>1</td>
<td>-2</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siemens Aon 5-7</td>
<td>Dave</td>
<td>Manager</td>
<td>Project Lead</td>
<td>3</td>
<td>7</td>
<td>11</td>
<td>0</td>
<td>-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. **Adding Financial data**

Financial data comes in Excel file. Same procedure as mentioned above is applied to bring in the excel file to SPSS environment.

Step 1: Make sure company name and other variable names are proper. Let us call this file financial.sav

<table>
<thead>
<tr>
<th>q1</th>
<th>Caterpillar</th>
<th>22763.00</th>
<th>30306.00</th>
<th>36339.00</th>
<th>41517.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>DJO</td>
<td>197.94</td>
<td>256.00</td>
<td>286.17</td>
<td>413.06</td>
<td></td>
</tr>
<tr>
<td>Eaton Corp</td>
<td>8061.00</td>
<td>9817.00</td>
<td>11019.00</td>
<td>12232.00</td>
<td></td>
</tr>
<tr>
<td>Franklin Electric</td>
<td>359.50</td>
<td>404.31</td>
<td>403.41</td>
<td>557.95</td>
<td></td>
</tr>
<tr>
<td>Global Crossing</td>
<td>2932.00</td>
<td>2487.00</td>
<td>1968.00</td>
<td>1871.00</td>
<td></td>
</tr>
<tr>
<td>Harman Becker Automotive Syst...</td>
<td>2228.52</td>
<td>2711.37</td>
<td>3030.89</td>
<td>3247.90</td>
<td></td>
</tr>
<tr>
<td>Hewlett Packard</td>
<td>73061.00</td>
<td>79905.00</td>
<td>86696.00</td>
<td>91658.00</td>
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</tr>
<tr>
<td>Tyco Safety Products</td>
<td>39987.00</td>
<td>36411.00</td>
<td>39305.00</td>
<td>17336.00</td>
<td></td>
</tr>
<tr>
<td>VW</td>
<td>95828.09</td>
<td>110566.10</td>
<td>116798.10</td>
<td>131587.80</td>
<td></td>
</tr>
</tbody>
</table>

Step 2: Create a copy of financial.sav as financial_2.sav

Step 3: In financial_2.sav change the properties of variable by going in variable tab. It will be observed that when property is changed many values are lost. Therefore, we created this copy of file so that data remains intact in financial.sav

Step 4: Copy data manually from financial.sav into financial_2.sav. Make sure you copy JUST the data and not the whole column in financial.sav otherwise while copying in financial_2.sav, the property would change again.
After the financial_2.sav SPSS file is ready, we can merge it in the main file by selecting Merge Files option as shown below.

NOTE: Make sure both the files are sorted before adding new variables. Also make sure that string length of ‘q1’ is same in both files.

Select the setting as show below to merge financial variables in main aggregated file.
6. Selection of project within a firm against which financial data be reflected

Financial data is for a firm and not for a project. When multiple projects from the same firm have participated in this FP project, financial information should be put in the data point of the project that best represents that bunch of projects. Procedure to find this representative data point is given below, and it is based on Categorical Principal Component Analysis (CATPCA).

In short Calculate aggregate performance -> Segment by company-> Identify median project-> Assign financial data to median

Calculate a SINGLE factor that represents all 17 outcome measures.

Select Some variables(s) are not multiple nominal.

Select all 17 outcome measures ( q164.1_1, ..q180.1_1).
Once all the needed variables are moved to ‘Analysis Variable’ window, select them from that window to change their properties. Click ‘Define Scale and Weight.’ button below the list. Set all variables to *Ordinal*.

Other settings of factor analysis can be accessed from buttons on the right. Their settings are given below.

Save your data results.
Uncheck all boxes in *Plots*.

Select *Dimension in Solution* to 1.

SPSS adds a column to data view tab. Rename this to *prf_all* through variable view tab.
Now, for a given firm with multiple project entries in database, find out median of this firm's `prf_all`. Assign financial value to data point with `prf_all = median`, as this project or data point best represents all the data points of that firm in our database.

**Analysis**

**Summary of Analysis**

1. Calculate aggregate practices scores
   1. Mean for 24 dimensions.
2. Calculate aggregate outcome scores
   1. CATPCA: Force to 1 factor; allow multiple factors
3. Segment outcome scores by quartiles (Hi-Med-Low) -> Compute new quartile variables (categorizes different performers)
4. T-test or F-test (1-way ANOVA) to see if they are different. Also, calculate means in each group. F-test compares these means to see if they are different.

**Finding Mean value of Practice dimensions**

There are 143 questions classified into 24 practice dimensions. Calculation of mean of each dimension is the one of the first steps of further analysis Ex. Correlation between practices and financial CAGRs etc.

Select *Compute Variable* from Transform drop-down menu.
Select *Mean* function from the *Functions and Special Variables* list.

Select the variables whose *Mean* needs to be calculated.

Target Variable is the name of the new variable that would be generated.

Shown below is the variable generated with above procedure.

<table>
<thead>
<tr>
<th>dimension1_Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.60</td>
</tr>
<tr>
<td>4.20</td>
</tr>
<tr>
<td>3.20</td>
</tr>
<tr>
<td>3.20</td>
</tr>
<tr>
<td>4.50</td>
</tr>
<tr>
<td>4.40</td>
</tr>
<tr>
<td>5.40</td>
</tr>
<tr>
<td>4.00</td>
</tr>
<tr>
<td>4.80</td>
</tr>
</tbody>
</table>

This way we select questions representing a given dimension and calculate mean values for that dimension.
Correlation of 24 Practice Measure dimensions with Financial CAGRs
There are 143 questions classified into 24 practice dimensions. After all dimensions representing practice measures are calculated, we can go ahead and calculate correlation between practice dimensions and financial CAGRs. This is to understand which practice have direct impact on output performance of a firm.

Select Bivariate correlation from the drop down menu.

Select practice dimensions and financial CAGRs.

Correlation matrix is displayed in the output window. This matrix can be exported to excel by clicking right mouse button and selecting 'Export'.

Factor Analysis on Practice Measures
There are 143 questions classified into 24 practice dimensions. Factor analysis is used to understand basic factor(s) driving each such dimension.

Factor analysis is done one dimension at a time. Practice measures are of ‘ratio’ data type. Select Factor from Data reduction menu.
Practice questions that represent a given dimension are added to the variables list as shown below.

Settings of Factor Analysis can be done through the tabs given on the right. Two properties are changed from the default.

1. Rotation method is set to ‘Varimax’
2. Score Factors are saved using ‘Anderson-Rubin’ Method.

The graphics below show the options selected.
In the output window ‘Rotated component Matrix’ is of interest. Weights of the components from this matrix can help us understand what each factor represents. These values are copied to the analysis Excel sheet.
Exporting data from Output window of SPSS to Excel

Right click on the table that needs to be exported to Excel. Select 'Export..' 

Select the location to save the excel file.