Goal Setting for Improvement in Product Development Performance of Organizations

by

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Abstract

Companies have been constantly trying for ways and means to improve R&D performance as it is one of the most important competitive advantage tools of an organization. Literature review on R&D performance improvement suggests that, lot of focus is on measuring R&D performance and on specific problem solving approaches like six sigma and lean. Frameworks like capability maturity model integration (CMMI) and product development self-assessment tool (PDSAT) provide holistic performance assessment, but fall short on providing clear guidance for performance improvement interventions. Goal setting theory, a proven theory that is widely applied in individual performance improvement has got limited attention in R&D performance improvement approaches and frameworks. Practitioners in the industry point to the need for goal setting in R&D and identify that as a gap in current performance improvement methodologies. This thesis attempts to fill this gap by proposing DEAL framework, a practical approach for defining future goals in R&D performance improvement efforts.

Thesis Supervisor: Eric Rebentisch

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1 Introduction

1.1 Motivation

Businesses in USA spent $282 billion on R&D in 2009 and this number was $291 billion in 2008 [1]. National science foundation notes that "Research & Development (R&D) accounted for five percent of real GDP growth between 1959 and 2004, and seven percent between 1995 and 2004" [2]. This report clearly indicates that R&D is one of the key drivers of economic growth. With such large sums being spent on R&D, it would be interesting to understand the efficiency and effectiveness of R&D. There are multiple views on calculating project success and failure and one estimate notes that almost 50%[1] of the R&D projects fail and are not commercialized [3]. When translated to actual numbers, this means that almost $140 billion spent on R&D is not utilized effectively. This analysis clearly demonstrates the need for improving R&D performance. At this point it is prudent to understand the definition and scope of R&D.

"Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications."[4]

The Organization for economic cooperation & development (OECD) Frascati manual divides R&D into three different categories, one is about Basic research, second is applied research and third is experimental development. Of these three my current focus is toward experimental development and is defined as "systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed"

[1] This is based on the number of projects that move from stage 4 to stage 5 as explained by Stevens & Burley.

[4]. Having a personal preference toward design of new products, this thesis attempts to understand the current state of R&D performance improvement measures & frameworks in product development and eventually proposes practical recommendation for enriching them.

1.2 Thesis Scope

Product development lifecycle has eight distinct stages which includes the six stages of planning, concept development leading up to production ramp up[5] and other two stages where products are mass produced and then the product eventually reaches end of life[6]. The product development process flow as presented by Ulrich & Eppinger in their book Product Design & Development is updated to reflect this complete product life cycle in Figure 1[5].

Figure 1: Product development lifecycle stages

Early R&D performance improvement frameworks were focused towards solving the problems faced by production/ manufacturing units and also improving the operations costs. This lead to development of different quality improvement efforts like Deming's cycle, total quality management (TQM), lean and six sigma philosophies. However with increasing competition and easy access to knowledge mandated performance improvement across the complete R&D spectrum starting from planning stage. Many of the improvement frameworks that worked in production setting, were not as successful in R&D environment, this meant adapting and customizing frameworks to suit the needs of different R&D setups.

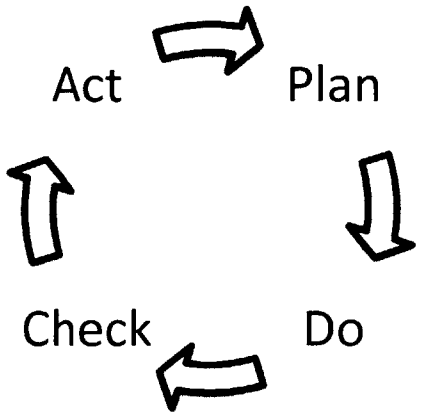

Figure 2: Deming's cycle, Plan-do-check-act [7]

Shewart cycle or Deming cycle [7] describes the fundamental logical stages of any performance improvement framework, it has four stages, Plan-Do-Check-Act (Figure 2). These stages of Deming's cycle are explained below:

Plan: The first step in any performance improvement is planning, which includes analyzing the current situation, doing process-mapping if needed and defining the problem. It then identifies the steps that must be taken to overcome the problem and arrive at a higher level of performance.

Do: The second step is to "do" or to perform actions based on the plan. A plan is as good as its execution and if faced with challenges one would have to move between plan-do stages to firm up the execution plan.

Check: The third step is that of checking performance after implementing changes. One has to ensure that the results match the intended performance improvement. Any deviations from desired performance must be analyzed and root-cause analysis must be done to recommend interventions for performance improvement.

Act: After finding the cause of deviation from planned targets, one must act to rectify the issues found.

This P-D-C-A is a continuous cycle and not one time effort. Organizations must strive for implementing this continuous process improvement culture for sustained improvement in R&D effectiveness and efficiencies. While analyzing different stages of the Deming's cycle for its failure modes, one notes that it has an even balance between analysis and execution and onus of failure could be due to lack of planning or improper execution.

Though the specific steps in the Deming's cycle are clear, implementing them in real life situation poses numerous challenges. This thesis aims to understand the state of the art approaches in R&D performance improvement and maps it with the different stages of Deming's cycle. This thesis is limited to understanding R&D and product development approaches in present day businesses. Though it briefly leverages the concepts in organization theory and change management, the thesis does not aim to study these literature fields in detail. Thus, through this research I intend to better understand the activities and best practices during a performance improvement engagement using the P-D-C-A cycle and analyze different tools available to facilitate a successful R&D performance improvement.

1.3 Thesis Structure

This thesis is organized into five chapters, where the first chapter describes the motivation for choosing this topic. It also provides scope of my research.

The second chapter delves into the details of literature review that was done to further refine the scope of research. It takes off from the stated research question, which is to

identify attributes of successful R&D performance improvement engagement. To do this first R&D effectiveness & efficiency literature is reviewed. This sub-section reviews literature on different R&D measures currently used by the industry and the well-known R&D performance improvement frameworks, like TQM, Six Sigma, Lean, CMMI and PDSAT. The section summarizes salient points from literature and maps it with key stages of P-D-C-A performance improvement framework. In line with the concept of lead user innovation, this chapter reviews literature from the field of "goal setting" and "strategy" to understand any attributes of planning that R&D performance improvement might be missing. Last section in literature review consolidates the finding of the review and presents key short-comings in the planning stage of performance improvement, further refines the research question and describes the research approach.

The third chapter builds upon the literature review summary and develops a framework that can help improve the planning stage of any performance improvement framework. It then describes a not so rigorous empirical validation of this framework, by interviewing practicing consultants in the industry.

The fourth and final chapter concludes the research and presents the summary along with major areas of future work.

2 Literature Review and Analysis

The field of R&D management is vast and there are multiple viewpoints of looking at the giant. Primary focus of the R&D literature has been towards identifying the right performance measures that must be used for controlling R&D. Multiple dimensions of looking at R&D further complicates the selection of performance measures. R&D performance measurement and analysis is a very important component of R&D performance improvement; however that is not sufficient for transformation or improving performance.

There is another segment of literature that talks about specific problem solving approaches to improve R&D. These include total quality management (TQM), Six Sigma and Lean philosophies. These frameworks have a heavy process focus and operate at more granular level where interventions are actually implemented. This process based philosophy is further extended in holistic frameworks like capability maturity model integration (CMMI) and product development self-assessment tool (PDSAT).

Eric Von Hippel in his book "Democratizing innovation" describes the concept of lead user innovation. It is suggested that if you want true innovation in a particular field, look at other fields who are clear leaders in those technology fields for inspiration and innovation[8]. For instance, coronary angioplasty is an invasive surgery which involves mechanically widening of narrowed or obstructed arteries of the heart [9]. This requires development of mechanical stents that are light weight, flexible, yet strong and are non-corrosive. To find a solution to this problem, the doctors consulted with the "lead users" who would know of such a material and in this case it turned out to be in defense research scientists working on missile and space technology. As the space and missile programs require strong yet lightweight materials the scientists in collaboration with

doctors were able to develop technologies that not only provided reliable solution to the problem but provided it at a significant lower cost than conventional technology [10]. Goal setting and strategy literature being the leaders in planning field are reviewed to find best practices that can be adapted in R&D performance improvement frameworks. This chapter ends with a summary of the literature review and further refines the scope of thesis. It also provides the research approach for this thesis.

2.1 R&D performance measures

R&D performance measurement is one of the most critical steps of performance improvement, however intense focus on this attribute has led to a performance measures "glut", as can be seen from the fact that the European Industrial Research Management Association (EIRMA) has listed over 250 measures in its 2004 study [11]. The primary reason for this proliferation of R&D performance measures is the multi-dimensional nature of R&D. Ojanen and Vuola propose a framework for looking at this multidimensionality and provide guidance in choosing the most suitable and appropriate metrics for organizations.

One viewpoint of R&D performance measures is the stakeholder perspectives; different stakeholders would need different performance measures for valuing R&D. Another dimension is that of different levels of analysis which spans global, nation, industry, organization, R&D department, R&D project or R&D team level. It is also noteworthy that there are different types of R&D having different attributes like qualitative vs. quantitative measurement and subjective vs. objective measurement. R&D performance can also be measured based on the different phases of R&D [12]. This multidimensionality is graphically represented in Figure 3.

Measurement perspectives FOR WHOM?	*The purpose of measurement WHY?*	*Measurement level WHERE?*	*R&D type WHAT?*	*Process phase WHEN?*
Customer	Strategic control	Industry	Basic research	Input
Internal	Justification of existence	Network	Exploratory research	In-process
Financial, shareholders	Benchmarking	Company	Applied research	Output
Other stakeholders	Resource allocation	SBU/department	Product development	Outcome
Learning	Development of activities/problem areas	Process	Product improvements (incremental)	
Others	Motivation, rewarding	Project		
	Others	Team		
		Individual		

Source: Ojanen and Tuominen (2002) and EIRMA (2004)

Figure 3: Dimensions of R&D analysis, [12]

R&D performance measures in the 1980's were heavily focused on behavioral improvements and internally focused. People were of the opinion that R&D productivity cannot be measured and any effort in that direction would discourage creativity and motivation among the professional. Brown & Svenson stressed that companies will have to focus on external measurements like return on investments and measuring outcomes to remain competitive and innovative [13].

Robert Szakonyi on the contrary in one of his early theories proposed that industry is very focused on result based performance measures, whereas problem lies in efficient integration of different functions of an organization[14]. It is argued that the current state of poor R&D performance of companies is primarily because they are working in isolation and the current need of the organizations is to develop efficient interface management techniques instead. It is further defined that organizations can be in

different stages of maturity and would need different techniques accordingly to move from one stage to another.

Szakonyi argues that companies can be classified into three categories

1) Remaining competitive – (Company A)

2) Companies that are growing by developing new businesses (Company B)

3) Companies that would dominate the competition in future (Company C).

The paper concluded that companies would normally move from company A to company C if they adopt progressive performance improvement approaches [14]. McGrath and Romeri propose an outcome based approach to calculate the R&D effectiveness index (EI), very different from what Szakonyi has suggested. It is proposed that ultimate value is delivered to the firm when a product developed by R&D generates revenues for the firm [15]. Thus, there is a need for a measure that provides an aggregated assessment of the product development efforts of a firm. The R&D effectiveness index compares the revenue generated from launch of new products to the total amount invested in R&D.

$$EI = \frac{\%New\ Product\ Revenue * (Net\ Profit\ \% + R\&D\%)}{R\&D\%}$$

The above formula calculates "the ratio of increased profits from new products and the total investment in new product development" [15]. A value greater than one indicates the return from new products is at a greater rate than the amount invested in new products.

Effective product portfolio management has become one of the prerequisites of effective R&D management. Another perspective of measuring R&D is from product family and

product platform renewal perspective [16]. Firm's effectiveness in managing R&D is reflected by its ability to successfully introduce new products that continues to meet customer demands. A product platform will have to go through three stages of evolutions starting from initial platform, platform extension and platform renewal. It is proposed that there should be a measure of platform efficiency which is defined as:

$$Platform\ Efficiency = \frac{R\&D\ cost\ for\ derivative\ product}{R\&D\ cost\ for\ platform\ version}$$

This measure analyses the cost involved in developing a derivative product as a fraction of the cost allocated for base platform architecture [16].

Another common and important way of measuring R&D performance is R&D intensity. This can be described as R&D expenditure as a percentage of total sales or other performance variables such as R&D expense per employee, asset turnover or return on assets. The study concludes that organizations that confirm to the parameters specified in this article, have shown a positive correlation between R&D investment and return on assets measured after a lag of two years [17].

The next stage in performance measurement was categorization of R&D measures into different stages of R&D value chain. Tipping & Zeffren proposed technology value pyramid (TVP) which divided R&D into five managerial factors. The first factor is focused on outcomes and value creation, where measures are focused on understanding the amount spent on R&D and the returns from investment in R&D. The second factor is portfolio assessment, which is primarily concerned about product platform and product portfolio strategy. The third factor looks at alignment of the business unit with the overall corporate strategy and integration with the organization. The fourth factor indicates the value of technology that the organization owns and it includes proprietary

assets, know-how, people etc. The last factor is practice of R&D processes to support innovation [18]. These factors were depicted in TVP pyramid (Figure 4) by Schwartz et al.

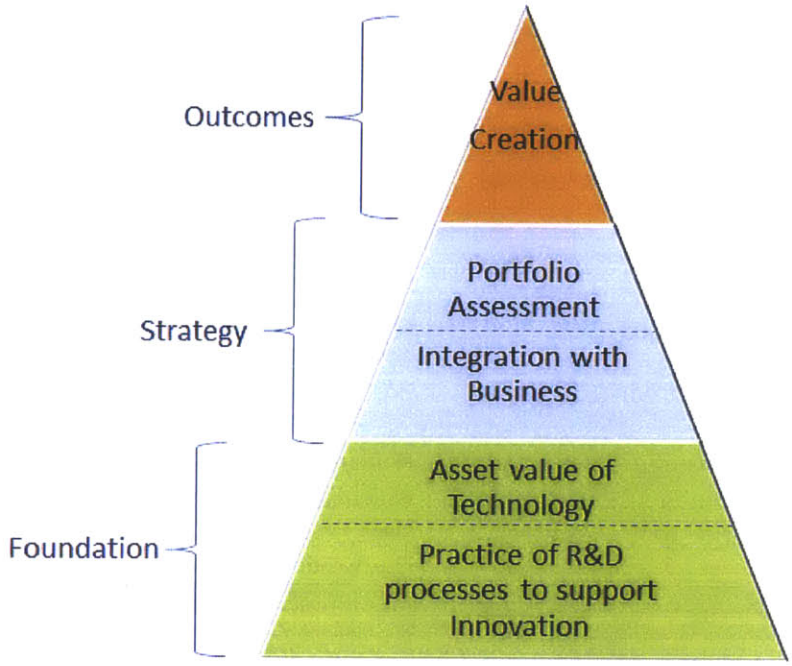

Figure 4: Technology Value Pyramid [11]

A questionnaire filled in by representatives from 161 companies was analyzed and top 33 metrics that were most used by these corporations were published. It is interesting to note that the top 10 metrics selected by the delegates had representation from each of the five managerial factors [18].

Industrial Research Institute conducted a review of this framework in 2009 and the participants confirmed the value of each of 33 measures identified in 1994, they also expanded the total count of measure to 50, to accommodate newer measures that were also found to be important in this survey [11]. It is interesting to note the comparison between top 11 measures in 1994 and 2009 (Table 1). We find that managers have shifted their focus more towards foundations related measures in 2009 as compared to outcome

measures preference in 1994. Table 1 clearly shows that of the top 11 measures ranked by the participating companies five measures each represented focus on outcome measure and the foundations measure and one strategy measure that links corporate strategy with product portfolio and product management.

Rank	Metrics 1994	TVP	Metrics 2009	TVP
1	Financial Return to the Business	Outcome	Financial Return to the Business	Outcome
2	Strategic Alignment with the business	Strategy	Strategic Alignment with the business	Strategy
3	Projected Value of R&D pipeline	Outcome	Projected Value of R&D pipeline	Outcome
4	Sales or Gross profits from new products	Outcome	Gross profit margin	Outcome
5	Accomplishments of Project Milestones	Foundations	Product quality & Reliability	Foundations
6	Portfolio distribution of R&D projects	Strategy	Sales or Gross profits from new products	Outcome
7	Customer Satisfaction Surveys	Outcome	Accomplishments of Project Milestones	Foundations
8	Market Share	Outcome	Achievement of R&D pipeline objective	Outcome
9	Development Cycle Time	Outcome	Quality of R&D personnel	Foundations
10	Product Quality & Reliability	Foundations	Level of business approval of projects	Foundations
11	Gross profit margin	Outcome	Comparative manufacturing costs	Foundations

Table 1: Top 11 performance measures 1994 vs. 2009 [11]

There have been huge changes in the R&D management approaches as the management style moved from behavior based performance assessment to more outcome/results oriented approach. There is also an increased focus on improved cross functional interaction and reduction in product development cycle times. Changing times have also placed constraints on resources availability therefore firms now have to deliver more with lesser resources [19].

Performance measures mentioned earlier provide the current performance status, but provide almost no guidance on the interventions that are needed to improve R&D performance. The maturity model/grid approach of measuring R&D performance bridges this gap to an extent. One of the important needs today is to link the maturity model based performance results to the outcome based performance measures.

Crosby proposed the Quality Management Maturity Grid (QMMG) model which divided firms' quality management performance into five levels [20]. One of the most well-known performance assessment framework based on maturity models is the Capability Maturity Model Integration (CMMI). CMMI uses capability and maturity of processes as the basis of R&D performance. It was initially developed for the software services industry and now has been expanded to include product development as well [21]. The framework identifies 22 process areas to be assessed for providing an effective performance rating.

Product development self-assessment tool (PDSAT) is another maturity model based assessment framework especially catered for product development. This framework takes the best practices accumulated at Lean Advancement Initiative, MIT over the years [22] . Maturity models are an improvement over outcome based measures in defining interventions for improvement, but come with their own constraints. The details provided in the maturity models lead to generation of large number of intervention options, which lead to implementation challenges.

Summary

R&D management has implications from strategic as well as tactical decisions of the firm. Strategy plays a key role in identifying the right projects to work on that would ensure profitability of the firm and good tactical management is needed in ensuring that one executes as per the plan and achieves desired strategic results for the company [23].

The following points summarize findings that can have an impact on the planning stage of R&D performance improvement:

1) There is a need to have high level outcome based performance measures to control R&D and there is also a need for holistic performance measures like CMMI & PDSAT that provide specific guidance for interventions for performance improvement.
2) The number of outcome based performance measures is too many and one would have to prioritize and choose minimum required for one's business.
3) There is lack of clarity on how to link outcome based performance measures to the prescriptive internal assessments like CMMI or PDSAT.
4) Aggregate performance measures must be decomposed into smaller set of specific action areas.

2.2 R&D Performance improvement

W. Edwards Deming, one of the early pioneers of the quality movement proposed fourteen points for the management of organizations. The important ones relevant for our current topic are:

1) Improve constantly and forever
2) Institute leadership
3) Eliminate slogans, exhortations and targets for work force
4) Eliminate Management by objective (MBO).

Deming's proposals have a very manufacturing setup bias and some of his principles will have to be adapted and modified for different industries and business types. Many of the principles suggested by Deming, point at leadership as the key issue of stagnancy in organizations. This is in line with the prescription from current change management theory that leadership plays a vital role in transformation.

Another important proposition is elimination of targets for work force and elimination of management by objectives. This is true only if the objectives have been set arbitrarily without providing for the means and method to achieve the goal. Crosby insists on "formulation of 30-, 60-, 90- day's goals which are specific and capable of being measured". Juran mentions that "the process of goal setting requires a degree of voluntarism and negotiation" [24].

Schneiderman defines that "a legitimate quality improvement process is one that achieves a benchmark rate of continuous improvement". He proposes a model that any defect level subjected to legitimate continuous process improvement will show a reduction in errors and this would follow a straight line [25]. The mathematical equation is:

$$(Y - Ymin) = (Y0 - Ymin)\ \exp\left(\frac{-a(t - t0)}{t\left(\frac{1}{2}\right)}\right)$$

Where

Y = Defect level

Ymin = Minimum achievable defect

Y_0 = Initial defect level

t = time

t_0 = Initial Time

a = ln(2)

$t_{1/2}$ = Defect Half Life

The word defect is used generally and can mean terms like rework, cycle time, downtime, cost of poor quality etc. Here he introduces term "half Life" which is the time it takes for the defect to reduce by half with each increment in time. This approach could be a fair assessment in manufacturing and production setup, where similar work is

repeated multiple times but would fall apart for R&D processes as they do not produce the same results every time. As we start applying this framework to R&D, we start reducing defects, it implies we are also increasing standardization, therefore are less likely to create more value in new products.

Juran trilogy defines the three stages for managing quality as Quality Planning, Quality control and Quality improvement [26]. Special emphasis is on training the managers and improving their understanding of the challenges and issues related to quality management. This is primarily needed to generate consensus for process improvement projects, without which the desired outcome of the improvement program cannot be achieved.

Quality planning is the stage when goals are set for process/performance improvement and outcome of the exercise is "A process capable of meeting quality goals under operating conditions"[26]. He also notes that managers are dissatisfied with performance improvement, because goal setting in most of the companies is based on past performance, which results in incremental improvements which might not be in tune with the changing times. Another issue is that of lack of training and clarity on measurement criteria for different goals. It is advised to focus on benchmarking and setting goals based on the best in class benchmarks in the industry. Juran also identifies a major issue of lack of resources which results in unsustainable process improvements.

The fact that quality planning cycle should result in a process capable of meeting quality goals under operating conditions is a clear indications that goals have to be arrived at after giving due considerations to all the options available and resources and constraints present with the organization.

Six sigma can be defined as a "an organized, parallel-meso structure to reduce variation in organizational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives" [27]. As one can clearly see that, though there is a focus on having strategic objectives, the process of defining goals is primarily left to the practitioners of six-sigma.

Program	Six-Sigma	Lean	Theory of Constraints
Theory	Reduce Variation	Remove Waste	Manage Constraints
Application Guidelines	1. Define 2. Measure 3. Analyze 4. Improve 5. Control	1. Identify Value 2. Value Stream 3. Flow 4. Pull 5. Perfection	1. Identify constraints 2. Exploit constraints 3. Subordinate processes 4. Elevate constraints 5. Repeat cycle
Focus	Problem Focused	Flow Focused	System Constraints
Assumptions	A problem exists. Figures and numbers are valued. System output improves if variation in process is reduced.	Waste removal will improve business performance. Many small improvements are better than system analysis.	Emphasis on speed and volume. Uses existing systems. Process interdependence.
Primary Effect	Uniform process output	Reduced flow time	Fast throughput
Secondary Effect	Less waste. Fast throughput, Less inventory, Fluctuations – performance measures for managers, Improved quality	Less variation, Uniform output, Less inventory, New accounting system, Flow – performance measures for managers, Improved quality	Less Inventory/waste, Throughput cost accounting, Throughput performance measurement system, Improved quality
Criticism	System interaction not considered, processes improved independently	Statistical or system analysis not valued	Minimal worker input, data analysis not valued

Table 2: Comparison of improvement programs, [28]

Six-sigma is a very detailed approach of problem solving and does not take into considerations various human interactions and interfaces that truly define product development. When we talk about performance improvement of R&D performance, if relegated to the approach of improving different measures one by one, it would be a humungous challenge to holistically improve the R&D performance. There is a need to bring in another level of abstraction and have an approach that can look at product development from different views and viewpoints.

Selection of projects for six-sigma have a very strong bias towards immediate short term financial performance as a result there could be loss of strategic intent, while implementing six sigma solutions. Six sigma uses tools that have been known to quality improvement experts for quite some time, but the true impact of six sigma methodology is the in the organizational changes that is desired for a successful implementation [27].

The framework in Table 2 proposed by Nave, provides a simple way to compare performance improvement framework and consequently helping organizations chose the right framework [28].

As we can clearly see from application guideline in Table 2, that all the three frameworks have planning as the first step of the process albeit, they use different words to mean the same thing. The framework highlights the fact that there are multiple ways of looking at the issues that the business has and it is important to understand which perspective is more suitable for the organization.

Russell Ackoff et al in their book "Idealized Design" propose that defining ideal goal and then working backwards is the best approach recommended by practitioners in the industry for transformative change [29]. They propose following steps to attaining the ideal state of performance:

Idealization

1. Formulating the mess
2. Ends Planning

Realization

3. Means planning
4. Resource planning
5. Design of implementation
6. Design of controls

The steps provided above is a general framework that can be used to transform or improve any organization and is not restricted to R&D. When comparing the summary of literature and the steps defined in "idealized design", we find that they propose formulating the mess and ends planning as their steps in idealization phase, which can be compared with the planning phase in P-D-C-A cycle.

Summary

Performance improvement frameworks for R&D having evolved from manufacturing settings have a focus on specific problem solving and lack the holistic performance improvement perspective [28]. Salient attributes that must be part of planning during any performance improvement are:

1) Each of the quality improvement frameworks work well for specific problem solving. It is better to decompose larger problem into specific focus areas and then use these tools. This is also identified as "formulating the mess" as per idealized design philosophy [29].
2) Ends planning or identifying goals is a key step of any performance improvement framework. One has to define the ideal state that the organization should be as the target for identifying interventions.

3) Planning should include use of statistical approach to identifying problem and to ensure processes are under control.
4) Literature reaffirms the importance of planning, control and improvement as key steps for quality improvement.
5) Literature highlights that any performance improvement effort would need exemplary leadership skills to motivate people for change.

2.3 Strategy

"Strategic positioning attempts to achieve sustainable competitive advantage by preserving what is distinctive about a company. It means performing different activities from rivals, or performing similar activities in different ways."[30]

Michael Porter differentiates strategy from operational effectiveness and limits the role to strategy to making choices. Thus, strategy defines the epitome of goal setting for the corporate world. Corporate strategy literature is vast and spans numerous views and viewpoints of looking at a corporation. To be consistent with goal setting in R&D establishments, I shall be looking at frameworks that provide answers and guidance for the following problems faced by the corporations:

1) Identifying the opportunity in various industries.
2) Identifying the product strategy for the business units.
3) Defining a control mechanism to effectively monitor the performance of the business units and the corporation as a whole.

Porter's Five Forces

Porter's five forces is the most dominant framework that is used to analyze industries and helps corporates in making critical investment decisions for corporations. The framework relies on competitive behavior and provides a structure approach to analyze the industry. Existing competitors had been obvious reference points for comparison;

however Porter identified four more areas, which can significantly impact the success of a corporation.[31]

a) Threat of new entrants or Barriers to enter: It is important to identify various barriers to enter the given industry. Organizations need to develop distinct competitive advantage that would be difficult for the competition to replicate and emulate and for new entrant to enter the industry.
b) Bargaining power of Buyers: Organizations need to understand customer loyalty and develop strategies to sustain this loyalty.
c) Bargaining power of suppliers: Developing the capabilities such that one does not become dependent on any single supplier. One should have the capability to quickly move and change suppliers to enhance and ensure profitability.
d) Threat of substitute products or services: This analysis is increasingly becoming more important. There have been many an examples where substitute products have completely taken industries off-guard and shown the door to bankruptcy. Kodak would be a classic example here, a world leader in photography & camera films is now nowhere in the race and has filed for bankruptcy [32]. This was made possible by the advent of digital cameras, which made camera films a totally redundant product. Inability of Kodak to recognize this new entrant as a threat proved to be its nemesis.

Figure 5 provides the graphical representation of these forces. This analysis helps corporations to develop strategies to improve upon their weaknesses and leverage their strengths to march towards market dominance.

Figure 5: Porter's five forces [31]

BCG's Growth-Share Matrix

Boston consulting group's (BCG) in 1970 developed the first product portfolio analysis tool, the growth-share matrix [33]. Portfolio analysis had some serious shortcoming in prioritizing and making decision based on only two parameters. This led to proliferation of different matrices developed by various consulting firms that helped in product planning and portfolio analysis and one of the more notable one is the GE/McKinsey nine-block matrix [33]. It would be fair to analyze BCG's growth share matrix to understand this family of frameworks.

The growth-share matrix analyses products on two parameters a) relative market share and b) market growth [34]. This four block matrix is depicted in Table 3.

	High Market Share	*Low Market Share*
High Market Growth	Star	Problem Child
Slow Market Growth	Cash Cow	Dogs

Table 3: BCG's Growth-Share Matrix, [34]

Star: One gets a star product if it has a high market share and market growth. These products have reached or are about to reach high level of maturity in the product lifecycle and their trajectory tends to move towards cash cows. The "star" products demand high investment to sustain the growth rate and the market share.

Cash Cow: These are products where the products are very mature and the market growth has started to decline. The intent is to extract as much benefit as possible and they do not need additional investment to sustain themselves.

Dogs: Products under this category basically have three routes to take. The first one is to make them profitable and stable by focusing on niche market segments, second is to use them as cash cows as long as they are profitable and the third option is to divest.

Problem Child: These products have potential but are not able to generate healthy profits for the company as they are early in the product lifecycle curve and need heavy investment. At this point one has to cautiously judge the potential as these products can eventually become "stars" and move towards "cash cows" or can easily move towards the "dogs" category.

Balanced Scorecards

It is said that one cannot improve performance if it is not measured. Good strategy and product planning needs meticulous execution to realize the desired outcome. At this point one cannot remain in the sphere of planning and has to move into operational

effectiveness. Balanced scorecard is one of the most widely used tools to define and monitor performance of business units for success.

"Balanced scorecard is like the dials in an airplane cockpit; it gives managers complex information at a glance" [35]. Kaplan and Norton during their research found that decisions are not just made on single performance parameter but instead need data from multiple performance parameters. They devised a performance measurement system that holistically mapped key elements for performance today and also included parameters that were indicative of performance tomorrow [35].

The framework suggests that vision and strategy of the organization should be at the core of the performance management system as shown in Figure 6. This vision and strategy must be translated into performance measure in four focus areas:

a) Measures for customer perception: Customers primarily value the cost, performance and quality of the product timeliness and service capabilities become the next most important parameters for building positive customer perception. Managers in the organization will have to define specific performance measures for each of these parameters to monitor customer perception [35].
b) Internal business performance measures: One has to define the internal business process and measures that have the highest impact on customer perception. It is here that companies lean towards TQM, Six Sigma and Lean for quality of products.
c) Learning & Growth measures: Companies also need to invest for the future and it is very important to look at innovation measures and measures that would ensure sustainability of the organization.

d) Financial Performance measures: Last but not the least organization has to perform to provide value to the shareholders. Measures for financial performance are most robust and accessible in most organizations.

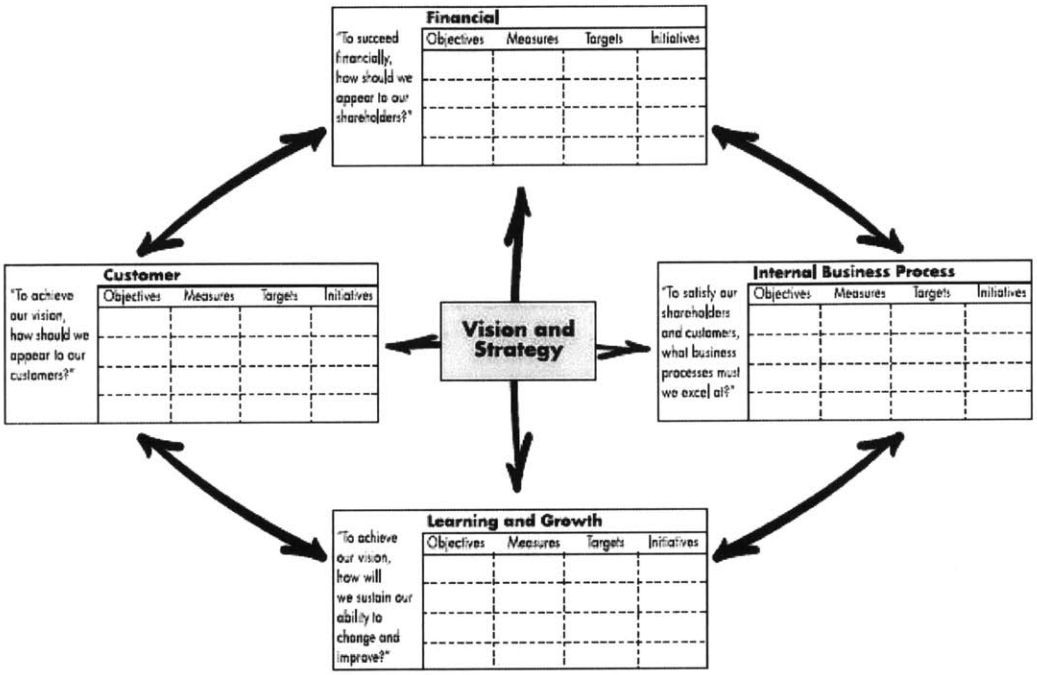

Figure 6: Balanced scorecard, [36]

The balanced scorecards highlight that each one these four categories are equally important, however depending on the current situation of the business one parameter could turn out to be more important than others.

Corporate Strategy: Resource Based View

It is imperative to talk about resource based view of the firm to highlight its importance in current context. Here is a question that deserves a mention, if all MBA's with equal expertise in strategy were hired by all the firms today, would all firms be equally successful [37] ? In reality irrespective of the intellect or ability of an organization to define strategy, it cannot be successful if it is not supported by appropriate resources.

This basic question led to the development of resource based approach to strategy and was first published in the literature in 1984 [38].

Collis & Montgomery contend that a successful corporate strategy has five key components. These five components together as a system provides a corporate advantage that creates value [39]. The five elements of their framework are: a) resources b) businesses c) organization d) vision e) goals and objectives. They proposed the "corporate strategy triangle" for producing corporate advantage, shown in Figure 7.

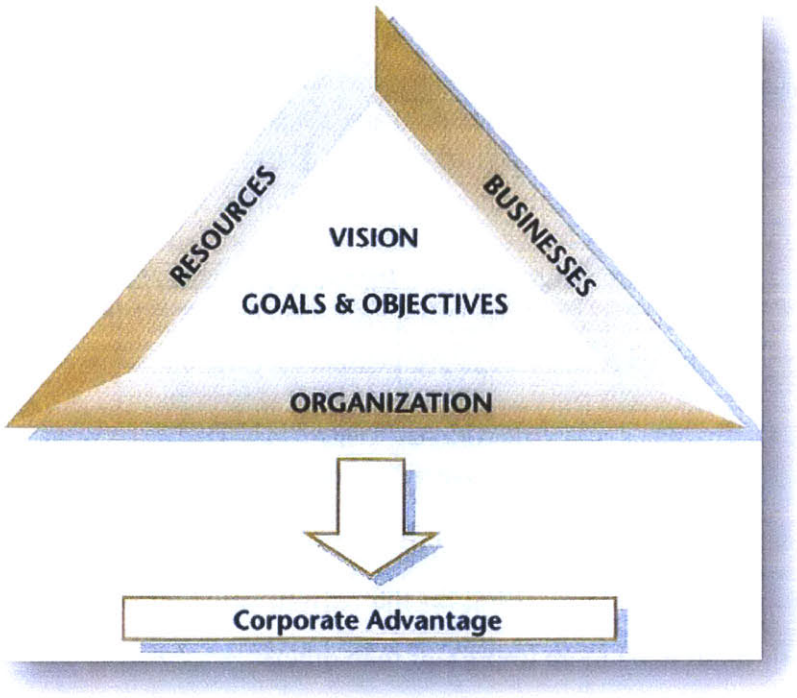

Figure 7: Corporate strategy triangle, [39]

The resource based view defines organization vision to be the guiding principle, which galvanizes the whole organization to action with a clear motive and purpose. This vision being long term is broken down into short and medium term goals and objectives that help in incrementally reaching the ultimate goal. However the goals must be decided

keeping its resources in mind namely: assets, skills and capabilities of the firm. It is these resources that "determine not what a firm wants to do, but what it can do". Thus having lofty goals that are not supported by resources of the firm is indulging in wishful thinking.

Summary

Each of the strategy frameworks discussed above provide key insight for R&D performance improvement, specifically for goal setting. The salient features of literature review are:

1) Porter's five forces frameworks show the importance of looking at the industry and external factors like knowing the best practices in the industry in deciding the future goals.
2) BCG's growth share matrix suggests at looking at the market share and market growth while devising the product strategy.
3) Resource based view recommends balancing the internal capabilities with goals and strategies of the firm.
4) Balanced score cards highlight the importance of holistic approach of looking at performance.

2.4 Goal Setting

"Advice on the subject of goal setting varies widely and is rarely specific and proven. Experiences of both people who set goals and people who must meet them are universally frustrating to say the least"[25].

Goal setting theory has its origin in human psychology and later moved into various fields like performance appraisal, motivation theory [40]. My key focus is in this section to understand the application of goal setting theory in research & development performance improvement framework for organizations. Defining new goals or "Goal setting" is a well-researched field that has conclusively proven that clear, specific and challenging goals result in higher performance than having no goals or do your best goals [40], yet we see lack of focus on goal setting in many a performance improvement frameworks that have developed over time for R&D and new product development [24].

The first theory on goal setting was published in the 1960's by Locke [41], where he tried to understand the relationship between planned achievement versus actual level of achievement. In its most simplistic terms, Goal setting theory proposes that "specific and challenging goals lead to higher performance". Goal setting also leads to more focus, channeling of energies and help in increasing persistence in achieving the set goals. Facilitating mechanisms that positively correlate goal setting and task performance are; specific and sufficiently challenging goals, capability and skill of the subject, regular feedback mechanism during the entire process of task execution, sufficient reward for the efforts, support from the management and finally goal acceptance by the subject [40].

In the second phase of goal setting theory development, Locke and Latham proposed the "high performance cycle" [42]. This theory can be also understood as a continuous performance improvement cycle, where goal setting as understood in phase I, is one of many variables responsible for high performance achievement.

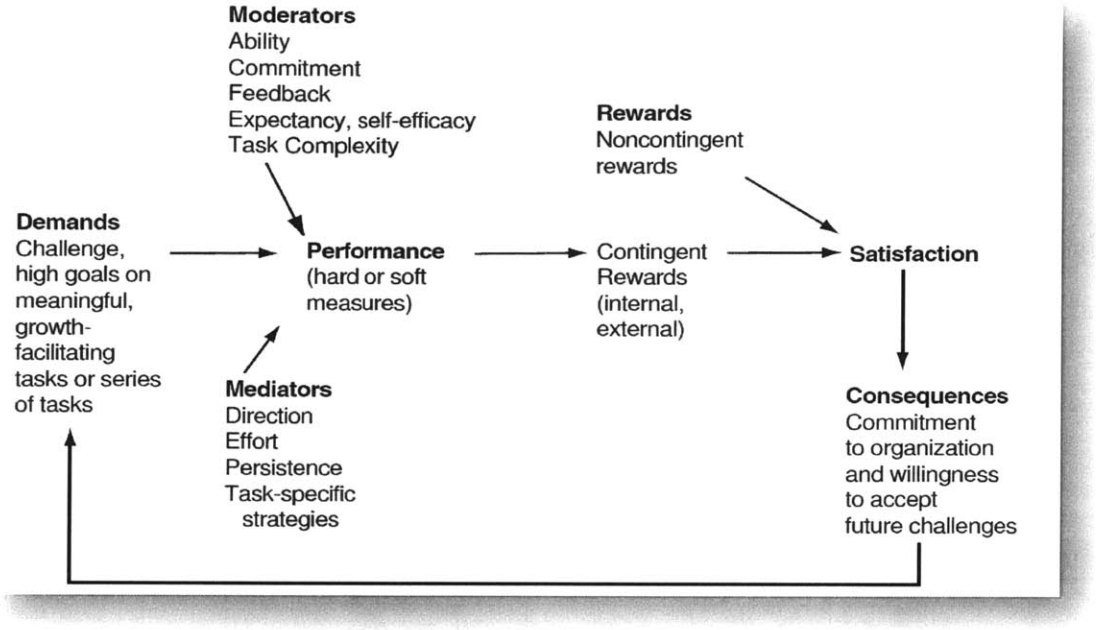

Figure 8: Model of High Performance Cycle, Locke & Latham (1990)

Through the model in Figure 8, they have tried to capture the entire process of performance improvement in an organization including key influencing factors. The model also highlights a strong interaction among goals, plans (task strategies) and performance. It is pertinent to note that, if the task strategies are constant, then the need for new goals is eliminated. This statement can be interpreted in multiple ways, one way would suggest that if your strategies are constant, then you cannot achieve new goals, hence your performance would be constant. On the other hand if your task strategies and plans are self-reinvigorating then you essentially implement a perennial continuous improvement cycle. This realization is the key motivation for looking at goal setting process as the corner stone for continuous performance improvement.

Locke and Latham are now in the process of defining the third phase of goal setting process, where they intend to look at this process from motivation perspective and then

evolve an updated high performance cycle theory. This theory is more holistic as it takes into consideration the motivation factors associated with any performance improvement. This theory accepts that goals setting is a key step in performance improvement but is incomplete without the motivation core which provides credence to the importance of transformational leadership and cultural change for any performance improvement. Figure 9 depicts the phase 3 philosophy of Locke and Latham.

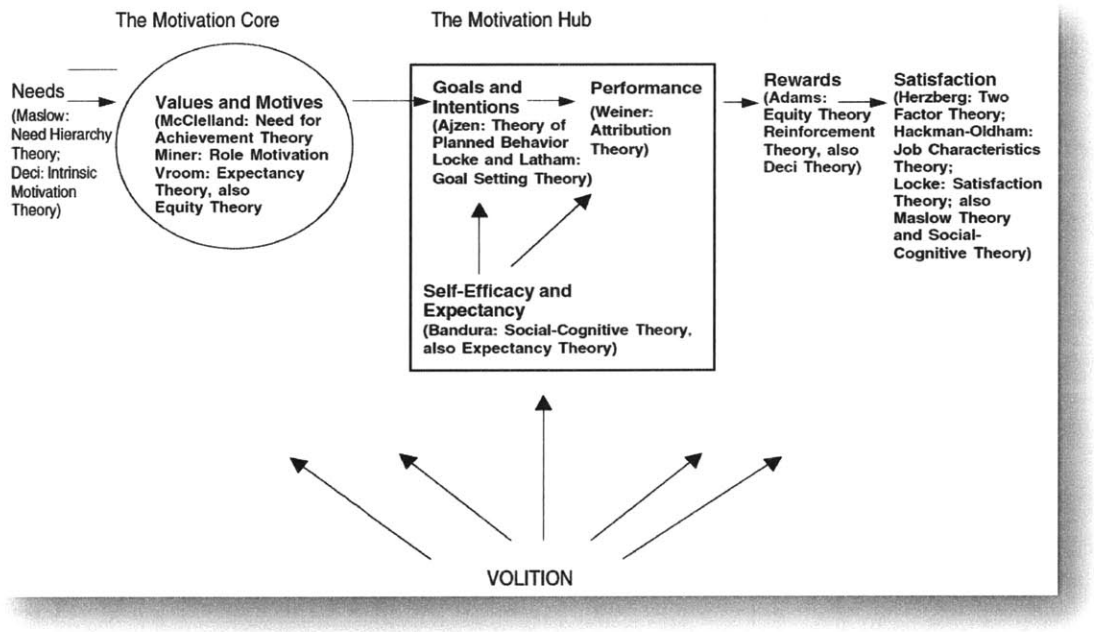

Figure 9: Model of Motivation Sequence (Locke 1991)

Many a times goal setting is assumed to be a single step of defining goal, however it is equally important that the defined goals have been accepted by the team/individual and are fully committed to the goals [43]. Goal acceptance and commitment can be achieved by different ways either by having an authoritative or participative goal setting approach. Research does not confirm superiority of any approach but it does confirm the importance of this step [42].

Summary

"Little empirical research has been done using goal theory in operations management and quality management in particular, a surprising fact given that goal theory is a well-established management theory"[24]

Goal setting theory proposes the following guidelines for a successful change implementation:

1) Set challenging yet attainable goals for people to constantly outperform.
2) Goal acceptance and goal commitment is a critical step that decides the success or failure of a transformation.
3) Any transformation should result in appropriate reward and recognition to motivate people for continuous improvement.
4) Leadership will have to strive to consistently motivate people, set clear goals, provide encouragement, feedback and eventually appropriately reward commensurate with performance.

2.5 Review of Research Goals

The initial scope of this research was to better understand the activities and best practices during a performance improvement engagement using the P-D-C-A cycle and analyze different tools available to facilitate a successful R&D performance improvement.

First stage in literature survey was to understand the current focus areas in R&D management and different R&D performance measures that are being defined and developed to control and set goals for performance improvement. R&D performance improvement frameworks like six sigma, CMMI and lean which provide different approaches of looking at R&D performance improvement were analyzed and summarized. Having looked at leading edge literature in R&D management, we also looked at "lead users" in the field of performance improvement for corporations, namely strategy and goal setting. An ideal performance improvement framework should take the best from each of these fields and propose a holistic performance improvement framework. Summary of the key attributes of performance improvement framework, leveraging the key insights from literature and adapting them to P-D-C-A cycle is presented in Table 4.

The literature survey provides key insights into the performance improvement framework that we discussed in chapter 1, the Plan-Do-Check-Act cycle. Multiple dimensions and approaches of R&D assessment and performance improvement communicates one very clear message, that is R&D is very complex and context dependent subject and there cannot be one size fits all approach to performance improvement. A framework that is successful in a given situation may fail miserably in a different setting.

Subject Area	Attributes
R&D performance Measures	1. Outcome measures 2. Different measures for different stage of R&D hierarchy (TVP)
R&D improvement frameworks	1. Identify value & Value Stream 2. Statistical approach to eliminate variation 3. Holistic approach to performance assessment. Could be process focused or have focus of static & dynamic capabilities
Strategy	1. Assess competitive environment and understand the best practices 2. Analyze product portfolio and plan product based on market share and market growth. 3. Holistic performance measures that strike a balance between internal and external effectiveness 4. Set strategic goals based on internal capabilities
Goal setting	1. Set clear and challenging goals. 2. Goal acceptance and goal commitment are critical for successful performance improvement. 3. Define the path to achieving goals 4. Leadership is important for any successful transformation

Table 4: Attributes of successful performance improvement

Table 4 summarizes key insights from literature review and analysis. It is now time to use these insights to develop the attributes for P-D-C-A cycle that would ensure successful performance improvement engagements.

Plan: The first step in planning stage is that of measuring performance at a various levels of R&D value chain. The technology value pyramid (TVP) provides a comprehensive list of measures that an organization can adopt. However performance

measures by themselves are not sufficient for performance improvement, one would have to take appropriate actions to overcome shortcomings in the current organization. It is for this stage that we will have to rely on holistic performance measures like CMMI and PDSAT. One will have to develop a correlation between outcome measures and CMMI. For instance the outcome measured for a CMMI performance maturity of 2.5 should show improvement if the CMMI performance maturity reaches level 5. Once an organization is at level 5 maturity, it would mean that it is continuously improving its performance based on quantitative data, at this stage the outcome measures should show a consistent reduction in defect [25].

Understanding the correlation between outcome measure and performance measure then leads us to setting future goals and actions that would improve outcome and holistic performance measures. It is important to note that setting future goals should be based on capability and resource availability with the organization. Holistic performance is performed by dividing the activities into different levels of aggregation, for instance CMMI prefers process based aggregation and PDSAT looks at static and dynamic dimensions of R&D.

Do: One can use different performance measurement tools like lean, six-sigma, total quality management (TQM) to overcome the varying types of challenges that the holistic assessment has identified. This could also mean setting sub-goals for each of the individual performance improvement activities.

Check: In this step one has to perform measurement to see if all the targets set at stage III have been achieved or not.

Act: This is the last step of P-D-C-A cycle, where one looks at the results of "check" stage and takes corrective actions to meet targets set in "plan" stage.

The above sequence must be performed in a loop for continuous improvement. A mapping of the steps mentioned above and tools available to perform those activities is shown in Table 5.

	Actions	Tools
Plan	Measure current performance 1. Outcome measures 2. Holistic internal performance measures	TVP, CMMI, PDSAT
	Set Future Goals 1. Outcome measures 2. Holistic internal performance measures 3. Goal Acceptance & Goal commitment	Discussion, Expert Opinion, Benchmarking
Do	Take steps to improve performance	Lean, Six Sigma, TQM
Check	Measure the impact of improvement actions.	Comparison with goals set in Planning stage
Act	Take action to bridge the gap between planned and actual outcome. Identify the lessons learnt in performance improvement endeavor and ensure mistakes are not repeated in future efforts.	Root cause analysis Documentation of lessons learnt and using it in next planning cycle

Table 5: P-D-C-A and associated toolkit for each stage

The analysis in Table 5 shows that defining future goals is an activity that does not have clear guidelines and is clearly an area where more work is needed. Both six sigma and lean have tools to identify customer requirement and value but as they are utilized predominantly for problem solving using those processes directly without appropriate modification will not help in holistic R&D performance improvement approaches.

With the above observation, I further refine my original scope of research to defining future goals in R&D performance improvement, within the planning stage of P-D-C-A cycle.

2.6 Research Approach

This research was sponsored by an internal consulting group of a large corporation. Primary focus of this work was to understand state of the art approaches for R&D performance improvement efforts and contribute towards gaps identified during the research. The thesis relies on formal theory and field study as the methods for conducting this research. The entire process can be broken down into three stages:

Stage I: This stage was about framing the problem and it began with the field study, where interviews were conducted with twelve expert consultants to understand challenges they faced in executing R&D performance improvement projects. They were all consistent in communicating one key message that they have access to reasonable and proven assessment tools, but when it comes to recommending actions to fill the gaps they faced many challenges. The recommendations varied from consultant to consultant and this variation could be due to the expertise and experience a consultant had or due to the challenge posed by the given assignment or both.. This observation was confirmed by analyzing formal theory on R&D performance improvement, where there were many approaches for measuring performance but very little guidance provided for defining future goals. This set the stage for refining the scope of research to defining goals in R&D performance improvement frameworks.

Stage II: The second stage in the research process was about developing the framework that would aid in defining future goal for any R&D performance improvement. The biggest challenge was to develop an operational framework that was synthesized using

the state of the art literature review but provided sufficient details for hassle free implementation in performance improvement engagements. While defining the framework in chapter 3, notional data is used to explain the concept.

Stage III: The third and final stage of research was validating the framework and this proved to be a huge challenge given the time constraints. As an alternative the framework was used to validate a successful engagement in the past within the corporation. The result of this simulated validation was very encouraging and provides confidence on its usefulness in defining goals for R&D performance improvement.

3 Defining future goals

While analyzing the P-D-C-A cycle in section 2.4, we found that future goals will have to be defined for outcome measures as well as holistic performance measures for R&D assessments. It would be fair to note that many of the outcome measures having financial implications have dependency not only on R&D but also on other functions of the organization for the desired outcome. It is perfectly possible to have a good internal R&D performance measure and still not have desired financial outcome. Thus, any goal setting for outcome measures must take into consideration competitive assessment and also assessment of other functions in the organization like sales, marketing, manufacturing and supply chain. Our prime focus being R&D performance improvement we shall focus on identifying goals for holistic performance assessments like CMMI or PDSAT which are mainly internally focused.

This chapter is organized into two main sections. In line with the P-D-C-A cycle first section is about performing current state assessment of the product development capabilities of the organization and then the second section describes the framework for defining future goals.

3.1 Assessment

Defining goals is the stage we arrive at after the current state assessment of R&D has been performed. It is very important to "formulate the mess" [29] and the performance assessment that one choses plays a very important role in deciding the usefulness of this process. Section 2.5 identifies two main R&D performance assessment frameworks CMMI and PDSAT that can be used in this context.

One of the oft repeated needs of the practitioners gathered through our interviews is that of standardization of assessment and R&D performance improvement process.

CMMI provides a high level of standardization, but it still needs higher level of customization for implementation. The twenty two process areas described in CMMI are fairly broad in their description and can be applied to wide variety of activities of product development. For instance the "configuration management" process area described in CMMI® for Development, Version 1.3 document can be applied to the following areas:

• *Hardware and equipment* • *Drawings* • *Product specifications* • *Tool configurations* • *Code and libraries* • *Compilers* • *Test tools and test scripts* • *Installation logs* • *Product data files*	• *Product technical publications* • *Plans* • *User stories* • *Iteration backlogs* • *Process descriptions* • *Requirements* • *Architecture documentation and design data* • *Product line plans, processes, and core assets*

Table 6: CMMI configuration management, [21]

Now defining the configuration management maturity level for each of these activities is a process of customization that every organization will have to initiate and will have to find the best practices, which is a time consuming process. On the contrary, PDSAT provides a list of sixteen activities that map to the configuration management process area in CMMI and has defined the best practices of each of these activities (Figure 10). Thus PDSAT provides a detailed and more standardized approach for performing product development assessment. This does not in any way imply that PDSAT would give superior results than CMMI assessment. As noted earlier, R&D has multiple dimensions and there is need for different approaches to resolve different problems. CMMI might very well provide good solutions in many situations. The goal setting

framework being defined in this thesis is a generic framework and is independent of the chosen performance assessment framework. PDSAT being more descriptive and detailed is used in this thesis to explain and demonstrate the application of goal setting framework.

Configuration Management	The purpose of Configuration Management (CM) is to establish and maintain the integrity of work products using configuration identification, configuration control, configuration status accounting, and configuration audits.	CM	Support	2	PDC 3: Product architecture PDC 4: Linkage to corporate objectives PDC 5: Product's functional content PDC 6: Definition of product attributes and their values PDC 9: Product variety management PDC 10: Re-use of physical and design assets PDC 11: Make-buy decision PDC 14: Release to manufacturing ramp-up PDC 15: Transition to sales PDC 16: Organizational readiness for sales PDC 17: Service and support complexity PDC 18: Product service processes PDC 21: PD project financial goals PDC 23: End-of-life strategy PDC 39: Technology readiness PDC 40: Investments in PD methods, tools and databases

Figure 10: CMMI to PDSAT mapping for configuration management [22]

Product development self-assessment tool (PDSAT)

Product development self-assessment (PDSAT) questionnaire developed after taking inputs from multiple sources is a comprehensive tool to assess product development capability & maturity in an organization [22]. We shall demonstrate use of the goal setting framework using product development self-assessment tool (PDSAT). Therefore, it is important to have a brief over view of the tool. The paragraphs below provide a brief summary of PDSAT questionnaire as described by Christoph Knoblinger in his Diploma thesis titled "A New Product Development Self-Assessment Tool" [22].

The main strength of the PDSAT questionnaire is its structure to capture static and dynamic capabilities of product development unlike other frameworks which are based on static capabilities and have functional approach of dividing product development [22]. PDSAT has three main parts:

1) Product Development (PD) Competencies: These set of questions analyze the capabilities of the organization to develop innovative products and capture the best practices known in the industry of different functions.

2) Product Development Dynamic Capabilities: Questions under this section focus on the change management capabilities of the organizations.

3) Product Development Results: PD results capture the ability of the firm to seamlessly integrate PD competencies and PD dynamic capabilities. It is this interaction which really produces the results or outcome of the PD activities.

The questionnaire is structured to provide clear understanding of the best practice in the industry for a given competency. Performance of an organization can be rated from level 1 to Level 5, where level 5 defines the best practice in the industry as shown in Figure 11. One can clearly note the clarity with which each level is described and the ease with which current assessment can be done at the same time identify the new goal that one would like to achieve. It is possible that organization can have a different understanding of ideal state of level 5 performance, but for this thesis the level 5 described in PDSAT is assumed to be the ideal performance for a given attribute of R&D.

The 91 questions of PDSAT are divided into three main sections and 24 subsections, these categories are tabulated in Table 7. Product development competencies have the major share of questions followed by PD dynamic capabilities and PD project results.

While doing an assessment one has to customize and adapt this questionnaire to suit to one's organization needs as it is possible that many questions may not be relevant and some new questions will have to be added. If for instance, we assess an organization on all the dimensions of PDSAT questionnaire, we can have average rating of current state

assessment plotted in radar plots for each of the 24 categories (Figure 12); this would immediately highlight the strengths and weaknesses of an organization.

PDC 41	1.9.3	Technology forecasting							
Competence Level Description:	Product development does not consider formal technlogy forecasting.	Product development system is a technology follower - new technology is adopted only when it is widely adopted in the market. PD system uses familiar and mature technology and reuses known manufacturing processes.		Technology forecasting is based on capabilities of the organization and knowledge of the state-of-the-art. Capabilities determine adoption and competitive pressures trigger make/buy decisions.		Technology and manufacturing roadmaps with a competitive lead are defined. Work is done with customers to understand technologies. New product pipeline planning considers this when scheduling development activity.		PD uses preemptive roadmaps in technology and manufacturing. Technology is validated in lead user application environments. New product pipeline planning highly considers this when scheduling development activity.	
Competence Level:	Level 1 (poor)	Level 2 (fair)		Level 3 (good)		Level 4 (very good)		Level 5 (excellent)	
	Functional area:	Product Design Systems Eng.	R&D (Techn. Dev.)	Finance & Accounting	Production & Quality	Sales & Marketing	Human Resources	Customer Services	Administration IT Support
	Organizational role:	Executive level	Project leader	Function leader	Project staff	Function staff	CI organization		
	Level of analysis:	Individuals	Teams	Projects Programs	Organization				
	Specific Lean Management Practice:	Specific Lean	Not specific Lean						

Figure 11: Product Development competency technology forecasting [22]

A depiction of these radar plots with notional data is shown in **Figure 12**. If this data were representative of any organization they would have to really worry about execution competence, social responsibility, and customer focus as they have fared very low on these parameters in the product development competencies. It is equally possible that on certain competencies where the company has fared high value of four, it is still desirable to improve it further than focusing on competencies which have fared very poor in the assessment but are a low priority from business perspective. It is prudent to note here that an organization can define its focus area and consciously decide not to focus on any specific competency.

	Questionnaire Categories
Product development competencies	1.1 Customer focus competence
	1.2 Product Concept and Design Competence
	1.3 Product Validation Competence
	1.4 Product Delivery Competence
	1.5 Project and Portfolio Management
	1.6 Execution Competence
	1.7 PD Staff Competence
	1.8 Data Management Competence
	1.9 Technology Competence
	1.10 Marketing Competence
	1.11 Social Responsibility Competence
Product development dynamic capabilities	2.1 Communication and diffusion channels
	2.2 Vision, strategy & plans
	2.3 PD Corporate culture
	2.4 People for change
	2.5 Helping, training & education
	2.6 Human resources for product development
	2.7 Openness to improvements
	2.8 Learning
Product development project results	3.1 Project Financial and Market Results
	3.2 Project Customer Satisfaction and Loyalty Results
	3.3 Organizational Effectiveness Results
	3.4 Product Results
	3.5 Project Benchmarking

Table 7: PDSAT questionnaire main categories [22]

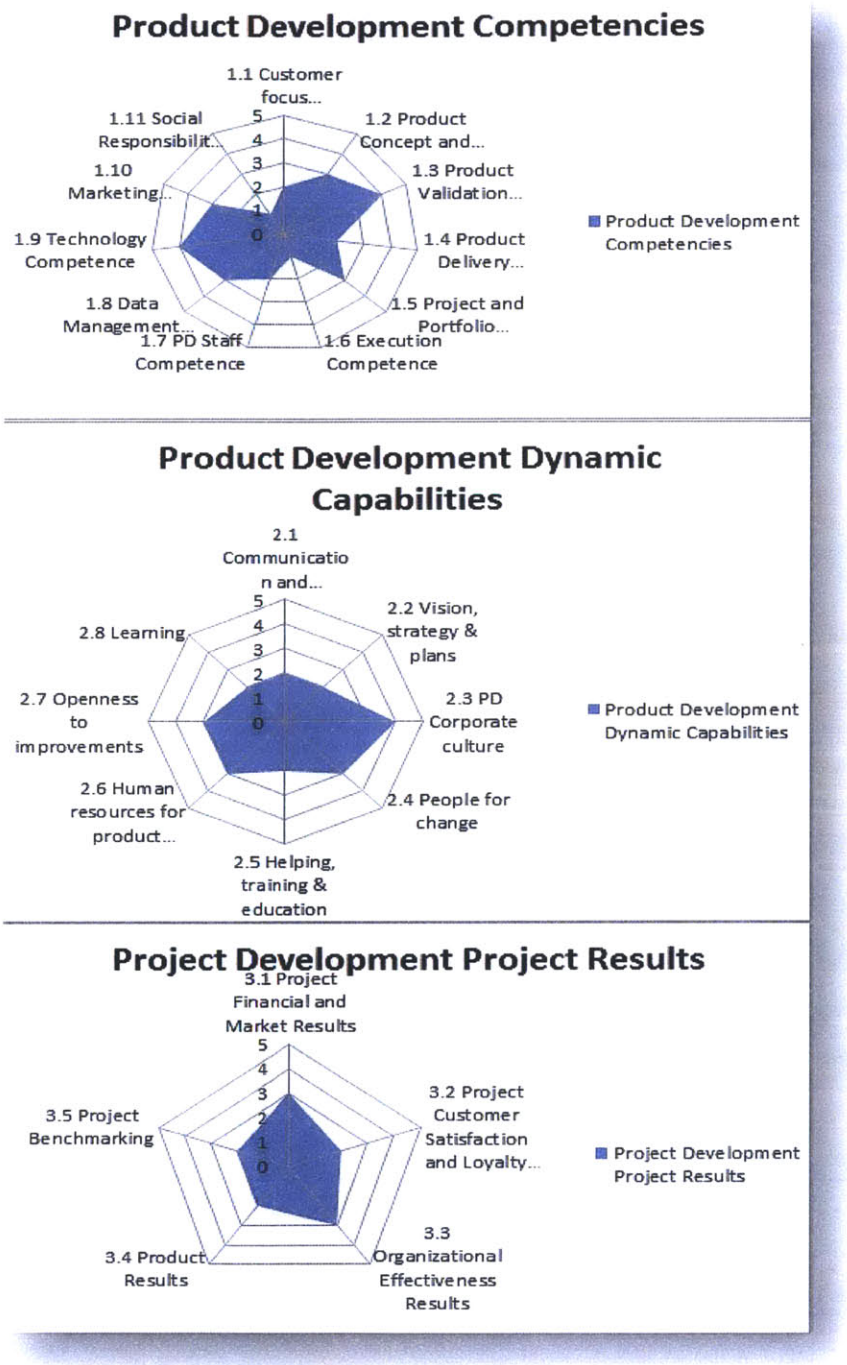

Figure 12: PD Assessment radar plots (notional)

3.2 "DEAL" Framework for setting future goals

Performing self-assessment of product development capabilities and competency now leads us to the next stage of defining future goals of the organization. Discussions with the practitioners in the industry suggested that goal setting is one of the most time consuming process in product development performance improvement efforts. PDSAT highlighted that product development is a complex process as it tightly integrates the PD competencies with PD dynamic capabilities. The key challenge with product development is that no two problems are the same. There is significant dependency on the context and type of product development activity the organization performs. Literature survey sections 2.2 and 2.3 provide guidance on how to identify measures for improving performance.

Strategy suggests that one must have good understanding of competitive performance and capture R&D best practices in the industry. Resource based strategy suggests that any goal must be decided based on the capability and resources available within the firm. Goal setting theory stresses that goals must be specific and challenging and further recommends that team should accept and commit to the goals. If the goals set are accompanied by plans that provide details of execution, it accelerates the goal acceptance and commitment process. Organizing all the findings in sequential steps provides an outline for the goal setting process.

Outline for goal setting process:

1. Identify R&D best practices in the industry
2. Be cognizant of the capabilities and resources available with the firm
3. Identify approaches to exceed the best practices followed by the industry
4. Set challenging goals for the team balancing points mentioned in steps 1, 2 & 3.

Incorporating some of the best practices from idealized design and key attributes summarized in Table 4, the updated goal setting process steps results in the DEAL framework:

1) **(D)**efine: This stage stresses on the process of identifying R&D best practices and defining the ideal state of R&D operation also known as "formulating the mess".
2) **(E)**numerate: This step requires listing of all interventions/options that would help make R&D reach the state of ideal performance or best practice. This is done taking into consideration the resources available within the firm.
3) **(A)**nalyze: In this step one performs a tradeoff analysis of all the listed options based on the criteria defined by the organization.
4) **(L)**ist: This is the last step of the process where one looks at the prioritized list of interventions and makes final recommendations for final implementation. Once the final interventions have been identified and agreed upon, one has to revisit the assessment questions of PDSAT and define the future state the organization would achieve if the interventions identified through the DEAL framework are implemented.

Performing these steps in the DEAL framework, involve coordination among multiple individuals and stakeholder and this exercise also acts as an effective mechanism of participative goal setting. The DEAL framework described below is a generic framework that can be used in any performance improvement framework. However while, describing this prescriptive approach, PDSAT would be used as the preferred assessment tool. The next sections review each of these steps in detail.

3.2.1 Define the Ideal State / Best Practice

This step of defining the ideal state assumes that the problem is well formulated. Product development self-assessment (PDSAT) questionnaire is one such assessment tool thatprovides a structure that can help in clearly formulating the problem. As we have seen in section 3.1, the questionnaire methodically breaks down the product development process into three categories and then goes on to define multiple dimensions of each of these categories. PDSAT questionnaire also provides detailed description of each question, which leaves almost no ambiguity in the interpretation of questions.

It is important to note here that there would be numerous instances where the problem faced by businesses would not need an assessment on all dimensions of the PDSAT questionnaire. In this situation one will have to understand the specific problem of the business and then chose appropriate questions that are relevant.

Formulating the problem then leads us to the next step of defining the best practice or ideal state of performance for a given function or dimension of performance. Even for identifying ideal state, PDSAT sets the bar for detailed description. Referring to Figure 11, let us understand the intent of ideal state definition. The product development competency under question is "Technology Forecasting", level 1 rating should be provided to the function if product development does not consider formal technology forecasting.

Level 4 or very good performance would be "Technology and manufacturing roadmaps with a competitive lead are defined. Work is done with customers to understand technologies. New product pipeline planning considers this when scheduling development activity."

Level 5 or the ideals state/best-practice of performance is defined as "PD uses preemptive roadmaps in technology and manufacturing. Technology is validated in lead user application environments. New product pipeline planning highly considers this when scheduling development activity."

It is very clear from the above definitions, what "technology forecasting" entails and it is easy to look for artifacts that would help confirm the level of performance of an organization for this dimension. Identifying these best-practices is very crucial in evaluating the product development performance of the business. In case a business using custom defined assessment, they would have to identify the best practices in particular the ideal state of performance in the industry for the assessment questions.

3.2.2 Enumerate Options/Interventions

Knowing the current state of performance and the ideal state of performance for a given set of dimensions, the next step is to identify interventions that would help reach the ideal state. As we are using PDSAT as the assessment tool, we need to look at each relevant question defined in the questionnaire and propose interventions that can help in improving performance in that question area. To better understand this step; let us refer to the section "1.4 product delivery competence", PD competence in the PDSAT questionnaire (Appendix A).

This PD competence has five questions. For argument sake let the current performance of the organization is at level 1 or level 2 for each of these questions. Identification of interventions for improving performance requires collaborative discussions with the key stakeholders of the process or action area and also to take note of the resources available with the organization. Resources here could mean skills and capabilities of team

members, financial resources, time available etc. Some of the possible interventions for the organization to reach the ideal state or level 5 in each of these questions in section 1.4 are tabulated Table 8. These are notional interventions that I defined from my experience, to illustrate the application of DEAL framework.

Question	Interventions
Release to Manufacturing ramp up	1. Product design process to integrate and incorporate manufacturing inputs right from the beginning of the project (including requirement gathering and concept design). 2. Clearly define project closure and release to manufacturing requirements in the design process. 3. Appoint full time representative from manufacturing team to the core product design team.
Transition to Sales	1. Sales team inputs are actively solicited during the product development process. Especially for requirements gathering and getting feedback from customers for early concepts. 2. Sales team representatives are part of the design review sessions.
Organizational readiness for sales	1. Sales readiness is an important part of the product development and has clear definition of artifacts needed to prepare sales force.
Service and support complexity	1. Service and support requirements are clearly identified and defined in the product development process. 2. Arrangement are made to do beta testing of service and support during beta testing
Product service processes	1. Product service requirements are clearly identified and defined in the product development process. 2. Representation from service functions in the product design development and review teams.

Table 8: Interventions for PD competency "Product delivery competence"

From the above list we, can see that a comprehensive list of interventions fairly quickly and if the number of questions to be assessed is large then this list can be daunting. In the event of such a scenario, one can do the following to reduce complexity:

1) Option one, is to prioritize the questions to reduce the list of interventions generated.
2) Options two is to categorize interventions into smaller groups and sub groups using tools like Design Structure Matrix (DSM).

Options two mentioned above is the recommended approach as it retains the holistic performance improvement intent and produces solutions that have a long term impact.

3.2.3 Analyze Options

By now, we have completed three crucial stages in the performance improvement process. Starting with the current state assessment, we then "formulated the mess by using PDSAT" and then defined the ideal state of operation for the organization. We have also identified interventions that would help us reach the desired ideal state of operation. Now is the time to perform trade-off analysis to prioritize interventions and chose the most important ones that would have the highest impact on the business, there could be situations where a business would be able to implement all interventions without any prioritization. DEAL framework uses the quality function deployment (QFD) tool for prioritizing the interventions. We first begin by understanding QFD tool and then move to the next stage for analyzing interventions.

3.2.3.1 Quality Function Deployment (QFD)

Gover describes QFD as a "way of concisely structuring communication and linking together information" [44]. Quality function deployment also known as the "house of quality" is defined as a product innovation process rather than just being a tool [44]. Over the years QFD has been updated, adapted and modified to perform tradeoff

analysis at all stages of the product development cycle. The most important and widely used function of QFD tool is to map customer requirements with technical capabilities of the organization. This section explains the most basic and fundamental application of QFD, which will be used in the DEAL framework for goal setting.

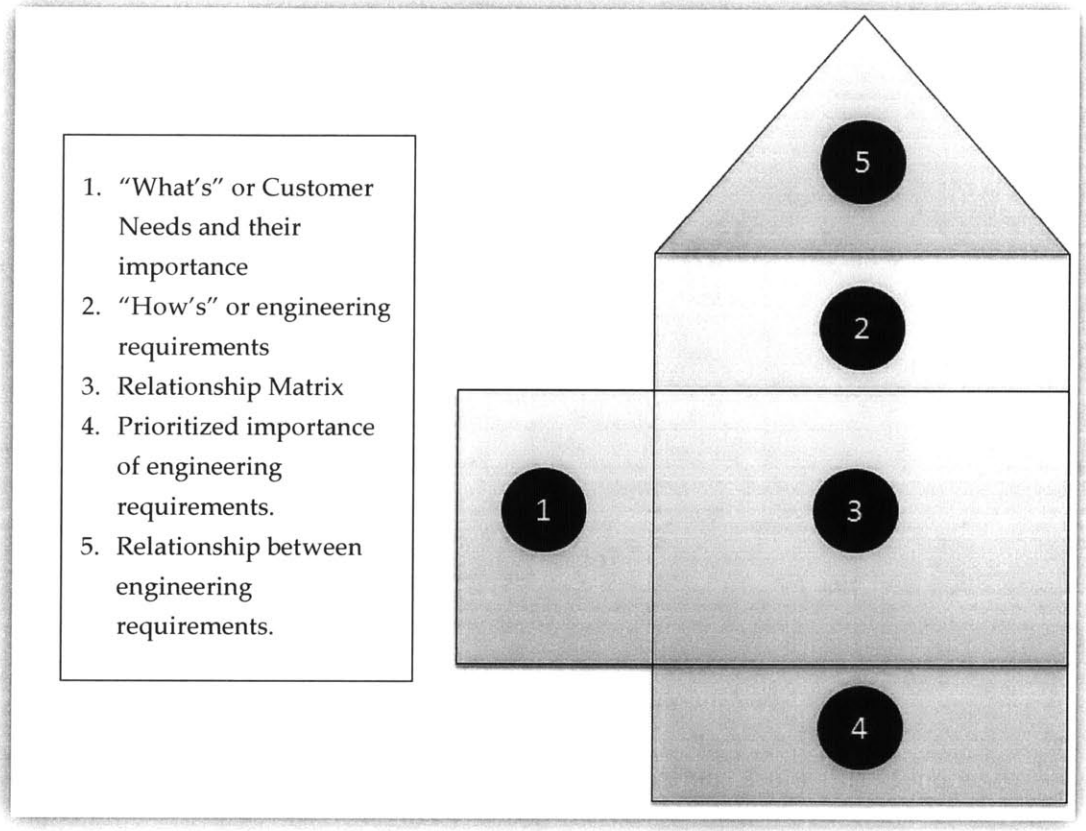

Figure 13: QFD House of Quality

Figure 13 describes the high level organization of house of quality. In its simplest depiction, the house of quality has five major sections. We shall now describe a simple situation of translating customer needs to design requirements or features using QFD to understand each of these sections.

Section 1: This is the starting point of QFD, where one captures the customer needs also the known as "What's". Each customer need is listed in a separate row. One also has to provide importance of each of the requirements on a scale of 1 to 5, where 5 indicates high importance and 1 indicates low importance. Figure 14 shows the customer needs being represented as $C_1, C_2, ...C_n$, each of the customer needs is also assigned a weight and is represented as $w_1, w_2, \ldots w_n$.

			Engr. Rqmt				
Normal Wt.	Weight	Need	ER1	ER2	ER3	...	ERm
A1	w_1	C1	a_{11}	a_{12}	a_{13}		a_{1m}
A2	w_2	C2	a_{21}				a_{2m}
A3	w_3	C3	a_{31}				a_{3m}
..	..	..	..				..
An	w_n	Cn	a_{n1}	a_{n2}	a_{n3}	..	a_{nm}
		Total	S1	S2	S3		Sm

Figure 14: QFD Relationship Matrix

Section 2: This block, defines the engineering requirements that are needed to achieve the customer requirements (a.k.a How's). The engineering requirements can span design, manufacturing, sourcing and all other aspects of product development based on customer needs. These are represented as ER1, ER2…ERm in Figure 14.

Section 3: This section defines the relationship between customer needs and engineering requirements. Each cell in this section connects an engineering need to a customer requirement and one has to provide a rating of 1, 3 or 9 to indicate a weak, moderate or strong relationship respectively. If the cell is left blank, it indicates there is no

relationship between the engineering need and the customer requirement. If we find blank row in this relationship matrix, it indicates that a customer need is not fulfilled by any of the engineering requirements. Likewise, an empty column indicates a redundant engineering requirement that does not meet any of the customer needs.

Section 4: After populating data in section 3, the importance of each of the engineering requirements is calculated by summing the product of weight of each customer need with the value in the relationship matrix for the given engineering requirement. The higher the value, higher is the importance of the engineering requirement. The calculations and prioritization mechanism used in QFD are mentioned below.

Referring to Figure 14, so far, variables have been assigned for customer needs, engineering requirements and the values in the relationship matrix. First step in prioritization process is the calculation of normalized weights for each of the customer needs. The variable for normalized weight is Ai, where i = 1 to n.

$$Ai = \frac{Wi}{\sum_{i=1}^{n} Wi}$$

Total value for an engineering requirement Sj, where j = 1 to m is:

$$Sj = \sum_{i=1}^{n} (aij * Ai)$$

One can prioritize the engineering requirements based on the value of Sj.

Section 5: This section provides a visual representation of interaction between different engineering requirements.

3.2.3.2 Adapting QFD for DEAL framework

QFD tool provides a very effective method to prioritize the interventions identified in the "Enumerate" phase of DEAL framework. We can consider the interventions equivalent to the engineering requirement described in section 3.2.3.1. The next step is to identify the customer need based on which these interventions can be evaluated. Every product development performance improvement effort has specific challenges due to type of industry, size of the company, work culture, stage of the company evolution and many more factors. Thus it is very important to understand and use these factors to prioritize interventions.

Our discussions with the practitioners in the industry highlighted the following factors that are critical in making decisions for performance improvement:

1) Time to see the impact of performance improvement.
2) The magnitude of impact short term and long term.
3) Ease of implementing the intervention
4) Cost of implementing the intervention

The above mentioned factors can be considered akin to the "customer needs" as defined in section 3.2.3.1. Having identified both the "what's" and "how's" of a QFD and one can start performing the analysis to identify the more important interventions. It is proposed to retain the weightage and relationship matrix valuing approaches as described in section 3.2.3.1.

This adaptation can be better illustrated with a notional example that we started off with in section 3.2.2, where Table 8, listed the possible interventions for product development competency problem that a business might be facing. These interventions need to be entered in the "How's" row of a traditional QFD. Earlier we described four

parameters based on which the interventions can be evaluated, these are listed in the "what's" column of a traditional QFD, this representation is shown in Figure 15.

			Column #	1	2	3	4	5	6	7	8	9	10
Row #	Relative Weight	Weight / Importance (Range 1.0 - 5.0, 5.0 being most important)	Interventions / Evaluation Criteria	Product design process to integrate and incorporate manufacturing inputs right from the beginning of the project (including requirement gathering and concept	Clearly define project closure and release to manufacturing requirements in the design process.	Appoint full time representative from manufacturing team to the core product design team	Sales team inputs are actively solicited during the product development process. Especially for requirements gathering and getting feedback from customers for early	Sales team representatives are part of the design review sessions.	Sales readiness is an important part of the product development and has clear definition of artifacts needed to prepare sales force.	Service and support requirements are clearly identified and defined in the product development process.	Arrangement are made to do beta testing of service and support during beta testing	Product service requirements are clearly identified and defined in the product development process.	Representation from service functions in the product design development and review teams.
1	31.3	5.0	Time to see the impact of performance improvement.	9									
2	25.0	4.0	The magnitude of impact short term and long term.	9									
3	25.0	4.0	Ease of implementing the intervention	3									
4	18.8	3.0	Cost of implementing the intervention	3									

Figure 15: QFD adapted for DEAL framework

The next step in this analysis is to identify weights for the evaluation criteria. As this is notional example, we shall assign highest priority to "time for implementation" and assign a value of 5, likewise weights can be assigned to other evaluation criteria as well.

After assigning priority to evaluation criteria it is now time to define the relationship matrix between interventions and the evaluation criteria. For instance the first intervention listed is "Product design process to integrate and incorporate manufacturing inputs right from the beginning of the project (including requirement gathering and concept design).", this intervention contributes to the release to manufacturing competency, which is one of the product development competency. We now assess this intervention against the four listed evaluation criteria shown in Figure 15.

Evaluation criteria 1: This intervention will have a significant impact on performance and the results would be noticed almost as this intervention is implemented. Therefore we would rate this as "nine" for the first evaluation criteria.

Evaluation criteria 2: The second criteria is "high impact in short term" and this intervention again fares high on this parameter as taking manufacturing inputs early on the design stage would have immediate results in the current projects that are being executed , thus this interventions is rated as "nine" against this criteria.

Evaluation criteria 3: Ease of implementation is highly dependent on the structure, organization and capabilities of the organization. If the design & manufacturing teams are highly organized and structured then this is fairly easy implementation. If teams aren't as organized then it might not be very easy to implement. For the current argument let's assume implementation is difficult, therefore the intervention gets a score of "three" against this criteria.

Evaluation Criteria 4: The cost of implementation will again depend on the situation that the organization is currently in for the similar reasons explained for evaluation criteria 3. Here again we can assign a weak correlation or a score of "three", which implies that implementing this intervention would not come cheap.

Figure 15 shows a demo QFD template with the values filled-in for evaluation criteria and for first intervention in the relationship matric section. One will have to complete filling in the details in the relationship matrix for all interventions, which would then provide the prioritized rating for each of the intervention.

3.2.4 List the shortlisted Interventions

We have now reached the last stage of the DEAL framework, where we list the prioritized set interventions and then select the interventions that the organization plans to implement. Any prioritizing technique just provides guidance on the most useful interventions, onus, then lies on the decision makers to appropriately select the right interventions for implementation.

Once the interventions have been identified, it is now time to go back to the questionnaire. Now that the interventions to be implemented are finalized, the questions need to be reassessed and a realistic estimate should be made about the level of performance that the intervention can achieve. This would form the new target that the organization should aim to achieve in a given stipulated time. The new set of radar plots can be plotted to depict new set of goals for performance improvement.

Figure 16 depicts the graphical representation of current state and future goals with notional data. This representation firmly strengthens continuous improvement philosophy as one can clearly see the steps one has taken to improve performance and eventually reached the ideal state of performance.

Identification of goals now clears the steps for implementation of interventions and to take R&D performance to higher levels.

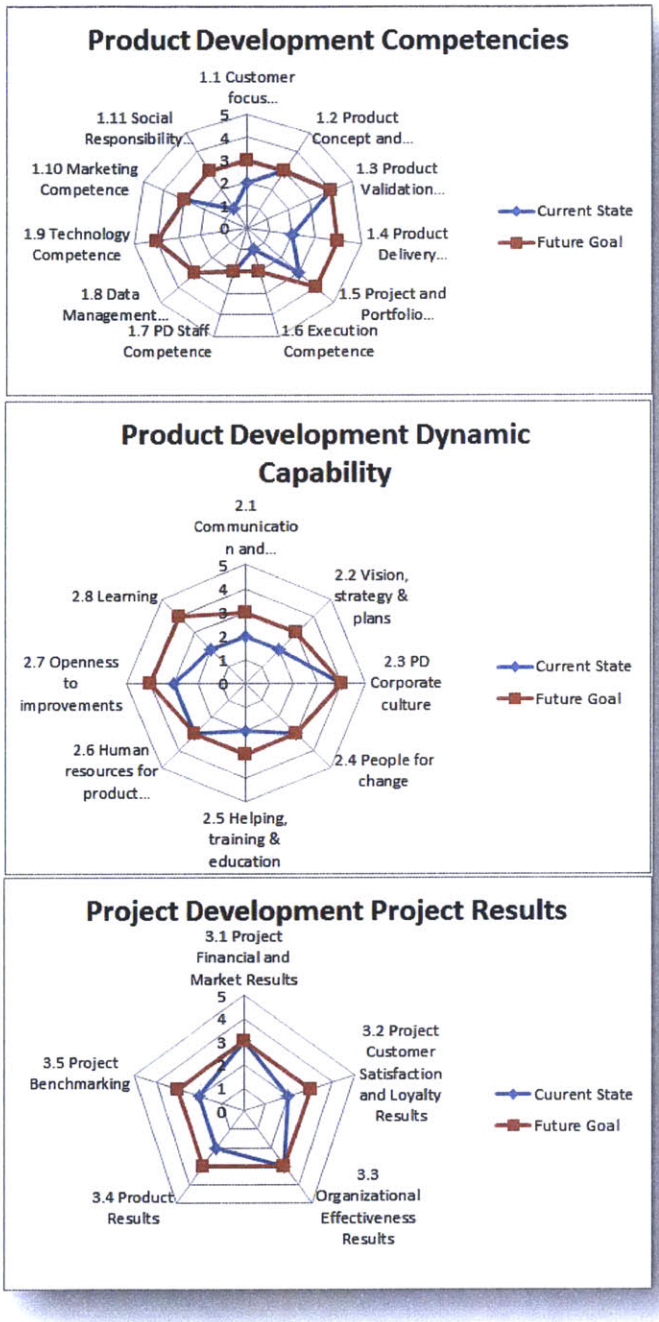

Figure 16: Future Goals

3.2.5 Practitioners feedback

As consultants from the industry were interviewed to understand their current challenges we also solicited their feedback on this goal setting framework. To further validate this approach the framework was applied to one of the successful projects that a consultant had executed in their recent past. This section describes the application of DEAL framework to a real life performance improvement engagement retrospectively.

The organization under consideration is a large business unit with its activities falling under electronics and manufacturing, let us call this organization XYZ Inc. The unit has global operations and provides sales and service support in almost every continent. Interview with the expert consultant indicated that the business had issues in product development cycle time and had other issues like the design review process which added to the cycle time problem. PDSAT questionnaire was used as the baseline assessment tool; the inputs provided by the consultant helped us in shortlisting a smaller subsection of the questionnaire to address the key challenges faced by the company.

Selection of questions is a very intensive process and a very critical step, which involves discussion with multiples stakeholders to arrive at relevant questions for the problems at hand. One can also go ahead with the complete list of questionnaire for a holistic assessment if the situation demands. Seventeen questions were shortlisted after interview with the consultant; these are shown in Table 9: Shortlisted questions for assessment. Details on the best practices can be reviewed in Appendix A.

No.	Question's Category	Question
1	1.2 Product Concept and Design Competence	Product's functional content
2	1.2 Product Concept and Design Competence	Definition of product attributes and their values
3	1.2 Product Concept and Design Competence	Concept development
4	1.2 Product Concept and Design Competence	Make-buy decision
5	1.3 Validation Competence	Rapid prototyping, simulation, testing
6	1.4 Product delivery competence	Service and support complexity
7	1.4 Product delivery competence	Product service processes
8	1.5 Project & portfolio management	Time to market
9	1.5 Project & portfolio management	Risk management analysis
10	1.5 Project & portfolio management	Schedule planning and control
11	1.6 Execution Competence	Development process
12	1.6 Execution Competence	Concurrent development
13	1.6 Internal Task coordination	Internal task coordination
14	2.7 Openness to Improvements	Motivating breakthrough ideas
15	3.5 Project Benchmarking	Benchmarks
16	3.3 Operational effectiveness results	Development time and slip rate
17	3.3 Operational effectiveness results	Development budget and schedule

Table 9: Shortlisted questions for assessment

After short listing the questions, we performed the current state assessment of the business unit under consideration. The results obtained are shown in Figure 17. We can clearly see that the organization faired low on execution competency, in the PD competency graph. A general assessment can be made that the organization needs significant improvement on all the five dimensions of the product development competency as it does not rank either 4 or 5 on any of the dimension, however it may chose to focus on specific attributes of the assessment which impacts the business most.. At the same time in PD dynamic capabilities and project results graph we can see that it performs very well on product benchmarking but lags behind in the other two dimensions of "openness to improvements" and "operational effectiveness results". This is a worrisome result as lot of work needs to be done to build a work culture that encourages "openness to improvements" which is the basis for any performance improvement.

The current assessment using PDSAT paves the way for using DEAL framework for setting future goals of the organization. An important point to note here is that, the analysis from this stage onwards was done independently without involving the consultant. The results were eventually presented to validate if it comes anywhere close to the recommendation that were actually made after the consulting engagement.

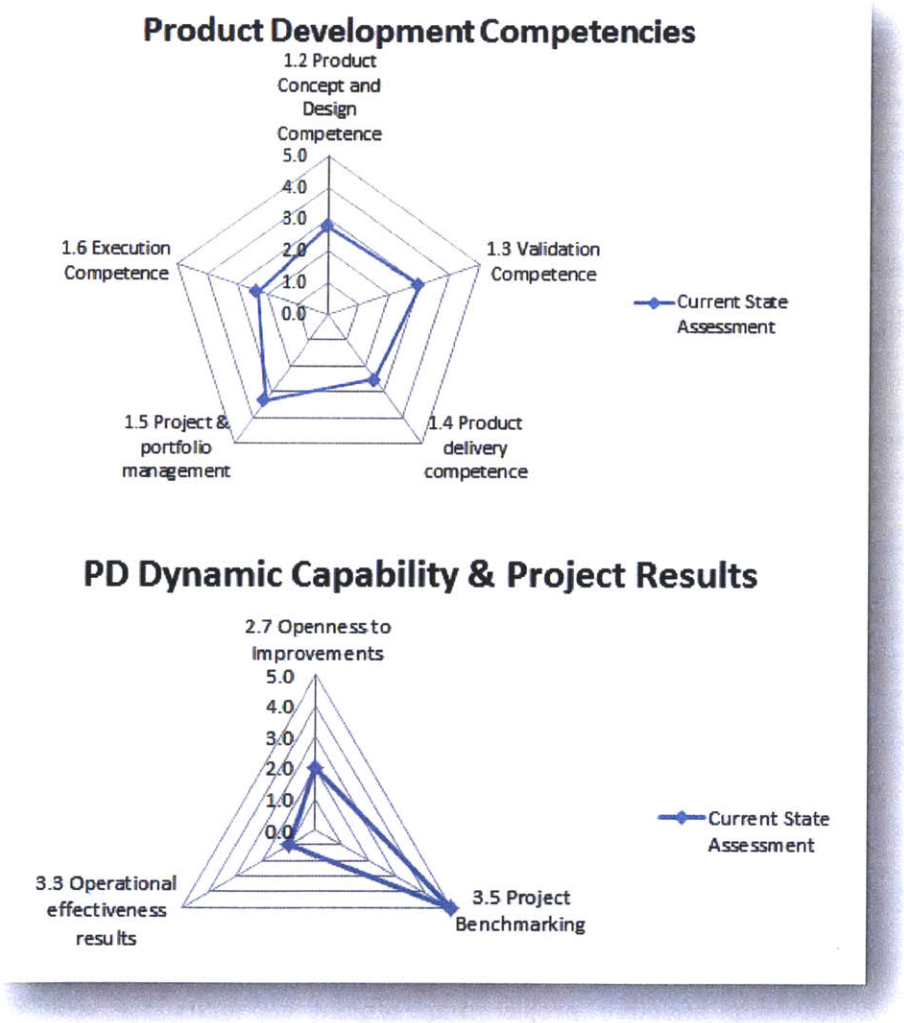

Figure 17: Current state assessment of company XYZ

Define

As explained in section 3.2.1, we leverage the PDSAT framework to identify the best practices for each of the seventeen questions identified. Here we assume that the level 5 defined in each of the PDSAT questions is the ideal state that an organization wants to be in, this assumption may not hold true in all circumstances, for the current situation in case, we shall assume this to be true.

Enumerate

The process of defining interventions was mainly to understand each question and think of interventions that can help the organization reach the ideal state of operation. It is possible that some interventions might have an impact on multiple questions and also that multiple interventions might be needed to reach the ideal state for one question.

The interventions I came up with are:

1. Develop effective product management team to define market requirements and customer needs effectively for new products
2. Define better alignment between product management team and the product development process
3. Define the product development process and enforce its strict use
4. Train the employees in product development process
5. Define roles and responsibilities for cross functional engagement
6. Develop effective project management capability for new products - Train internal people
7. Develop effective project management capability for new products - Hire external project managers
8. Encourage risk taking - provide for acceptance of failure for new and untried concepts in product development
9. Implement latest IT tools for project planning and scheduling

Analyze

The first activity in analyze phase is to identify the criteria on which the interventions would be assessed. The discussions with the consultant revealed that the business was keen to implement interventions that would highly impact the immediate pain point of cycle time. However, knowing that assessment can also unveil other issues in the organization, he was open to other interventions provided they did not impact the short term performance of the organization. The organization was also very conscious of the cost implications of any intervention. These inputs helped us in identifying the following criteria for evaluating the interventions:

- Alignment with the problem
- Alignment with Time requirement
- High Impact – Short term
- High Impact – Long Term
- Current Performance - improves or status Quo
- Low Cost of implementation
- Low Risk of Intervention
- Capable to perform task within org

With the identification of interventions, the next logical step is to analyze the interventions using QFD.

Row #	Relative Weight	Weight / Importance (Range 1.0 - 5.0, 5.0 being most important)	Column # / Interventions / Evaluation Criteria	1	2	3	4	5	6	7	8	9
				Develop effective product management team to define market requirements and customer needs effectively for new products	Define the product development process and enforce its strict use	Train the employees in product development process	Define roles and responsibilities for cross functional engagement	Develop effective project management capability for new products - Train internal people	Develop effective project management capability for new products - Hire external project managers	Encourage risk taking - provide for acceptance of failure for new and untried concepts in product development	Implement latest IT tools for project planning and scheduling	Define better alignment between product management team and the product development process
1	16.1	5.0	Alignment with the problem	3	3	3	9	9	1	1	3	9
2	12.9	4.0	Alignment with Time requirement	1	1	1	3	3	3	9	9	1
3	16.1	5.0	High Impact – Short term	3	9	1	3	1	1	1	1	1
4	9.7	3.0	High Impact – Long Term	9	3	9	3	3	3	3	9	3
5	9.7	3.0	Current Performance - improves or status Quo	1	1	3	3	9	1	3	3	3
6	16.1	5.0	Low Cost of implementation	3	9	1	3	9	3	9	1	3
7	9.7	3.0	Low Risk of Intervention	1	3	9	1	9	1	1	1	9
8	9.7	3.0	Capable to perform task within org	3	1	9	1	3	9	3	1	9
			Weight / Importance	254.8	519.4	487.1	609.7	603.2	254.8	396.8	338.7	461.3
			Normalized Relative Weight (Impact)	6.5	13.2	12.4	15.5	15.4	6.5	10.1	8.6	11.8

Figure 18: QFD, Analyzing interventions for XYZ Inc.

Figure 18 shows the tradeoff analysis done using QFD to arrive at prioritized interventions. We can see that while rating the evaluation criteria, Alignment of intervention with the problem, impact in the short term and low cost of implementation have been rated as the highest priority as per business needs. Please note that in the above analysis we are not using one of the important features of QFD, which is the interrelations matrix that defines interactions between interventions. This is currently a weakness of this framework and more work needs to be done to include this feature in this goal setting framework.

List

The list of interventions prioritized on the basis of normalized relative weight is shown in Table 10: Prioritized list of interventions. Observing the top five interventions, it clearly seen that the most important interventions suggested are to have better clarity in roles and responsibility and also in better definition of the process. It also provides importance to appropriate training to employees about the processes. These suggestions

are in line with the challenge of improving the score of "Openness to improvements", which is one of the key requirements for taking the first step towards any performance improvement effort. The list also accords high priority to developing project management capability, which would have a high impact on the product development cycle time.

No.	Intervention	Relative Weight
1	Define roles and responsibilities for cross functional engagement	16
2	Develop effective project management capability for new products - Train internal people	15
3	Define the product development process and enforce its strict use	13
4	Train the employees in product development process	12
5	Define better alignment between product management team and the product development process	12
6	Encourage risk taking - provide for acceptance of failure for new and untried concepts in product development	10
7	Implement latest IT tools for project planning and scheduling	9
8	Develop effective product management team to define market requirements and customer needs effectively for new products	6
9	Develop effective project management capability for new products - Hire external project managers	6

Table 10: Prioritized list of interventions

Assuming that we intend to implement top five interventions, the future goals for the specific questions shortlisted in assessment phase were defined and are shown in Figure 19. This process of defining future state involves judgment and a good understanding of the organizations' strengths and weaknesses and involves three specific steps:

1) Form a core committee of key stakeholders and understand the implications and impact of implementing the shortlisted intervention.
2) Review the assessment questions, and evaluate how the currently identified interventions will impact them. Debate and discuss the possible future state organization can achieve if these were implemented.
3) Arrive at a consensus and assign the future state value for each relevant question.

For instance, the top five interventions listed in Table 10, do not have significant impact on building the technical competence of the staff either in concept design, validation or technology enhancement. All the top interventions are focused on improving the process; this will definitely have an impact on the deliverables for design but would not be significant. The decision of assigning future goals will have to be arrived at by looking at past experience of implementing performance improvement, its success rate and also the impact intervention will have on the actual activity as described in PDSAT. Thus, even though interventions were identified to reach the ideal state of performance, while rating the future state we would only make incremental improvement.

The interventions short listed have a significant impact on execution competence and product delivery competence, hence it is expected that the future state of these focus areas should improve significantly. The value is still not at level 5 as the ideal state includes tight control and prediction of process improvements, which will be achieved only if process stabilizes and can be part of second phase of performance improvement. Overall, we can see that interventions have an even impact on almost all categories of performance selected for assessment.

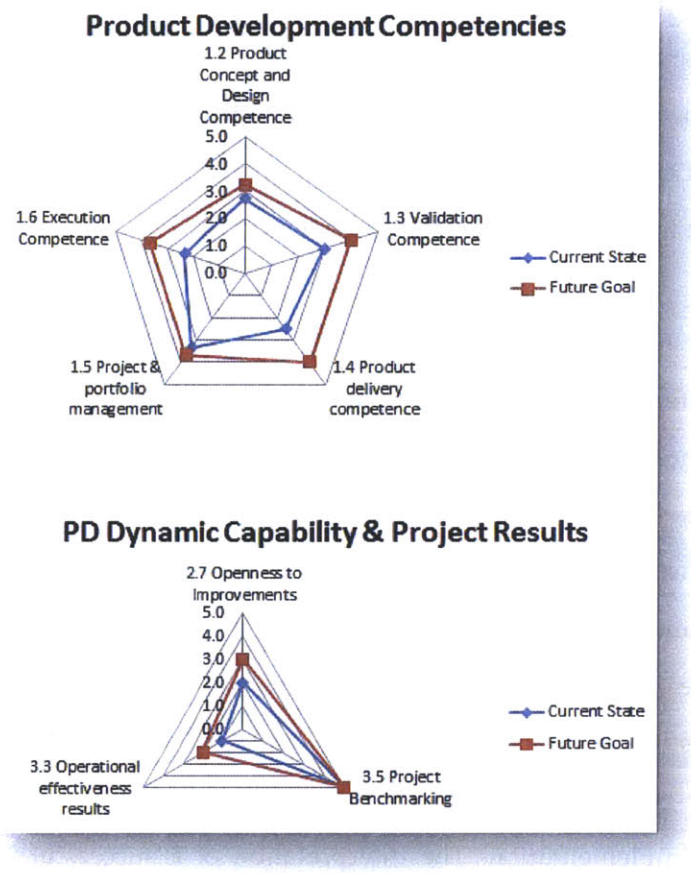

Figure 19: Future goals XYZ Inc.

Discussion

With identification of future goals, the results were presented to the experts for their review. It was surprising to note that the top five recommendations arrived at by following the DEAL process closely mapped with the recommendations they had proposed for the defined problem statement. It is important to note that the engagement was a much larger one and this framework was applied to only one section of the problem, which was related to the product development cycle. This experiment gives confidence on the usefulness of this approach.

4 Conclusion & Future Work

This research began with intent to understand and analyze the R&D performance improvement approaches currently known and to identify gaps, for which solutions can be identified or developed. Deming's cycle of Plan-Do-Check-Act was the logical starting point to analyze different frameworks.

Literature review revealed that the planning stage in the P-D-C-A cycle has many implicit steps that are not well defined and much of the literature is focused on performance measurement and assessments. The focus on R&D outcome measures though useful does not provide clear guidance on improvement initiatives. Holistic performance assessment frameworks like CMMI & PDSAT act like a bridge between outcome measures and performance improvement frameworks like lean, six sigma, TQM. One of the most common issues observed in performance assessment frameworks is lack of sufficient details about best practices. CMMI framework for instance provides very clear guidance on the each of the five levels of maturity, but then leaves it to the team for implementation. The interpretation of a successful implementation can also vary considerably from individual to individual. This customization approach to implementation poses a high learning curve in using this framework. PDSAT questionnaire provides a novel approach by not only identifying different actions areas of measuring performance, but also providing clear guidance on the best practices currently available in the industry for each of those action areas. It is highly desirable that such repository of best practices are collected and expanded for different types of performance improvement approaches. One of the key limitations in R&D performance assessment literature is establishing clear link between outcome measures and holistic performance measures like CMMI and PDSAT. There are case studies that point to this correlation, but more research is needed.

Literature clearly states that setting future goals is a proven and critical step for any performance improvement. . Goal setting theory defines setting goals as a two-step process, where the first step is to define goals and the second step is goal acceptance and goal commitment by the team or individual who is supposed to execute that goal. Literature review concludes that setting future goals for R&D performance improvement, is an area, which needs more attention and formal approaches and frameworks must be developed to facilitate this activity. Another drawback found in the literature is the lack of prescriptive approach in defining future goals. This research adds to the current literature by providing a prescriptive approach to define future state during R&D performance improvement effort.

Limitations and Future work

DEAL framework is developed and proposed as a feasible approach to identify future goals for R&D performance improvement. The framework developed is in a concept stage with limited validation. The next steps of evolution should include benchmarking of this framework against current practices of defining future goals over multiple cases and samples to assess the overall effectiveness of this approach. One of its current limitations is the dependency of DEAL framework on the chosen performance assessment approach; an assessment questionnaire which is not well defined may not provide satisfying results. The other limitations of this approach, are 1) Inability of the approach to incorporate interactions between the interventions in the final prioritized results 2) Lack of clear guidelines to group interventions if the number of interventions are way too many for simple analysis. These two limitations will have to be evaluated while executing practical projects. Another limitation of the current framework is its extensive reliance on expert opinion to identify future goals.

Future study could be done to better understand different types of interventions that organizations implement and then document and record the key challenges faced by

them. The same intervention can pose different level of complexity to different organizations and it would be valuable to understand the attributes contributing to this variation. More research is also needed to eliminate the current limitations of the framework mentioned above, particularly that of performing prioritization if the number of interventions are too many. Some of these limitations can be overcome by building intelligent database to capture the knowledge of multiple engagements in such a way that over time, one could start leveraging this repository to effectively set future goals based on past performance.

The most important conclusion is the acceptance of the fact that performance improvement is a journey one has to continuously strive for attaining higher levels of performance. This realization needs a cultural shift and a mindset that seeks constant challenges to improve self and this change can only be brought about by exhibiting true leadership skills, thus every exercise of performance improvement is also an exercise of developing leaders.

Appendix A

This section presents the detailed list of ninety one questions developed by Christoph Knoblinger in his Diploma thesis titled "A New Product Development Self-Assessment Tool"[22]. The questionnaire is divided into three main sections 1) Product Development Competencies 2) Product development dynamic capabilities and 3) Product Development Project Results. The questionnaire is extensively used to illustrate application of DEAL framework in this thesis.

	Product Development Competencies					
1.1	Customer Focus Competence					
1.1.1	Customer relationships	Customers have no contact with the design or development teams.	Customers have little contact with the design or development teams.	Customers are visited occasionally, particularly in the up-front activities.	Customers are consulted regularly throughout the development cycle about the product and lifecycle requirements (service, updates, availability, etc.), but do not have a voice in the design decision-making.	Users and customers are co-developers throughout the PD cycle and critics during field operations. They review development specs, field manuals, and key functional strategies. They are readily consulted on unexpected problems.
1.1.2	Customer satisfaction data	Customer satisfaction data is not collected.	Customer satisfaction data is anecdotal or generic making it difficult to react and improve customer satisfaction. A large effort is needed to improve the accuracy and completeness of the data in order to make it useful.	Customer feedback, warranty and repair data is made available by the sales and service staff. System promotes extended enterprise communications with customers.	Customer feedback, warranty and repair data is made available in reports, documented and structured. System promotes customer extended enterprise teamwork to make the project succeed.	Web site exists for customer feedback. Warranty and repair data is also online and easily available for use by product development teams and functional groups. Customers and partners readily provide proprietary data for their mutual benefit.
1.2	Product Concept and Design Competence					

1.2.1	Product architecture	A standardized process for defining the product architecture is not performed at any time.	Consideration is limited to the single product.	There is a product architecture that considers future upgrades and derivative products.	Architectural integrity is enforced in product design and system validation. Architecture reinforces brand identity.	Architecture is a strategy issue determined by senior executives. Architecture addresses all key functions of the firm.
1.2.2	Linkage to corporate objectives	Project's/Program's/Product's benefits are not mapped onto quantifiable business goals and objectives.	Most of the project's/program's/product's benefits are vaguely mapped onto quantifiable business objectives and goals. Many inconsistencies remain with no plans for their resolution and are left to personal interpretation.	Many of the project's/program's/products benefits can be mapped onto quantifiable business goals and objectives. Remaining inconsistencies are known but avoided and deferred for later resolution (no comeback dates are defined).	Project's/Program's/Product's benefits are explicitly mapped onto key quantifiable business goals and objectives. Mission and goal inconsistencies are known and delegated with due dates for resolution.	All project/program/product benefits are explicitly and comprehensively mapped onto key quantifiable business goals, objectives, and business initiatives. Few and only trivial mission and goal inconsistencies remain open.
1.2.3	Product's functional content	The definition process of the product's functional content is based on extensions of existing products and customer complaints.	Process of defining the product's functional content is largely driven by extensions of existing products and customer complaints.	Process of defining the product's functional content is largely derived from extensions of current products and product family consistency. Known customer base and competitors shape the product's functional content.	Process of defining the product's functional content is driven by market segment needs, strategic positioning, architecture, and input from benchmarks. Use of repeatable methods is made to prioritize and determine value to customers and of the firm.	Markets new to the firm and to the industry shape product's functional content. Architectural advantages are leveraged. Functional content sets new level of competitive advantage.
1.2.4	Definition of product attributes and their values	The product definition and planning process does not follow any standardized approach.	Product definition process is dominated by current products, engineering doability, and costs.	Product definition process considers current products' strengths and weaknesses relative to its competitors' products.	Product definition process is based on consumer preference methods, such as conjoint studies, to select product attributes and their values.	Product definition process considers consumer preferences and EVA in their use environment. Specifications are validated with lead users and suppliers. Cost-benefit analysis is performed by using quantified value propositions and models.

1.2.5	Concept development	There are no standardized supporting processes for concept development in place at all.	Only very simple methods (e.g. brainstorming sessions are in use for supporting the concept development process. Participation in concept development is limited to a very small group.	Participation in concept development is limited to a small group. Concepts are extensions of existing products. Bold ideas are not adequately considered. Concepts are shown to customers after the fact.	Concept development is unconstrained and uses generation tools and methods with broad participation from key functions (i.e. manufacturing, quality assurance, purchasing . Options are explored with lead users and partners. Industrial design is a key consideration.	Brilliant people with proven track records are given unconstrained freedom to create concepts. Concept space is large and "down-selection-systematic". Concept development relies on broad internal and external participation.
1.2.6	Set-based concurrent engineering	There is "no time" for considering alternative solutions for a product module. Concepts for a product module are frequently revised during all stages of development.	Only few alternative solutions for a product module are considered in the concept development stage. Early found solution ideas are quickly assessed. The most promising solution idea is selected at an early stage in the concept development. A quick selection process is preferred over a detailed objectively grounded assessment. Concepts for a product module are usually revised after they have been selected.	A variety of possible solutions for a product module are considered in the concept development process. Decisions for a particular solution are based upon all the data available at the time of the decision. Concepts for a product module are sometimes revised after they have been selected.	Different possible solutions for a product module are considered early in the process. Alternative solutions for a product module are designed simulaneously until a particular solution has to be selected. Most decisions are based on objective data. If data is not available decisions can be delayed once. Once concepts have been selected for product modules they are rarely revised afterwards.	A large number of possible solutions for a product module is considered early in the process. A large number of alternative solutions for a product module is designed simultaneously. Decisions in favor of a particular solution are delayed until objective data is available. Once concepts have been selected for product modules they are not revised any more.

1.2.7	Product variety management	Product variety management is not in place.	Product variety management (reuse of parts, product platforms, modules, use of commodities) is not explicitly addressed in the product development system. Some of these ideas are used implicitly, though.	Catalogued parts are used within a product, but there are no clear rules. Product parts among different modules, products and product families are reused, but there are no clear rules either. Some components are modular and have standardized interfaces. Some products are built on the same platforms.	There are clear goals for the use of off-the-shelf components within a product and for the reuse of product parts among different modules, products and product families. Most components are modular and have standardized interfaces. There are common product platforms encompassing several product lines.	There is a common understanding among all the staff responsible for product development for the use of off-the-shelf components within a product and for the reuse of product parts among different modules, products and product families. Almost all components are modular and have standardized interfaces. All the products produced by the company are based on the platform idea.
1.2.8	Re-use of physical and design assets	Re-use is not addressed at all.	Re-use is not actively addressed.	The goal of re-use is driven by cost only. Engineering managers are given targets for the re-use of electrical and mechanical design, software, packaging, purchased parts, test programs and test equipment.	The product architecture enables reuse that optimizes cost. From this a re-use target is established for electrical and mechanical design, software, packaging, purchased parts, test programs and test equipment.	Product families are established on architectures. Re-use also includes subsystems and their ability to interoperate. This analysis is used to target and maximize the reuse of systems, software, test programs, and hardware assets.
1.2.9	Make-buy decision	Make-buy decision are ad-hoc considerations without considering the strategic implication to the firm.	Mostly dominated by tactical and ad-hoc considerations, without considering strategic implications to the firm.	Process is led by product planning and principally determined by engineering and cost reasons.	There is a cross-functional team to ensure PD, manufacturing, and finance are considered. Customers and partners are informed. Scalable parameters are identified which provide a range of applications for the technology.	Considered a strategic decision. Deliberated with senior executives to consider architecture, IP, manufacturing, finance, strategic and competitive implications to the product. Full critical parameter model developed, including scalable and sensitive parameters.
1.3	Product Validation Competence					

1.3.1	Prototypes	Alpha and beta prototypes both work in a controlled environment after a couple of iterations.	Subsystems are developed and integrated into the product. Alpha prototypes work in a controlled environment. Beta prototypes are developed using parts from real tooling, and the prototypes work as expected in a controlled environment.	Subsystems are developed and debugged. Manufacturing suppliers are consulted and standard tolerances used. Alpha prototypes work as expected. Beta prototypes are developed using parts from real tooling and system integrated from short runs, and the prototypes work as expected. Key tolerances are assigned. Design consults with production, service, and sales on their development efforts.	For alpha prototypes architecturally consistent and robust subsystems for system integration are developed. Explicit key dimensions are used. Prototypes work in wide range of conditions. Beta protoypes use critical parameters management and robustness for key dimensions and tolerances. Test customers use short runs using real tooling. Prototypes work. Manuals, sales and service plans proceed concurrently.	Alpha prototypes are fully functional under a range of conditions. Lead users have alpha units. All learned product features and customer operation changes by doing. Critical parameters are validated using the alpha prototype. For beta, lead customers, given short run prototypes, work at the development site to test performance and usability. Design, service, production and sales all use the beta to validate their plans.
1.3.2	Rapid prototyping, simulation, testing	Designs are validated by using physical prototypes at a very mature design stage. Simulation and testing methods are practically not used.	Basically, designs are validated by using simulations and tests at a mature design stage. Detailed physical protoypes are built at the end of the product development process. Product design and product validation act sequentially.	Closer interaction between product design and product design validation begins usually towards the end of the product design process. Standardized and well-established tools like computer-aided modeling, simulation and physical models are used for design validation.	Designs are quickly modeled and usually validated at an already early stage in product development as well as at later stages. Simulation, testing, rapid prototyping and physical models are used for validation. There is a close interaction between product design and product design validation.	Designs are tested and simulated throughout the product development process. Physical models and prototypes are built very fast and are already used in early stages of product development. Designer can react with changes within one day. There is a very close interaction between prototype specialists, production engineers, designers and quality assurance experts throughout the product development process. Computer aided modeling, simulation, digital assembly and rapid prototyping are well established and perfectly aligned within the company. Methods of Lean Production are used in prototype build and tool manufacturing.
1.4	Product Delivery Competence					

1.4.1	Release to manufacturing ramp-up	Manufacturing is considered at a very late stage in the product development process. Product development and manufacturing act rather sequentially.	Manufacturing commits to the product and ramp-up plan, both of which contain many qualifications and contingencies for PD, other key functions, and suppliers.	Manufacturing commits to the product and ramp-up plan with negotiated engineering assistance during early production and relief/slack from other key functions and suppliers.	Manufacturing, development have proceeded in parallel development with suppliers for some time. There is a formalized process for evaluating design proposals regarding manufacturing and assembly compatibility. Manufacturing commits to the product without reservation and with support from other key functions. Critical parameters identified.	The release to manufacturing is a non-event; manufacturing has been developing (with suppliers) their systems for some time and is well prepared to ramp-up with credible plans. Critical parameters quantitatively related to requirements and scalable parameters are identified.
1.4.2	Transition to sales	Sales presence is completely absent during the PD cycle.	Sales organization develops sales plans when PD "releases" to sales. Readiness takes great effort. Sales presence is largely absent during PD cycle except when the product is tossed "over the wall."	Sales participates in all key review checkpoints during PD. Sales has reviewed and critiqued the product specs and prototypes during PD.	Product is validated with lead users and beta customers with sales groups as full-fledged team members. Sales is confident of the product and its ability to perform in customer environment.	Product readiness is a non-issue. Sales has been a co-developer from the concept development stage. Product issues from sales are resolved as they arise throughout development.
1.4.3	Organizational readiness for sales	Sales issues are not considered during the product development process.	Sales commits to units, revenue, and expenses after negotiating technical support from development, pricing flexibility from finance, delivery from manufacturing and other issues from key functions.	Sales commits to units, revenue and expenses with negotiated engineering assistance during early customer usage.	Sales and development have proceeded in parallel for some time. Sales commits without reservation - conflicts were resolved during development.	Sales readiness is a non-issue. Sales persons, systems, campaigns, and service and support are all coordinated. Sales has been an integral part of development along with other key functions.

1.4.4	Service and support complexity	Service and support issues are not considered during the product development cycle.	PD concentrates on function and performance, not service and support, which are viewed as "downstream" responsibilities of other functional groups.	There is a formal PD process that brings in the service and support groups to ensure design addresses serviceability and support. The functions have equal clout.	A cross functional team, that includes customers, has been working on this issue early in the process. Customers review S&S specs and comment.	Service and support has been part of the beta prototype testing with lead users to refine S&S strategy and plans. This issue has strong support from the project leader.
1.4.5	Product service processes	Product service processes are not considered during the product design process.	Product service processes are not a high priority for product design. The PD process concentrates on costs rather than customer satisfaction. Service is viewed as a "downstream" issue.	Engineering leads the process and brings in the service groups to ensure that the product design addresses serviceability and support issues.	There is a cross-functional team to ensure product design, manufacturing and finance address serviceability and support. Customers and partners are informed.	The PD process includes a cross-functional team that includes customers and partners to ensure product design, manufacturing, and finance address serviceability and support.
1.5	Project and Portfolio Management					
1.5.1	Schedule planning and control	There are no standardized tools (Gantt charts, PERT, CPM, etc.) in use for schedule planning and control of projects.	Delays ranging from small to 100% are common. Used tools do not really guarantee meeting the time schedule.	Monthly review meetings are held to monitor delays and take action. Key dependencies are informed of status of delays.	Weekly review meetings are held to monitor delays and take action. Meetings and actions are coordinated with key functional dependencies. Project planning and control process usually utilizes standardized tools.	There are daily updates to the project plan. Project slips are measured versus commitment at project funding time - not just versus most recent revised schedule. Standardized tools are used for the project planning and control process.
1.5.2	Time to market	Time to market is not measured nor controlled.	TTM is not controlled versus product specs. Product goes to market when development is complete.	TTM is controlled by inflating schedules with large buffers. When buffers are exhausted, forced overtime and additional people are placed on the project.	PD project/system has the flexibility to cut functions to meet delivery and/or schedule. Knowledge of market and competition enables the minimization of market impact.	TTM is addressed by concurrent development and co-development with customers and partners.

1.5.3	PD project financial goals	Financial goals of PD projects are set by finance only.	Meeting the project's financial goals is led by finance with participation of PD and other key functions. PD role is passive other than meeting budget and product cost.	Finance has the lead to ensure project meets financial goals. PD's financial metrics are budget and product cost. PD can comment, but has limited power on sales, distribution, and service expense strategies and tactics that influence financial goals.	PD is part of a formal multifunctional group that addresses financial issues. PD's responsibilities are budget and product cost. PD is also in a group that addresses sales, distribution, and service expense strategies and tactics.	Financial goals are determined through options-assessment and flexible planning during the development cycle.
1.5.4	Portfolio of product opportunities	The managment of the product portfolio is not actively addressed.	Current offerings and customers dominate the organization's view of opportunities. Portfolio planning is ad-hoc and informally led by a single function. Consistent methods and business processes are sparse.	A collection of product families exists. They are rationalized qualitatively, by organizational structure and product managers. There is financial planning and roll up, but no real portfolio optimization.	A collection of product families exists. Finance and product managers plan and manage revenue and profit. Optimization is accomplished through simple scenarios and a handful of alternative cases.	Portfolio decisions drive new product development. Portfolio planning is linked to market, business, and functional strategies. Its methods are quantitative and qualitative engaging senior executives and PD managers.
1.5.5	End-of-life strategy	There is no EOL strategy process. Surprises from competitors drive product withdrawals.	EOL strategy process is not formalized but reactive. Management reacts predominantly to the deceleration of sales.	EOL strategy process is partly formalized but largely reactive. Management reacts to technology maturation, deceleration of sales and profit, and increasing competitive pressure.	EOL is opportunistic. New products are ready at early signs of technology maturation, deceleration of sales and profit, and increasing competitive pressure.	Business strategy and corporate goals set EOL strategy. EOL strategy is planned by architecture, technology, and pricing. There is no problem cannibalizing any existing product.
1.5.6	Risk management analysis	Risk management analysis is not considered in the product development process.	Uncertainties and risks are barely considered. Uncertainty and risk mitigation is not part of the PD process and neither is robustness.	Few uncertainties and risks are characterized and most of them remain vague. Some plans exist to address the risks. Robustness is not part of the PD process.	Many uncertainties and risks are characterized. Based on this, plans are formed to ensure robustness.	Key uncertainties and risks are characterized. Sensitivity analysis is done to identify key sources of risk. Based on this, plans are formed to ensure robustness.
1.6	Execution Competence					

1.6.1	Project leader's responsibilities and power	Project leader has many "responsibilities" but very little "power" compared to functional managers.	Executive micromanagement is visible. Project leader must frequently request approval for simple decisions.	There is visible executive support for projects when requested. Some senior executives buy-in, but their visibility is not strong.	There is visible and frequent executive support for projects initiated by the executives. Senior executives buy-in and actively work to form high-majority consensus.	Project leader has final say on all project tradeoffs. Project leader defines the product concept and advocates the customer value. Project leader leads the product development project from concept to market. Project leader chooses the technology and makes major component choices. Project leader sets the project timeframe and controls the adherence to it. Senior executives do not and cannot easily subvert or slow down the project. Executives communicate forcefully their trust and confidence in the project leader.
1.6.2	Project leader's experience	Project leader needs help and rework very frequently.	Project leader's experience is limited to narrow product issues, and is weak in other areas. Needs help often.	Project leader is experienced in many of the technical issues, but requires some direction on business, financial and customer issues. Needs help occasionally.	Project leader manages technical, business, financial and customer issues. Does not need help.	Project leader has track record of delivering complex technical projects, business, financial, and customer issues. His advice is frequently sought after.
1.6.3	Concurrent development	Product development is organized sequentially with separate functions.	Product development is organized rather sequentially. Functional silos are connected by specs and formal meetings.	PD uses a functional orientation with informal and personal cross functional relationships to work out dependencies and concurrencies.	Formal cross functional groups organize tasks for maximum concurrency.	Strong cross functional teams are led by experienced project leader. Leader is supported by motivated and skilled functional participation.
1.6.4	Internal task coordination	Information handoffs between different functions occur in a completely unstructured way. As a result, a high number of negative surprises occur at al levels of the company.	More time is spent in meetings than with product development. There are many surprises at all levels of the organization.	Specs between silos are used for task coordination. Personal initiative and informal relationships help close many gaps but cannot prevent surprises.	Formal specs and formal cross functional meetings are used to discuss dependencies, timing, and content of task coordination.	Information handoffs include detailed walkthroughs of specs, functions and dependencies. Results are reflected in extended task mapping documents.

1.6.5	Workload leveling	The idea of workload leveling is not applied for product development.	The idea of workload level is known but the execution fails. Different projects are not aligned regarding resource allocation. Resources are rarely flexibly adapted in advance. Project leader is not fully aware of the capacity utilization for his project. Development activities are rarely scheduled and prioritized.	Product development resources (financial, technical, human) are planned and scheduled, but mostly independently for different projects. Most critical resources are flexibly adapted in case of occuring bottlenecks. Actual and planned capacity utilization are compared occasionally. Development activities are basically scheduled and prioritized.	Product development resources (financial, technical, human) are planned and scheduled on a cross-project basis. Most resources are flexibly adapted in case of occuring bottlenecks. Actual and planned capacity utilization is compared frequently. Most development activities are scheduled and prioritized.	Product development resources (financial, technical, human) are planned on a cross-project basis. Different projects are classified, staggered and launched in constant intervals. Cumulated demand in resources is very well levelled throughout the project's time frame. All resources are flexibly adapted in case of occuring bottlenecks. Project leader is constantly aware of the gap between actual and planned capacity utilization. All development activities are scheduled, synchronized and prioritized.
1.6.6	Development process	Basically, projects do not follow a standardized process.	Projects follows a standardized process.	A standard process with no changes is used. Go/no-go decisions are made at each phase gate. Decisions are passed that should not be passed.	Well defined go/no-go criteria exist at each phase gate. Measured planvariances, are assessed their overall effects, and specified contingency plans to reduce risk.	Standard process is redesigned for the current project by the project champion and core team who have proven competence and a successful track record.
1.6.7	Supplier integration	The relationship between PD and the suppliers is problematic, partly because they do not trust each other.	Ties between PD and suppliers are formal, colored by a zero-sum "we/they" attitude. Mutual trust is minimal.	Ties are formal with informal personal ties. There is sufficient mutual trust and confidence that development proceeds unimpeded.	Both formal and informal ties exist. Suppliers are integrated in the concept definition phase (e.g. review development specs and key functional strategies). They are consulted on problems. Mutual trust and respect is strong.	A small number of high-capability suppliers are used for critical parts, i.e. suppliers are co-developers throughout the PD cycle. They define some of the development specs and key functional strategies. They are assigned to solve tough problems. Supplier loyalty is firm. Suppliers are mentored to improve their performance.
1.7	PD Staff Competence					

1.7.1	PD staff competency	Staff is weak in most areas and needs help very frequently.	Staff understands limited to narrow product issues, but is weak in other areas. Often needs help and reworks tasks.	Staff is capable of solving problems in their domain. Needs help occasionally.	Core staff has experience from previous projects, is equipped with advanced degrees, and is able to provide and guide others. Staff does not need help.	Core staff has demonstrated capability in many breakthrough concepts. Has 10 years experience and is equipped with advanced degrees from top institutions. Staff's advice is frequently sought.
1.7.2	Multi-disciplinary staffing	Multi-disciplinary staffing of project teams in considered secondary.	Although the project leader tries to get members from non-engineering disciplines, teams consist mostly of engineers only.	For every team of a few dozen engineers, there is one marketing person, one industrial designer, and a few production engineers involved.	For every two dozen engineers, there are two marketing persons, two industrial designers, two systems engineers, and eight test engineers.	The team is fully loaded with non-engineers for disciplines needed as determined.
1.7.3	Specialist career path	There is no specialist career path for engineers in product development. All career paths are built in a way that with promotions technical focus gets increasingly substituted by general management and administrative tasks.	Most career paths are built in a way that with promotions technical focus gets increasingly substituted by general management and administrative tasks.	There are no clear promotion guidelines but a number of PD employees is promoted based on functional experience and knowledge. Specialists usually do not spend a long period of time in the same functional division, though.	There is a designated career path for technical specialists in their functional areas which promotes the development of technical expertise. Promotion is mostly based on functional experience and knowledge. Performance of individuals is evaluated and discussed in feedback meetings every now and then.	There is a well-defined and accepted advancement path for technical specialists in product development and all over the organization. Technical expertise and knowledge is the main criterion for promotion. More experienced managers are responsible for mentoring and supporting junior engineers. Performance of individuals is regularly evaluated and discussed in feedback meetings.
1.8	Data Management Competence					
1.8.1	Use of project performance metrics	Project performance metrics are measured but barely communicated. Very few people really "use" them.	Use of project performance metrics is dominated by corrective actions and surprises. Metrics are tracked or measured, but not always consistently. People are not well informed about the project's progress. Data accuracy and completeness is lacking.	Use of project performance metrics includes proactive actions. Metrics are regularly measured and reviewed by management. People and management are kept informed of project's performance. There are efforts to improve data accuracy and completeness. Usage is isolated in functional silos.	Bias is to proactive actions, team morale and learning. Many metrics are derived from predictive models. Metrics are tracked regularly. Key customers and partners are kept informed. Operational data is readily usable and it is accurate and complete.	Bias is to proactive actions, morale, learning, and knowledge capture - in the firm, with lead users and with partners. Metrics are available online, always measured and reviewed against corporate objectives. Usage promotes cross-functional teamwork. Data can be trusted.

1.8.2	Productivity metrics	There is no standardized approach for measuring the productivity of a project.	PD system uses aggregate measures, which again are used for diagnosis of corrective and proactive improvement actions. Total project hours and errors are obtained with great difficulty.	Productivity and total project error data are collected and analyzed against historical norms. Heuristics are relied upon. There is limited use of predictive modeling.	Productivity is measured and tracked using analytical models that permit proactive action. Information is available online for management review and queries.	Productivity is measured and tracked with predictive models for proactive actions. Information is available online for management and key team members' review and queries. Information is also linked to other functional systems for a complete picture of project productivity.
1.8.3	System of data collection, management and usage	PD does not have a formalized system of data collection, management and usage.	There is such a system, but for a variety of reasons, large volumes of data remain unused or ignored. Personal libraries and collection mechanisms dominate the practice.	There is such a system and it provides large volumes of data. Senior managers have budget to collect more data and develop local expertise.	Such a system exists. Senior managers budget to collect more data and develop local expertise. Members must share expertise via reports, on demand consultations, etc.	Such a system exists. Senior managers budget to collect more data and develop local expertise. System is highly integrated with learning, knowledge, and information tools and processes.
1.8.4	Knowledge management system	Best practices and lessons learned are not captured.	Capturing and cataloguing project's knowledge assets is a low priority activity. Past project info is not easily accessible for probing questions. Project knowledge begins and ends with personal knowledge.	Capturing and cataloging project's knowledge assets is seen as deemed necessary by the project leader for sharing within the team. Past project info not really accessible.	Standard practices include efficient means and standardized documents to naturally capture and catalogue project's knowledge assets for the team. Past project info is accessible, but hard for probing questions. Experts who can help are informally known to people.	Project's knowledge assets are systematically captured and catalogued. Standardized documents are used for capturing knowledge and lessons learned. Past project info is easily accessible for probing questions. Formal knowledge communities exist and are available to share and expand knowledge.
1.9	Technology Competence					

1.9.1	Technology readiness	Technology readiness is not actively addressed as an issue in the company-wide product innovation process.	Technology readiness is determined by technology demonstrations under controlled environments. Executive orders influence timing of technology transfer to PD, and require large engineering resources to make ready.	Technology readiness is a joint effort between scientists and PD. Transition to PD is rocky. PD invests substantial resources to stabilize technology for transfer toPD.	Technology readiness is determined by internal simulation and application in prototype systems. Customers and partners are consulted. Readiness is a joint process between engineering, technologists, and manufacturing.	Readiness is determined by the actual application of the technology in the final form, in a stressed system and in actual customer environments. Products used are from actual short run manufacturing lines. Readiness is a joint process between engineering, technologists, and manufacturing.
1.9.2	Investments in PD methods, tools and databases	Hand product development do not work together effectively. PD methods, tools, and databases are not widely accepted. Therefore they often are a "source" of problems.	PD methods, tools, and databases are a low budget priority. They retard progress. IT infrastructure is inconsistent with the project. IT is always behind, and too many PD resources are diverted and spent on IT. PD has to develop many of the tools required.	Methods, tools, and databases are sporadically improved and created. IT infrastructure and support are adequate for the project, but some PD resources are spent on 1T. All need improvement. PD has to justify to management the acquisition of key tools.	Methods, tools, and databases are continuously improved and created. IT infrastructure fits the project and works to support it; it is generally timely, with some priority conflicts. PD progress is not inhibited by tools and their support.	Methods, tools, and databases are the envy of the industry. IT infrastructure is tailored for the project. IT support is dedicated to the projects, and not vice versa. Domain experts are identified and assigned to support PD.
1.9.3	Technology forecasting	Product development does not consider formal technlogy forecasting.	Product development system is a technology follower - new technology is adopted only when it is widely adopted in the market. PD system uses familiar and mature technology and reuses known manufacturing processes.	Technology forecasting is based on capabilities of the organization and knowledge of the state-of-the-art. Capabilities determine adoption and competitive pressures trigger make/buy decisions.	Technology and manufacturing roadmaps with a competitive lead are defined. Work is done with customers to understand technologies. New product pipeline planning considers this when scheduling development activity.	PD uses preemptive roadmaps in technology and manufacturing. Technology is validated in lead user application environments. New product pipeline planning highly considers this when scheduling development activity.
1.10	Marketing Competence					

1.10.1	Product positioning	Product positioning is a purely passive process. The main reason for a new product introduction is the replacement of a preceding product. Neither lead users nor customers are involved in the product positioning process.	Most new products are positioned in a replacement business. Specifications are determined with no direct links to customer needs.	Products are positioned as improvements for the current customer base.	Products are positioned to new markets, with strong competitors. New growth opportunities, buying behavior, and market evolution are characterized. Product definition is differentiated and competitive.	Product and its derivatives are targeted for market creation in the industry. Product is unique -there are no competitive products or precedents. All key functions and processes are realigned for the product.
1.10.2	Knowledge of market potential	Market potential is determined from historical sales data only.	Market potential is predominantly determined from historical sales data and sales of known competitors.	Market potential is determined from expected sales of product line extensions and from currently served market segments. PD uses momentum models.	Forecasts of industry and market growth, adoption curves, pricing and revenues are considered. Focus is on key competitors' future actions. Some formal models are used.	Products are used to create a new market. Knowledge of market growth and acceleration is more important than potential size of the market.
1.10.3	Product pricing strategy	Target price is determined based on the development and production costs of the products.	Momentum pricing. Target price is determined by ensuring consistency with the current and to-be-replaced product offers.	Price to competition. Target price is determined through positioning analysis against competitor product offers.	Price to customer preferences. Use front-end consumer analysis methods, such as conjoint studies, to establish target price, consistent with the desired competitive market position of the product.	Price to customer value. EVA is used to price the product. Analysis uses lead users within their business processes. Pricing consistency with strategic intent is validated.
1.11	Social Responsibility Competence					
1.11.1	Social responsibilities	Product meets minimum legal requirements.	Product meets most of the legal requirements and exceeds in a few areas.	Product meets all legal requirements and exceeds in many areas.	Product meets all legal requirements and exceeds in many areas. Manufacturing meets and exceeds many regulatory standards in environmental compliance.	Product leads in meeting legal requirements and environmental compliances relative to its leading competitors. Product has proactively addressed many social responsibility issues not in statutes or regulations.
	Product Development Dynamic Capabilities					
2.1	Communication and Diffusion Channels					

2.1.1	Communication of vision, strategy and plans	Executives do not communicate their vision and strategy statements. Project leaders and project staff develop change plans that are not aligned with the company's vision and strategy.	Executives' communications are thin and sparse. Project's change plans are narrowly defined and vague. Project leader consistently needs executives' help to set direction and priorities.	Executives communicate vision, strategy and change plans, but their actions are not consistent. Project leader has to overcome these obstacles to drive the change project.	Executives actively communicate vision and strategy, reinforced frequently and supported by consistent actions. That makes the job of setting the change direction and prioritizing easy for the project leader.	CEO and senior management actively communicate the current vision and strategy. This is reinforced by visible actions, rewards and incentives. Consistent change messages arrive at all levels. People are encouraged to look at all of their daily activities through the lens of the organization's vision and strategy. Communication is effective and simple and uses examples and analogies.
2.1.2	Communication and change diffusion barriers	Organizational, hierarchical and functional boundaries limit the movement of people and ideas considerably. A large part of employees does not share information and even hides it from other employees.	Organizational, hierarchical and functional boundaries limit the movement of people and ideas in a number of ways. Information is not available openly to a number of PD employees. Information about changes is generally undercommunicated.	The movement of people and ideas is only limited in parts of the PD organization. Information is openly shared among most parts of the PD organization but there is a number of people who do not get access to the information they need. Changes are communicated to a number of revelant people related to the topic.	The movement of people and ideas is not limited by organizational, hierarchical and functional boundaries. Information is available openly to most people in the PD organization. Changes are communicated to the most revelant people related to the topic.	The permeability of organizational, hierarchical and functional boundaries facilitates the movement of people, ideas, and the formation of communities of inquiry around systematic issues that cross boundaries. Information is available openly to everyone in the PD organization. Changes are communicated to those who are concerned as well as to those who are involved.
2.1.3	Formal change diffusion in PD	There are very few meetings between PD employees. PD teams try to solve most of their problems themselves.	PD-related meetings are scheduled far into the future. There is no real agenda for the meetings. Participants consist almost always of the same people who feel forced to attend. Most meetings can be described as ineffective, time-consuming and chaotic.	Time, place, contents and participators of PD meetings are usually rigorously planned far into the future. Meetings are fairly effective but often fail to address the most important topics.	PD meetings are planned according to the current priorities. There is a planned agenda which can be adapted to current important topics. Participants usually consist of people who are necessary in order to discuss the topics. Outcomes of the meetings can be described as effective and useful.	There is a highly effective mix between fix planned meetings and flexible planned meetings for product development activities. Participants consist of people from different functional areas necessary to discuss current important topics. Meetings are very effective and focused on few important topics which are discussed intensively. Communication is open, direct, and honest. There is propensity to listen.

2.1.4	Informal change diffusion in PD	Informal change diffusion does not take place. Employees act in a very competive environment and keep their information for themselves.	There are a few established informal networks in place that diffuse change knowledge and information related to product development activities. Informal change diffusion usually takes place between certain individuals. The majority of PD employees is not aware of the existence and the benefits of informal networks. There are no incentives for creating such networks. Communication is dominated by stylized and formal mechanisms and lacks spontaneity.	Informal networks are used for diffusing PD-related change knowledge and information, but only within small parts of the organization. Informal networks are barely visible to the management. There are few incentives for building new "communities of practice".	Many already existing informal networks within the company are accepted and used for diffusing PD-related change knowledge and information. There are a number of incentives for building new informal networks.	There are a numerous incentives which encourage people to become "network leaders" or to form "communities of practice". PD employees do not only understand and acknowledge the importance of informal networks but also constantly try to spread the idea and importance of informal networks. There is a huge number of highly effective and different informal networks across different functional areas within the company. Communication is open, direct, and honest. There is propensity to listen.
2.2	Vision Strategy and Plans					

2.2.1	Establishing a vision	The company does not have an official vision statement.	The company has an official vision statement. It has been created by the CEO a long time ago and does not really fit to the PD organization. Vision has little effect in motivating and directing people of the PD organization.	The vision statement is created top-down and in a systematic way but is updated rarely. Vision is understood at all levels of the PD organization and "part" of most of the operations. Vision is aligned with the organizational structure.	The company has a vision statement which suits very well to its current profile. It meets almost all the requirements for an effective vision. The statement is created in a systematic way and continuously improved and adapted. Key employees and most other employees buy into. Most of the external stakeholders (customers, suppliers) buy into. Vision is perfectly aligned with the organizational structure.	The company has a vision statement which can be described as clear, imaginable, desirable, feasible, sensible, focused, flexible, communicable and ambitious. The vision takes advantage of fundamental trends and has moral power. Vision is created in a systematic way and is continuously improved and adapted. Everyone from key executives to first-level employees buys into, also investors, customers, suppliers. Everything from the structure of the organization to the leadership style, management methods, and action plans is designed to support the vision.
2.2.2	Establishing a strategy	Company relies more on short-term plans and budgets than on a real strategy.	The guiding team creates the company's strategy, but it is not really aligned with the company's vision, ongoing plans and current budgets.	The guiding team creates the company's strategy which is sufficiently aligned with the company's vision, ongoing plans and current budgets.	A variety of different functional groups are included into the company's strategy definition process which is based on a formal strategic planning method. Strategy is perfectly aligned with the organization's vision.	All relevant different functional groups work collaboratively to achieve the company's strategic objectives, they include also young employees, people at the organization's geographic periphery and newcomers. A variety of different strategic planning methods (e.g. scenario thinking) are used. Assumptions behind the current strategy are continually exposed and tested. Both vision and strategy are mutually reinforcing each other.

2.2.3	Short term wins	There is no change management coalition that collaboratively sets goals for the change effort.	Change management coalition does not focus on short-term wins. All effort is put into the realization of the "big goals".	Relevant short-term wins are achieved but change management coalition fails to communicate the results to a large number of key employees. Moreover, management does effectively leverage them for building momentum for the change effort.	Short-term wins are successfully used in order to build momentum for the overall change effort. They are related to the overall change effort and seem meaningful to the majority of key employees. Short-term wins are achieved within 6 to 18 months.	The change guiding coalition uses the right balance between short-term goals and the "grand vision"-goals. Short-term wins are perfectly aligned with the "grand vision" and clearly related to the overall change effort. They are actively created and achieved successfully and fast. Short-term wins are visible and meaningful to almost all employees, and unambiguous. People who make wins possible are visibly recognized and rewarded.
2.3	Product Development Corporate Culture					
2.3.1	Understanding and leveraging organizational culture	PD project tries to push change without considering the established organizational culture.	Understanding and leveraging organizational culture is not considered high priority. PD projects does not fit well to the cultural values of the firm; it is a forced-fit that impacts PD in many ways.	Firm's current PD projects and its cultural values are not completely aligned with each other. Projects have some difficulty fitting.	PD projects are aligned with the strategy and values of the firm.	Organizational culture and PD projects are mutually reinforcing. PD projects promote the culture and values of the firm and vice versa. Vision, strategy, plans and budgets are perfectly aligned with each other.
2.3.2	Teamwork culture	The teamwork culture in PD can be described as hostile and competitive.	Parochial loyalties are deeply rooted in PD teamwork culture. Group interactions are guarded with too many power games. Management intervention need to make groups work together and resolve disputes.	Intra-functional teamwork exists, but inter-functional teamwork and problem solving need management push. Conflicts remain unsolved too long and require management intervention.	Management has leveraged informal networks to promote cross functional teamwork and problem solving in PD-related areas. Conflicts are open, business-like, and readily resolved.	Self-organized cross-functional networks (formal and informal, with customers and with partners) actively promote problem solving in PD-related areas. They interact freely, and conflict resolution is fast and effective.

2.3.3	Work environment	Work environment is a hostile and very competitive environment. Maximizing individual work output is the main goal for a high number of employees.	Focus is on maximizing work output. PD employee well-being, satisfaction, and services are a low budget priority.	Focus is on maximizing work output, but with a concern for morale. There is enough attention to PD employee wellbeing, satisfaction, and services to avoid high turnover.	Focus is on high performance and high morale. Initiatives are in place to support PD employee well-being and satisfaction in order to sustain productivity, quality, and morale.	Recognized as an industry leader. The organization's policy addresses workplace, systems, and programs for PD employee well-being and satisfaction. Focus is also on the well being of the community.
2.4	People for Change					
2.4.1	Core change team composition	There are practically no "change teams" that want to create any type of organizational change.	PD employees try to implement changes with the help of already established groups.	There are people with ideas for PD-related changes, but it is hard to get together the right people who are needed in order to successfully implement these ideas.	The majority of people within the PD organization are open-minded about changes. They constantly try to form "change teams" in order to realize their change ideas. They often succeed in creating "change teams" which consist of the right people who successfully work together in order to create sustainable change. Pilot groups are used to introduce greater changes to the organization.	Single open-minded individuals with good ideas for changes can motivate and pull in the necessary people needed for PD related change implementation. "Change teams" can be established within a short period of time. "Change teams" consist of different individuals with the appropriate skills, the relevant knowledge, the leadership capacity, the formal authority, the organizational credibility, and the connections to handle a specific kind of organizational change. Personalities in the team fit the respective organization. Pilot groups are used to introduce greater changes to the organization.
2.4.2	Teambuilding efforts	Company does not provide teambuilding events for its PD employees. PD employees are not interested in teambuilding activities either.	Teambuilding efforts are not really acknowledged by most of the PD staff within the organization. Responsible management does not support the idea of active teambuilding.	There are teambuilding incentives provided by the PD organization but these efforts seem to have no real goals behind.	Well-considered teambuilding efforts (e.g. informal blocked off site meetings) are provided for a number of employees in product development and help to create trust and common goals between them.	Teambuilding efforts are carefully planned and customized by internal staff and/or external consultants. The purpose of teambuilding efforts is understood and appreciated throughout the PD organization. There is a common belief that teambuilding efforts are highly effective for creating trust and common goals among the staff.

2.4.3	Roles, responsibilities and empowerment	Employees do not know their role. Their work can be described as carrying out tasks in order to satisfy their bosses. They are confused about the assignments from both their functional bosses and their project leader.	Roles are narrowly defined, largely at the task level. For many, it is difficult to link their work to the overall goals or the project mission. There is micromanagement, slow decision making, and false starts.	Team members understand their roles and responsibilities. They know how their work promotes goals, i.e a project's mission. There is respect for multifunctional views.	Team roles and responsibilities are determined through extensive discussions among management and employees. How to meet project goals is delegated to the project leader. Suppliers and partners review and comment.	Roles and responsibilities are determined via extensive discussions at all levels with participation from suppliers and partners. Strong power delegated to the project leader. Most have a desire to go beyond the job descriptions. All know their role and responsibilities relative to key functions.
2.5	Helping Training and Education					
2.5.1	Mentoring & coaching	Cultural learning process of PD employees is not supported by a mentoring or coaching program.	Mentoring or coaching relationships between mentors and mentees are not facilitated by the company but exist on an individual basis between PD employees. Mentors are usually in a higher position than their mentees and are able to give them valuable advice and help.	Company is using a formal mentoring program which is effective. However, only a limited number of employees participate in the program.	Company is using a formal mentoring program. Mentoring serves as a dual support system for both mentors and mentees. Mentors provide formal or informal support and offer to share their own network. Mentors and mentees have a professional relationship.	A highly effective company-wide mentoring program, which is accepted by employees, has been in use for years. All participating mentors and mentees take advantage of their regular interactions. Mentors are in a position of influence and coach their mentees in how to leverage the culture. They guide their mentees through pulling change processes and help them to expand their network by sharing their own network. Mentors and mentees like and respect each other.
2.5.2	Attitude education	Organization provides no attitude training for its PD employees.	Attitude courses are offered only to key PD employees before starting their job.	Attitude courses are offered predominantly to key PD employees before starting their job as well as afterwards.	Not only skills but also attitude is trained to a high number of PD employees. Courses are offered also after starting the job. Training is aligned with the organization's vision and cultural values.	Organization attaches importance on attitude education among its PD staff. Senior executive leaders participate in teaching the culture of the company. Employees at all levels regardless their experience attend regular courses and can openly ask for help. Attitude training facilitates employees to understand the organization's vision and cultural values.

2.5.3	Technical training	Training is limited to on-the-job learning.	Delivery pressures limit scope and extent of training. Training and education are constantly limited by other budget priorities. Technical effectiveness and proficiency measurements are subjective.	Technical training activities are planned and ensured for employees who really need it. Technical effectiveness and proficiency measurements are subjective, though.	Senior executives, functional managers and project champion are committed. Training is fully funded and effectiveness is measured objectively. Product delivery pressures rarely circumvent training plans.	The company's culture values technical proficiency. Training is fully funded, is never an issue, and effectiveness is measured. Product delivery pressures do not circumvent training. Training includes partners.
2.6	Human Resources for Product Development					
2.6.1	PD rewarding & promotion	There is no formal system for rewarding PD employees. There is no clear promotion regulation for PD employees.	Current rewarding & promotion system is conservative and risk averse and lacks a coherent structure and seems a mystery to a majority of the PD employees. Rewarding and promotion system is solely an affair of the human resources department. Compensation system promotes individuals instead of teams.	There is a good rewarding & promotion system for product development in place. Details of the design, implementation and administration should be improved, though. Alignment with current change processes and with the organizational structure and culture is considered but not paid enough attention. PD employees are informed about the rewarding & promotion system every now and then but there are a number of people remaining who do not really understand it.	Organization uses an effective and well-structured rewarding & promotion system in product development. Most PD employees understand how the rewarding & promotion system is functioning. There are continuous efforts to align the current PD rewarding & promotion system with business strategy, organizational structure, organizational culture and ongoing change efforts. Both extrinsic and intrinsic rewards are used.	PD rewarding & promotion system can be described as individualistic, flexible, well-designed, tied to strong performance and highly motivating. All relevant PD employees are frequently informed about changes in the system and understand how it is functioning. The PD rewarding & promotion system is perfectly aligned with business strategy, organizational structure and organizational culture. Changes to the system are implemented at the right time (as early as possible) in the change process. They are constantly monitored and adapted in order to guarantee compatibility with achieved new practices and alignment to current change efforts. PD organization uses both extrinsic {e.g. pay) and instrinsic rewards (e.g. job design) that are congruent and consistent.

2.6.2	PD recruiting & hiring	Having technical skills and experience are the only criteria for recruiting and hiring new PD employees.	The main selection criteria for recruiting and hiring new PD employees are profound technical skills and experience of the applicants.	Human resources department acts pretty independently from other functions. Selection criteria for recruiting and hiring involve technical skills and for key PD employees also behavioral skills.	Selection criteria for new PD employees involve both technical and behavioral skills. Behavioral interviews are part of the recruiting and hiring process. Recruiting and hiring system is aligned with the change vision and change strategy of the company.	Recruiting and hiring system is perfectly aligned with the change vision and change strategy of the company. Human resources department is constantly updated about ongoing change efforts and adjusts its selection criteria continuously. PD employees are selected not only based on their technical skills and experience. Heavy emphasis is put on behavioral interviews which are held in order to ensure "cultural fit" of new PD employees.
2.7	Openness to Improvements					
2.7.1	Raising and maintaining urgency level for change	High complacency on change within the PD organization. PD employees are opposed to changes and feel comfortable with the current situation.	Too much complacency on change within the PD organization. There is little motivation for change among the PD employees. Leaders and managers seem to push through their ideas.	Complacency is present in some PD-related functional areas. Guiding change coalition understands the role of urgency for change. There are efforts for raising the urgency level for change but they often come to late or seem not adequate.	The guiding coalition for change is constantly looking for cheap and easy ways to reduce the already low level of complacency on change. Moreover, they continually try to motivate relevant PD employees for the change effort. There is a growing group of believers.	There is no complacency on change. The guiding coalition for change is constantly trying to understand why people in PD resist or welcome change and to reduce complacency, fear and anger that prevent change from starting. All change efforts are started with raising a feeling of urgency among relevant PD people. All relevant PD employees feel motivated by visually compelling, dramatic, attention grabbing, memorable presentations, reports and other evidence that they can see, touch and feel.
2.7.2	Motivating breakthrough ideas	Employees are opposed to changes and innovations. They do not support breakthrough ideas.	PDP innovations occur when management pushes them forward.	Innovations are considered and implemented when it is clear how they will benefit.	Employees are open to PDP innovations. If the benefit is unclear, respect for the project leader will still carry it forward.	Management system and culture that promote fresh ideas. Innovation is prized and rewarded, especially from sources outside their normal expertise.
2.8	Learning					

2.8.1	Pursuit of organizational learning	Organizational learning begins and ends with personal learning.	There is an information system to capture lessons from prior projects, but it is not accepted by the PD employees.	An information system to capture lessons from prior project is used by the majority of PD employees. PD employees agree that the system could be used in a more effective way.	The PD organization takes advantage of lessons from its latest projects and pursues its key people to learn how to apply those lessons to its new project.	The PD organization has many formal and informal incentive mechanisms. Effective practices are readily adopted by the PD organization. A high percentage of employees reads journals, books and trade press.
2.8.2	Cross-project knowledge transfer	Product development projects are considered independent and unrelated. There is no knowledge transfer between different projects.	Knowledge transfer between different projects is not facilitated. Knowledge transfer happens through informal communication channels but not in a systematic way.	A variety of best practices and lessons learned from different projects are documented, but not in a systematic and logical way. Documented knowledge is unsteadily updated. A number of employees frequently use the knowledge database but there is also a high number of people within the organization who have never heard about it.	There are methods and devices to collect information on successful procedures, tools and designs across projects. Best practices and lessons learned from previous projects are reviewed. Documented knowledge is updated every now and then. The collected knowledge is simplified and generalized every now and then. All employees have access to the centralized knowledge database and sometimes use it.	A high number of methods and devices is effectively used in order to collect information on successful procedures, tools and designs across projects. Best practices and lessons learned from previous projects are reviewed. Documented knowledge is continuously updated by the engineers. The collected knowledge is frequently simplified, reorganized and generalized. All employees have access to the centralized knowledge databases and regularly use it.
	Product Development Project Results					
3.1	Project Financial and Market Results					
3.1.1	Project IRR and NPV	Project does not meet IRR and NPV financial metrics by far.	Project does not meet IRR and NPV financial metrics even after many retargeting decisions and many other accounting and financial adjustments.	Project meets IRR and NPV financial metrics after some accounting and financial adjustments.	Project meets IRR and NPV metrics as committed during project funding.	Project exceeds 1 RR and NPV metrics committed during project funding.
3.1.2	Product volumes	Product volumes are far below forecast established during funding stage.	Product volumes are below forecast established during funding stage.	Product volumes are on track with forecast established during funding stage.	Product volumes exceed forecast established during funding stage.	Product volumes far exceed forecast established during funding stage.
3.1.3	Product revenues	Product revenues are far below forecast established during funding stage.	Product revenues are below forecast established during funding stage.	Product revenues are on track with forecast established during funding stage.	Product revenues exceed forecast established during funding stage.	Product revenues far exceed forecast established during funding stage.

3.1.4	Product costs	Product costs do not meet the plan established during funding by far.	Product costs do not meet the plan established during funding, and its negative impact is visible in the product's financial performance.	Product costs are on track with the plan established during funding.	Product costs meet all, and even exceed some performance targets established during funding.	Product costs' performance far exceeds the plan established during funding and the positive impact is visible in the product's financial position.
3.1.5	Product SG&A	Product's SG&A does not meet the plan established during funding by far.	Product's SG&A does not meet the plan established during funding. Negative impact is visible in the product's financial performance.	Product's SG&A is on track with the plan established during funding.	Product's SG&A meets all, and even exceeds some performance targets established during funding.	Product's SG&A performance far exceeds the plan established during funding and the positive impact is visible in the product's financial position.
3.1.6	Product's market share in revenue	Product's revenue market share trends show that market share is strongly decreasing in key targeted segments.	Product's revenue market share trends show that market share is decreasing in key targeted segments.	Product's revenue market share trends show that market share is uneven in target markets specified during funding stage of base plan, but adequate in aggregate.	Product's revenue market share trends show that market share is increasing in many key segments established during funding stage, and increasing in aggregate versus base plan.	Product's revenue market share trends show that product has established a new market segment. Its share is growing dramatically.
3.2	Project Customer Satisfaction and Loyalty Results					
3.2.1	Customer loyalty	Customers are displacing the product with competitor's products.	Customers start to displace the product with competitor's products at an increasing rate. They are not recommending the product to others.	Customers will consider competitive products for repurchase. They recommend the product with some qualifiers.	Customer's repurchase rate is exceeding forecast. They recommend the product when asked.	Customer's repurchase-rate is exceeding expectations by a wide margin. Without prompting, they are visibly endorsing the product in important forums.
3.2.2	Satisfaction with price for value	Customers consider the product to be extremely overpriced for the value they are deriving from its use.	Customers consider the product to be overpriced for the value they are deriving from its use.	Customers consider the product price to be fair considering the value they are deriving from its use.	Customers consider the product price to be attractive due to the value they are deriving from its use.	Customers consider the product price to be an extraordinary value due to the unique benefits they are deriving from its use.

3.2.3	Satisfaction with product function and performance	Customers consider the product's function and performance to be very disappointing.	Customers consider the product's function and performance to be rather disappointing.	Customers consider the product's function and performance to be acceptable and to have met their expectations.	Customers consider the product's function and performance to have exceeded their expectations.	Customers consider the product's function and performance to have created unprecedented and extraordinary competitive advantages.
3.2.4	Satisfaction with service and support	Customers consider the product service and support to be very disappointing.	Customers consider the product service and support to be rather disappointing.	Customers consider the product service and support to be acceptable. Overall, their expectations have been adequately met.	Customers consider the product service and support to have exceeded their expectations.	Customers consider the product service and support to be surprisingly competent and efficient considering the unprecedented functions and applications of the product.
3.3	Organizational Effectiveness Results					
3.3.1	Strategic intent	Product does not help the strategic and competitive position of the firm at all.	Product provides little support to help the strategic and competitive position of the firm.	Product maintains the strategic and competitive position of the firm.	Product improves the strategic and competitive position of the firm.	Product redefines the strategic and competitive position of the firm.
3.3.2	Development time and slip rate	Project slippes considerably from original schedule committed during funding. Huge management intervention, descoping, and additional resources are required.	Project slippes from original schedule committed during funding. Management intervention, descoping, and additional resources are required.	Project misses milestones committed during funding by small and acceptable margins. Needs some management intervention and incremental resources to maintain scope and schedule margins.	The project is completed on time and meets every schedule milestone defined during funding. No management intervention is required.	Project beats the every schedule milestone.
3.3.3	Development budget and schedule	Project slippes considerably from original schedule and overruns budget by far. Huge management intervention, descoping, and additional resources are required to keep revised schedule on time.	Project slippes from original schedule and overruns budget. Management intervention, descoping, and additional resources are required to keep revised schedule on time.	Project misses milestones and budget by small yet acceptable margins committed during funding. Some management intervention and incremental resources to maintain scope and schedule margins are needed.	The project is completed on budget, on time, meeting every milestone, and without any slips. No management intervention is required.	The project beats the budget and every schedule milestone.

3.3.4	Partner satisfaction and loyalty	Key partners discontinue their business relationships. Company has difficulty in recruiting new ones.	Partners are unsatisfied and not loyal.	All things considered, partners are satisfied and loyal.	Partners' satisfaction and loyalty exceed targets. Partners recommend the firm. Company has no difficulty in finding new candidates.	Partner's are excited and enthusiastically recommend the firm. New candidates compete to become business partners.
3.3.5	Project team morale	The project team morale is very low. Staffane! management turnover and absenteeism are extremely high. Staff and management recruiting is very difficult.	The project team morale is low. Staff and management turnover and absenteeism are high. Staff and management recruiting is difficult.	The project team morale ¡s acceptable with some exceptions. Staff and management turnover is acceptable.	The project team morale is high and surveys support this fact. Staff and management turnover is low. Recruiting is easy.	The project team morale and excitement are high and surveys support this fact. Staff and management fight to join the project.
3.3.6	Productivity	Project team's productivity misses its objectives by far. Productivity deficits visibly affect the financial measures or the schedule in a very negative way.	Project team's productivity does not meet its objectives. Productivity deficits visibly affect the financial measures or the schedule negatively.	Project team's productivity indicators meet their targets within adequate margins. Productivity deficits' impact on financial measures and the schedule is within adequate margins.	Project team's productivity indicators meet and exceed most of their targets. Productivity results in incremental improvements in financial measures and the schedule.	Project team's productivity indicators exceed all key targets. They do so sufficiently to have a positive and visible impact on financial measures and schedule.
3.3.7	Contribution to knowledge assets	PD has no knowledge assets in the archives.	PD has project documents in the archives.	PD does a lessons learned.	Lessons learned are actioned. Process is changed and information improved. PD now prevents a failure from occurring.	Lessons, actions, process, and information improvements now transform organizational processes and information in fundamental ways.
3.4	Product Results					

3.4.1	Functions and performance versus specifications	Product misses key specifications committed after beta prototype by far. A huge number of renegotiations are required to continue development. These negotiations are impacting financial performance and customer/partner satisfaction and loyalty in a very negative way.	Product misses key specifications committed after beta prototype. A number of renegotiations are required to continue development. These negotiations are impacting financial performance and customer/partner satisfaction and loyalty negatively.	Product meets specifications committed after beta prototype. Minor renegotiations are required to adjust specifications to continue development.	Product exceeds specifications. Product is competitive. No negotiations are required to adjust specifications to continue development.	Product's specifications are setting industry de facto standards. Product is widely imitated. Positive impact is visible in financial performance and customer and partner propensity to recommend the product.
3.4.2	Industry awards	No industry awards for products.	No industry awards for this product. Mentioned in the trade press, but not visible in analyst's and consultant's reports.	Very few industry awards for this product. Mentioned in the trade press, but barely visible in analyst's and consultant's reports.	Few industry awards, but many visible and favorable industry reports for the product.	Prestigious industry awards for the product. Me-too imitators appearing.
3.4.3	Core technology newness	PD technology focus is on cost reduction only.	PD technology focus is on cost reduction, product repositioning and/or update.	Technology is new to the firm. Competitor already offers technology in the market.	Core technology exists and is implemented in completely different types of products. New to the market.	Technology is entirely new, has never appeared in any type of product sold in the market. The technology is fresh out of the research lab and is causing competitive disruption.
3.4.4	Platforming extent	Project considers only the single product.	Project partly considers accommodating future derivatives and/or updates.	Project considers accommodating future derivatives and/or updates. There is a planned architecture.	Project develops multiple variants and uses full platform development for a product line. The architecture is developed along product variants.	Project develops multiple variants and accommodates future technologies requiring architectural changes.

3.4.5	Manufacturing complexity	Manufacturing processes are neither changed nor improved.	Negligible changes are made to the manufacturing processes. There are small adjustments in vendors, tools, and parts, but they are fundamentally very familiar and have been used before.	Minimal new parts, vendors, custom parts, tools, materials, and small process changes are introduced to manufacturing. New skills training is localized and for small groups.	New parts, vendors, custom parts, major tools, materials, and redesigned processes are introduced to manufacturing. Specialized skills development and training are required.	A large number of new parts, new vendors, new custom parts, major retooling, new materials, and new and redesigned processes are introduced to manufacturing. A large range of skills training and education are required.
3.4.5	Sales and service complexity	Sales and service approach is unchanged. Product sales are predominantly based on cost reductions.	Sales and service approach is largely unchanged. Product sales are mostly based on cost reductions, update, or similar repositioning to slow down customer defections.	Sales and service approach is tuned and adjusted in order to maintain customer base against competitors.	Sales and service approach is redefined to showcase product's function, performance, and technology in order to expand existing market share.	Product's unique value proposition and functionality requires new sales and service processes to expand market share and occupy new market segments.
3.5	Project Benchmarking					
3.5.1	Benchmarks	Benchmarking is not applied in PD. Therefore, PD does not know how good a product is performing versus its key competitors.	Benchmarks are only occasionally done. Results show that the product is underperforming versus its key competitors in many key measures.	Benchmarks show that the product is about equal to its key competitors in key measures.	Leading product development organizations benchmark their products against yours. Product is used as a model of best of breed.	Industry, standards groups, and PD groups seek to study your product, PD practices and organizational issues to develop PD norms and defacto standards.

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