The International Center for Research on the Management of Technology

Time versus Market Orientation in Product Concept Development: Empirically-based Theory Generation

Gary Burchill*
Charles H. Fine

May 1994   WP # 107-94

SLOAN WP# 3694

* U.S. Navy

Sloan School of Management
Massachusetts Institute of Technology
38 Memorial Drive, E56-390
Cambridge, MA   02139-4307

Acknowledgement

Abstract

In collaboration with industry partners, a normative model of the product concept decision process was developed, supported with tools and techniques, and codified as a decision support process for product development teams. This process (Concept Engineering) was then introduced into a number of product development teams in different companies. A comparative analysis of actual product concept development activities, with and without the use of Concept Engineering, was conducted. All of the observed teams viewed time to market as a critical measure of their success. However, the development processes differed significantly depending on whether relatively more emphasis was placed on time or market considerations. Key variables associated with the product concept development decision process and time-to-market dynamics were identified and a theory of the concept development process was developed using the inductive system diagram technique, a research methodology developed in the course of this work.

We believe this work contributes to the operations management literature in three ways. First, it introduces a very detailed, structured decision process for product concept development, enhancing the literature on Quality Function Deployement (QFD). Second, it presents a theory of product concept development that can improve understanding of success and failure in product concept development. Third, this work develops new methodology (Inductive Systems Diagrams) for field work in operations management. This methodology marries the grounded theory methods familiar to sociologists with causal-loop modeling familiar to systems dynamicists, yielding a rigorous tool for systematically collecting, organizing, and distilling large amounts of field-based data.

1. Introduction and Motivation

The simplified model of a generic product development process in figure (1) suggests that product concept development is one of the earliest tasks to be completed in the development of any product. A reading of the vast and rapidly growing product development literature as well as a survey of existing practice suggests however, that this "front-end" of the product development process is not well understood. For example, in Cooper and Klienschmidt's (1986; p.76) study of 252 new product case histories in 123 firms "the weakest rated activities were the 'up front' or pre-development activities, namely initial screening, preliminary market assessment and detailed market study." Supporting this finding, many studies conclude there is potential benefit from research on the product development process, particularly the early activities (Rothwell, et al.. 1974, Cooper & Klienschmidt 1986, Clausing & Pugh 1991, NRC 91, Mahajan & Wind 1992).

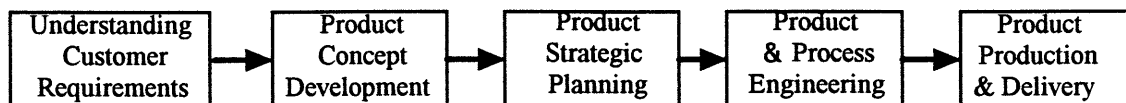| Understanding Customer Requirements	→	Product Concept Development	→	Product Strategic Planning	→	Product & Process Engineering	→	Product Production & Delivery

Figure (1): Simplified model of generic product development process

In pursuit of this identified need, a new process, termed Concept Engineering (Burchill & Shen 1992, Burchill 1993 a,b) was developed for integrating customer driven requirements into structured design activities. Concept Engineering is a detailed, structured process for enhancing the initial stages of Quality Function Deployment (QFD). This paper outlines the evolution and essential features of the Concept Engineering process. In addition, we present a new theory for the product concept decision process. This theory was generated from a rigorous comparative analysis of the application of Concept Engineering by several product development organizations.

In the remainder of section 1, we describe the Concept Engineering methodology and its evolution. Section 2 describes the research design, philosophy and implementation, including the inductive system diagramming process, a research methodology developed in the course of this work. Section 3 describes the principal findings of the research, in the form of a causal-loop model of concept development dynamics. Section 4 explains the key insights provided by the model. Section 5 presents a discussion of plausible rival hypotheses to the proposed theory and findings. Section 6 provides a summary and conclusion.

We believe this work contributes to the operations management literature in three ways. First, it introduces a very detailed, structured decision process for product concept development, enhancing the literature on Quality Function Deployment (QFD). Second, it presents a theory of product concept development that can improve understanding of success and failure in product concept development. Third, this work develops new methodology (Inductive Systems Diagrams) for field work in operations management. This methodology marries the grounded theory methods

familiar to sociologists with causal-loop modeling familiar to systems dynamists, yielding a rigorous tool for systematically collecting, organizing, and distilling large amounts of field based data.

1.1 Concept Engineering Description

Concept Engineering is a structured process, with supporting decision aids, for developing product concepts by a product development team. The process alternates between the level of thought (reflection) and level of experience (data) (Kawakita 1991) in a way that allows participants to understand what is important to the customer, why it is important, how it will be measured and how it will be addressed in the product concept. Concept Engineering has five stages each with three steps[1] (see figure 2).

Stage 1: Understanding Customer's Environment

The objective of Stage 1 is for the team to develop empathy for the customer in the actual use environment of the product or service. Stage 1 consists of developing a plan for the team's exploration and conducting the exploration with cross-functional teams at the customers' sites. Images of the customer's use environment are selected and analyzed with a KJ diagram[2] (Ofuji 1990, Kawakita 1991, Shiba et al. 1991). This "Image KJ" is a link to the customer's real world and acts as a common mental map of the customers' environment for all future product concept decisions.

Stage 2: Converting Understanding into Requirements

Stage 2 distills what was learned from the customer exploration into a small set of well understood, carefully articulated, critical customer requirements. In this stage, the Image KJ developed in Stage 1, is used as a contextual anchor in the development of requirement statements to ensure they are consistent with the customers' environment. The transformation process converts the customer's language, often laden with subjective language, into an objective, fact-oriented customer requirement statement better suited for use in downstream development activities (Ofuji 1990). A small set of the vital few from the useful many requirements is selected and the relationships between them are analyzed.

Stage 3: Operationalizing What Has Been Learned

The goal of Stage 3 is to ensure that the key customer requirements are clearly, concisely, and unambiguously communicated in measurable terms. The key customer requirements are validated with customers, operationally defined in measurable terms and the resulting information is displayed in such a way that the relationships between requirements, metrics and customer feedback is easily seen. This stage concludes with the development of a traditional Quality Function Deployment (QFD) quality chart and operational definitions (Deming 1986, Hauser &

---

[1] For more complete documentation contact the Center for Quality Management (617) 873-2152.

[2] KJ diagrams structure detailed language (vs. numerical) data into more general conclusions using semantic and abstraction guidelines. They are one of a family of tools invented by Jiro Kawakita and known as the KJ method (Kawakita 1991).

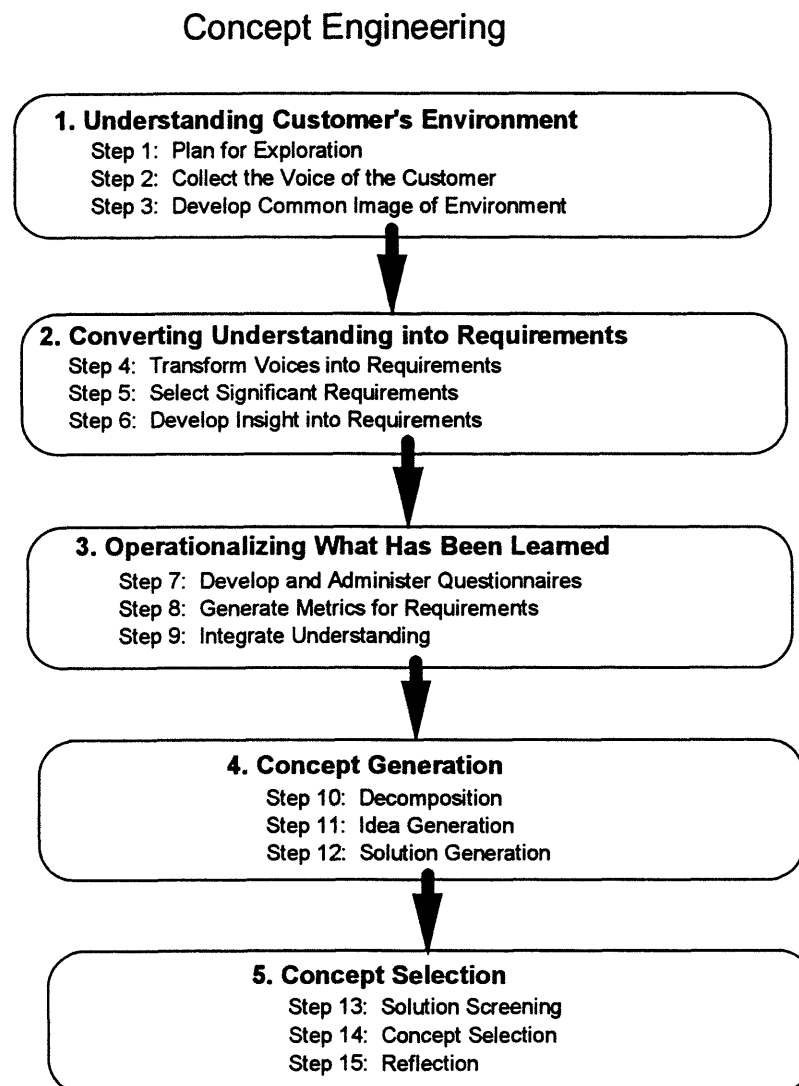Clausing 1988, Juran 1988, Akao 1990) to integrate customer requirement understanding clearly and concisely.

Concept Engineering

1. Understanding Customer's Environment
Step 1: Plan for Exploration
Step 2: Collect the Voice of the Customer
Step 3: Develop Common Image of Environment

2. Converting Understanding into Requirements
Step 4: Transform Voices into Requirements
Step 5: Select Significant Requirements
Step 6: Develop Insight into Requirements

3. Operationalizing What Has Been Learned
Step 7: Develop and Administer Questionnaires
Step 8: Generate Metrics for Requirements
Step 9: Integrate Understanding

4. Concept Generation
Step 10: Decomposition
Step 11: Idea Generation
Step 12: Solution Generation

5. Concept Selection
Step 13: Solution Screening
Step 14: Concept Selection
Step 15: Reflection

Figure (2): The five stages and 15 steps of Concept Engineering

Stage 4: Concept Generation

This stage marks the transition in the development team's thinking from the "requirement or problem space" to the "idea or solution space." The complex design problem is decomposed into smaller, independent sub-problems based on the customer's perspective and also from the engineering development perspective. The team creates, through individual and group collaboration efforts, an exhaustive list of ideas (both feasible and unfeasible) for each sub-problem; working first from the customer's vantage point before exploring the internal engineering perspective. Generated ideas are systematically reviewed and enhanced. This stage concludes when each team member creates their ideal solution concept from the generated list of ideas.

3

Stage 5: Concept Selection

In the final stage of Concept Engineering, building on a methodology developed by Pugh (1981), a product concept is selected for downstream development. The team thinks individually and collectively, seeks expert help, and experiments in the laboratory in an iterative process of combining and improving initial solution concepts to develop a small number of superior concepts. The "surviving" complete concepts are evaluated in detail against customer requirements and organizational constraints in order to select the dominant concept(s). When completed, an audit trail exists for tracing the entire decision process from project scope determination through detailed concept analysis as the Concept Engineering process is self-documenting.

1.2 Concept Engineering Evolution

Concept Engineering had its genesis in the teachings of Professor Shoji Shiba (Shiba 1993). Professor Shiba presented several Total Quality Management decision aides in the context of a quality deployment case study. Coupling Shiba's work with Dr. Deming's concept of operational definitions (Deming 1986) led to the outline of a process for operationally defining customer requirements which one author (Burchill) used to design, patent and license a product.[3] This initial effort at MIT evolved into a two year collaborative effort among member companies of the Center for Quality Management (CQM)[4] and MIT to apply the Plan-Do-Check-Act cycle (Ishikawa 1985) to the development of the Concept Engineering process. During this two year period, representatives from three companies and MIT met collectively (and often intensively) to discuss objectives and findings and worked independently pursuing particular assignments. A high level of collaboration between one author (Burchill) and CQM company practitioners allowed insights into what worked and didn't work to be rapidly spread among participating companies. (An innovation at one company could be applied at another company usually in the matter of days or weeks at most.) The resulting rapid feedback on process improvement opportunities was a major contributing factor in Concept Engineering's development into a complete decision support process (Burchill 1993a, 1993b).[5]

A significant advantage of practitioner research partners is the ability to focus effort on substantive issues. "Practitioners often bring the pursuit of irrelevant or ill-conceived lines of inquiry to a rapid halt, correcting or refining the questions asked in ways that lead to sharper formulation and more productive research" (Whyte et al. 1991; p. 54). In this research effort, the problems investigated were those which product development professionals in the firms

---

[3] The saltwater flyfishing stripping basket, which has been patented and licensed, has been reviewed in the New York Times and was widely acclaimed in the flyfishing trade press in 1992 and 1993.

[4] The Center for Quality Management is a not-for-profit consortium of over thirty companies headquartered in New England which are committed to the development and diffusion of Total Quality Management.

[5] Although the term Decison Support System has generally been applied to problem-solving assistance systems using computers (Elam, et.al. 1986), there is evidence that pencil and paper delivery systems are just as effective as computerized versions (Cat-Baril & Huber 1987). Therefore, we use the term Decision Support Process (DSP) to refer to a problem-solving system without the requirement to include computers. We define a complete DSP as one that supports the decision maker in all phases of the problem solving process.

4

were facing. As a result of the collaboration and the investment made by the organizations in researching "their" problems, a built-in incentive for implementing "their" solutions existed. This provided the opportunity for a detailed inter/intra company comparative analysis of the product concept decision process.

2. Research Design

As the details of the Concept Engineering method were being finalized, we evolved a research design to develop a theory for understanding the product concept decision process and to generate data for evaluating the effectiveness of Concept Engineering as a method for developing product concepts. In the proposed design, each of three participating companies would identify two pairs of development teams. Each pair would be approximately similar in scope, demographics, and history. One team from each pair would be randomly assigned to use the Concept Engineering process while the other team would use Pugh's Concept Selection process (Pugh 1981) which is similar to Stage 5 of the Concept Engineering process. The teams would be observed and interviewed by multiple researchers using a variety of measurement methods. This design, agreed upon by representatives (a chief operating officer, a general manager and a director of product development) of the participating companies, attempted to minimize internal, external and construct validity threats (Cook & Campbell 1979, Kidder & Judd 1986).

The actual implementation fell short of the research design. All three companies that agreed to participate in the study in the fall of 1991 sent representatives to the two-week training session in January 1992. It was immediately obvious that the first teams were not assigned on a random basis – two companies subsequently admitted selecting initial teams with a high likelihood of success. As a result, random assignment to address some of the traditional threats to validity (selection, maturation, etc.) did not take place in this study. With respect to the control groups, two companies provided a non-Concept Engineering comparison team in the spring of 1992. However, these teams were assigned on the basis of availability rather than on matching characteristics of scope, demographics, etc. (The third company decided that all development activities would use Concept Engineering for product concept development.) As a result, the study of matched comparison groups called for in the research design did not materialize.

Ultimately, the number and nature of cases investigated was significantly fewer than anticipated. Therefore, any attempts to evaluate the relative effectiveness of Concept Engineering were now subject to considerable threats from rival plausible hypotheses. However, we were able to extensively observe five development teams, three that used Concept Engineering and two teams that did not. In addition, in two companies it was possible to make historical comparisons with the prior project completed by development teams assigned to use Concept Engineering. For each development team studied, a researcher typically attended every scheduled meeting, approximately 80 hours per team, and conducted two to three in-depth open-ended interviews with each member of the team and their managers;

each interview lasting at least one hour. Therefore, although they lacked random assignment, the available teams did provide a rich comparative setting to explore for theory generation.

2.1 Theory Generation

In theory generation research, data collection and analysis are conducted in an iterative process (Glaser & Strauss 1967, Barton & Lazarsfeld 1969, Miles & Huberman 1984, Schein 1987). "Qualitative research in general and theory generation in particular, is essentially an investigative process, not unlike detective work. Observing one class of events calls for a comparison with a different class. Understanding one relationship reveals several facets which have to be teased out and studied individually. The theory is developed in large part by contrasting, comparing, replicating, cataloguing, and classifying the subject of the study" (Miles & Huberman 1984; p.37). Without joint data collection, coding, and analysis, the subtleties in the area of study, and opportunities to investigate them, can be lost. As a result, the evolving nature of desired information precludes the establishment of detailed, pre-specified sampling plans (Glaser & Strauss 1967, Barton & Lazarsfeld 1969). In the words of C.I. Lewis (1929) "Knowledge begins and ends in experience; but it does not end in the experience in which it began."

Glaser and Strauss (1967) make an additional distinction between sampling required for theory generation and theory verification. Theoretical sampling, sampling designed to develop rich comparative settings, is conducted to identify and investigate variables and their interrelationships in the generation of theory. Statistical sampling is conducted to collect evidence to be used in descriptive or verification studies. As a result, they state that the researcher generating theory need not use random sampling techniques. A brief overview of the theory generation literature (with further references) appears in the Appendix.

2.2 Research Methodology: Inductive System Diagrams

In this research, the Inductive System Diagram methodology (Burchill 1993a, Burchill & Kim 1993) was developed for building a theory (which meets the criteria described in the Appendix) of product concept development from intensively-gathered field data. Inductive System Diagrams combine aspects of Grounded Theory methods (Glaser & Strauss 1967, Glaser 1978, Strauss 1987) and System Dynamics (Forrester 1968, Goodman 1974, Randers 1980, Sterman 1989). Grounded theory approaches are used to develop the variables which have a great deal of explanatory power and are intimately tied to the data. The cause and effect relationships among these variables are then shown using causal-loop diagramming techniques from System Dynamics. This combination of grounded theory and causal-loop diagramming allows researchers to generate and communicate substantive theories intimately tied to the data which can be evaluated against the criteria of: verifiable data, explicit inferences and disconfirmable predictions.

To illustrate the methodology, an example of the use of ISD in the development of our theory for product concept development activities follows. The specific coding and analysis examples come from teams using the Concept Engineering method. All field notes were

exhaustively coded and analyzed (an average of three hours of off-site effort for every hour of recorded notes) by one author (Burchill) and/or a research assistant. Additionally, much of the coding and analysis was reviewed by colleagues in a Field Research Methods Seminar.

One team went from kick-off to product requirement determination in less than two months and on to final product concept selection in only two more months – considerably faster than historical performance. As a result, Development Time was selected for focused investigation (theoretical sampling/axial coding). Examples of relevant quotes from field notes (italics) are provided to illustrate the ISD process.

"(On the previous project) This process would have provided a clearer vision[1], a straighter path to the end result[2]. I see the process saving time[3] by eliminating missteps[4]." - Engineering Development Manager

Coding this statement for variable development might create categories for: 1) Design Objective Vision, 2) Straighter Path, 3) Development Time, and 4) Missteps. Straighter Path and Missteps are conceptually similar and at a higher level of abstraction could both be dimensions of the category Misdirected Effort. These variables can be diagrammed as follows[6]:

Design
Vision ⟶ Misdirected ⟶ Development
Clarity   O   Effort   S   Time

This diagram indicates that as Design Vision Clarity increases Misdirected Effort decreases causing Development Time to also decrease.

The constant comparison method employed in a Grounded Theory approach requires that events be compared to other incidents in the same category. Accordingly, the following incident, from the same team, which relates to Design Vision Clarity was compared to the instance above.

"Someone that has buy-in[1] understands the how and why and can explain to other people horizontally or vertically[2]. Along with buy-in is a belief or passion[3]. I think that where there is passion there is ownership and those two combined[4]; when they exist in the same group of people and the team encounters problems they don't last[5]. The team fixes it and moves on[6]." - Marketing Product Manager

Coding this statement for variable development might create categories for: 1) Buy-In, 2) Design Objective Understanding, 3) Passion, 4) Ownership, 5) Substantive Accomplishments and 6) Development Progress. To simplify coding, Buy-In, and Design Objective Understanding are conceptually similar to the variable Design Vision Clarity in the diagram

---

[6] An "S" indicates that the two factors move in the same direction, i.e., all other things being equal, as one variable increases the other variable also increases. An "O" indicates that variables move in opposite directions, i.e., all other things being equal, as one factor increases the other factor decreases.

above and are abstracted into the variable Design Objective Credibility. Additionally, Passion, and Ownership can be combined into an abstracted category Conviction. Development Progress is conceptually similar to the variable Development Time; Development Time will continue to be used as it is less ambiguous then Development Progress. The resulting diagram, integrated with the previous diagram, is shown below:

Misdirected Effort
O

Design Objective Credibility

S
Development Time
O

S
Conviction

S
Substantive Accomplishments
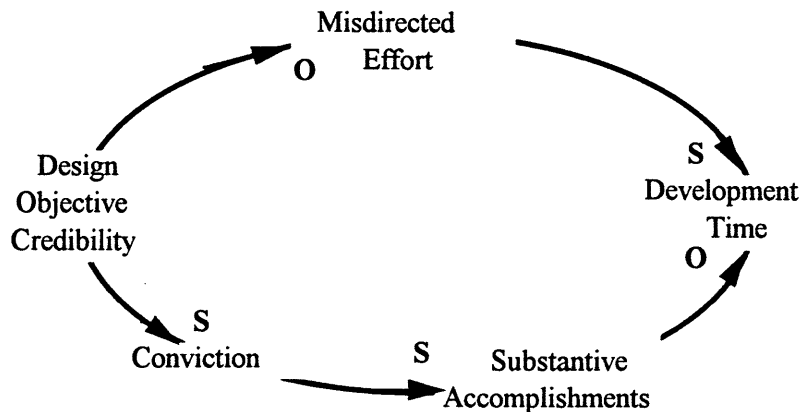
This diagram adds the conditions that Development Time decreases as Substantive Accomplishments increase which in turn is driven by Conviction through Design Objective Credibility. The integrated diagram enhances the ability to compare future instances of Design Objective Credibility with the accumulated knowledge by clearly and concisely displaying the current state of accumulated evidence and inferences.

In comparing instances of Design Objective Credibility from a second team at another company, using the Concept Engineering approach, an important difference was identified. This difference is exemplified by the following quotes:

"Also, since we spent a lot of time with the requirement labels yesterday, perhaps we could shortcut a bit on the time without discussion and talk a little sooner." Process Facilitator

"We should generate (requirement metrics) in pairs, then bring the result to a vote. Why not skip the voting step in pairs and vote as a group." Team Leader

From these quotes a new category, Short-Cuts, can be derived. The second team, as a result of several disruptions in their project, planned to complete seven (of fifteen) steps of the Concept Engineering process in one week. Prior efforts, including the first team addressed above, allocated two to three weeks for these same activities. This caused the second team significant, self-imposed, time pressure. Time Pressure was also identified as a relevant variable relating to Development Time. A possible consequence of taking Short-Cuts can best be seen in one of the final comments during the second teams reflection period late Friday afternoon.

"Surprises me, that after all the discussion this week, some people don't know what others are talking about. I should say everyone doesn't know what the others are talking about." Development Engineer

Adding the new categories, Short-Cuts and Time Pressure, to the diagram of accumulated knowledge above, results in the following diagram:
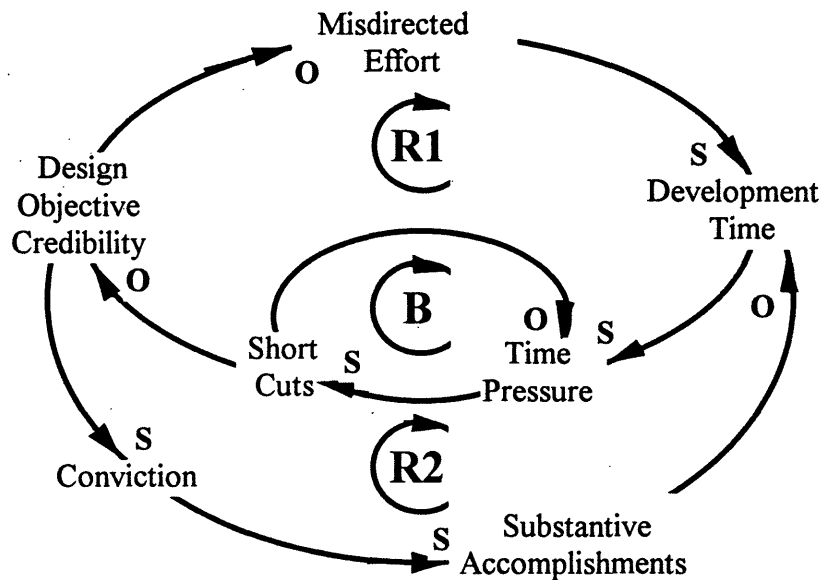
This causal-loop diagram (Goodman 1974) shows two reinforcing loops (R1 and R2) and one balancing loop (B). The reinforcing loops imply that increases in Design Objective Credibility can decrease Development Time and subsequently Time Pressure as a result of less Misdirected Effort and/or as a result of increased Conviction and Substantive Accomplishments. The reduction in Time Pressure leads to decreased Short Cuts which increases Design Objective Credibility. The balancing loop implies that as Time Pressure increases Short Cuts also increase, thereby decreasing Time Pressure. However, Short Cuts also decrease Design Objective Credibility causing an increase in Misdirected Effort and a decrease in Conviction.

This diagram was continually validated; new variables were added and relationships modified as dictated by the data. Eventually, modifications became fewer and a theory about the product concept decision process, grounded in the data, could be clearly and concisely stated.

The discussion and example illustrate how inductive system diagrams can be used by researchers who are engaged in intensive field-based theory generation efforts. The strengths of the inductive system diagram method are: 1) its clarity and conciseness in representing and structuring the proposed theory and its dynamics, 2) its flexibility to be continually updated to reflect the accumulated body of knowledge and field data, and 3) its rigor attributable to a focus on verifiable data, explicit inferences, and testable predictions, all of which provide a high level of transparency and auditability, easing the process of evaluating the validity of both the proposed theory and the theory generation process.

3. Analysis of Product Concept Development Teams

The application of the inductive system diagram method in our research identified *Design Objective Credibility* as a core variable related to all of the development projects we studied. We observed that the actual realization of the product concept during development activities was essentially a process of constrained optimization, often under conditions of significant uncertainty and time pressure. Repeatedly during this study, development engineers reflected on the large number of design tradeoff decisions they are required to make for which there is no clear guidance and/or time to solicit additional direction. *Design objective credibility* served as a roadmap for the development team, providing direction, flexibility and confidence in making downstream development decisions which led to *substantive development progress*. In the following sections we will: 1) identify the consequences associated with the presence or absence of *design objective credibility* , 2) describe the conditions this research associated with the presence or absence of *design objective credibility*, 3) outline the factors this research indicates leads to *design objective credibility* , 4) highlight the critical constraint related to developing *design objective credibility* and 5) integrate these causes, conditions and consequences into an inductive system diagram which communicates our theory of the product concept decision process.

3.1 Design Objective Credibility — Consequences

Understanding user needs has long been recognized as a significant factor to new product development success (Rothwell et al. 1974, Cooper & Kleinschmidt 1986). Additionally, the absence of a clear product definition has been linked to instability in product and marketing plans (Gupta & Wilemon 1990, Wilson 1990). Instability can manifest itself in significant changes in direction or in "creeping elegance" (Gupta and Wilemon 1990). Additionally, Wilson (1990) found that product definition instability could lead to more staffing, funding and time. Gupta and Wilemon (1990) found poor definition of product requirements was the reason most cited for product development delays. In this study, it was observed that increased *design objective credibility* led to increased *substantive development accomplishments*, and conversely a lack of *design objective credibility* led to *misdirected effort*.

Substantive development accomplishments are development actions which lead directly to progress towards realizing the design objectives. *Substantive development accomplishment*, in the context of the concept development decision process, has two dimensions: *concept commitment* and focused effort. *Concept commitment* represents the ability of a product concept to garner enough enthusiasm and support from the development team that it does not change during downstream development activities. Focused effort describes a development process which is direct compared to one filled with delays and detours.

Several authors claim commitment is a result of participation in the formulation stage of a project (Gupta, Raj & Wilemon 1986, Shapiro 1988, Moenaert & Souder 1990, Gupta & Wilemon 1990, Bailetti & Guild 1991). Gupta & Wilemon (1990) indicate that a lack of commitment is related to changes in product definition and low management support. We observed that *design*

objective credibility led to *concept commitment* which in turn led to reduced *misdirected development effort*. *Concept commitment* represents the level of support the product concept has earned from both the development team and their managers. Committed individuals ensure that the necessary work gets accomplished. Committed managers provide the necessary resources to support the team's efforts. Changing product concepts increase delays and rework increasing total *development time*.

The System Dynamics literature has investigated the impact of project changes in a variety of development settings, e.g. construction (Homer et al. 199), research and development (Roberts 1964, 1978, Richardson & Pugh 1981), shipbuilding (Cooper 1980, Reichelt & Sterman 1990), and software (Abdel-Hamid & Madnick 1989, 1991), and consistently finds project changes directly and indirectly increase development time and costs. Additionally, Roberts' discussion of research and development project control indicates that "there is no intrinsically correct measure either of engineering effectiveness or of problems solved or of the task left to be done....the obvious concrete and measurable variables are often basically unrelated to the amount of effort required to get the job done" (1964; p.169). Roberts indicates (1964, 1978) that one result of this measurement difficulty is a delayed response to events which impact the development schedule. We observed that development pressure for progress could be temporarily relieved by the presentation of the product concept even if the design objectives were not commonly held as credible by the entire development team. This condition can exist because of delays between the establishment of the product concept and realization that substantive accomplishments towards the stated objectives are not being achieved.

3.2 Design Objective Credibility — Conditions

On all observed projects, the development team attempted to clearly identify a small subset of the total requirements which would differentiate the proposed product from its competition. Additionally, each observed development team made a concerted effort to establish clearly the relative priorities of acknowledged design objectives. Finally, it was consistently observed that development team members assessed requirements for credibility in order for them to have confidence in the merit of the tradeoff decisions. Therefore, these three conditions (*requirement clarity*, *prioritization* and *credibility*) were identified as common to all observed teams and are considered necessary and sufficient for *Design Objective Credibility*.

3.3 Design Objective Credibility — Causes

In the observed teams where significant *pressure for progress* was evident, the resulting decision speedup were observed to have two immediate consequences. First, and predictably, *analysis depth* decreased; decisions were observed to be made with both recognized and unrecognized data deficiencies. This observation is consistent with those of other researchers who indicate that the pressure for accelerated new product development can cause development organizations to conduct a less-than-thorough job in order to have the appearance of progress (Van de Ven 1986, Gupta & Wilemon 1990). Second, when *pressured for progress*, development team members were observed to display self-interested behavior

based on a functionally-oriented *"prejudiced" perspectives*. In other words, marketing participation was confined to "traditional" marketing roles and engineering participation was confined to "traditional" technical roles. Van de Ven (1986) claims the first, of four, central problems in managing innovation involves the problem of managing human attention: overcoming individuals' and organizations' natural tendency to be focused on and protective of existing practices. The self-interested behavior of individuals (or groups) in settings which require interdependencies can lead to conflict (Kohli & Jaworski 1990, Ancona & Caldwell 1992). Furthermore, self-interested behavior and conflict lead to reduced *cross-functional integration* (Gupta et al. 1986, Souder 1988, Kohli & Jaworski 1990, Ancona & Caldwell 1992).

In contrast to the stakeholder-oriented self-interested behavior observed in teams with significant *pressure for progress*, other teams were observed to collaborate in developing a *customer-oriented perspective*. A *customer oriented perspective* is present when team members bias innovation efforts towards customer (rather than team-member) benefits. This customer-oriented bias was evidenced by the use of numerous, specific references to customers during all phases (requirement identification, idea development, and concept selection) of the concept decision process. In the *market-oriented* teams, it was observed that the development of a common understanding of the users' perspectives enhanced information transfer and communication between the different functions represented on the team. In related research, Dougherty (1992) suggests that viewing the product from the users' perspectives can provide a basis for the different "thought-worlds" of marketing and engineering to develop a common understanding of the desired innovation. Additionally, crossfunctional participation in market research has been reported to increase the effectiveness of information exchange between functions (Deshpande & Zaltman 1984, Kohli & Jaworski 1990) which has been linked with innovation success (Rothwell et al 1974, Moenaert & Souder 1990, Ancona & Caldwell 1992).

Developing the users' perspectives involves more than obtaining the customers' verbalized needs and preferences; it includes analysis of the factors which influence those needs and preferences (Kohli & Jaworski 1990). Moenaert and Souder (1990; p.221) describe the contextuality of information as "the degree to which the source has given the receiver the necessary information and references such that the receiver can see the relevance of this information for his/her work on a particular project." They conclude that extrafunctional information, without supporting context, cannot be processed and used. We define *contextual awareness* as the ability of development team members to place a requirement statement in the context of the customer's environment. In this study, it was observed that stories of real customer experiences, usually obtained during customer requirement identification investigations, were used by *market-oriented* development teams to develop written *requirement statement clarity*. Written requirement statements ideally represent a high fidelity translation of the customers' actual needs. However, even in the best processes for capturing the voice of the customer, the written requirement statement lacks the affective qualities of an actual customer interaction and is subject to different interpretations. *Contextual awareness*, by placing requirement statements in the context of the customer's use environment, helps clarify the intent

of requirement statements. This observation is consistent with research which indicates placing design engineers in direct contact with customers provides an opportunity for developing deeper levels of contextual understanding (Rothwell et al. 1974, Kohli & Jaworski 1990, Bailetti & Guild 1991). In contrast, the *time-oriented* teams did not systematically include engineering personnel on customer requirement identification investigations and their use of "stories" in the development of *contextual awareness* was noticeably absent.

Another observed benefit of the *market-oriented* team's customer collaboration was the active involvement of all participants in the complete decision process. *Process participation* implies that individuals participate in requirement identification, idea development and concept selection activities. This is contrasted with event participation in which individuals participate in some activities and not others, (i.e. participation in requirement identification but not idea development), which was the observed pattern in *time-oriented* teams. *Process participation* provides the opportunity for the entire development team to develop appreciation of the often tacit knowledge which leads to *design objective credibility*. Several studies indicate that interaction between producers and users of market information significantly impacts the credibility and utilization of the information in the innovation process (Deshpande & Zaltman 1982, Deshpande & Zaltman 1984, John & Martin 1984). Deshpande and Zaltman (1982) conclude that personal interaction increases trust in the source and consequently the content of the research. These findings are consistent with the observations that *process participation* led to increased *requirement statement clarity and credibility*.

Another aspect of the concept decision process which led to *design objective credibility* was decision *traceability*. *Traceability* includes documentation of the outcomes of the decision process as well as the concept development decision process itself. Van de Ven (1986) states that the legitimacy of the decision process is the dominant evaluation criteria used to assess innovative ideas as the ideas themselves can rarely be judged. Moenaert and Souder (1990) found that information which was not formally substantiated by convincing evidence was less likely to be used. In this study, it was observed that the ability to document the product concept decision process increased the credibility of the design objective decisions within the team and their managers.

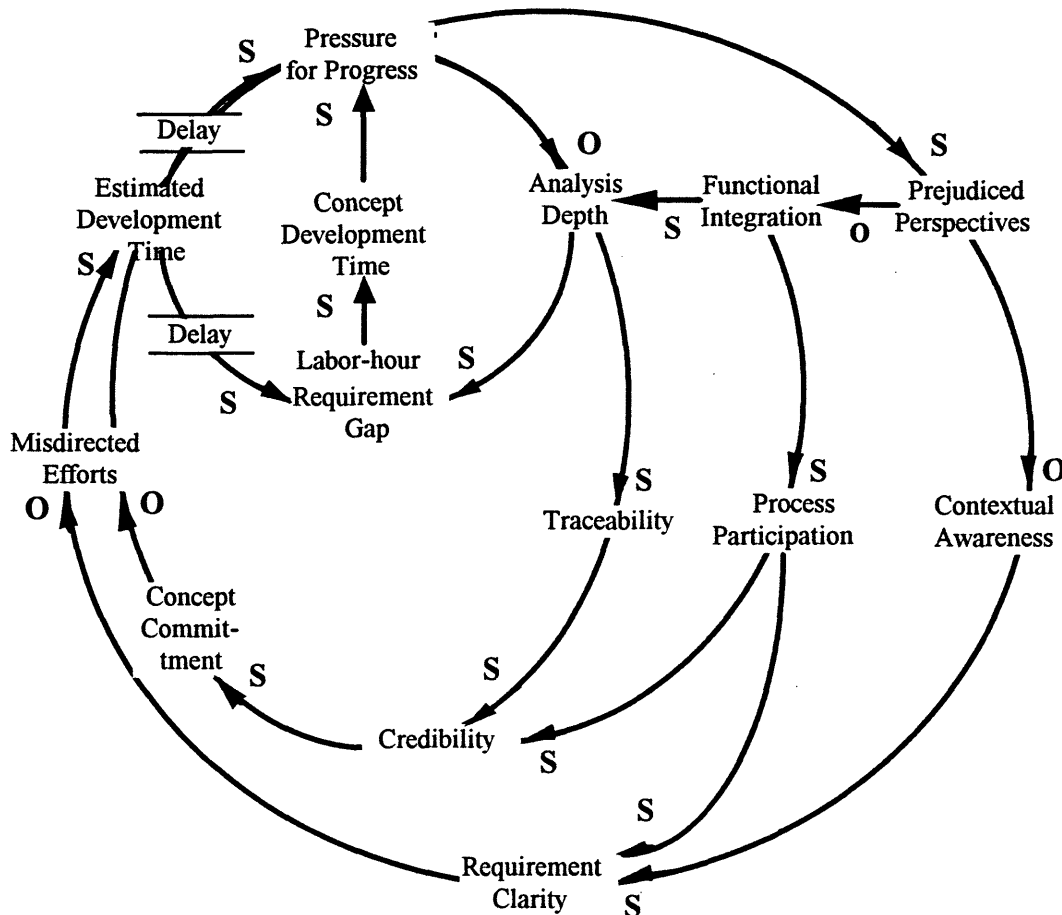## 3.4 Design Objective Credibility — Constraint

Finally, although the list of conceivable constraints which can be imposed on the product concept decision process is considerable, one, required labor-hours, dominated the observations in this study. As the innovation process is primarily informational (Moenaert & Souder 1990) it can be argued that mental capacity (labor) is the critical resource. The labor-hour requirement gap represents the difference between required labor hours and available labor hours. When labor-hour requirements exceed availability a gap exists. In this study, labor availability was fixed by the team size. In every observed development team, the membership remained the same or was reduced during the roughly six month observation period of each team. The labor requirement can be driven by the project itself or by other projects team members participate in. In this study, it was observed that when a labor-hour requirement gap

existed, all other things being equal, there was an increase in concept development time. We also observed that systematic concept development (comprehensive, collaborative, customer oriented analysis) increased the labor requirement.

3.5 Design Objective Credibility — Integration

Combining the detailed relationships identified above into an integrated inductive system diagram allows us to better understand the interactions of the variables identified with the product concept development decision process.

Pressure for Progress
S
S
Delay
Estimated Development Time
S
Concept Development Time
S
Delay
Labor-hour Requirement Gap
S
Analysis Depth
O
Functional Integration
S
Prejudiced Perspectives
S
O
Misdirected Efforts
O O
Concept Commitment
S
Traceability
S
Process Participation
S
Contextual Awareness
O
Credibility
S
Requirement Clarity
S
S
S

This inductive system diagram can describe a vicious or virtuous cycle of product concept development depending on which decision variables are emphasized. A vicious cycle begins when *pressure for progress* leads to *shallow concept analysis* and stakeholder *prejudiced perspectives* in decision analysis. The resulting decrease in *functional integration* further degrades *analysis depth* and reduces participation of all team members in the concept decision process. The resulting lack of *requirement clarity* and *credibility* leads to low concept *commitment* and *misdirected development effort*. Ultimately, the waste and rework increases *development time* further increasing *pressure for progress*.

The diagram also describes a virtuous cycle in which an increase in *customer orientation perspectives* lead to an increase in *functional integration* and *contextual awareness*. As a result,

14

a *deeper analysis*, grounded in the *context* of the customer's environment, is conducted with the *active participation* of all development team members. This common understanding of the concept decision process and outcomes leads to a higher degree of *requirement clarity and credibility*. In turn, *commitment* to the product concept is higher and *misdirected development effort* is reduced. Ultimately, *development time* is reduced, thus decreasing *pressure for progress* and *labor requirements*.

4. Time vs. Market Oriented Strategy

The dynamics of the concept development process discussed above suggest a fundamental difference in project strategies and outcomes depending on whether teams focused on TIME or MARKET in the expression time to market. That is, we found all teams focused on the importance of time to market in their work. However, some teams were much more focused on TIME and consequently generated significant pressure for progress with the attendant consequences described above. Other teams focused more on MARKET, exhibited a greater customer oriented perspective, and realized the benefits of the virtuous cycle described above. In this section, we elaborate further on these observations, their consequences, and the implications for concept development strategy.

4.1 TIME to market Oriented Strategy

Decreased time to market has been identified as a key ingredient in successful new product development (Takeuchi & Nonaka 1986, Mansfield 1988, Gupta & Wilemon 1990). There are significant market share benefits to early market entrants (Urban et al. 1986) and considerable penalties for being late to market. For example, McKinsey and Company claims shipping a product six months late can reduce life cycle profits by one third in high growth, short life cycle markets (Reinertsen 1983). Additionally, competitive pressures are reducing product life cycles, further increasing the pressure to reduce product development time (Mansfield 1988, Schmenner 1988, von Braun 1990).

Millson, Raj and Wilemon (1992) outline a general framework for categorizing development cycle time reduction approaches. Four of their categories: simplification, delay elimination, step elimination, and parallel processing all have the common requirement of detailed process understanding to be effective. (Their fifth category, operation-speedup, simply doing what is traditionally done except doing it faster, was considered to be undesirable.) The process understanding requirement is consistent with that specified by Bower and Hout (1988) who state that fast-cycle companies must have development processes which are well defined and understood. However, in many companies, the product concept decision process is not well defined or understood. The observed disconnect between the requirement for process understanding in theory and the lack of process knowledge in practice is consistent with other studies of product development theory and practice which indicate that what the literature recommends and what actually happens are significantly different (Cooper & Kleinschmidt 1986, Gupta & Wilemon 1990, Mahajan & Wind 1992). As a result, a relative emphasis on time orientation leads to pressure for progress and ultimately to decision process speedup.

A *time-oriented* team was observed to be one which attempted to specify the design objectives in an accelerated period of time. The team was under a great deal of pressure for progress and displayed a willingness to make decisions with recognized and/or unrecognized data deficiencies in order to meet the (usually aggressive) development schedule. Participants oriented their analysis of the issues to support their preconceived perspective of the product concept. In the development team meetings, partisan behavior, in which individuals staked out positions and vigorously defended them was the dominant mode of operation. The engineers discussed product attributes from the perspective of technology opportunities and constraints. Marketing managers discussed product attributes from the perspective of market segments and competitors. Although both groups were at the same meetings, they didn't participate in the same process: the language used was different, the relative emphasis on product attributes was often different, and individuals could be observed to periodically disengage from the decision process based on discussion subject matter. Product concept decisions were ultimately made, but it was difficult for the entire team to re-create and defend the decision choices to the management review board. When all was said and done, one or more groups lacked commitment to the product concept and there was a high expectation that the final product would differ from the initial concept.
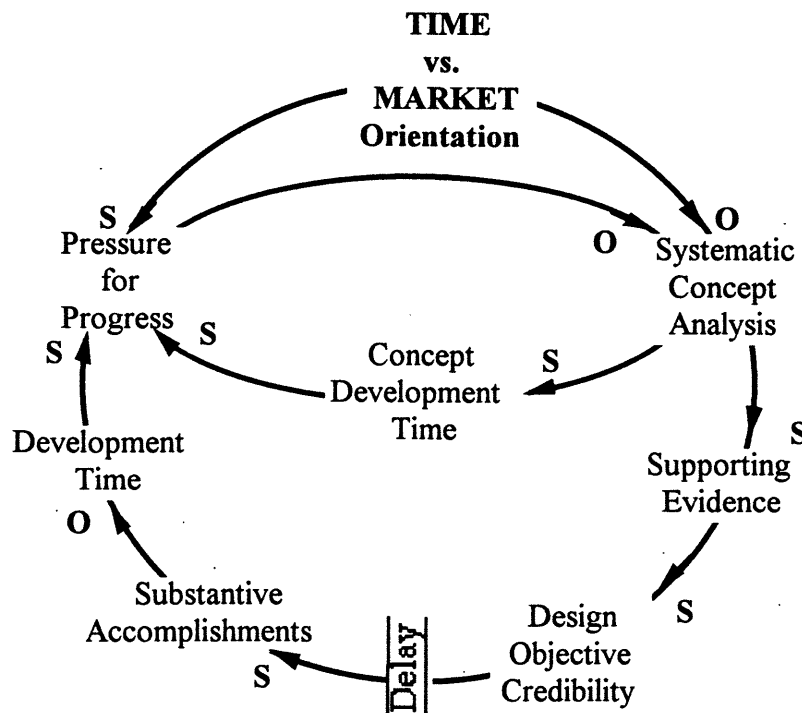
4.2 time to MARKET Oriented Strategy

Considerable research on new product development success highlights the central importance of understanding user needs, i.e., the market (see for example: Rothwell et al. 1974, Cooper & Kleinschmidt 1986; Pavia 1991). Houston (1986) states that customer focus, profits and organizational integration are frequently associated with the marketing concept and have become synonymous with having a customer orientation. Shapiro (1988) describes the characteristics of the market driven company to include widespread dissemination of important buying influence information, interfunctional decision making, and committed coordinated decisions. Narver and Slater (1990) state that marketing orientation consists of three behavioral components: customer orientation, competitor orientation, and interfunctional coordination. Kohli and Jaworski (1990) in an extensive review of the literature found three core themes related to market orientation: customer focus, coordinated marketing and profitability. However, the results of their 62 field interviews, conducted with a diverse cross section of managers, found that managers felt profitability was a consequence not a condition of market orientation.

A *market-oriented* team was observed to be one which attempts to develop credible design objectives that reflect a deep appreciation of the customers' requirements. The team was characterized by decision analysis oriented to maximize customer benefit. In development team meetings, every individual participated in all aspects of the decision process. Members frequently put their statements in the context of specific customer encounters to clarify or emphasize their positions. Relevant issues and information regarding design objectives were considered to everyone's satisfaction before the team moved on to subsequent development activities. This cross-functional collaboration created a common appreciation of the design

objectives which was apparent when the team presented the product concept to the management review board. All team members displayed a commitment to the product concept and could credibly trace their decision process when required to justify their choices.

4.3 Development Dynamics

The dynamics of a TIME versus MARKET orientation in the expression Time to Market may be easier to understand by representing the behavior described above in a higher level (i.e. *Analysis Depth, Functional Integration,* and *Prejudiced Perspectives* are abstracted into the variable *Systematic Concept Analysis*) representation of the inductive system diagram presented in section 3.5.

TIME vs. MARKET Orientation

S
Pressure for Progress

O
Systematic Concept Analysis

Concept Development Time

S

Development Time

Supporting Evidence

O

Substantive Accomplishments

Delay

Design Objective Credibility

S

A relative emphasis by a Product Development Team on *time* increases *pressure for progress* and reduces the opportunity for *systematic concept analysis*. This reduction in *systematic concept analysis* decreases the *concept development time*, alleviating the *pressure for progress* against the initial stages of the development schedule. However, it also decreases the *supporting evidence* generated to justify concept decision choices. The resulting reduction in *design objective credibility* subsequently reduces *substantive accomplishments* as time and resources are spent on delays and detours in downstream development efforts. The net result is increased *development time* leading to increased *pressure for progress*, exacerbating the overall time pressure problems in the system.

On the other hand, a *market-orientation* decreases *pressure for progress*, relative to the *time-oriented* development teams, and increases *systematic concept analysis* which leads to increased *supporting evidence*, but also increases the *concept development time*. However, the resulting increase in *design objective credibility* focuses development efforts thereby increasing

substantive accomplishments which in the long run will decrease total *development time* and *pressure for progress.*

The dynamics described in the diagrams above represent a classic "Fixes that Fail" archetype (Senge 1990) in which the unintended consequence of a problem solution exacerbates the problem it was intended to solve. In this case, the emphasis on reducing *time* to market decreases *concept development time* but inadvertently reduces *design objective credibility* resulting in delays and detours in downstream development activities increasing total *development time.* On the other hand, the fundamental solution, an emphasis on *market* orientation, increases *design objective credibility* which reduces total time by eliminating the time spent on misdirected downstream development efforts.

This finding has significant implications for the management of product development projects and the achievement of the time to market objectives of those projects. Too much focus on time can be counter-productive. Time devoted early in the project to getting the concept right for the market is time well spent.

5. Plausible Rival Hypotheses

The inferences and propositions integrated into the TIME vs. MARKET inductive system diagrams above are the result of a comparative analysis of product concept development teams. The full range of behavior observed in this study is accounted for by the inductive system diagrams. However, we also find it useful to consider plausible rival hypotheses which are discussed below.

5.1 Senior Management Support

Numerous authors describe the important role senior managers play in creating the "market-oriented" organization (Shapiro 1988, Kohli & Jaworski 1990, Narver & Slater 1990). Gupta & Wilemon (1986, 1988, 1990) specifically identify senior management support as a necessary ingredient for creating interfunctional integration and cooperation. In this study, it might be argued that those teams using Concept Engineering received, or at least could be perceived as receiving, a higher level of support (staffing, resources, etc.) from their senior managers than the teams which did not use Concept Engineering. The original research design attempted to address this threat by using pairs of teams from the same division each of which received a beneficial treatment. Unfortunately, the actual design implementation precludes elimination of this threat and thus suggests an opportunity for future research.

5.2 Functional Integration

Functional integration has been shown to be a key factor in successful innovation (Rothwell et al. 1974, Gupta et al. 1986, Gupta & Wilemon 1988, Pinto & Pinto 1990, Moenaert & Souder 1990, Dougherty 1992, Song & Parry 1992). In this study, all observed teams consisted of both marketing and engineering personnel who attended all scheduled development team meetings. All of the development teams described themselves as having a high degree of functional integration relative to their prior development practices. However,

18

our study showed considerable differences in the development of design objective credibility and subsequent substantive accomplishments. This study indicates that *contextual awareness*, the ability to place requirement statements in the context of the customers' use environment, is also a necessary condition for *design objective credibility*. We feel this represents an area with considerable opportunity for further research.

5.3 Analysis Depth

Several studies indicate that innovation success is positively related to the number of product development process steps completed; the more thorough the job the more likely the success (Cooper & Kleinschmidt 1986, Gupta & Wilemon 1990, Wilson 1990, Mahajan & Wind 1992). Janis (1985; p.167), based on studies of errors in strategic decision making, outlines seven major decision process criteria which can influence the quality of individual or group decisions. High quality group decisions: 1) thoroughly canvass a wide range of alternatives; 2) take account of the full range of objectives to be fulfilled; 3) carefully weigh whatever is found out about negative and positive consequences that flow from each alternative; 4) intensively search for new information relevant for alternative evaluation; 5) conscientiously take account of any new information, even when the information does not support the course of action they initially prefer; 6) re-examine the positive and negative consequences of all known alternatives before making a final choice; and 7) make detailed provisions for implementing the chosen policy, with special attention to contingency plans. Janis (1985) states it is plausible to assume that failure to meet these criteria are symptoms of defective decision making that increase the chances of undesirable outcomes. Further, he states that the decision maker who "searches painstakingly for relevant information, assimilates information in an unbiased manner, and appraises alternatives carefully before making a choice" is more likely than others to lead to decisions that meet the main criteria for sound decision making (p. 184). Janis' research might indicate that comprehensive analysis is a necessary and sufficient factor for success in the product concept decision process.

In this study, those teams which were successful in developing product concepts achieving a high degree of commitment from development team members and managers were also those teams which completed a comprehensive analysis (Concept Engineering) which satisfied the requirements outlined by Janis. However, one team which used Concept Engineering was not successful in developing concept commitment. This team had a relative emphasis on *time-orientation* and was under considerable pressure for progress. Although a relatively complete investigation was conducted not all participants were active in the entire concept decision process, e.g. three members did not conduct customer interviews, two members did not participate in idea generation. As a result, a common appreciation of the design objectives was not obtained and commitment to the product concept was low. This would indicate that in addition to the decision process criteria outlined by Janis, *process participation* may also be necessary for success in the product concept development process and thus represents an opportunity for further study.

6. Conclusion

In this research, product development professionals collaborated with the authors in the identification and resolution of problems related to the product concept decision process. This effort led to the development of Concept Engineering as a complete product concept decision support process. Additionally, the active collaboration led directly to the opportunity to conduct a comparative analysis of product development teams. The efforts of the authors to ensure this analysis was conducted rigorously led to the development of Inductive System Diagrams. The theory generated from their analysis attempts to explain and predict product concept decision dynamics based on the time vs. market orientation of the development team.

Inductive System Diagrams have been introduced as a diagram-based method for systematic field-based hypothesis generation. The Inductive System Diagram method builds on the strengths of accepted coding practices for variable development and causal-loop diagramming for variable integration. As a result, it facilitates the ability of researchers to use the constant comparative method of analysis, an accepted approach for theory generation. Additionally, it allows for theory validity testing against the criteria of: verifiable data, explicit inferences and disconfirmable predictions.

The analysis generated a theory regarding the causes, conditions and consequences of Design Objective Credibility in the product concept decision process. Some of the constructs identified as influential in this process have been operationalized and investigated in other studies, e.g. functional integration (Rothwell et al. 1974, Gupta et al. 1986, Gupta & Wilemon 1988, Pinto & Pinto 1990, Moenaert & Souder 1990, Dougherty 1992, Song & Parry 1992). Other constructs (e.g. traceability, process participation, contextual awareness) have not been investigated and their significance on product concept development has not been statistically validated. However, even after the hurdle of developing multiple construct operationalizations is overcome, the data collection process will be formidable as product concept development data is not systematically collected, if it is collected at all. Therefore, another path to model validation could be through system dynamic simulation. In the system dynamic approach, model validation follows from a multi-method analysis of computer simulations (Maas & Senge 1980, Richardson & Pugh 1981, Sterman 1984, Barlas 1989, Barlas & Carpenter 1990). The Design Objective Credibility inductive system diagram would serve as the conceptual model around which a computerized model can be formalized into equations to precisely specify the system structure.

Finally, this comparative analysis indicated that a relative emphasis on *time-orientation* created an environment where pressure for progress encouraged development teams to conduct incomplete analysis oriented to self-interested outcomes during the concept development decision process. The resulting lack of design objective credibility and commitment by the development team led to delays and detours in downstream product development activities. On the other hand, a relative emphasis on *market-orientation* increased design objective credibility and commitment but increases the time required in concept development. These dynamics indicate that increased time spent systematically developing a product concept, which remains stable over the balance of the development process, results in getting a product to market

faster. Schmenner (1988) reminds us of the applicability of the fable of the tortoise and the hare to product development acceleration. The tortoise won the race with a diligent, focused effort and the hare, while very fast, had a pattern of stops and starts in his detour-filled route to losing.

Appendix: Overview of Theory Generation

In verification research to test a hypothesis, the investigator must operationalize the variables they expect will explain the phenomenon under investigation (Kirk & Miller 1990). In theory generation research, by definition, the researcher may not have even identified, let alone operationally defined, the variables associated with the investigation. Accordingly, the relatively small sample sizes and lack of reliance on random sampling techniques associated with the theoretical sampling requirements of theory generation methods generate conflict with many of the traditional tests of validity in "normal science", e.g. those outlined by Cook and Campbell (1979). As a result, a fundamental issue of theory generation research is how to express the validity of the developed theories.

Argyris, et al.. (1985) propose four criteria for testing the validity of a theory. First is intersubjectively verifiable data — competent members of the scientific community should be able to agree at the level of observation, even if they disagree at the level of theory. The second criterion is explicit inferences — the logic that connects theory and observation should be explicit. Third is the use of disconfirmable propositions — the results of observations must relate to the acceptance or rejection of the theory. Finally is the concept of public testing — the users of a theory test its validity by comparing actual and predicted consequences following a change in their actions based on the research.

Glaser and Strauss (1967) discuss the four properties any grounded theory must have for practical application. The theory must fit the substantive area in which it will be used — the concepts and hypotheses supplied by the theory are closely tied to the data. Second, it must be readily understood by people in the area — it will make sense to the people working in the area. Third, it must be sufficiently general to be applicable in diverse situations — the level of abstraction must be sufficient to make a variety of situations understandable but not so abstract as to be meaningless. Finally, the theory must allow the user partial control over structure and process — the theory must contain sufficient concepts and their plausible interrelations to allow a person to produce and predict change. In short, the theory can be, and is, used by practitioners to guide what they do.

From the Clinician's perspective Schein (1987) states that the validity of a theory can be determined by its ability to predict the response to an intervention. The ethnographic view of validity emphasizes the issues of replication and internal consistency (Van Maanen 1983).

Walter Shewhart, the acknowledged developer of statistical process control, may have said it best when he wrote: "there is an important distinction between valid prediction in the sense of a prediction being true and valid knowledge in the sense of a prediction being justifiable upon the basis of available evidence and accepted rules of inference" (Shewhart 1938). Shewhart (1938) points out that it is possible for predictions to be realized even when the knowledge supporting them is not. Similarly, valid inferences can be made from faulty evidence. Therefore, if theories result in testable predictions, then the validity of theory generation research can be judged on the basis of its evidence, inferences and predictions.

Revisiting the validity criterion outlined above it would appear that Schein is concerned primarily with prediction while Van Maanen's concerns seem related to evidence and inferences.

Argyris, et al. appear to address evidence, inference and prediction. Glaser and Strauss also appear to address evidence inference and prediction; in addition they are concerned with generalizability and user accessibility. These observations are summarized in the table below.

Glaser & Strauss	Argyris, et al..	Van Maanen Schein	Shewhart
fit	verifiable data	replication	evidence
understanding	explicit inferences	internal consistency	inferences
produce and predict change	disconfirmable propositions / public testing	prediction	prediction

These three concepts: evidence, inferences and predictions, constitute a set of requirements which, if addressed in theory generation research, would allow researchers to observe and distinguish both the validity of the hypotheses (predictions) and the validity of the theory creation process (evidence and inference). (An important caveat is drawn from Kuhn's (1962) arguments on how paradigms affect our abilities to interpret the arguments of others. Because we interpret issues from our paradigm not others, it will be difficult for distinct schools of thought to agree on whether any given piece of "knowledge" is valid because the accepted rules of inference may be different.)
Inductive System Diagrams, which allows the researcher to build and explain their theory through a tightly coupled process of data collection, coding and analysis, meet the criteria of verifiable data, explicit inferences and testable predictions.

Inductive System Diagrams

Inductive System Diagrams combine aspects of Grounded Theory methods and System Dynamics. Grounded theory approaches are used to develop variables which have a great deal of explanatory power and are intimately tied to the data. These variables are analyzed and integrated using Causal Loop diagramming techniques from System Dynamics. This combination allows the researcher to generate theory which meets validity requirements of verifiable data, explicit inferences and testable predictions (Burchill 1993).

Grounded Theory

Grounded theory approaches to generating hypotheses are characterized by the use of an exhaustive (and exhausting) data-coding and memo-writing regimen, as well as the use of the constant comparison method of analysis. A grounded theory development process generally consists of the following activities:

1) The researcher starts by coding each incident in his data for as many categories of analysis as possible. While coding an incident, the researcher attempts to compare this incident with all other incidents in the same category.

2) The researcher regularly stops to record in "theoretical memos" his or her thoughts on the developing theory.

3) As the coding continues, the unit of comparative analysis changes from comparison of incident with incident to comparison of incident with the accumulated knowledge of the category.

4) The accumulated knowledge is integrated into a unified whole.

5) The theory is solidified as major modifications become fewer, non-essential categories are pruned, and higher level concepts are abstracted from the detailed categories previously developed from the data (Glaser 1965, Glaser & Strauss 1967, Glaser 1978, Strauss 1987).

In the constant comparison method, the objective of the sampling process is to allow for comparisons of differences and similarities among the units of analysis. This process of analyzing the similarities and differences produces the dense category development essential to well grounded theory generation. Minimizing differences among comparison groups increases the likelihood that a lot of information is available for developing of the basic properties and conditions of a category. Identifying similar data under comparison conditions of maximum differences identifies the fundamental explanatory variables. To integrate these variables into theory requires investigating the causes, consequences and constraints of these variables also under comparison conditions of maximized differences (Glaser & Strauss 1967; p56-58).

One of the strengths of grounded theory methods is the coding process for category development (Glaser & Strauss 1967, Glaser 1978, Strauss 1987). "The code conceptualizes the underlying pattern of a set of empirical indicators within the data. Coding gets the analyst off the empirical level by fracturing the data, then conceptually grouping it into codes that then become the theory which explains what is happening in the data" (Glaser 1978; p.55). The process begins with "open-coding", a line by line analysis of the data which is diametrically opposite to the process of coding with preconceived codes. In open-coding the analyst attempts to code the data in as many different ways as possible. The analyst constantly looks for the "main theme", for what appears to be the main concern of or problem for the people in the setting (Strauss 1987; p.35). As the analyst's awareness of the central problem(s) emerges, they alternate open coding with very directed "axial coding". Axial coding consists of analysis done around one category at a time. As core variables begin to emerge, the analyst employs "selective coding" to focus coding to only those variables that relate to core variables in sufficiently significant ways to be used in parsimonious theory. In all 10 to 15 codes are typically enough for a monograph on a parsimonious substantive theory (Strauss 1987; p.32).

System Dynamics

The field of System Dynamics (see for example: Forrester 1968, Goodman 1974, Randers 1980, Richardson and Pugh 1981) focuses on building models of inherently dynamic phenomena. Causal-loop diagrams (Goodman 1974) are one tool used for describing symbolically part of the dynamic structure in systems.

Causal-loop diagrams identify the principal feedback loops in a system without distinguishing between the nature, i.e. level or rate, of the interconnecting variables (Goodman 1974).[7] Goodman (1974) outlines the steps of developing a causal-loop diagram as follows:

---

[7]Interconnecting feedback loops are the basic structural elements in systems which generate dynamic behavior (Forrester 1968, Goodman 1974). "Feedback loops are a closed path connecting in sequence a decision that

24

1. establish the pairwise relationships of relevant variables;
2. ascertain the polarity of the causal pairs;
3. fit together the causal pairs into closed loops; and
4. test for loop polarity.

Pairwise variable relationships are diagrammed with directed arcs. Arcs are used to connect the factors which influence each other; the arrow indicating the direction of influence. Each arc is annotated with an indication of the causal change (polarity) between the two factors. These pairwise arcs can then be connected to form feedback loops.

Through this process, the causal-loop diagram allows the analyst to integrate the variables they have developed, explicitly state the inferences they are making and clearly communicate their hypotheses regarding the dynamics associated with the structural relationships of the system.

ISD Step by Step Methodology

The development of Inductive System Diagrams starts with developing, through a verifiable process, the central variables using grounded theory methods and then mapping the explicit inferences drawn from the data analysis through causal loop diagrams. The diagrams are then validated for internal and external consistency.

Step 1: Selecting a Variable

The focus of the investigation is established by identifying significant (core) variables (categories) and their symptoms. The initial selection of a variable is decided by its apparent explanatory ability or central importance in the events being studied. (This implies that considerable open coding and comparative analysis has been conducted by the researcher.) This can be done through axial coding – the process of specifying the varieties of causes, conditions and consequences associated with the appearance of phenomenon referenced by the variable (Strauss 1987;64).

Step 2: Identifying Causes and Consequences

After a significant variable is identified, the next step is to identify other variables closely related to it. The data are analyzed to identify key factors which appear to drive or be driven by the selected variable. This can be accomplished by selective coding, wherein all other subordinate variables and their dimensions become systematically linked to the selected variable. (Strauss 1987)

Step 3: Describe Factor Relationships

After key factors associated with a variable have been identified, their interactions are diagrammed as causal-loop diagrams. The pairwise directed arcs developed during axial and selective coding are integrated into a closed system. There are usually many variables to explore and it doesn't matter which one is selected first assuming all will be investigated.

---

controls action, the level of the system, and information about the level (or condition) of the system, the latter returning to the decision-making point" (Forrester 1968; p.1-7). However, at a lower level of hierarchy, feedback loops contain a substructure composed of two types of variables — levels and rates (Forrester 1968). The level (or state) variables describe the condition of the system at any particular time while the rate variables tell how fast the levels are changing (Forrester 1968).

Step 4: Check Diagram Consistency

The diagrams should be compared to the collected data to ensure they are grounded in the available facts. Often early diagrams contain links which are not supported by the presented evidence. If upon review, the researcher is confident the loop reflects the system dynamics, additional theoretical sampling or coding is necessary to ensure the theory remains "grounded" in the available data. Additionally, the diagrams should be investigated for "leaps of logic", i.e.. can the diagram describe the patterns of events without explanation. Finally, the diagram is reviewed to ensure factor labels are at the same level of abstraction (Hayakawa 1990). For example, "*Design Constraint Tradeoff*" and "*Performance Comparison*" would be at the same level of abstraction while the abstracted category, "*Systematic Analysis*" would be at a higher level of abstraction.

Step 5: Integrating Causal-loop Diagrams into an Inductive System Diagram

After all significant variables have been diagrammed, the individual causal-loop diagrams are combined to articulate the underlying structure or theory. A central theme is developed using a clearly dominant (core) variable or by linking variables which are common to multiple causal-loop diagrams. Remaining causal-loop diagrams are incorporated into the central theme. Variables may be combined and re-labeled at a higher level of abstraction (Hayakawa 1990). Additionally, low impact loops are eliminated to simplify the diagram. This integrated ISD is validated for logic flow, abstraction levels, consistency with the data and participants in the area of investigation.

References

Abdel-Hamid, T. K., & Madnick, S. E. (1989). Lessons Learned from Modeling the Dynamics of Software Development. Communications of the ACM. Vol. 32 (12), 1426-1438

Adbel-Hamid, T. K., & Madnick, S. E. (1991). Software Project Dynamics: An Integrated Approach. Englewood Cliffs, NJ: Prentice Hall.

Akao, Y. (1990). Quality Function Deployment. Cambridge, MA: Productivity Press.

Ancona, D. G., & Caldwell, D. (1992). Demography and Design: Predictors of New Product Team Performance. Organization Science. Vol. 3 (3), 321-341

Argyris, C.,Putnam, R., & Smith, D. M. (1985). Action Science. San Francisco: Jossey-Bass.

Argyris, C., & Schon, D. A. (1991). Particpatory Action Research and Action Science Compared: A commentary. In W. F. Whyte (Eds.), Participatory Action Research Newbury Park: Sage.

Bailetti, A. J., & Guild, P. D. (1991). Designers' Impressions of Direct Contact Between Product Designers and Champions of Innovation. Journal of Product Innovation Management. Vol. 8, 91-103

Barlas, Y. (1989). Multiple Tests for Validation of System Dynamics Type of Simulation Models. European Journal of Operations Research. Vol. 42 (1), 59-87

Barlas, Y., & Carpenter, S. (1990). Philosophical Roots of Model Validation: Two Paradigms. System Dynamics Review. Vol. 6 (2), 148-166

Barton, A. H., & Lazarsfeld, P. F. (1969). Qualitative Data as Sources of Hypothesis. In G. McCall & J. L. Simmons (Eds.), Issues in Participant Observation Reading, MA: Addison-Wesley.

Becker, H. S., & Geer, B. (1969). Participant Observation and Interviewing: A Comparison. In G. McCall & J. Simmons (Eds.), Issues in Participant Observation Reading, MA: Addison-Wesley.

Blanck, P. D., & Turner, A. N. (1987). Gestalt Research: clinical-field-research approaches to studying organizations. In J. Lorsch (Eds.), Handbook of Organizational Behavior Englewood Cliffs: Prentice Hall.

Bower, J. L., & Hout, T. M. (1988). Fast-Cycle Capability for Competitive Power. Harvard Business Review. Vol. Nov-Dec, 110-118

Burchill, G., & Shen, D. (1992). Concept Engineering: The key to operationally defining your customer's requirements. Cambridge, MA: Center for Quality Management.

Burchill, G. (1993a). Concept Engineering: An investigation of TIME vs. MARKET orientation in product concept development. Unpublished doctoral thesis, Massachusetts Institute of Technology, Cambridge, MA.

Burchill, G. (1993b). Concept Engineering: A Complete Product-concept Decision-support Process. Design Management Journal. Vol. Fall, 78-85.

Burchill, G., & Kim, D. (1993). Inductive System Diagrams (Working Paper No. 93-93) MIT - International Center for the Management of Technology.

Cats-Baril, W. & Huber, G. (1987). Decision Support Systems forIll-Structured Problems: An Empirical Investigation". Decision Sciences. Vol. 18 , 350-372.

Clark, K., & Fujimoto, T. (1991). Product Development Performance. Boston, MA: Harvard Business School Press.

Clausing, D., & Pugh, S. (1990). Enhanced Quality Function Deployment. In Design and Productivity International Conference, . Honolulu, Hawaii:

Cook, T. D., & Campbell, D. T. (1979). Quasi-Experimentation: Design & Analysis Issues for Field Settings. Boston: Houghoton Mifflin. pp.405.

Cooper, R. G., & Kleinschmidt, E. K. (1986). An Investigation into the New Product Process: Steps, Deficiencies, and Impact. Journal of Product Innovation Management. Vol. 3, 71-85

Deming, W. E. (1986). Out of the Crisis. Cambridge: MIT: Center for Advanced Engineering Study. pp.507.

Deshpande, R., & Zaltman, G. (1982). Factors Affecting the Use of Market Research Information: A Path Analysis. Journal of Marketing Research. Vol. XIX, 14-31

Deshpande, R., & Zaltman, G. (1984). A Comparison of Factors Affecting Researcher and Manager Perceptions of Market Research Use. Journal of Marketing Research. Vol. XXI, 32-38

Dougherty, D. (1992). Interpretive Barriers to Successful Product Innovation in Large Firms. Organization Science. Vol. 3 (2), 179-201

Elam, J., Huber, G. & Hurt, M. (1986). An Examination of the DSS Literature (1975-1985). In E.R. McLean & H.G. Sol (Eds.), Decision Support Systems: A Decade in Perspective. North Holland: Elsevier Science Publishers.

Elden, M., & Levin, M. (1991). Cogenerative Learning: Bringing Participation into Action Research. In W. F. Whyte (Eds.), Participatory Action Research Newbury Park: Sage.

Forrester, J. W. (1968). Principles of Systems. Cambridge, MA: Productivity Press.

Forrester, J. W. (1992). Policies, decisions, and information sources for modeling. European Journal of Operational Research. Vol. 59, 42-63

Glaser, B. (1965). The Constant Comparitive Method of Analysis. Social Problems. Vol. 12,

Glaser, B. G., & Strauss, A. L. (1967). The Discovery of Grounded Theory: Strategies for Qualitative Research. Chicago: Aldine.

Glaser, B. G. (1978). Theoretical Sensitivity: Advances in the Methodology of Grounded Theory. Mill Valley, CA: Sociology Press.

Goodman, M. (1974). Study Notes in System Dynamics. Cambridge, MA: MIT Press.

Griffin, A., & Hauser, J. R. (1992). Patterns of Communication Among Marketing, Engineering and Manufacturing - A Comparison Between Two New Product Teams. Management Science. Vol. 38 (3), 360-373

Griffin, A., & Hauser, J. R. (1992 (forthcoming)). The Marketing and R&D Interface. In G. L. &. E. Lilien J. (Eds.), Handbook: MS/OR in Marketing Amsterdam: Elsevier Science Publishers.

Gupta, A. K.,Raj, S. P., & Wilemon, D. (1985). The R&D-Marketing Interface in High-Technology Firms. J. Product Innovation Management. Vol. 2, 12-24

Gupta, A. K.,Raj, S., & Wilemon, D. (1986). A Model for Studying R&D-Marketing INterface in the Product Innovation Process. Journal of Marketing. Vol. 50, 7-17

Gupta, A. K., & Wilemon, D. (1988). The Credibility-Cooperation Connection at the R&D-Marketing Interface. Journal of Product Innovation Management. Vol. 2, 20-31

Gupta, A. K., & Wilemon, D. (1990). Accelerating the Development of Technology-Based New Products. California Management Review. Vol. Winter, 24-44

Hayakawa, S.I., (1990). Language in Thought and Action 5th ed. New York: Harcourt Brace Jovanovich Publishers.

Hauser, J., & Clausing, D. (1988). The House of Quality. Harvard Business Review. Vol. 66 (3), 63-73

Hauser, J. R. (1991). Comparison of Importance Measurement Methodologies and their Relationship to Consumer Satisfaction (Working Paper No. 91-1). MIT: Marketing Center.

Houston, F. S. (1986). The Marketing Concept: What It Is and What It Is Not. Journal of Marketing. Vol. 50, 81-87

Ishikawa, K. (1985). What is Total Quality Control? Englewood Cliffs, NJ: Prentice-Hall.

Janis, I. L. (1985). Sources of Error in Strategic Decision Making. In J. M. Pennings (Eds.), Organizational Strategy and Change San Francisco: Jossey-Bass Publishers.

Jick, T. (1979). Mixing Qualitative and Quantitative Methods: Triangulation in Action. Administrative Science Quarterly. Vol. 24, 602-612

John, G., & Martin, J. (1984). Effects of Organizational Structure on Marketing Planning on Credibility and Utilization of Plan Output. Journal of Marketing Research. Vol. XXI, 170-183

Juran, J. M. (1988). Juran on Planning for Quality. New York: The Free Press.

Katz, R., & Tushman, M. R. (1979). Communication Patterns, Project Perfromance and Task Characteristics: An Empirical Evaluation and Integration in an R&D Setting. Organizational Behavior and Human Performance. Vol. 34, 139-162

Kawakita, J. (1991). The Original KJ Method. Tokyo: Kawakita Research Institute.

Kidder, L., & Judd, C. (1986). Research Methods in Social Relations, 5th.ed. New York: CBS College Publishing.

Kirk, J., & Miller, M. (1990). Reliability and Validity in Qualitative Research, 6th ed. Newbury Park: Sage.

Kohli, A. K., & Jaworski, B. J. (1990). Market Orientatoin: The Construct, Research Propositions, and Managerial Implications. Journal of Marketing. Vol. 54, 1-17

Kuhn, T. (1970). The Structure of Scientific Revolutions, 2nd ed. Chicago: University of Chicago Press.

Lawrence, P., & Lorsch, J. (1967). Organization and Environment. Boston: Harvard Business School Press.

Lewis, C. I. (1929). Mind and the World Order. New York: Dover Publications.

Mahajan, V., & Wind, J. (1992). New Product Models: Practice, Shortcomings and Desired Improvements. Journal of Product Innovation Management. Vol. 9, 128-139

Manning, P. K. Analytic Induction. In R. B. Smith & P. K. Manning (Eds.), Qualitative Methods Volume II of Handbook of Social Science Methods Cambridge: Harper & Row.

Mansfield, E. (1988). The Speed and Cost of Inductrial Innovation in Japan and the United States: External vs. Internal Technology. Management Science. Vol. 34, 1157-1169

Mass, N., & Senge, P. (1980). Alternate Tests for Selecting Model Variables. In J. Randers (Eds.), Elements of the System Dynamics Method Cambridge, MA: Productivity Press.

Miles, M. B., & Huberman, A. M. (1984). Qualitative Data Analysis. Beverly Hills: Sage.

Millson, M.,Raj, S., & Wilemon, D. (1992). A Survey of Major Approaches for Accelerating New Product Development. Journal of Product Innovation Management. Vol. 9, 53-69

Moenaert, R. K., & Souder, W. E. (1990 (a)). An Information Transfer Model for Integrating Marketing and R&D Personnel in New Product Development Projects. Journal of Product Innovation Management. Vol. 7 (2), 91-107

Moenaert, R. K., & Souder, W. E. (1990(b)). An Analysis of the Use of Extrafunctional Information by R&D and Marketing Personnel: Review and Model. Journal of Product Innovation Management. Vol. 7 (3), 213-29

Morecroft, J. (1982). A Critical Review of Diagraming Tools for Conceptualizing Feedback System Models. Dynamica. Vol. 8, 20-29

Morgan, G. (Ed.). (1983). Beyond Method. Beverly Hills: Sage.

Narver, J. C., & Slater, S. F. (1990). The Effect of a Market Orientation on Business Profitability. Journal of Marketing. Vol. 54, 20-35

National Research Council (1991). Improving Engineering Design: Designing for Competitive Advantage. Washington, DC: National Academy Press.

Ofuji, T.,Ono, M., & Akao, Y. (1990). Hinshitsu Tenkai-Ho (1) (Quality Deployment Method (1)). Tokyo: JUSE.

Patton, M. (1990). Qualitative Research Methods. Beverly Hills: Sage.

Pavia, T. M. (1991). The Early Stages of New Product Development in Entrepeneurial High-Tech Firms: Journal of Product Innovation Management. Vol. 8, 18-31

Pinto, M. B., & Pinto, J. K. (1990). Project Team Communicatons and Cross-Functional Cooperation in New Product Development. Journal of Product Innovation Management. Vol. 7, 200-212

Pugh, S. (1981). Concept Selection - A Method that Works. In International Conference on Engineering Design, . Rome, Italy:

Randers, J. (Ed.). (1980). Elements of the System Dynamics Method. Cambridge, MA: Productivity Press.

Reichelt, K. S., & Sterman, J. (1990). Halter Marine: A Case Study in the Dangers of Litigation. In MIT Sloan School of Management, Cambridge MA:

Reinertsen, D. G. (1983). Whodunit? The Search for the new-product killers. Electronic Business. Vol. July,

Richardson, G. P., & Pugh, A. L. (1981). Introduction to System Dynamics Modeling with DYNAMO. Cambridge, MA: Productivity Press.

Richardson, G. P. (1986). Problems with Causal-Loop Diagrams. Systems Dynamics Review. Vol. 2 (2), 158-170

Roberts, E. B. (1964). The Dynamics of Research and Development. New York: Harper and Row.

Roberts, E. B. (Ed.). (1978). Managerial Applications of Sytems Dynamics. Cambridge, MA: Productivity Press.

Robinson, W. S. (1951). The Logical Structure of Analytic Induction. American Sociological Review. Vol. 16, 812-818

Rothwell, R.,Freeman, C.,Horlsey, A.,Jervis, V.,Robertson, A., & Townsend, J. (1974). SAPPHO updated - project SAPPHO phase II. Research Policy. Vol. 3, 258-291

Schein, E. H. (1987). The Clinical Perspective in Fieldwork. Beverly HIlls: Sage. pp.71.

Schein, E., H. (1991). Legitimating Clinical Research in the Study of Organizational Culture No. 3288-91-BPS). Sloan School of Management, MIT.

Schmenner, R. W. (1988). The Merit of Making Things Fast. Sloan Management Review. Vol. Fall, 11-17

Senge, P. (1990). The Fifth Discipline: The Art and Practice of the Learning Organization. New York: Doubleday Currency.

Shapiro, B. P. (1988). What the Hell Is 'Market Oriented'? Harvard Business Review. Vol. Nov-Dec, 119-125

Shewhart, W. A. (1939). Statistical Method from the Viewpoint of Quality Control. Washington, DC: US Dept. of Agriculture. pp.155.

Shiba, S. (Ed.). (1991). KJ Manual. Cambridge: Center For Quality Management.

Shiba, S.,Walden, D., & Graham, A. (1993). A New American TQM: Four Practical Revolutions in Management. Cambridge: Productivity Press.

Song, X. M., & Parry, M. (1992). The R&D-Marketing Interface in Japanese High-Technology Firms. Journal of Product Innovation Management. Vol. 9, 91-112

Souder, W. E. (1988). Managing Relations Between R&D and Marketing in New Product Development Projects. J. Product Innovation Management. Vol. 5, 6-19

Sterman, J. D. (1984). Appropriate Summary Statistics for Evaluating the Historical Fit of System Dynamics Models. Dynamica. Vol. 10 (2), 51-66

Sterman, J. (1989). Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment. Management Science. Vol. 35 (3), 321-339

Sterman, J. (1992). System Dynamics Modeling for Project Management. In MIT Sloan School of Management, Cambridge, MA:

Strauss, A. (1987). Qualitative Analysis for Social Scientists. Cambridge: Cambridge University Press.

Takeuchi, H., & Nonaka, I. (1986). The new new product development game. Harvard Business Review. Vol. Jan-Feb, 137-146

Urban, G. L., & Hauser, J. R. (1980). Design and Marketing of New Products. Englewood Cliffs: Prentice-Hall.

Urban, G. L.,Carter, T.,Gaskin, S., & Mucha, Z. (1986). Market Share Rewards to Pioneering Brands: An Empirical Analysis and Strategic Implications. Management Science. Vol. 32, 645-659

Van de Ven, A. (1986). Central Problems in the Management of Innovation. Management Science. Vol. 32, 590-607

van Maanen, J. (Ed.). (1983). Qualitative Methodology. Beverly Hills: Sage.

von Braun, C.-F. (1990). The Acceleration Trap. Sloan Management Review. Vol. Fall, 49-58

Whyte, W. F.,Greenwood, D. J., & Lazes, P. (1991). Particpatory Action Research: Through Practise to Science in Social Research. In W. F. Whyte (Eds.), Participatory Action Research Newbury Park: Sage.

Wilson, E. (1990). Product Definition: Assorted Techniques and Their Marketplace Impact. In IEEE International Engineering Management Conference, (pp. 64-69).