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Application Of Total Quality Management To Research And Development: An Historical Perspective

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APPLICATION OF TOTAL QUALITY MANAGEMENT TO RESEARCH AND DEVELOPMENT: AN HISTORICAL PERSPECTIVE

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Abstract

This paper discusses the historical applications of Total Quality Management (TQM) to Research and Development (R&D). Research aimed at establishing an effective model for the application of TQM philosophies and tools to the R&D environment must start from this historical perspective. The emphasis of this paper is on the relationship of quality tools and techniques to the application of TQM in R&D, providing the foundation for further model development.

The scope and definition of R&D is presented and is followed by an overview of the TQM philosophy and its associated tools and techniques. Special attention is given to defining performance measures for R&D as a back-drop to measuring the success of TQM actions in an R&D organization. Implementation models for TQM in R&D, which are derived from an extensive review of the open literature, are also examined. Industry controversies surrounding the applicability of TQM philosophies and tools in professional work environments is discussed. The paper concludes with a brief discussion of future work that will be necessary to develop a complete model for the application of Total Quality Management to R&D.

Introduction

In recent years the United States has met with increasing competition from Europe and East Asia. Current world events are the catalyst for present global economic changes that are partly responsible for a reshaping of the U.S. industrial landscape. The promise of greater international cooperation has resulted in a significant decline in military spending. The "New World Order", however, needs the resulting peace dollars to aid financially troubled nations of the former Communist Bloc.

These world events have combined with the already serious problems of foreign competition to produce a shrinkage of available dollars for investment in new markets. This has resulted in less available money for research and innovation at a time when it is needed the most in order to retain competitiveness. This dilemma facing U.S. industry today has potentially serious consequences. TQM, however, may improve the effectiveness of industrial research and development in this country so that it can meet the demands posed by this new economic climate.

R&D : Definition and Focus

In order to relate TQM philosphies and tools to R&D, one must begin with an understanding of R&D and the innovation process. Jain and Triandis [1] paraphrase the National Science Foundation classification and definition of R&D as follows:

Basic Research. The objective of Basic Research is to gain "a fuller knowledge or understanding of the subject under study, rather than a practical application thereof." For industry, "such investigations may be in fields of present or potential interest."
Applied Research. Applied Research is directed toward gaining "knowledge or understanding necessary for determining the means by which a recognized and specific need may be met."
Development. Development is the "systematic use of the knowledge or understanding gained from research, directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes."

Other classifications for R&D are given in the literature, but they merely expand upon this basic definition. For example, Pappas and Remer [2] define R&D by the stages of *Basic Research, Exploratory Research, Applied Research, Development* and *Product Improvement. Science Indicators* (Jain and Triandis [1]) categorizes R&D functionally as *Basic Research, Applied R&D* and *Innovation.* Innovation, in this case, is defined as "combining understanding and invention in the form of socially useful products and processes".

This paper will concentrate on applied R&D and innovation. Basic research is not considered for two reasons. First, it is difficult to find meaningful measures of success for this type of work (in fact, it may be inappropriate). Second, according to the National Science Foundation (NSF) [5], the majority of government and industry R&D dollars are spent in applied research. This is shown graphically for basic research in Exhibit 1 on the following page. Although the percentage of dollars for basic research has risen from 14% to 17.6% of total R&D dollars since 1989, this is mainly due to the reduction in military spending and likely doesn't reflect a long term strategy to increase the percent of dollars allocated to basic research. Industry

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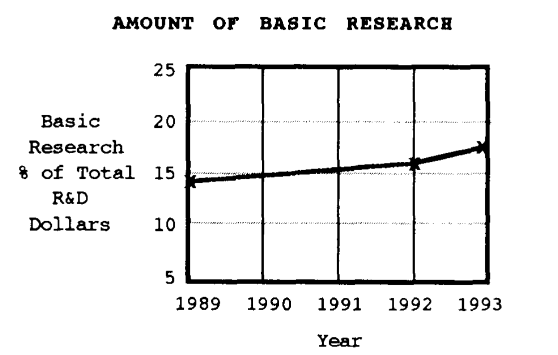

EXHIBIT 1 The NSF Past and Projected Basic Research Budget.

basic research has traditionally run at about 6% of total R&D dollars (NSF Fiscal Year 1993 Budget). Therefore, government and industry, together, focus about 90% of total R&D dollars on applied R&D. Since this is where the U.S. spends its money, it is also the area that will receive the most benefit from TQM in R&D.

A schematic of the innovation process is shown in Exhibit 2. The R&D group is organized to take advantage of new ideas and opportunities. Inputs are fed into the process and the indicated outputs result. Along the way, various interfaces with Engineering, Finance and Marketing occur. These interfaces are defined as internal customers of the R&D group. They generally utilize the R&D outputs to obtain outcomes aimed at benefiting the overall organization. These benefits are derived from meeting or exceeding external customer desires and expectations. Similar innovation models are presented in the literature by Radhakrishna and Varadarajan [6] and Brown and Svenson and [3].

Overview of Total Quality Management

Although TQM came into fruition in Japan almost twenty years ago, its introduction into the United States occurred only as recently as the early 1980's. Widespread recognition of this new management philosophy has taken place in the past five years. TQM has spread from repetitive manufacturing to the service industry and is now moving into R&D and higher education. There has been one notable exception to this in the R&D area. The Borg-Warner Research Center, which was cited by Schainblatt [4] in 1982 for its vanguard customer-focused approach to productivity measurement of scientists and engineers, demonstrated an early interest in Japanese-style management.

A concise, uniformly accepted definition of

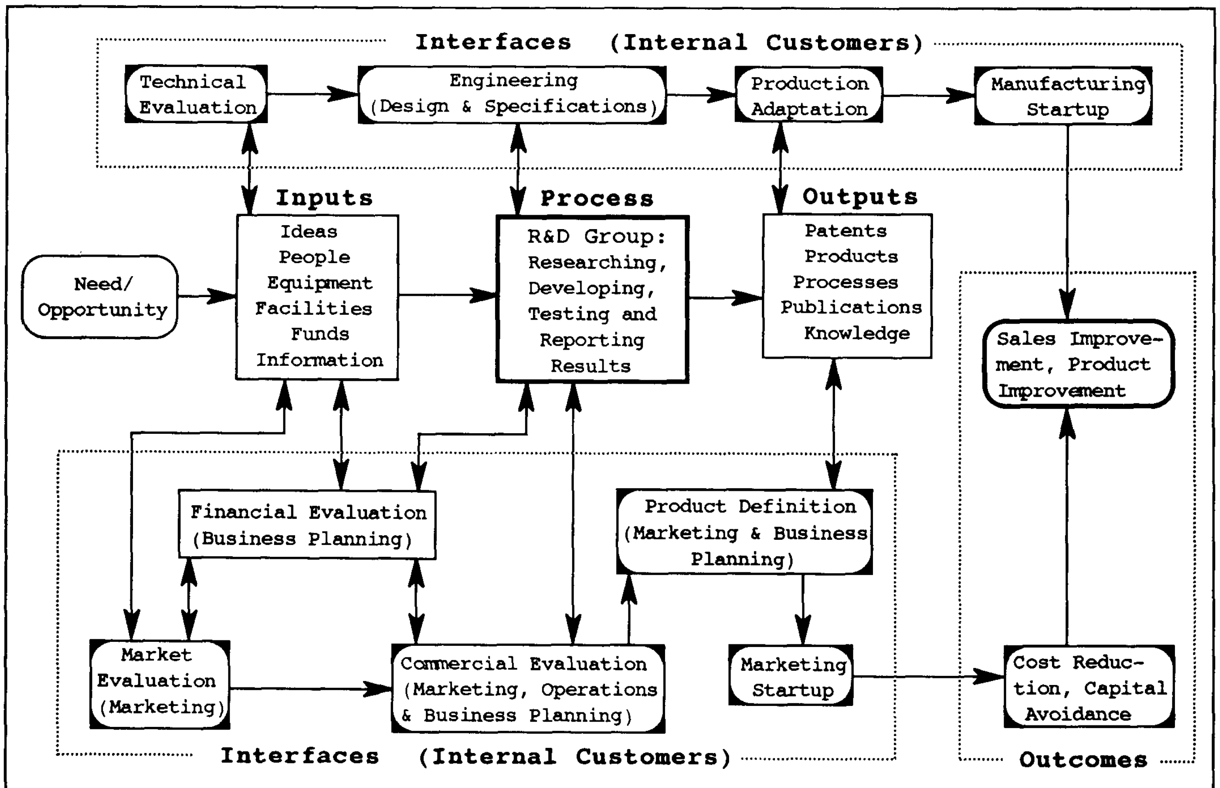

EXHIBIT 2 Typical Innovation Process Flow Chart

TQM is not found in the literature. Rather, its varied characteristics or principles of implementation are often listed. The terminology of TQM includes expressions such as "*continuous improvement* ", "*customer focus*", "*empowerment of the worker* " and "*supportive business culture* ". Two typical TQM definitions that have been found are included here. Stimson [7], of Advanced Technology Corporation defines TQM as:

"A philosophy and [set of] management principles that foster a continuously improving organization. The application of quantitative and qualitative management tools. A means to integrate fundamental management techniques, existing improvement efforts, and tools under a disciplined approach directed toward customer satisfaction."

Clark [14], of the Department of Defense (DOD) Special Projects Office, gives the following definition of TQM as it applies to R&D.

"Continuous process improvement activities involving everyone in an organization in a totally integrated effort toward improving performance at every level. This improved performance is directed toward satisfying such cross-functional goals as quality, cost, schedule, mission need, and suitability. TQM integrates fundamental management techniques, existing improvement efforts, and technical tools under a disciplined approach focused on continuous process improvement. The activities are ultimately focused on increased customer/user satisfaction."

The various philosophies of TQM as set forth in the above definitions have found relatively easy translation in manufacturing organizations where formal quality assurance infrastructures and measurements already exist. Translation of the TQM philosophy into practice normally centers around the use of a few key quality improvement tools. A list of typical tools associated with TQM and described in the open literature is shown in Exhibit 3. The results of a typical TQM implementation in the manufacturing environment can usually be observed with relative ease in the form of items such as reduced scrap and fewer customer complaints. If the results are not satisfactory, a modified approach, perhaps using new tools, can be implemented.

This heuristic approach to the implementation of TQM is vital for many organizations as they try to find the unique structure of TQM that works best for their particular situation. Needless to say, the selection of tools to be used and the measurement of achieved results plays an important role in this process. The creation of an effective model for TQM in R&D, however, requires a re-examination of TQM tools and measurement techniques and their applicability.

1. Process and Flow Charting
2. Pareto Analysis
3. Ishikawa/Cause-and-Effect Diagrams
4. Statistical Process Control
5. Quality Function Deployment
6. Brainstorming and Nominal Group Technique
7. Design of Experiments
8. Surveys, Interviews and Focus Groups
9. Forcefield Analysis
10. Scatter Diagrams
11. Stratification
12. Benchmarking
13. Histograms and Bar Charts
14. Process Capability Analysis
15. Stream Analysis

EXHIBIT 3 Typical TQM Tools

TQM and R&D Productivity Measurement

As indicated earlier, an important component of TQM implementation in any organization is the development of realistic performance measures against which to assess the effectiveness of quality improvement actions. Performance or productivity measurement of the knowledge worker and the R&D function is less developed than in the manufacturing sector. It is a topic that many have struggled with over the years. Productivity measurement in R&D is tied to the individual performer as well as to the performance of the R&D organization.

Individual performance stresses items such as the number of patents received, papers published, literature citations and books written. Moser [8] conducted a survey of companies in the mid-1980's to assess the status of performance measurement in R&D. The three most often used measures were quality of output, degree of goal attainment, and amount of work completed on time. These were followed by the more traditional measures mentioned previously. A popular method of measuring performance, reviewed by Pappas and Remer [2], is the Peer Rating Approach. This method simply involves R&D professionals rating each other.

R&D organizational productivity measurement is even more elusive than individual performance measurement. In 1965, Seiler [9] published various financial appraisal methods including selected financial ratios, cash flow analysis and income statement evaluations. He stated, however, that the effectiveness of these measures is constrained by factors such as the time span between research and product, the periodicity of research productivity, and serendipity. In 1983, Patterson [10] reported on discounted cash flow analysis for the ALCOA Laboratories over the previous ten year period. He observed that year-to-year performance was not a good indicator of

R&D effectiveness and that at least ten years would be required to obtain any significant measure. He concluded, however, that long-term financial tracking could provide some benefit. There is a risk that measurement methods could change over such a long time span, rendering earlier data obsolete. Schainblatt [4] provides a good overview of corporate R&D productivity measurement status in the early 1980's. He highlights the Borg-Warner Internal Objective Rating approach and the Program Value Algorithm. In 1985, Pappas and Remer [2] published a useful article on R&D productivity measurement and presented a framework for qualitative versus quantitative measurement, which is reproduced in Exhibit 4. The limitation to Applied R&D would indicate that semi-quantitative and quantitative evaluation techniques are in order. None of these approaches to measurement, however, has been documented as having found widespread support in industry.

RESEARCH FUNCTION	EVALUATION TECHNIQUE
BASIC RESEARCH	QUALITATIVE
EXPLORATORY RESEARCH	↓
APPLIED RESEARCH	SEMI-QUANTITATIVE
DEVELOPMENT	↓
↓ PRODUCT IMPROVEMENT	QUANTITATIVE

EXHIBIT 4 Research Function Versus Evaluation Technique.

TQM Implementation Models for R&D

The literature also contains several attempts to describe TQM implementation models suited for the R&D environment. Tenner [11] promotes a six-step process improvement model designed to bridge the gap between manufacturing and non-manufacturing applications of quality improvement methods. This model, which is a slight modification of the Deming or Shewhart Cycles, is reproduced in Exhibit 5. Tenner provides some insight into each step and hints at the effective use of quantitative tools, but fails to make any concrete suggestions. In a recent article, Roberts [12] reviews the Deming cycle and then provides a good start by explaining a few quantitative tools that might be used. Tribus [15] hints at a model of TQM in R&D and gives some practical applications of flow charting, Ishikawa diagrams and Quality Function Deployment.

The U.S. Government has also made its contribution to the application of TQM to Research and Development. Clark [14], of the Air Force Special Projects Office, recently published the results of a TQM implementation program in the Air Force Human Resources Laboratory. A model called "Method for Generating Efficiency and Effectiveness Measures (MGEEM)" was employed. Quality teams were formed and key result areas were identified, along with performance indicators. A unique feature of the system was the use of statistical process control charting with subjective data. This was an interesting experiment that yielded mixed results. Some considered the use of this quantitative tool inappropriate for measurement in an environment characterized by subjective, creative activity.

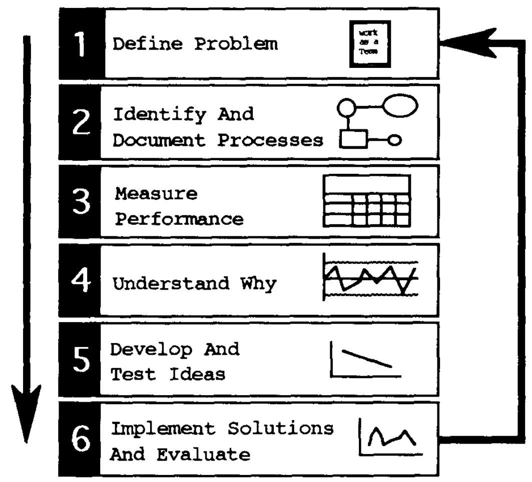

EXHIBIT 5 Tenner's Six-Step Improvement Model for R&D.

Another snag in the Air Force Laboratory TQM implementation project was the difficulty in defining leadership roles within TQM. The authors have observed this same problem occurring in industry today. Dubbed the TQM "Management by Committee Syndrome", it is the result of the hands-off management approach when inter-disciplinary teams reach impasses and there is no single individual with final decision-making authority. In highly charged projects with sophisticated products and dogmatic functional representatives, impasses are very common. Unfortunately, the TQM manager-as-consultant role runs contrary to this type of environment. These suggestions for TQM implementation models have not found common usage in industry, just as was the case with the suggested approaches to R&D productivity measurement.

Conclusion and Future Direction

It is evident that a reassessment of TQM tools needs to be conducted. There is a general

lack of guidance in the literature on the applicability of various TQM tools and measurement techniques for the knowledge worker environment. Although some tools and some models are proposed, there appears to be no published work that is comprehensive, practical and universally accepted. This is an area that requires special attention and a great deal of future research.

A recent article in the Wall Street Journal [13] cites a study conducted by the American Quality Foundation that points to this problem. In the article, the author claims that despite plenty of talk and action, many American companies are struggling in their implementation of quality-improvement efforts. To quote Ozan of Ernst & Young, "A lot of companies read lots of books, did lots of training, formed teams and tried to implement 9,000 new practices simultaneously. You don't get results that way." Further research in this area is needed to help build solutions to the quality implementation problems facing American industry today.

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