

THE FRONT END OF PRODUCT DEVELOPMENT IN THE ELECTRONICS INDUSTRY: A RESEARCH PROPOSAL

Thomas A. Carbone, University of Alabama in Huntsville
Donald D. Tippett, University of Alabama in Huntsville

Abstract

New product development has been an area of intense study during the last decade. This is not surprising, considering the significant amount of resources a typical company expends in this area each year, and the fact that the survival of many companies is dependent on new product revenue. Yet published market success rates for new products are low. The product development process starts with what has been termed “The Fuzzy Front End.” There have been few intensive and methodological studies of the front end of product development focusing on specific industries and categories of new products. This paper reviews the literature of product development with a focus on the front end segment. A proposal is outlined for a research topic related to finding out what information is gathered, shared, and used in the front end for new product introductions of non-breakthrough products within the electronics industry.

Introduction

The process surrounding new product development (NPD) has been extensively studied over the years. Studies have evaluated success factors (Cooper, 1994; Griffin and Page, 1996), cycle time (Smith and Reinertsen, 1991; Griffin, 2002), and the various stage-gate processes (McGrath, 1996; Cooper et al., 2002) used for product development. The new product development process is often depicted as a funnel, where more ideas exist than can or should be developed. Exhibit 1 depicts a general new product development model similar to the one by Wheelright and Clark (1992). Ideas enter the front end funnel segment, pass through a number of development segments, and are ultimately released to market. The front end is depicted here as a cloud due to the fuzziness and challenge of making sense of the uncertainty in this segment. This early part of the process, from when the product idea is initiated up to the point just prior to the formal development phases, has been termed “The Fuzzy Front End” (FFE) (Smith and Reinertsen, 1991). A formal and accepted definition for the FFE is given in Exhibit 2.

Following the front end segment, there is typically a more formal process for the design phase through the launch phase. The exact number and nature of the segments in the front end and the following development phases, depends on the

Exhibit 1. The Major Product Development Segments with Average Product Mortality.

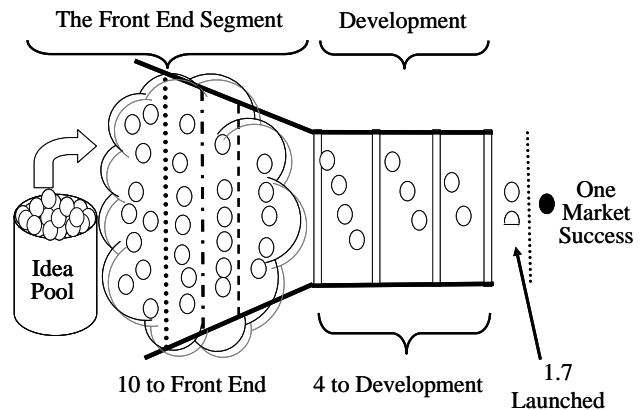


Exhibit 2. Definition of the Fuzzy Front End.

The Fuzzy Front End (FFE) is defined as the messy “getting started” period of product development, when the product concept is still very fuzzy. Preceding the more formal product development process, it generally consists of three tasks: strategic planning, concept generation, and, especially, pre-technical evaluation. These activities are often chaotic, unpredictable, and unstructured. In comparison, the subsequent new product development (NPD) process is typically structured, predictable, and formal, with prescribed sets of activities, questions to be answered, and decisions to be made (Belliveau et al., 2002).

particular model employed by an organization. Segments are further broken down into what have been termed phases or stages

For financial, technical, or market reasons, some products do not pass through the entire development process for release to the market. In addition, not all products released to the market can be considered a success. The funneling aspect from the front end to market launch has been plotted in what have been called new product development mortality curves (Griffin, 1997). It has been reported that it typically takes about 7 to 10 ideas to have one market success (Cooper 2001, 11; Adams 2004). Others argue it takes as many as 3000 ideas to achieve one success (Stevens and Burley, 1997). Averages for the product mortality as reported by Griffin (1997) are shown under each development segment in Exhibit 1.

Wheelright and Clark (1992) argue that managing the development funnel requires a widening of the mouth of the funnel, while at the same time narrowing the neck of the funnel. The narrowing of the neck should occur by using improved screening criteria during the FFE phase to increase the percentage of products that will become a market success.

The initial screening criteria are placed at each of the transitions from one phase to another within the FFE. Additional reviews, acting also as screens are placed within the development segment. As of the latest Product Development and Management Association (PDMA) survey, 71.6% of organizations are using some form of formal, cross-functional product development process that relies on deliverable review and approval (Adams, 2004). The reported use of this type of process has increased by almost 20% since the previous survey (Griffin, 1997).

While it is reported that cycle time for development has improved as the use of the phase and stage-gate processes has increased, the overall market success of a product once it is launched has remained steady! The PDMA studies from 1990, 1995, and 2003 report the product market success numbers at 58%, 59%, and 58%, respectively (Adams, 2004). These success numbers are for those products that are actually launched to the market place and do not reflect those products that were cancelled or failed for one reason or another within any of the prior phases. The failure rates for the combined development through launch phases are reported at 75% (Griffin, 1997; Cooper, 2001). Considering that most of the man-hours and dollar expenses occur in the development phases (Cooper and Kleinschmidt, 1988), if an organization improves the screening and selection of products before they enter development, then the financial success of the firm could improve as well.

To improve project screening, organizations must first have an idea of what makes a product a success. Second, they must have a process to manage and use the information in the front end phases for improved screening. In order to improve the success of product development, researchers have studied the process in search of the success factors. Montoya-Weiss and Calantone (1994) completed a meta-analysis of the new product development literature published between 1974 and 1992. They found that the literature on new product performance "is not highly consistent in terms of which factors are included in each study and which statistics are reported," (Montoya-Weiss and Calantone, 1994). In their review of 47 prior studies, these authors found 18 factors leading to product development success within the four categories: strategy, market environment, development process, and organizational aspects.

Given the amount of prior research into success factors, Poolton and Barclay (1998) summarize it accurately when they say, "despite this knowledge it is demonstrated that the factors associated with success have largely failed to be translated into practical guides for action."

The research proposed in this paper will build upon the prior work in the area of success factors, but with a focus on the way organizations, specifically in the electronic industry, gather, share, and use the information from the front end, to develop and launch new products. This procedure of gathering, processing, and sharing the information is defined as the information processing for the front end of new product development. In particular, this research will focus on product innovations in the categories of new-to-the-company (NTC), major revisions (MR), and additions-to-the-existing-product-line (AEL) type products. A research statement is proposed to examine the nature of information processing in the front end phases and its impact on the overall market success of new products. This research will improve upon the definitions of the construct items required for the front end information needs and processing for this particular industry. The additions to the knowledge base for this segment of the new product development process can then later be extended to additional industries for more general validation.

In the next section of the paper, the literature is reviewed for the overall new product development process, as well as the front-end-focused literature. The specific research statement is provided in the third section. Following that, details for the research methodology are provided. Finally the paper concludes with the expected results, benefits, and contributions of this research.

Literature Review

New Product Development Models. There have been numerous models proposed for the NPD process. In theory the models are similar in their intent to screen out the 'dogs' before expending too many company resources. Cooper and Edgett found the NPD process in most organizations is like a tunnel, not a funnel (1997). This means all products proposed enter the NPD process without proper analysis and screening. However, like a tunnel, or a pipeline, a company's new product development has a limited capacity and some sort of filtering must occur to improve effectiveness. Cooper et. al. (1997), point out that even though some organizations use maximization models, scoring models, bubble diagrams, and other portfolio selection tools in the early phases, managers have a difficult time making sense of all the related information. Because of this difficulty, the product filtering then occurs later by

default during one of the more formalized and more expensive product development phases, when products fail for technical or market reasons that were not fully explored earlier.

As was shown in Exhibit 1, the development process typically has a number of phases or gates. Exhibit 3 provides a summary of the more well known and publicized NPD models. Cooper's (2001) general Stage-Gate™ model includes five formal stages and five corresponding gates for: scoping, building the business case, development, testing and validation, and product launch. The discovery phase in this model is prior to the idea screen gate and is outside the numbered stages. Yet, that early discovery and ideation stage is certainly part of the fuzzy front end and deserves attention. In addition, the second stage in this model which is called "building the business case," is fairly heavy in requirements, so customization is likely required when it is applied to various industries or product types. It is also likely that breaking this stage into multiple stages based on collaboration needs, as well as adding to the model for firm specific needs, is warranted.

McGrath (1996) describes a five phase development model consisting of concept evaluation, planning and specification, development, test and evaluation, and product release with decision gates at the conclusion of each phase. Within Phase 1 of this model, called 'Planning and Specification', the development team is expected to plan the project while at the same time defining the product specifications. Others suggest that the product specifications must be set prior to detail planning (Buggie, 2002). If the product specifications are not set prior to detail planning, the product being planned is also being scoped, which causes increased uncertainty and fuzziness during the planning that likely continues into development. In addition, the organization members who set product specifications are sometimes different from the team that will develop the product. So, it is conceivable that a formal sharing of information is needed from the venture team to the development team. By having a separate phase, this review would be built into the process.

Clausing (1994) takes a total quality view of the development process with a four phase model of concept, design, preparation, and production. Within the framework, he defines specific tools that can be used within each of the phases. This model is mostly focused on the technical attributes of the product and does not claim to cover the entire new product development process. For example, the planning is largely skewed toward planning the product and not the project. For this model to be more complete, it would require details for portfolio review, and an

additional focus on project versus product planning and execution.

The quality initiatives have also sparked a move towards what is called, "Advanced Product Quality Planning (APQP)," (Chrysler et al., 1995). APQP, as part of QS-9000, was originally developed for the auto industry and is now widely applied across many industries (Stamatis, 1998). This is a five phase model that defines in much detail what needs to be done in each phase of the project. The model however has no recommendations for the front end segment.

While these models have very good points for product development, in many instances they lack the details required to manage the front end. These models were developed to improve the development process. Research shows that use of the models improves such metrics as cycle time, yet product success remains flat (Adams, 2004). The next obvious improvement is to the early part of the process where managers can make an impact on what products should continue to development. It is in these early front end phases where, if unresolved, ambiguity and uncertainty cause delay and confusion over what the actual product being developed will become (Smith and Reinertsen, 1991). Even more dangerous than the increased cycle time in the front end, is the cost of developing a product that has little chance of being a success. Further, due to differences in product innovation levels, the specific industry, and the markets being served, the information gathered, shared, and used between the front end and the development phases for decision making, will likely vary among firms. To that end, a more focused research effort on the front end is now underway to define the front end processes to improve product success.

The Front End. In an effort to improve product success, the activities prior to the development phases are receiving additional researcher attention due to the belief that the greatest opportunity to improve product success rates rests with improving the front end process (Smith and Reinertsen, 1991; Cooper, 1997; Khurana and Rosenthal, 1997). Khurana and Rosenthal (1998) state that the problems in the FFE are "due to lack of disciplined execution of front-end activity, rather than underlying confusion about what ought to be done." Zahay et. al. (2003) support these findings and note that the "reality is that no formal process for integrating the sources and forms of data into NPD exists." This is complicated by the fact that the FFE is the most information intensive phase of the NPD process (Zhang and Doll, 2001; Zahay et al., 2003).

Exhibit 3. A Sample of New Product Development Models.

Author(s)	Type of Model *	Description
Cooper, 2001	NPD	The Stage-Gate™ model with five stages and five gates. Stage 1: Product Scoping Stage 2: Build the Business Case Stage 3: Development Stage 4: Test and Validation Stage 5: Product Launch
McGrath, 1996	NPD*	A Five Phase Model. Phase 1: Concept Evaluation Phase 2: Planning and Specification Phase 3: Development Phase 4: Test and Evaluation Phase 5: Product Release
Clausing, 1994	NPD*	A Four Phase Model. Phase 1: Concept Phase 2: Design Phase 3: Prepare Phase 4: Produce
Ford, GM, and Chrysler APQP, 1995	NPD	A Five phase model. The project scoping phase is prior to the first formal phase Phase 1: Plan & Define Program Phase 2: Product Design & Development Phase 3: Process Design & Development Phase 4: Product & Process Validation Phase 5: Launch, Feedback, Assessment & Corrective Action

* These NPD models include the development phases, plus some portion of the front end.

Other researchers such as Reid and de Brentani (2004) also note that, “a search for better processes in support of the fuzzy front end appears to be called for in order to help firms achieve greater success in their efforts to develop new products.” Given this intense information overload during the front end, an improvement of how information is gathered, used, and shared, defined here as information processing, for project selection is warranted.

It is reported that by improving the upfront homework in the pre-development phases, the market success rate will improve (Cooper, 1996). It is also recognized, that too much formality in the screening process will lead to less risk taking and the possibility of missing a big winner (Reinertsen, 1999). So, a process is needed that has a balance of screening out what have been called the “dogs,” while, at the same time, not being excessively rigid to the point that it screens out too many winners. The process to gather, share and use the required information to make these decisions takes time.

All too often, there is a desire to do the development before the proper time is spent on the homework. Page and Stovall (1994) studied the early stages in the new product development process as it relates to the overall development cycle time. They found that those companies that spent more time on the front end activities have improved speed to

market, allocated more in R&D for successful products, had higher profits from new products, and had increased revenue from new products. However, critical information needs to be analyzed. Without a process and framework to help the organization through the uncertainty of the front end, all too often, the decision to go to the development segment is flawed. Cooper reports that 37% of projects have no pre-development financial or business analysis and that 88% of projects are deficient for front end screening (1997). As was done for the development segment decades ago, models have now been developed to help structure the front end to improve the screening and decision making process.

Front End Models. Exhibit 4 lists a few of the more developed models of the front end segment. Smith and Reinertsen (1998) specify a three-stage front end model to help with the front end planning and decision making. In the first stage a project proposal is presented, the second stage prepares a business plan for financial and market justification, and the third stage is for detailed project planning prior to detail design activity. This is a high level model and it is not known if it has been validated. In addition, the Smith and Reinertsen model gives very little treatment to the initial idea generation process.

Exhibit 4. A Sample of Specific Front End Models Focused on the Phases Prior to Development.

Author(s)	Description
Smith and Reinertsen, 1991	Three stage Front End Model. Stage 1: Project Proposal Stage 2: Business Plan Stage 3: Detail Project Plans & Product Specifications
Paul, 1996	Three Step Front End Model. Step 1: Idea screen Step 2: Concept Development and Testing Step 3: Business analysis
Khurana and Rosenthal, 1997	A Three Phase Front End Model. Pre-phase Zero: Preliminary Opportunity Identification and Market and Technical Assessment; in Parallel with the Product and Portfolio Strategy Evaluation Phase 0: Product concept is defined Phase 1: Product feasibility and project planning

Paul (1996) studied business to business product development and stressed the importance of having an idea screen process within the front end segment. He proposed a general three-step approach consisting of the internal idea screen, concept development and testing, and business analysis. However, again very little is discussed on capturing the idea generation process. Additionally, it is questionable whether or not one should perform concept testing before a business analysis. That is something that is very likely dependent on an industry and type of product.

Spanjol (2003) studied the importance of the idea generation process as part of the front end. This idea generation process happens even earlier than the project proposal of the Smith and Reinertsen model or the idea screen step of the Paul model. Spanjol suggested that it is the organizational and managerial creativity and not functional knowledge (marketing and technical) that is more strongly associated with new product creativity. This finding could have large implications for the proper organization of the information processing aspects of the front end.

Khurana and Rosenthal (1998), using interviews, analyzed problems reported in the front end at twelve companies in the U.S., Japan, and Europe. From this study, they summarized that organizations either used a formal process approach or a culture-driven approach for their front end. The majority of the companies in their sample tended not to have any formal front end process, a situation the authors called a shortcoming in need of remedy. Another key point the authors argue is that the front end process should be adapted to the innovation level of the product, the target market, and the organizational context. Their front end model has a pre-phase zero, a phase zero and a phase one. In the pre-phase zero phase they suggest a preliminary opportunity identification and a market and technical assessment, in parallel with the product and portfolio strategy evaluation. During phase zero the product concept is defined. Phase one is used for

product feasibility and project planning. Within this model, a significant amount of work is expected in the pre-phase zero and phase 1 phases. This includes both product feasibility studies and project planning. Separating out the activities of these phases into a more structured process could improve on the decision making. This is especially needed if information is transferred amongst organizational units or teams doing this work.

Front End Collaboration. Having a model to use and follow is only one portion of what is needed during the front end. As information is gathered it must be shared across various groups in the organization using a defined and understood process. To clarify the fuzzy front end, some sense must be made of how the information is shared and ultimately used for decision making.

Olson et. al. ((2001)) studied the cooperation between marketing, operations, and R&D across 34 projects in nine different industries. From interviews and surveys of the project leaders and team members, they conclude that the cooperation between these groups depended on both the phase of the development process and the innovation level of the product. In a study across the chemical, industrial machinery, plastics, glass, metal products, information technology hardware suppliers, textiles, and "a wide diversity of other industries," Moenaert, et. al. (1995) researched the communication occurring during the front end between R&D and marketing and also found that the necessary collaboration depended on the innovation level of the product.

Ottum and Moore (1997) describe the requirement for market research during the front end of product development and conclude that the final "usage" stage of that information across groups is the most critical in the context of marketing data. In a related theme, Flint (2002) discusses the use of

customer information to improve the product definition aspect for the FFE.

In all of these examples, it is apparent that information must be obtained and utilized. This requires a method to organize and process the data so the organization can make use of it for decision making in the front end.

Gathering, sharing, and using the market, customer, and team-generated data is a challenging task regardless of who is responsible. A number of software products have emerged to help new product development teams gather, share, and use the information they need. Zahay et al. (2003) reviewed how product developers manage knowledge during the creation of new products. In their review of information computer software they note, "none of the systems were developed with an eye to the full set of uncertainties that need to be reduced throughout the product development process." Since it was found that collaboration is dependent on the product innovation level, it is likely that the system used for information processing may depend on this factor as well.

With the complexity of the market, customers, and product innovation levels, the task of gathering, sharing, and using the information needed in the front end is a daunting task. These early models have been a good start at understanding the factors in the front end that contribute to product success. The shortcomings of these models are that they are high level, inconclusive, and all are not validated for specific industries and innovation levels. Given the state of existing models, a more comprehensive model that ties together the information processing with the product development requirements is needed for the respective innovation level. In order to create such a model, the organization must first understand the information required and then create a process to share and use that information so as to improve product market success rates.

Research Statement

The overall process of new product development relates information about the product idea, the analysis of the idea, the product concept, the development of the concept into a validated product, and the release of the product to the market. This research focuses on the information gathered, shared, and used for the front end of product development in the electronics industry for product innovations in the categories of new-to-the-company (NTC), major revisions (MR), and additions-to-the-existing-product-line (AEL) type products. The focus on a specific innovation level is based on previous research findings noting that much of the collaboration depends on the innovation level of the product. If the collaboration and information

sharing depends on the innovation level, then it is likely this impacts the process used and the resulting product success. In addition, past studies have been criticized for being too general in trying to cover almost all industries and innovation levels at the same time. The specific research statement used here is, "the information gathered, shared, and used during the front end of new product development, positively impacts the market success of new products." The research will include a framework to utilize the findings for improved portfolio project selection from the front end to the formal development phases leading to improved success. Specific research hypotheses will be developed and tested to correlate the factors identified for the full construct during the formal research phase.

Research Methodology

Multiple methods will be required to gather the data for this research topic. The researcher will conduct interviews with management from product development and marketing organizations of the targeted firms. As in Khurana and Rosenthal (1998), the organizations considered for the study will already have a formal product development process for the detailed design to launch phases. The researcher will determine if the development methodology in use by the firm meets the research requirements.

As recommended by prior research, product selection from the candidate product list will be done on a random basis (Montoya-Weiss and Calantone, 1994). The list will then be divided into those that were released to the market and failed, those released and deemed successful, and those that were stopped during any of the development phases. It is a goal of this research to obtain an approximately equal number of successes and failures for analysis from each firm.

The instrument for the individual project evaluations will be developed from the study of the nomological network based on an in-depth literature review in accordance with survey development best practices (Churchill, 1979; Nunnally and Bernstein, 1994). The specific factors that will be included in the instrument to validate the construct will depend on the antecedents, correlates, and consequents identified for the research. Prior work on survey development for the FFE will be used (Carbone, 2004).

As in other studies, the instrument will likely include items from previously developed surveys, as well as new items required for this specific research (Ottum, 1994; Spanjol, 2003). The survey will be evaluated prior to pilot testing by subject matter experts in the area of NPD. The target sample for the main survey instrument is a minimum of two people involved with each new product development project in the sample.

This research aims to contribute to the knowledge base with enhanced analysis. Montoya-Weiss and Calantone (1994) point to the lack of rigorous statistical analysis reported for new product development studies in the literature. Therefore, the data collected for this research will be analyzed using correlation statistical techniques and multivariate procedures. A full set of validity testing will also be completed.

Expected Results, Benefits and Contribution

This research will be an in-depth analysis of specific projects, in the categories of new-to-the-company (NTC), major revisions (MR), and additions-to-the-existing-product-line (AEL) type products, within one industry. By testing the research hypotheses, it is expected that an improved framework will be developed for managing the critical front end of NPD. This new framework can then be expanded into a model that spans the entire new product development process and is specific and applicable to this industry.

The contribution of this research is to help organizations understand that how they process information in the front end impacts the overall market success of the product. To the academic community, this knowledge will lead to further investigation and research across industries and product innovation levels. For the applied researcher, the findings will have a positive financial impact on the development pipeline by providing guidance for an improved information process within the front end of product development.

By having a more clearly defined information process, it is expected that the Fuzzy Front End segment of new product development can be renamed by removing the term "fuzzy." While it may certainly be true that the product ideas, concepts, and even the markets will be fuzzy during this time, this does not mean the processes and activities of this stage need to be fuzzy as well.

References

Adams, Marjorie, "The PDMA Foundation's Comparative Performance Assessment Study (CPAS) Results," *Comparative Performance Assessment Conference*, Product Development Management Association (PDMA) New Orleans, LA, (2004).

Belliveau, Paul, Abbie Griffin, and Stephen Somermeyer, *The PDMA Toolbook for New Product Development*, John Wiley & Sons, Inc. (2002).

Buggie, Frederick D., "Set the "Fuzzy Front End" in Concrete," *Research Technology Management* 45:(4) (2002), pp. 11-14.

Carbone, Thomas A., "Developing a New Survey Instrument for the Fuzzy Front End of New Product Development: The Agony and Ecstasy," *Proceedings of the American Society of Engineering Management Annual Conference* Alexandria, Virginia, (October 20-23, 2004).

Chrysler, Ford, and General Motors, *Advanced Product Quality Planning and Control Plan: Reference Manual*, Automotive Industry Action Group (1995).

Churchill, Gilbert A., "A Paradigm for Developing Better Measures of Marketing Constructs," *Journal of Marketing Research* 16 (1979), pp. 64-73.

Clausing, Don, *Total Quality Development. A Step-By-Step Guide to World-Class Concurrent Engineering*, ASME Press (1994).

Cooper, Robert G., "Debunking the Myths of New Product Development," *Research Technology Management* 37:(4) (1994), pp. 40-50.

Cooper, Robert G., "Overhauling the new product process," *Industrial Marketing Management* 25:(6) (1996), pp. 465-482.

Cooper, Robert G., "Fixing the fuzzy front end of the new product development process. Building the business case.," *CMA Management* 71:(8) (1997), pp. 21-23.

Cooper, Robert G., *Winning at New Products: Accelerating the Process from Idea to Launch*, (2001).

Cooper, Robert G., Scott J. Edgett, and Elko J. Kleinschmidt, "Portfolio Management in New Product Development: Lessons from the Leaders - I," *Research Technology Management* 40:(5) (1997), pp. 16-28.

Cooper, Robert G., Scott J. Edgett, and Elko J. Kleinschmidt, "Optimizing the Stage-Gate Process: What Best-Practice Companies Do - II," *Research Technology Management* 45:(6) (2002), pp. 43-49.

Cooper, Robert G., and Elko J. Kleinschmidt, "Resource Allocation in the New Product Process," *Industrial Marketing Management* 17 (1988), pp. 249-262.

Flint, Daniel J., "Compressing new product success-to-success cycle time: Deep customer value understanding and idea generation," *Industrial Marketing Management* 31:(4) (2002), pp. 305-315.

Griffin, Abbie, "PDMA Research on New Product Development Practices: Updating Trends and Benchmarking Best Practices," *Journal of Product Innovation Management* 14 (1997), pp. 429-458.

Griffin, Abbie, "Product development cycle time for business-to-business products," *Industrial Marketing Management* 31:(4) (2002), pp. 291-304.

Griffin, Abbie, and Albert Page, "PDMA Success Measurement Project: Recommended Measures for Product Development Success and Failure," *Journal*

- of *Product Innovation Management* 13:(6) (1996), pp. 478-496.
- Khurana, Anil, and Stephen R. Rosenthal, "Integrating the Fuzzy Front End of New Product Development," *Sloan Management Review*:(Winter) (1997), pp. 103-120.
- Khurana, Anil, and Stephen R. Rosenthal, "Towards Holistic "Front Ends" in New Product Development," *Journal of Product Innovation Management* 15:(1) (1998), pp. 57-74.
- McGrath, Michael E., *Setting the PACE in Product Development, A Guide to Product and Cycle-time Excellence*, Elsevier (1996).
- Moenaert, Rudy K., Arnoud De Meyer, William E. Souder, and Dirk Deschoolmeester, "R&D/Marketing Communication During the Fuzzy Front End," *IEEE Transactions on Engineering Management* 42:(3) (1995), pp. 243-255.
- Montoya-Weiss, Mitzi M., and Roger Calantone, "Determinants of New Product Performance: A Review and Meta-Analysis," *Journal of Product Innovation Management* 11 (1994), pp. 397-417.
- Nunnally, Jum C., and Ira H. Bernstein, *Psychometric Theory*, McGraw-Hill, Inc. (1994).
- Olson, Eric M., Orville C. Walker Jr, Robert W. Ruckert, and Joseph M Bonner, "Patterns of Cooperation During New Product Development Among Marketing, Operations and R&D: Implications for Project Performance," *Journal of Product Innovation Management* 18 (2001), pp. 258-271.
- Ottum, Brian D., and William L. Moore, "The Role of Market Information in New Product Success/Failure," *Journal of Product Innovation Management* 14 (1997), pp. 258-273.
- Ottum, Brian Douglas, "The Role of Market Information in New Product Success/Failure," University of Utah, (1994), 263.
- Paul, Ronald N., *Evaluating Ideas and Concepts for New Business-To-Business Products*. in The PDMA Handbook of New Product Development. M. D. Rosenau, A. Griffin, G. A. Castellion and N. F. Anschuetz. John Wiley & Son, Inc. (1996).
- Reid, Susan E., and Ulrike de Brentani, "The Fuzzy Front End of New Product Development for Discontinuous Innovations: A Theoretical Model," *Journal of Product Innovation Management* 21 (2004), pp. 170-184.
- Reinertsen, Donald G., "Taking the Fuzziness Out of the Fuzzy Front End," *Research Technology Management* 42:(6) (1999), pp. 25-31.
- Smith, Preston G., and Donald G. Reinertsen, *Developing Products in Half the Time*, Van Nostrand Reinhold (1991).
- Smith, Preston G., and Donald G. Reinertsen, *Developing Products in Half the Time: New Rules, New Tools*, John Wiley & Sons, Inc. (1998).
- Spanjol, Jelena, "Idea generation in new product development: A cognitive framework of the fuzzy front end," UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN, (2003), 298.
- Stamatis, D. H., *Advanced Quality Planning. A Commonsense Guide to AQP and APQP*, Productivity Press, Inc. (1998).
- Stevens, Greg A., and James Burley, "3,000 Raw Ideas = 1 Commercial Success!," *Research Technology Management* 40:(3) (1997), pp. 16-27.
- Wheelwright, Steven C., and Kim B. Clark, *Revolutionizing Product Development*, (1992).
- Zahay, Debra, Abbie Griffin, and Elisa Fredericks, "Sources, uses, and forms of data in the new product development process," *Industrial Marketing Management* 32 (2003), pp. Online, Uncorrected Proof.
- Zhang, Qingyu, and William J. Doll, "The fuzzy front end and success of new product development: a causal model," *European Journal of Innovation Management* 4:(2) (2001), pp. 95-112.

About the Authors

Thomas A. Carbone is manager of the Global Operations Project Office at Fairchild Semiconductor in South Portland, Maine. He received a BSEE from the Rochester Institute of Technology and an MS in Engineering Management from the University of Massachusetts at Amherst. Mr. Carbone is pursuing a Ph.D. in Engineering Management from the University of Alabama in Huntsville. His research interests are in the areas of product development. Mr. Carbone is a member of the IEEE, PMI, ASEM, PDMA, and ASQ. He is a certified Project Management Professional (PMP®) and a certified Six Sigma Black Belt.

Donald D. Tippett holds Master and Doctor of Engineering Degrees in Industrial Engineering from Texas A&M University, and a Bachelor's Degree in Mechanical Engineering from the U.S. Naval Academy. He is a member of the Engineering Management Faculty at the University of Alabama in Huntsville. His experience includes ten years' active duty as a carrier-based naval aviator with the U.S. Navy. Subsequently he held a project management position in materials management systems with Union Carbide Corporation, served as Program Manager, Advanced Technology with Newport News Shipbuilding, working the area of computer integrated manufacturing, and was a member of the EM faculty at the University of Tennessee.