

24 Page Preview

TITLE A study in management: Appropriate management practices for the research and development project

AUTHOR Guthrie, Hudson

DEGREE DSc

SCHOOL WASHINGTON UNIVERSITY IN ST. LOUIS

DATE 2006

**WASHINGTON UNIVERSITY
THE HENRY EDWIN SEVER GRADUATE SCHOOL
DEPARTMENT OF ENGINEERING AND POLICY**

**A STUDY IN MANAGEMENT:
APPROPRIATE MANAGEMENT PRACTICES
FOR THE RESEARCH AND DEVELOPMENT PROJECT**

by

Hudson Guthrie

Prepared under the direction of
Professors Jack Clancy and Tom Browdy

**Dissertation presented to the Henry Edwin Sever Graduate School
of Washington University in partial fulfillment of the
requirements for the degree of
DOCTOR OF SCIENCE**

May 2006

St. Louis, Missouri

UMI Number: 3220570

Copyright 2006 by
Guthrie, Hudson

All rights reserved.

INFORMATION TO USERS

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleed-through, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

UMI[®]

UMI Microform 3220570

Copyright 2006 by ProQuest Information and Learning Company.
All rights reserved. This microform edition is protected against
unauthorized copying under Title 17, United States Code.

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

copyright by
Hudson Guthrie
2006

**WASHINGTON UNIVERSITY
THE HENRY EDWIN SEVER GRADUATE SCHOOL
DEPARTMENT OF ENGINEERING AND POLICY**

ABSTRACT

**A STUDY IN MANAGEMENT: APPROPRIATE MANAGEMENT
PRACTICES FOR THE RESEARCH AND DEVELOPMENT PROJECT**

by

Hudson Guthrie

ADVISORS: Professors Jack Clancy and Tom Browdy

May 2006

St. Louis, Missouri

The subject area for this dissertation is the Management of Research and Development (R&D) Projects. The purpose of the study was to determine the effect of Structured Management Practices on the Research and Development (R&D) Project. Of particular interest was the effect of these Structured Management Practices on innovation and performance at the level of the individual R&D Project.

A two-part approach, consisting of a case study followed by a widely distributed survey was used to investigate the effect of management practices on innovation and performance at the level of the individual R&D project within a company's central research organization. The research provides strong support for the hypothesis that rigorously structured production style management is inappropriate for R&D projects. The study results also provide valuable knowledge for making significant improvements in the management of R&D projects. The results indicate that structured management practices and innovation are in tension. The appropriate level of management practices is inversely related to the level of innovation desired.

Table of Contents

List of Figures.....	v
Acknowledgements.....	vii
1 Introduction and Summary	1
1.1 Research Methodology	1
1.2 Summary of Results.....	2
2 Background.....	3
2.1 Importance of Research	3
2.2 R&D Project Environment.....	4
2.3 Personal Interest.....	7
3 Related Theories and Research.....	9
3.1 Prior Research on Topic	10
3.2 Support for Structured Management Practices	11
3.3 Against Structured Management and for Innovation.....	12
3.4 For Productivity and Innovation	14
3.5 The Role of Leadership in Project Management	16
3.6 The Role of Reward and Measurement Systems in Project Management....	17
3.7 Complex Adaptive Theory.....	18
3.8 Polarity in Project Management	20
3.9 Conclusions on Related Theories and Prior Research	21
4 Hypothesis	24
5 Research Methodology	25
5.1 Study Theory and Philosophy.....	26
5.2 Study Approach	26
5.3 Operationalization and Metrics.....	27
5.3.1 Structured Management Practices	27
5.3.2 Demographics	29
5.3.3 Metrics	30
5.4 Case Study Methodology.....	32
5.5 Survey Development.....	34
5.5.1 Development of the Survey Instrument	35
5.5.2 Survey Distribution.....	37
5.5.3 Survey Responses and Bias Testing	39
5.6 Limitations of the Study Methodology	40
5.6.1 Case Study	40
5.6.2 Survey Limitations.....	42
6 Case Study	43
6.1 Case Study Projects and Personnel	44
6.2 Case Study Results.....	45
7 Survey	51
7.1 Analysis Methodology -- Dependency Testing and Results.....	52
7.2 Distribution of Responses.....	61

7.3	Management Practices and Project Performance.....	72
7.4	Management Practices and Project Innovation.....	80
7.4.1	Management Practices and Rigor versus Innovation.....	85
7.4.2	Technical Challenge and MP Effect on Innovation.....	89
7.5	Postulated Effect of Rigorous Management Practices on Innovation	91
7.6	Appropriate Project Size and Research Type for Rigorous Management Practices	94
7.7	Qualitative Responses.....	96
8	Conclusions.....	96
8.1	Tension between Management and Innovation	96
8.2	Let Managers Manage	96
8.3	Importance of Results	96
8.4	Follow-up Research	96
Appendix A	Case Study Questionnaire	96
Appendix B	Survey and Cover Letter	96
Appendix C	Analysis of Survey Results	96
References	96
Vita	96

List of Figures

Figure 2-1 Typical Company Management Structure	5
Figure 3-1 Research Productivity (Bean 1995)	16
Figure 3-2 Polarity Work.....	21
Figure 3-3 Relevant and Supporting Theory	23
Figure 5-1 Two Part Analysis Approach	27
Figure 5-2 Structured Management Practices.....	28
Figure 5-3 Levels of R&D Organization	30
Figure 5-4 Case Study Projects.....	32
Figure 5-5 Management Practices Experts	33
Figure 5-6 Organization of Survey and Interviews Results.....	35
Figure 5-7 Case Study Methodology	36
Figure 5-8 Target Population for Survey	38
Figure 6-1 Case Study Organization.....	43
Figure 6-2 Project R&D Type and Size.....	44
Figure 6-3 Effect of Management Practices on Performance and Innovation.....	46
Figure 6-4 Postulated Effect of Rigorous Management Practices on Innovation.....	47
Figure 6-5 Project Size and the Effect of Management Practices on Innovation	48
Figure 7-1 Position of the R&D Organization.....	51
Figure 7-2 Dependency Testing.....	59
Figure 7-3 Comparison of Research Levels	60
Figure 7-4 Refining the Survey Database.....	61
Figure 7-5 Distribution Characteristics of Survey Projects	62
Figure 7-6 Research Project Size Distribution	62
Figure 7-7 Position of Subjects.....	63
Figure 7-8 Technology Readiness Level	64
Figure 7-9 Innovation Goal Level	65
Figure 7-10 Distribution of Technical Challenge (Innovation Goal – Initial TRL)	66
Figure 7-11 Number of Management Practices versus Project Size	67
Figure 7-12 Management Practices x Rigor versus Project Size.....	68
Figure 7-13 Cumulative Distribution of MP x Rigor versus Project Size	69
Figure 7-14 Number of Management Practices versus Research Level.....	70
Figure 7-15 Cumulative Distribution of Number of MPs versus Research Level.....	70
Figure 7-16 Number of MPs x Rigor versus Research Level.....	71
Figure 7-17 Cumulative Distribution of MPs x Rigor versus Research Level.....	72
Figure 7-18 Effect of Management Practices on Project Performance	73
Figure 7-19 Effect of MP on Performance	74

Figure 7-20 The Effect of MPs on Project Performance	75
Figure 7-21 The Effect of MP on Project Performance as a Function of Project Size, Research Level and Technical Challenge	76
Figure 7-22 Effect of Number of MPs on Project Schedule Performance	77
Figure 7-23 Effect of Number of MPs x Rigor versus Schedule Performance	78
Figure 7-24 Number of MPs versus Effect on Project Budget Performance.....	79
Figure 7-25 Number of MPs x Rigor versus Project Budget Performance	80
Figure 7-26 Innovation Goal Level versus Project Research Level	81
Figure 7-27 Technical Readiness Level versus Project Research Level	82
Figure 7-28 Initial TRL versus Innovation Goal	83
Figure 7-29 Technical Challenge (Innovation Goal – Initial TRL).....	84
Figure 7-30 Number of Management Practices versus Technical Challenge.....	85
Figure 7-31 Effect of Risk Management Practice on Achieving Innovation Goal.....	86
Figure 7-32 The Use of CLCA versus MP Effect on Innovation	87
Figure 7-33 CLCA Rigor versus the Effect of MPs on Innovation	88
Figure 7-34 The Effect of MPs and Technical Challenge on Innovation Goals.....	89
Figure 7-35 Trend Lines for the Effect of Management Practices on Achieving Innovation Goals.....	90
Figure 7-36 Postulated Effect of Rigorous MPs on Innovation.....	92
Figure 7-37 Current MP Effect on Innovation versus	93
Figure 7-38 Current Experience with Management Practices	94
Figure 7-39 Appropriate Project Size and Research Level.....	95
Figure 7-40 Appropriate Project for Structured Management Practices	96
Figure 7-41 Effect of Current Research Level and Size on Choice of Appropriate Research Level and Size for Rigorous Management Practices	96
Figure 7-42 Projects That Thought They Were Appropriate For Rigorous Management Practices	96
Figure 7-43 Project Personnel Position versus Appropriate Size for Rigorous Management Practices	96
Figure 7-44 Current Effect of MPs on Performance and Innovation Induce Selection of Project Size and Research Level for Rigorous Management Practices.....	96
Figure 7-45 Selections of Appropriate Research Level and Size by Small Research Projects.....	96
Figure 7-46 Selections of Appropriate Research Level and Size by Small Development Projects.....	96
Figure 7-47 Selections of Appropriate Research Level and Size by Large Research Projects.....	96
Figure 7-48 Selections of Appropriate Research Level and Size by Large Development Projects.....	96
Figure 8-1 The Tension Between Innovation and Management Control	96
Figure 8-2 Effect of Management Practices on Project Innovation.....	96

Acknowledgements

The author wishes to thank his advisors Professors Clancy and Browdy for their guidance. I also wish to thank the other members of my committee for their suggestions. Special thanks are due to the members of my doctoral study group for their encouragement and suggestions. Also thanks to Dr. Tom Irish for help with the statistical analysis.

Last but by no means least; I thank my wife and children for their patience, understanding, and support.

Hudson Guthrie

Washington University in St. Louis

May 2006

1 Introduction and Summary

The subject area for this dissertation is the *Management of Research and Development (R&D) Projects*. The research question that I addressed is *What Management Practices are Appropriate for the Research and Development (R&D) Project*. The focus of the study was to determine the effect of structured management practices at the level of the individual Research and Development (R&D) Project. Of particular interest was the effect of these Structured Management Practices on the innovation and productivity of the R&D Project.

Sub-questions that were addressed are:

- How are appropriate management practices different between R&D projects and production programs?
- How do rigorously structured management practices affect innovation at the R&D project level?

1.1 Research Methodology

A two-part approach, a case study followed by a widely distributed survey was used to investigate the effect of management practices on innovation and performance at the level of the individual R&D project. The case study and the survey both involved the R&D projects of a single company. The case study used the position of

an inside-observer to gather information from a small but diverse group of R&D projects. The survey involved sending a questionnaire to 500 technical leads and project managers in the research organization of the same company and then analyzing the responses. The in-depth knowledge gained from the case study provided a strong base from which to evaluate the survey responses. The large target population of the survey compensated for the size limitations of the case study.

An extensive literature search of related research supported both the basic premise of my proposed study and also supported the conclusion that this was an original effort.

1.2 Summary of Results

The research provided strong support for my hypothesis that rigorously structured production style management is inappropriate for R&D projects. Structured management practices and innovation are in tension, you can have one or the other, but not a full measure of both. The appropriate level of management practices is inversely related to the level of innovation desired. The study results also provide valuable knowledge for making significant improvements in the management of R&D projects.

2 Background

The area of this research is the *Management of Research and Development (R&D) Projects* and the specific topic of my research is the appropriateness of using highly structured management practices on R&D projects. The central reasons for conducting research on this subject are:

- Research & Development Projects are important to both individual companies and to the United States.
- The management of R&D projects is undergoing significant changes. The effects of these changes are not fully understood.
- I am personally interested in improving the management of R&D projects and specifically in the effect of that structured management practices have on the innovation of R&D projects.

2.1 Importance of Research

This research is important because it is critical that U.S. high-technology companies are both innovative and profitable and yet there are few real-world companies that can serve as models of how to be both innovative and profitable. The collapse of the entire “dot.com” industry points to the folly of innovation without

profits. However, the lack of innovation is just as fatal, as is clearly shown by the demise of the U.S. home electronic (non-computers) manufacturers.

Many prior research studies (see literature research, Section 3.0) examined various factors at the macro level of countries, entire industries, or individual companies. Many of these macro studies looked at the relationship between the total resources expended on R&D by a company and a company's profits. There are also studies on the relationship between the total resources expended on R&D by countries (or regions) and the growth of income in those countries (or regions). However, this study proposes to look at management and innovation at a micro-level, at the level of individual R&D projects. Some R&D projects work well, they mature valuable technology or innovative new products; but many R&D projects fail because of poor management and / or because of the lack of innovation.

2.2 R&D Project Environment

This research is focused on the *Management of Research and Development* at the micro or individual project level. By Research and Development (R&D) projects, I mean those entities formed by a company to discover and create new technologies, processes, and products. R&D project management is responsible for the day-to-day decisions about how the resources – funds, people, equipment, and time – that are allocated to the project are expended. However, the goal of all R&D projects is innovation – the creation of valuable and new products and processes.

The typical structure of a large high-tech US company is shown in Figure 2-1. The business units manufacture the current products that the company sells to make the profits. While the research group is responsible for discovering and developing the new technologies and products that the company needs so that it can continue in business. The upper management (headquarters organization) directs the activities of supporting business units and research groups. Upper management is also responsible for providing the resources that each R&D project needs and they are responsible for providing an environment that is conducive to discovery and innovation.

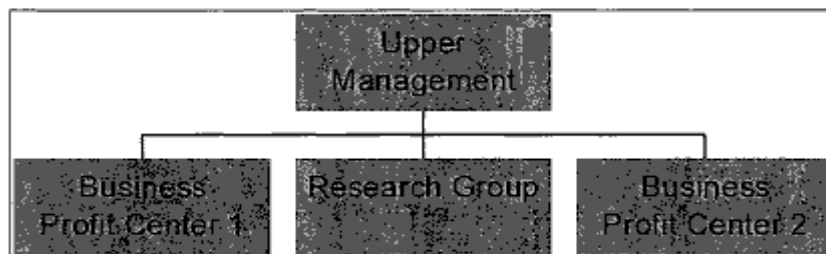


Figure 2-1 Typical Company Management Structure

The management of a typical large company has competing goals. First, they are responsible to the owners to make a profit. Second, to continue to make a profit, they must also invest company resources including profits to create new products.

There is a broad movement within all U.S. industries to increase profits and shareholder value. The US high technology industry in particular is undergoing tremendous change – reorganizations, takeovers, mergers, downsizing, rightsizing,

vertical integration, out sourcing, etc. There is a greater emphasis on meeting financial goals. Product lines are judged and often terminated based on their projected RONA (Return on Net Assets) and IRR (Internal Rate of Return). All of these changes have lead companies and business schools to see management practices as a way to increased productivity, quality, and company profits.

Many companies create structured management practices with the goal of increasing the profits of their business groups and production programs. For most companies, these structured management practices have been successful when applied to production programs – they reduce waste and increased profits. The also make it easier for upper management to review subordinate programs. As a result, many companies have established highly structured and standardized management practices; and have deployed them across all their business units and production programs. The production programs are evaluated for their adherence to these structured management practices and to their use of the management practices versus company standards.

The same market and environment forces have also brought increased scrutiny for R&D projects (Ford and Ryan 1996). However, there is no immediate return from R&D projects; many projects take five to ten years from the start of the basic research to the delivery of a new product to the customer. Companies not only wait years for a return on their R&D investment, but many R&D projects fail to create anything of value. In an attempt to improve the performance of their R&D organizations, many companies are starting to deploy the management practices that were successful with their production programs, to their research organizations and projects. While

improving the productivity of research and development is an objective for management in high technology companies, it is unclear what the effect on innovation is when the management practices that are used to increase productivity in manufacturing and in service industries are applied to R&D projects.

There is also an increased recognition that high-tech companies depend on the innovation of their R&D organizations to create and transfer to their business units' marketable technologies and products. Upper-level management, including CEOs, are pushing for increased innovation from their R&D organizations (Seil 2003). Thus, management must balance the push for short-term profits with the need for long-term investment in research.

2.3 Personal Interest

I have both significant interest in and personal experience with the management of R&D projects. It is the existence of the need and challenge of these competing goals of simultaneously increasing both profits and innovation that make this research a subject of great personal interest. How do you make R&D projects more productive without destroying the innovation process that was the initial reason for forming the R&D project? I want to understand what management practices are appropriate for R&D projects and on what program phase or time basis they should be used. The objective of my research was to provide answers to these questions so that R&D projects can be both productive and innovation.

Two additional reasons for choosing this research area and question was first my literature search (Section 3) discovered little prior research and second I had access to the required information and sources. A common set of management practices was being deployed across the R&D projects of a large high-technology company and the deployment timeline for the management practices was sufficiently short to make the study of the effect on project innovation and performance practical. Not only were there a large number of R&D projects from which to gather the needed data, but I also had first-hand observation of the effect of the practices as the formal management practices were applied to the management of a small but diverse group of R&D projects. These personal observations provided the foundation for the development of a survey instrument that was sent to the other R&D projects within the company. Selection of this topic allows me to combine my own observations and knowledge of the management of R&D projects and the results of this new research.

3 Related Theories and Research

There were two objectives of my search for supporting theories and prior research: the first was to insure that my proposed research was an original subject and the second was to determine if it was a sufficiently widespread problem to be worthy of research.

I concluded from my search for supporting theories and prior research that the management of R&D projects is a subject of both much interest and much debate. Many other researchers were investigating R&D management, innovation, and the interaction of new processes and organizations. The problem of how to manage R&D was widespread with support both for and against using structured management practices. There were several theories that interacted with the topic of R&D management and with my research question.

I was also pleased to note that while many of the papers support my own initial observations concerning R&D management, no one has performed a study similar to the one I plan to perform. There was also support for my proposed methodology of using both a case study and a survey.

3.1 Prior Research on Topic

My search for prior research on my topic was divided into two areas: "subject matter experts" (these were people who were recognized within the company as experts in the areas of R&D management or management practices) and published literature. I was interested in whether other researchers thought that this was an area for productive research and whether my research topic was original.

I discussed my topic and question with five "subject matters experts" that are involved with either technology innovation, the transfer of technologies from R&D organizations to business or production units, or with the deployment of management practices to production programs and R&D projects. While they all were able to provide insights to the individual elements, they knew of no prior analysis of my research question.

My literature search covered several topics: R&D Management, R&D Productivity, Leadership, Innovation, and Complex and Adaptive Organizations. While I was able to find many good documents, I did not find any source that analyzed the interactions between structured management practices and innovation at the level of the individual project. Many of the sources discussed ways to measure productivity or the need to align R&D to the company's business strategy. Most of the sources dealt with R&D productivity at the macro-level by studying the differences among companies. For example one paper discussed the effect of differences in R&D organizational and structural characteristics among pharmaceutical companies on the productivity of their R&D projects (Kamath 1996). Three sources found problems

between the movement to align R&D to business strategy and the drive for creativity and innovation.

3.2 Support for Structured Management Practices

This category of literature helped me to understand the reasoning behind the movement to apply structured management practices to R&D projects.

Several authors discussed the relative merits of centralized versus distributed R&D organizations (Francis 1984; Ginn and Rubenstein 1986; Larson and Gobeli 1991; Kamath 1996; Kapsales 1997). They also discussed how to make R&D projects more responsive to the needs of the production divisions. Several sources made the case to align R&D closer to company strategies, to the business units, and to use market pull to set priorities (Knott 1996; Meyers and Rosenbloom 1996; Purdon 1996; Takahashi 1997). The problems of transiting technology from the R&D organization to the production units was an area of extensive research (Ginn and Rubenstein 1986). There were sources advocating central management strategies (resource and portfolio management) to increase R&D productivity and there were also suggestions for integrating R&D projects with businesses units (Hildebrand 1995; McGrath 2004). Tapping a wider range of research, a closer alignment with business and customer needs were discussed as advantages of out-sourcing basic research (Ford and Ryan 1996; Florida and Branscomb 1998; De Propriis 2002; Edler, Meyer-Krahmer et al. 2002; Duke 2004). *One Size Does Not Fit All Projects* discussed how the degree of required technology and complexity directly drives the need for greater structured

management practices (Shenhar 2001). This study by Shenhar was very helpful to my research in that it added required technology and complexity to the relationship between structured management practices and the performance of development and production programs. There were also sources advocating a greater use of communication, monitoring, control, and other management practices (Liyanage and Greenfield 1999; Norrie and Walker 2004). And there was a source that discussed how organization structures and management systems can be employed to support the employment of project management practices (Kendra and Taplin 2004).

3.3 Against Structured Management and for Innovation

The theories and studies in this area by others provided the foundation supporting my own belief of the tension between structured management practices and innovation and were a central element to providing the foundation for my own research. These supporting studies make the point that in trying to make R&D more productive it is possible to destroy innovation.

Making R&D More Effective at Westinghouse, noted that the constant financial control associated with today's business climate; the third generation management approach to the selection of projects based on risk, return, competitive position and market impact; and the movement to tie R&D closer to business units can all be destructive to innovation and technical success (Foster 1996). The pressure to increase profits is fierce and managers' efforts at cutting costs are often shortsighted

and can have unintended negative effects on innovation and risk taking (Hymowitz 2005).

The Customer for R&D is Always Wrong, “The current fad of corporate management, taking a short-term view and distributing R&D assets to operating divisions, is like a farm investor who is interested only in harvesting and will not invest in planting ----- we know what happened to that farmer. That farmer—ends up with no crop and no harvest.” (Frosch 1996) This book also noted that:

- *Production Divisions and the supporting R&D organizations are on different time scales.*
- *To suck up the entire R&D effort into day-to-day business is to destroy the possibility of new business.*
- *To be innovative and productive the R&D project must be capable of connecting all kinds of knowledge and must be able to think about the future.*
- *In measuring productivity*
 - *You cannot measure the future*
 - *You cannot quantify the value of single R&D projects*
- *IRR of R&D at GM was about 70%. Many projects are failures but a few are a big success.*

Many studies suggest that structured management and high levels of innovation cannot co-exist. Sources also advocated moving from traditional to more imaginative management practices in order to foster innovation (Single and Spurgeon 1996; St. Germain 1997; McAdam and Keogh 2004). Several companies recognized this tension and created special organizations and processes (Foster 1996). For example, the 3M Corporation allocates some of their R&D funds directly to their researchers to be used solely at the direction of the researcher, with no management oversight. Xerox created new innovation processes and the Technology Enterprise (Loutfy and Belkhir 2001). Boeing has created the “Chairman’s Innovative Initiative”

to remove high-potential startup programs from their normal management oversight (Seil 2003).

One source discussed the recent trends in restructuring R&D organizations and the effect on management practices (Brockhoff, Koch et al. 1997). A second source discussed the advantage of the central R&D organization in generating innovative products (Chester 1997). Moreover, a third source discussed the problems with outsourcing research (Fichman and Kemerer 1999). Companies that used technology push, rather than customer pull, were cited as producing radical product innovation (Salavou and Lioukas 2003). Another source discussed how some mature companies lose their innovative spirit, but how other mature companies stayed innovative (Buckler 1997). Two source discussed the need for long term (ten-year) planning to foster innovation and the need to overcome management obstacles (Hollins 2000; Topalian 2000). In addition, the processes and practices that several companies used to foster innovation was the subject of considerable research (Hargadon and Sutton 1997; Garner 2000; Lapierre and Giroux 2003). Several sources discussed the importance of innovation to the health of both companies and countries (Znaiden 1996; Yates and Skarzynski 1999; Vence, Guntin et al. 2000; Jeffcutt and Pratt 2002; Zachariadis 2003; Schneider 2004).

3.4 For Productivity and Innovation

This area of prior research is important to my own research because it discusses what management can do to increase R&D productivity and innovation.

The most relevant report was *Why Some R&D Organizations are More Productive Than Others* (Bean 1995). A measure for productivity was developed and used to determine the seven factors that most affect R&D productivity. The seven factors were:

- *The greater the intensity (the larger the share of resources spend on R&D) the greater the growth in R&D productivity will be at the company.*
- *The greater the level of basic and applied research the greater the growth of the company.*
- *The longer the planning and review cycle the greater the growth. The most productive firms had 4-6 year planning and 2-3 year review cycles.*
- *The greater a company's emphasis on external sources of knowledge the greater the growth.*
- *The higher the expectations for R&D contributions the greater the growth the company will experience.*
- *The greater the complexity in the R&D organization the lower the growth will be in R&D productivity. Specifically the greater the percentage of R&D carried out in business units (versus central labs) the lower the growth.*
- *The greater the perceived importance of government regulatory requirements as a factor in R&D project selection, the lower the growth. (R&D can't be reactive.)*

Bean also developed the relationships between different types of R&D and the productivity in a company's R&D as shown in Figure 3-1. Bean concluded that basic research contributes the most to R&D productivity. As discussed in the next section on methodology, these definitions for different types of R&D was used to categorize R&D projects.