PRODUCT DESIGN AND DEVELOPMENT

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INNOREGIO: dissemination of innovation and knowledge management techniques

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1 DESCRIPTION

1.1 What is the technique

As many companies have demonstrated over time, product design contributes greatly to the improvement of competitiveness, because it permits reduction of costs, increase of quality, and often, shortening of the time necessary to get the product on the market. The product, in turn, generally satisfies customers' necessities and demands.

Until few years ago, the process of product design and development was basically focused on defining the characteristics that a product should have in order to make it the correct response to certain functional specifications, the latter often being defined by restrictions imposed by manufacturing processes. However the design process is now contemplated from a wider perspective: instead of merely referring to the products own characteristics, it now takes into account 'external' factors such as:

- Customers' requirements
- Quality
- Reduction of manufacturing costs and controls
- The assembly and distribution process
- Environmental impact before and after manufacture
- Product disassembly reuse and recycling
- Safety, hygiene, ergonomic factors, etc.

These factors must be taken into account from the very conception of the product, in order to satisfy the dynamics of ever more competitive markets as regards price, quality and time to market of new products. The changing demands of customers must also be satisfied, a factor involving new social perceptions, like concern for the environment. All this has a direct effect on the way in which products must be designed, produced and recycled, and introduces new ways of looking at the Product Development process – design included, of course- as well as at the techniques and technologies involved. The implications of this new perspective on design are important:

a) The new product must satisfy numerous criteria simultaneously
b) These criteria must be taken into account during the conception of the product. Consequently, each of them must be identified, made explicit and related to the others. The synergies and restrictions that may exist between them during the entire life of the product must be analyzed.
c) As a result, the designer can no longer act in an isolated fashion; instead he/ she must interact with many other specialists both inside and outside the company in order to define the different criteria that characterize a product. In addition, systems that enable the proper filtering, storing and recovery of the information generated in each of these concurrently – working teams are also necessary.
d) The information that must be managed therefore increases almost exponentially. Design and manufacture characteristics are considered basic information to be handled jointly and simultaneously during the design process.

Product Design is similar to Industrial Design (ID) but differs in several important ways. ID as taught in the United States is concerned with a broad spectrum of design activity, spanning everything from graphics and package design to exhibit and environmental design. Product Design focuses on 3-dimensional design. Typical Industrial Design training entails a broad art education that does not delve into any one subject in great depth. It is typically interested in the skin of products but not the actual workings of the inside. As a consequence this education tends to focus on the communication skills, which are expected by potential employers. The typical ID graduate anticipates many years "on the board" and is expected to be aesthetically accomplished to the smallest detail.

The main difference of Product Design from Mechanical Engineering is that the later is primarily involved with the application of analysis and scientific theory to the design of engineering systems. Primary concerns include understanding the behavior of materials, fluid flow and thermodynamic issues of an assigned problem. Tools are often analytical as in stress analysis, kinematics and the modeling and optimization of system components. Typically pure engineering problems do not have product's appearance or use by humans as primary concerns. On the other hand, Product Design is involved in products where these issues and their interaction with the internal technology are critical to the success of the product.

1.2 Objectives of Design and Development Techniques

Design techniques form a set of tools that enable product innovation, improving their quality, functionality, image and differentiation, and thereby permitting SMEs to better greatly their competitiveness. Main goals of Product Design methodologies include:

1. help new products meet the specifications related to customers needs, quality, price, manufacturing, recycling, etc
2. reduce development costs and time necessary for commercialization.
3. co-ordinate and schedule the activities involved in the design and development of products within the entire set of activities, taking into account time, tasks, resources, manufacturing, etc, all in the context of the company.
4. integrate the above objectives into a development strategy in line with the company's capacities.

1.3 Techniques that can be used in Product Design and Development

Many 'technology ready' techniques and tools are currently in use. The comprehensive and simultaneous conception of the Product Development process entails specific design and development techniques that permit managing the relevant information. These techniques can be classified into two broad groups.

1. Techniques and Tools for Design Improvement

These provide the company with analytical techniques and tools designed to analyse the product concept in the context of its restrictions. Main techniques of this group are: escribed:

- *Concurrent Engineering (CE)*
  Concurrent Engineering also known as Simultaneous Engineering is primarily an expression of the intention to increase competitiveness by decreasing the lead-time, while still improving quality and cost. Concurrent Engineering is a system in which the various

engineering activities in the product production and development process are integrated and performed as much as possible in parallel rather than in sequence.

Implementation of Simultaneous Engineering means that multi-functional teams cooperate in the early stages of the Product Development process to fulfill these objectives. As a result, most modifications of the product will not be made in the production stage (more costs) but in the design stage. The product must be designed taking into account all the requirements necessary to each stage of each life cycle, from design deactivation. These include functional factors but also aesthetic, ergonomic, easy manufacturing assembly, repair and recycling.

Product oriented SE-organizational strategies establish a specific platform, so that those involved in all relevant company functions have the chance to articulate their interest and concerns. Thus, the enterprise establishes cooperation as a basic component of the Product Development process at an early stage.

- *Quality Function Deployment (QFD)*
  This methodology is a means to convert the client's opinions into the specifications of the product at every step of its development. It is helpful to structure and systematize several steps usually carried out in a discovered and incoherent way. To perform QFD, interdisciplinary teams are formed, bringing together marketing, research and development, process planning, quality assurance and manufacturing.
  This multidisciplinary approach permits:
  - ✓ Listening to the voice of the customer
  - ✓ Improving horizontal and vertical communications
  - ✓ Setting priorities for Product Development
  - ✓ Improving product reliability
  - ✓ Defining technical goals
  - ✓ Sequencing the individual goals
  - ✓ Defining areas of cost reduction

- *Design for (DfX)*
  As the process of Product Development and Design is how conceived, products must meet a broad series of optimization requirements, generically denominated 'X'. Design of various factors, such as manufacture, assembly, environment, etc., is defined as DfX and aims to optimize design, manufacture, and support, through the effective feedback of the 'Xs" within the design domain knowledge, in order to incorporate it during the design stages, X in DfX stands for manufacturability, inspectability, recyclability, etc. These words are made up of two parts: life cycle business process (x) and performance measures (bility), that is

  X=x + bility

  For example, "x=total" and "bility=quality" in "design for total quality"; "x=whole life" and "bility=costs" in "design for whole – life costs"; "x=assembly" and "bility=cost" in "design for assembly cost", and so on. On another hand, "design" in DfX is interpreted as concurrent design of products and associated processes and systems.

The proliferation and expansion of "Xs" has led to a string of new terms such as design for Manufacturability, design for Quality, Design for Recyclability, etc. Design for X has been devised as an umbrella for these terms. Most of them are closely related and decisions made on any one of them may affect the other "Xs" in the final product performance.

DFMA (Design for Manufacturing and Assembling) is the integration of the separate but highly interrelated issues of assembly and manufacturing processes. It aims to help companies make the fullest use of the manufacturing processes that exist, while keeping the number of parts in an assembly to a minimum. First, Design For Assembly (DFA) is conducted, leading to a simplification of the product structure. Then, early cost estimates for the parts are obtained, for both the original designed and the new design, in order to make trade-off decisions. During this process the best materials and process for the various parts are considered. Once the materials and processes have been selected, a more thorough analysis for Design For Manufacture (DFM) can be carried out for the detail design of the parts.

- *Failure Mode and Effects Analysis (FMEA)*
  FMEA evaluates, in a systematic and structured way, the effects of failures on customers. A list of possible failures, their effects and causes, is drawn up and classified by effects on the client. This evaluation makes it possible to give priority to corrective actions. There are two kinds of FMEA: process (client=final user of next process stage) and design (client=final user). To use this method effectively, FMEA concentrates on selected system components. It is used for the following:
  - ✓ New development of a product
  - ✓ Security and problem parts
  - ✓ Product or process modification, and
  - ✓ New operation or other conditions of existing products

2. Computational Techniques and Tools

These are techniques that support design integration through shared product and process models, and databases. The advantages of using effectively Computational Techniques and Tools are to allow different teams to share information and to manage all data required to proceed on the process. Main techniques of this group are:

- *Computer Aided (CAx) Systems*
  These computer applications are used in the creation, modification, analysis and optimization stages of Product Design. The term CAx means Computer Aided (CA) support of the industrial production, where the "x" stands for different activities within the Product Development and manufacturing process, such as D for Design, Q for Quality, E for Engineering, etc. Since 70 to 80 percent of product costs are determined during the development phase, the most important systems in this group of tools are CAD (Computer Aided Design). The competitive pressure in the development of industrial products adds new demands on the development process, which cannot be fulfillment by traditional approaches of CAD technology, Industries that want to keep their market position need to develop strategies which take into account new solutions for information technology. Some characteristic features of current and future trends in CAD development are listed below:
  - ✓ x – D geometric modeling (2 – D, 3 – D)

- ✓ Employment of process chains and product models
- ✓ Parametric and associative design
- ✓ Open architecture of hardware and software systems
- ✓ User driver software development
- ✓ Distributed Product Development and life cycle engineering

CAPP (Computer Aided Product Planning) is the meeting of Cad and CAM. This system is used to automate the repetitive functions of process planning. It produces more constant and efficient plans taking into account the available equipment, updated designs and the most recent engineering changes. There are tow kinds of CAPP systems:

- ✓ Variant: These systems select one plan from a library of already existing process plans and modify it to adapt it to the specific manufacturing requirements of a new product.
- ✓ Regenerative: These systems create the production process plan with no reference to any existing plan.

- *Engineering / Product Based Data Management (E/P BDM)*
  These systems are also considered CAx systems. An E/P BDM system manages all the information – data and processes – related to the product electronically. It allows two different possibilities: Firstly creating reports, data transport, images and translation services, files, NC programs, documents etc., and secondly providing interfaces to other systems (CAD, CAM…) or integration with different databases.

- *Knowledge Based Engineering (KBE)*
  KBE is a system that can be programmed to reproduce the decisions that an engineer has to take when producing designs. This system using databases, a knowledge base and a set of rules called algorithms, which are able to take decisions using the knowledge contained in the knowledge base.

  Knowledge Based Engineering (KBE) is a step ahead in the development of CAD systems, since it does not only use design information; rather, it includes the rules that are used to create design. KBE systems are also known as expert systems.
  KBE systems are used like CAD systems, throughout the entire design process, especially in the detail design phases. Moreover, they store engineering information generated during the design process.

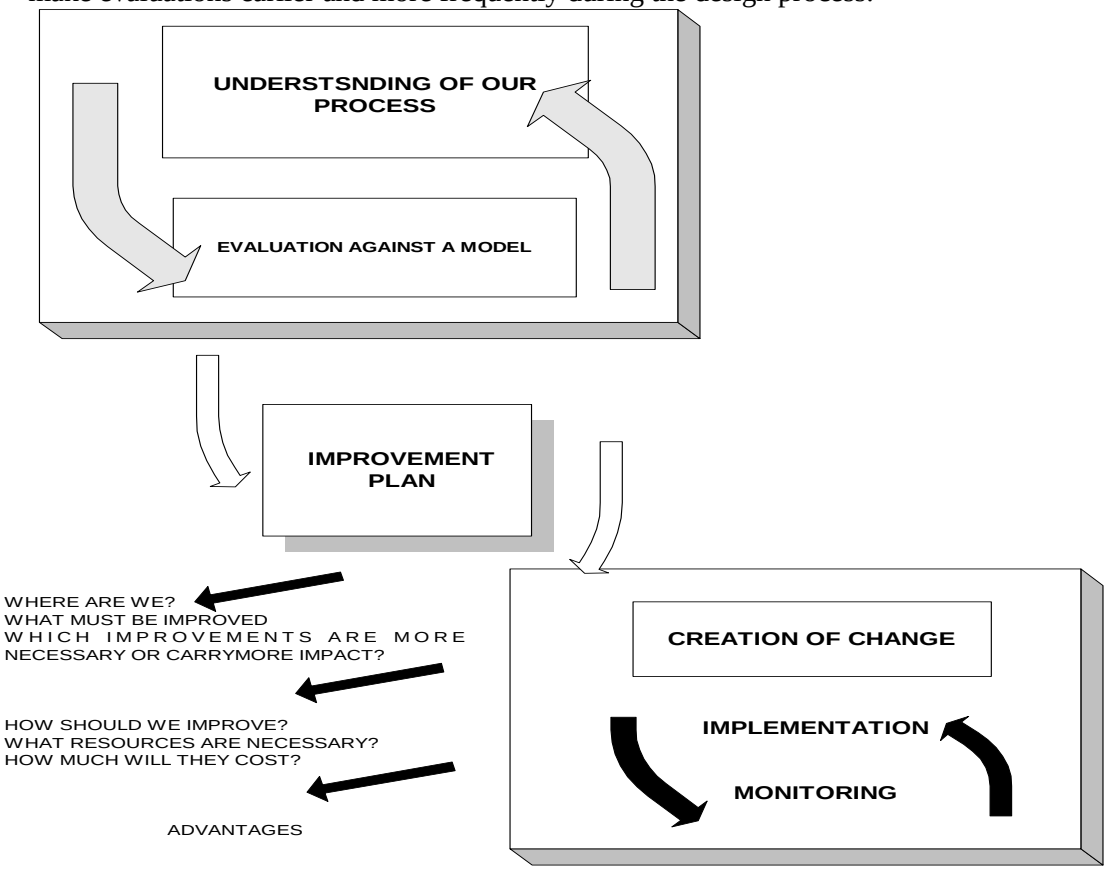
- *Finite Element Analysis (FEA)*
  The Finite Element Analysis method is based on the breaking up of the goal model into a series of finite elements. In other words, the model is divided into numerous small parts which are then used as study units for analysis. The model obtained is a meshwork of elements joined together by common nodes. These elements can be flat (representations of surfaces), or volumetrically (representation of solids). They can also be triangular (three nodes), tetragonal (four nodes), parallelepipeds, etc.

  The system contains a series of equation that define the behavior of a node, based on the conditions of the nodes contiguous to the first one, and on the surrounding condition, which affect it. The application of FEM permits side stepping the traditional design cycle based on prototype – testing – modification – prototype. There is no need to physically

have the prototype on hand to perform the analyses (stresses, displacements or deformed model visualizations). The FEM method is part of Process Simulation, a technique that has been growing over the last years, thanks to every increasing capability of current day systems to process large quantities of information. The method of process simulation encompasses all the stages of manufacture and operation of a product, from its machining or shaping phases, through assembly (by robot), to its operation and maintenance.

- *Rapid Prototyping (RP)*
  Rapid Prototyping is a generic name for a group of technologies that can translate a Computer Aided Design (CAD) model directly into a physical object, without tooling or conventional matching operations. RP requires a CAD solid or surface model which defines the shape of the object to be built. The electronic representation is then transferred to the RP system, which using various technologies, transforms this information into a physical object.

  Several techniques exist for prototype building. Among the most recent are MIME (Material Increase Manufacturing) techniques: SLY (Selective Laser Sintering), SGC (Solid Group Curing), FDM (Focused Deposition Modeling), LOM (Laminated Object Manufacturing). RP has had a significant impact on the design process, since designers can obtain a physical object as soon as a CAD object is available. This enables them to make evaluations earlier and more frequently during the design process.



1.4 Expected Results / Benefits

These activities help ensure maximum effectiveness in developing the design process, thereby enabling tasks to be undertaken that otherwise would not be carried out. Effective Design Engineering can improve the following three important parameters of the company's competitiveness:

- Enhance Quality
- Cut costs
- Speed up time -to- market

The following table shows the proven benefits obtained by the implementation of Design Engineering Techniques (Manufacturability, Quality, and Maintainability concepts) in the early stages of the Product Design and Development process:

Development time	**30-70% less**
Engineering Changes	65-90% fewer
Time – to – Market	20-90% less
Overall Quality	200-600% higher
White – collar Productivity	20-110% higher
Dollar Sales	5-50% higher
Return on Assets	20-120% higher

Source: Concurrent Engineering – Integrating Best Practices for Process Improvement

1.5 Characteristics of firms and service providers

The outside consultants required will differ greatly depending on the type of tool or technique to be implemented. The consultant's function is more relevant for the implementation of techniques and tools for Design Improvement than it is for the introduction of Computational Techniques and Tools. This is because the latter are more instrumental than the former and therefore require that the company personnel that use them have specific training. The consultants must also posses industrial experience both at the consultancy level and at the management level. It is also recommended that they have experience in the specific industrial sector to which the company belongs. Still, consultants main role in the implementation of the methodologies is that of organizing, leading and training the company's work teams and acting as a project leader, until the company can manage by itself. Whether or not the company continues with innovation depends to a great extent on the success of the initial project it undertakes. Good and effective leadership requires a series of conditions such as professional competence, strength of character and the capacity to generate enthusiasm and creativity in the work teams.

2 APPLICATION

2.1 Systems application

Systems may be used in different ways to support the design and development process. Whatever the application, a thorough and proper definition of the requirements must be the

first step. There is a whole spectrum of different application tools or systems that can be applied independently or in an integrated way. A carefully thought-out strategy and implementation plan are essential and may cover, for example, a Computer-Aided Design and Manufacture (CADCAM) strategy, the local automation of support for production engineering, or a complete Computer-Integrated Manufacturing (CIM) strategy covering market, commercial, design, manufacturing and distribution aspects.

The objectives of installing the system may be:

- to replicate the paper system but to provide secure storage and access
- to automate a particular aspect of the process (eg Computer-Aided Draughting, project planning and management, process planning or numerically controlled part programming)
- to model or simulate some aspect of the product such as appearance, physical layout, performance under stress, temperature or deflection
- to manage or control data, documents or drawing records
- to maintain all of the data associated with a product in the form of a product data model or database
- to manage the process and procedures
- to maintain a full configuration history of the product
- to set up a design support system capturing various design rules and experience.

Each system, if properly planned and implemented, will bring about change. Companies must be sufficiently sophisticated in their choice and use of systems if they are to gain a significant competitive advantage. The benefits and the extent to which changes affect individual tasks should be measured by whether the user can:

- do it faster (time saved by system support for a specific task)
- do it better (lower cost or higher quality through considering more options)
- not do it at all (the task has been eliminated, automated or combined with another activity, thereby saving time)

2.2 Where the technique has been applied

The product development process focused on the company's technological strategy
In the framework of the Innovation Program, the National Finnish Technology Development Center, TEKES, has coordinated a project to disseminate several IMTs, including Product Development Techniques. The target group of SMEs comprises operational technological SMEs, as well as starting high-tech SMEs. The major emphasis of the project is the definition of the company's strategy and the development of actions to be implemented. The project is focused on the systematization of and strategies for product development processes, as well as on the development of strategies for production technology.

The Innovation Consultancy Assignment takes 10 man-days of work, of which 5 days are addressed to defining the company's status concerning technological strategy, and 3 days are employed in defining strategies for specific Product Development projects. Additionally, a two-day follow up action is provided for in the project schedule.

In the market Opportunities study a careful analysis of the potential client's technology requirements is carried out in order for the company to check both its technological update

requirements and the degree of agreement between the required technologies and its core technological competencies.

The Company's competitive position in *New Product Development*

Product Development Know-how	Definition of Strategy	Marketing and Sales Expertise
• Technology Know-how	• Suitability to Core Technologies	• Market Know – how
• Development Time	• Product Range Suitability	• Sales Force
• Other Product Requirements		
• Product Cost Structure	Competitive Pricing Potential	Client Requirements' Know-how
• Product Characteristics	• Production Know-how	• Product support
• Market Needs	• Production Technologies	• Service Skills
	• Time – to - market	

A practical example on how company processes may be effectively improved

Management of the Product Development Process was a key issue in one of 12 companies participating in the IDEAS project, at INNOVATION Program project run by Ireland's company developmental agency FORBAIRT. The company was set up in 1992 and it currently employs 36 people-manufacturing specialist-heating products. It has maintained steady growth and profitability through continuous development of its products and manufacturing processes.

The IDEAS project forced this small busy company to stand back day-to-day urgencies, bring in an independent point of view, and has helped it to plan its development over the medium term and to organize its technical development activities over the short term.
The company completed in December 1997 the first (audit) phase from which 2 key issues were identified and an implementation action plan was agreed between the consultant and the company for the period January – May 1998. The 2 key issues were:

- Preparation of a 3 year Product and Technology Map
- Preparation of an R&D program schedule for the company's financial year March 1998 – 1999.

The company, with pro-active support from the consultant, has addressed these issues with great commitment. They have completed the preparation of an integrated Technology and Market Development plan. This will allow the company to plan and to co-ordinate the costs and manpower required for product development, process development, improved R&D facilities, market development, product launch and distribution support. With assistance from the consultant, the company has drawn up an R&D Program Schedule to include:

- Objectives and Targets to be agreed and monitored
- Costing of Resources
- Time schedules and key milestones

The company has also adopted the discipline of a weekly R&D meeting, which maintains and minutes progress on the R&D schedule. So far the company speaks of noticeable benefits of greater clarity of objectives, and greater consensus amongst its staff across disciplines (Finance, Production, R&D, Marketing).

In parallel with the IDEAS project, the company had prepared a 3-year business plan, and saw these exercises as helping to ensure R&D was clearly related to business objectives. Where before there was ad hoc prioritization of development tasks, requiring constant intervention of the managing Director, now there is a structure and staged planning system for R&D. This has allowed the MD to delegate the day – to – day R&D planning and control to the nominated R&D manager and adopt a more strategic role in this company's innovation process.

2.3 Types of firms/organizations concerned

The types of companies to which design and development techniques are best applied are those which design and manufacture their own products, and in which competitiveness is described by factors such as:

- Quality
- Price
- Functionality
- Development Time
- Commercialization Time

Furthermore, if a company is to apply these techniques, it must have a well-defined operating structure, not to mention the necessary human and technical resources to implement and use the techniques. Should this not be the case, the implementation and use of these techniques will yield few benefits.

2.4 Duration and implementation cost of Product Design and Development

A competitive product must address factors such as cost, performance, aesthetics, schedule or time-to-market, and quality. The importance of these factors will vary from product to product and market to market. And , over time, customers or users of a product will demand more and more, e.g., more performance at less cost.

Cost will become a more important factor in the acquisition of a product in two situations. First, as the technology or aesthetics of a product matures or stabilizes and the competitive playing field levels, competition is increasingly based on cost or price. Second, a customer's internal economics or financial resource limitations may shift the acquisition decision toward affordability as a more dominant factor. In either case, a successful product supplier must focus more attention on managing product cost. The definition of the following terms will provide a common basis for discussion:

Recurring production cost =	Production labor + direct materials + process costs + overhead + outside processing
Non-recurring costs =	development costs + tooling
Product costs =	Recurring production costs + allocated non-recurring costs
Product price or acquisition costs =	Product costs + selling, general & administrative + warranty costs + profit
Life cycle costs =	Acquisition costs + other related capital costs + training costs + operating costs + support costs + disposal costs

2.5 Conditions for implementation (infrastructures required etc.)

Industrial design techniques enhance quality and reduce both costs and time to market demand and thus contributing to increasing the competitiveness of an SME.
However, it is important to note that the above techniques must be properly implemented: faulty implementation can render them practically ineffective. This is not surprising, as the same is true whenever advanced technological systems are used to improve competitiveness and the proper company framework and environment do not exist. The introduction and use of these methodologies require the following on the part of the company:

1. A long – term commitment, to improving products and production processes.
2. The integration of design methodologies and technologies in production processes and the implementation of new production methods.
3. The establishment of methods for developing new products in a manner that optimizes design systems. To do this, the design process, as a whole must be studied, the proper techniques must be used at each phase of the process, and the different techniques and tools must be implemented interactively.
4. The adaptation of the company's structure to the information flow that these techniques require, in order to obtain maximum effectiveness. Moreover, the design of new products must be undertaken in accordance with the companies with the company's capacities, so that the effort required is coherent with its competitive strategy, and may thus be assumed by the company.

2.6 Organizations supporting the implementation of the technique

- Irish Productivity Center (IPC), 42-47 Lower Mount Street, Dublin 2, Ireland, Tel: 00353 1 6623233 Fax: 00353 1 6623300, email: ipc@ipc.ie

- Department of Trade and Industry (DTI): http://www.dti.gov.uk/, **http://dtiinfo1.dti.gov.uk/mbp/bpgt/m9fa30001/m9fa300016.html**, 123 Buckingham Palace Road, London SW1W 9SR; telephone: 0171 730 9000

- Product Development & Management Association
  236 Route 38 West, Suite 100
  Moorestown, NJ 08057-3276
  Phone: (800) 232-5241 or (856) 231-1578
  Fax: (856) 231-4664
  E-mail: pdma@pdma.org

- The Journal of Product Innovation Management: An International Publication of the Product Development & Management Association by *Elsevier Science Inc. All rights reserved*

- The Product Development Forum, sponsored by DRM Associates, provides a source of information on new product development (NPD), concurrent engineering (CE), integrated product development (IPD), integrated product & process development

(IPPD) practices, time-to-market (TTM), integrated product teams (IPT), and product development best practices. Start with the IPD Body of Knowledge as a topical index with links to resources and information, For more information, contact Kenneth Crow, DRM Associates, 2613 Via Olivera, Palos Verdes, CA 90274, USA, telephone: (310) 377-7623, fax: (310) 377-1315, email: kcrow@aol.com.

3 IMPLEMENTATION PROCEDURES

3.1 Steps / Phases

In general, three activities associated with the implementation of Product Design and Development techniques can be defined.

1. Presentation of the Methodologies
In this first phase, the fundamental concepts of the methodology and its application, the goals to be attained and the how to reach them, are presented to the company's management. The idea is for the company to change the way it thinks about technology, by giving it a strategic and not merely instrument nature. Moreover, it is necessary to involve management in the acceptance of a process of ongoing improvement, in order to adapt to a continuously changing environment.

2. Development of practical aspects
An initial diagnostic methodology is normally used. This focuses on defining the weakness that the company may have in competitive strategy for Product Design and Development, since this is the area that will be transformed into the axis around which the entire process turns.

The adoption of a strategy for Product Design and Development is reflected in the degree of integration of the different activities involved. The different stages of development can be defined as follows:

a) Initial: No type of process of Product Development exists
b) Informal: The process is undertaken in an erratic manner, without a formal structure and without monitoring the results obtained. Therefore, no feed – back exists that can enable the company to begin the process of ongoing improvement.
c) Planned: Projects are managed and their results are monitored, taking corrective measures when deviations are detected.
d) Defined: A standard procedure exists for Product Design and Development. The process is a part of the work system in the company and is documented.
e) Controlled: The process is fully defined, as are the objectives, both quantitative. There is maximum feed back on methods and results, which enables ongoing improvement to function fully.

An Action Plan is proposed based on results obtained during the diagnostic phase. This focuses on the weakest points in the process, taking into account the requirements, necessities and capacities of the company. The Action Plan analyses the following aspects and proposes guidelines for implementation, among others:

- Goals of the Action Plan
- Results and Advantages expected from its application
- Scheduling of the time and resources
- Definition of tasks
- Training needs
- Implications for the management structure
- Management of change, etc.

3. Creation of Work Teams

One of the fundamental aspects of design management is the development of work teams. They must have the support of management, and require a reorganization of functions, and the assuming of responsibilities on the part of the entire company. The members of the work teams are assigned responsibilities execution times and resources. Above all, effective leadership is essential in order to coordinate activities. This leadership must keep the focus on the objectives and provide the necessary support to foster enthusiasm and commitment.

3.2 Related Software

The categories of software used in implementing a Product Design and Development project is explained in annex.

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Annex: Software supporting New Product Development

Companies operating in today's competitive markets are compelled to develop new products that simultaneously accomplish several objectives. The products should be competitive in global markets, offer good value to customers, be environment-friendly, enhance the strategic position of the company, and be introduced at the right time. To meet this formidable set of objectives, companies are embracing new concepts and techniques, to support changes in the new product development (NPD) process. These new approaches include *techniques* such as "quality function deployment," and "stage-gate reviews," *measures* such as "cycle time," and *organizational mechanisms* such as "cross-functional" teams. An accompanying trend has been the growth of software tools to facilitate the new NPD processes. There is, however, very little in the marketing literature that reports on the role and impact of these tools, with the exception of software for new product design tradeoffs, such as conjoint analysis.

In this section, we identify and classify the major categories of software tools that are available for supporting NPD. In the following sections, we briefly explain their role in the NPD process, and outline some research issues in evaluating these tools. Our objective is to highlight the goals, and the advantages and disadvantages of these tools, rather than to provide complete evaluations of the merits of specific software packages. Although we describe some individual packages, space does not permit us to compile a compendium of all the software available in this area. In selecting software for this review, we applied three criteria. The software should:

1. support activities typically associated with marketing's role in the process. Thus, we exclude software tools that are used in physical product design such as CAD/CAM.
2. be commercially available for general-purpose use, rather than being proprietary, or customized for a particular firm or industry.
3. be available for use on personal computers, and were available for our evaluation.

Software tools for new product development

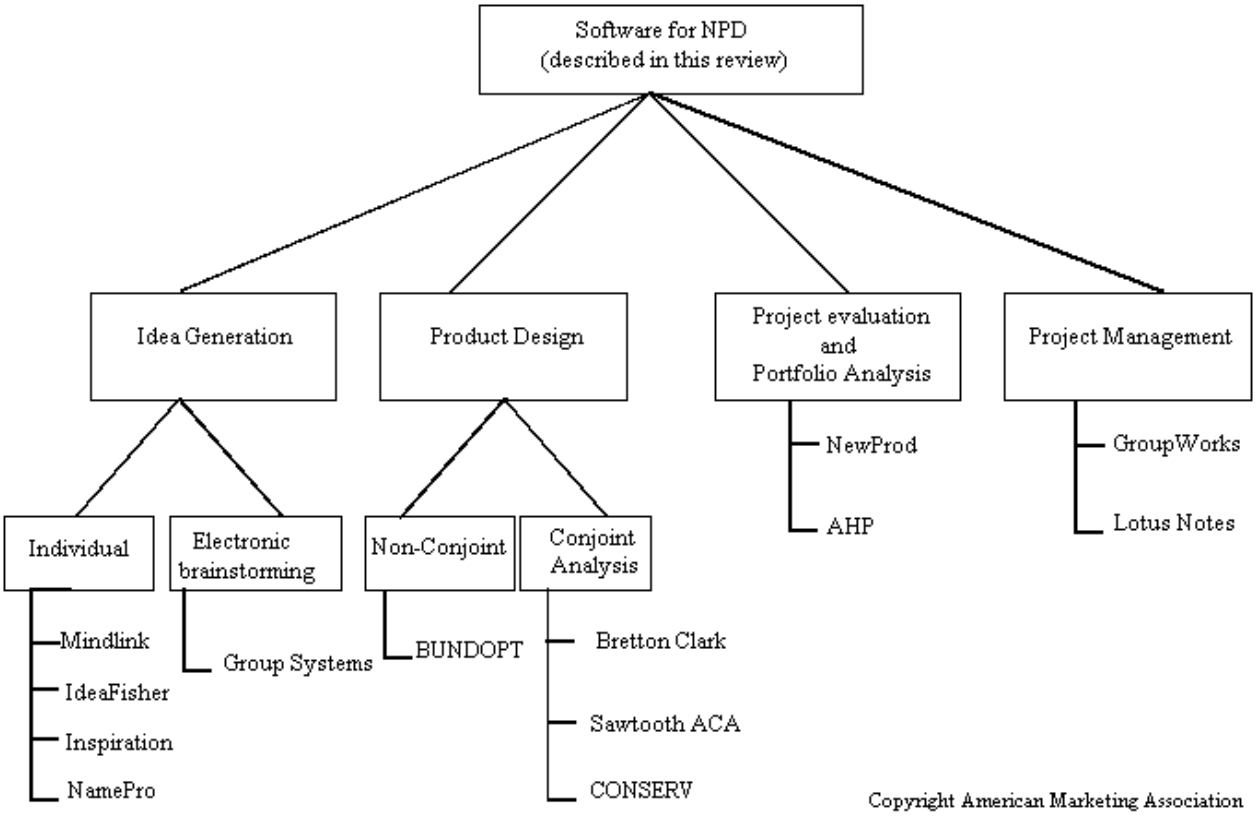
New product development is a process with a start, an end, and various stages in-between. Typically, the process starts with the opportunity identification phase and continues through product launch and beyond. It is a process characterized by activities carried out by people from different functional areas of a firm. Given the broad scope and complex nature of the processes associated with NPD, there is no single software package that supports all the NPD activities. Instead, there are a number of packages that are potentially useful for supporting specific stages and aspects of the process. Some of the available software are designed primarily for use by individuals, while others are designed to be used by groups. Some require market research data from consumers; others require user judgment as inputs.
Software included in this review are listed in Figure 1, and fall into two broad, non-exclusive categories:

- Software designed to enhance *decision making* associated with NPD. Such software include packages such as NamePro for selecting product names, Mindlink for generating new product ideas, Conjoint Analysis systems for product design, NewProd for strategic evaluation of new product projects, and Group Systems for facilitating brainstorming in groups. These packages enhance decision making by enabling managers to use available information more effectively (e.g., Mindlink), by

encouraging the generation and evaluation of more decision options (e.g., Conjoint Analysis), or by improving consistency of decision making (e.g., NewProd).

- Software designed to facilitate the *process* of new product development. Software in this category include products such as GroupWorks for project management and Lotus Notes, a groupware product for managing workflow between project members. They are designed to improve project planning, coordinate communication between members, maintain record of activities and discussions during the project, allocate project resources carefully, and provide tracking and analysis to evaluate project progress. The use of these software helps the firm meet process objectives such as speed to market, reducing costs of development, improving quality of the product, minimizing rework, etc.

Figure 1



Software for idea generation

Creativity in NPD requires both divergent thinking (lateral thinking) and convergent thinking. Divergent thinking results in the generation of a large number of ideas, while convergent thinking helps one to converge toward the most promising ideas. Several commercial software have been introduced in recent years to support the creative process, with the basic premise that the interaction between people and software leads to creativity

enhancements. In Table 1, we summarize the benefits and limitations of a sample of creativity enhancing software for NPD.

Table 1 A summary of software for idea generation and evaluation

Software	Description	Potential benefits	Limitations
Mindlink	Software implements the well-known synectics process, combining structured problem-solving with techniques for stimulating creative thinking. The user states a problem she is trying to resolve (e.g., increase battery life of notebook computers). The program encourages divergent thinking by using "wish-triggers" (I wish computers could store energy the way cacti store water), and "idea triggers" (ways to realize the wishes - e.g., a battery mechanism dispersed throughout the body of the notebook computer). To converge to an effective solution, it uses "option triggers" to structure the evaluation of possible solutions to the problem. The software also comes with exercises designed to help the user learn the process of creative thinking (e.g., forced juxtapositioning of unrelated thoughts), and a database to facilitate the triggering process.	Useful at several stages in NPD, particularly at the idea generation stage - use of software could result in more ideas generated on the problem, than if it is not used. After doing this 2 or 3 times, the user should be able to internalize the key elements of this process, and therefore, be able to use these concepts even without the software. The software is easy to use.	The Thought Warehouse is low in content.
IdeaFisher	Software combines two databases: one with 65,000 words and phrases together with an extensive set of cross-referenced links between them, and the other with a question bank of about 700 questions (e.g., how would a child solve this problem?) organized by various categories. When the user provides a word or phrase, the software retrieves a number of associated words and phrases. For example, the word "new product" retrieves several associated words and phrases such as marketing, imagination, research experiments, etc., and each of these (e.g., imagination), in turn, triggers other connections (e.g., imaginary people, places, etc.). This process may be continued iteratively.	It encourages divergent (lateral) thinking through free association. It appears to be particularly good for making non-obvious verbal connections. The software has an elegant design that simplifies use.	Seems to be more useful for areas such as advertising design that are word-rich, than for generating new product ideas. While the software enhances the generation of ideas, it provides no structured mechanism to narrow down the options. In some cases, the number of ideas generated is too large to be useful.
Inspiration	A software environment for visual thinking based on "mind mapping" techniques. Starting from a core concept, the user "spans outward" to develop links to other concepts that are relevant to the core concept. This is done using various visual aids such as charts, maps, symbols, and outlines. For example, starting with the core idea of developing a notebook computer with a 10-hour battery life, the user can link this visually (with arrows) to other activities such as "check patent office for battery technology," "contact R&D in sister company," "initiate feasibility study within the company," etc. Each of these can then be visually linked to other concepts.	A user-friendly system that is useful both for idea generation, and for project management. Enables users to visually see the "whole picture" which could help them to see new connections or structures that may not be evident otherwise. The software keeps a record of the idea maps for future use and enables quick revisions, a feature that is useful when new information becomes available.	Unlike Mindlink or IdeaFisher, it has no specific tools to directly encourage creativity or problem solving. It is difficult to generate symbols that convey multiple things or have multiple meanings. The software imposes a task structure that may be unfamiliar or unnatural to some users.

	Once concepts are put on a computer screen, they may be easily re-arranged as the idea generation process proceeds. The software contains an extensive database of symbols useful for generating visually useful representations.		
NamePro	A set of databases and software tools for developing names of products and companies. The program allows 1) string searches of its database to identify names and potential conflicts with existing names, and 2) combining or partitioning parts of names to generate new names. One of the databases is the namebase consisting of over 30000 names organized by category (e.g., computers), connotation (e.g., innovative), and trademark , i.e., whether a renewed or pending trademark registration is associated with a name. Another interesting database is the "profanity database" that contains common profane words in 5 European languages.	Useful both to end-user manager, and to attorneys involved in registering product names. Simple and straightforward to use.	Some program options (e.g., combining two name parts) generate large numbers of irrelevant names, while other options that generate names satisfying specific criteria (e.g., connotations) sometimes generate too few names. An enhancement that would be valuable is a module to assess the strategic value of a name, based not just on whether it is pre-empted by existing trademarks, but also based on average market performance of names with similar characteristics.

The software listed in Table 1 were all simple to install, easy to use, and some were very stimulating. However, there is some danger in relying too heavily on these tools. Each software takes a particular approach to creativity that is likely to be most useful only in specific contexts. They all promote a cookbook approach, thereby possibly undermining the very objective of encouraging experimentation and thinking "outside the box." Further, they focus on idea generation, and provide only minimal support for idea evaluation. One way to incorporate idea evaluation is through decision-aiding models such as the Analytical Hierarchy Process described later in this review.

Although all the software in Table 1 could be used in group settings with a moderator running the software and projecting the results on a screen, other types of software are available for directly promoting group interactions in the generation of ideas. Software such as GroupSystems from Ventana corporation may be used to set up electronic brainstorming with a number of participants. The system can be used to create agendas (e.g., problems to be resolved), allow for simultaneous and anonymous generation of ideas from participants, obtain votes on action items, produce reports summarizing the discussion, and maintain records for future use. Participants may all be present in the same room, or log-in remotely to participate in the discussion. Although the system seems to be robust in the session we participated in, it is complex and requires the presence of a technically competent moderator to facilitate its use.

Research suggests that in face-to-face brainstorming, non-interacting individuals working separately generate more ideas, and more creative ideas than an interactive group with the same number of individuals (McGrath 1984). Also, Cooper and Gallupe (1993) and Nunamaker et al. (1991) find that as compared to face-to-face meetings, the use of an electronic brainstroming system improves both the efficiency of idea generation (e.g.,

number of ideas per participant), and the effectiveness of the ideas (e.g., range of ideas generated; successful implementation of ideas). Among those using electronic brainstorming, interacting groups generate more ideas, and better quality ideas than non-interacting groups (Valacich et al. 1994). Thus, overall, it appears that electronic brainstorming with interacting participants is an effective method of brainstorming.

Software for product design

Many products and services may be viewed as "bundles" of product attributes, i.e., products may be represented as combinations of levels of product attributes. For example, a Toyota Camry car could be described as SIZE=mid-size, TYPE=sedan, MPG=30 in city, ENGINE=V-6 fuel-injection, OPTIONS=sunroof, etc. In purchasing products, customers make tradeoffs between the various attributes, for example, between a sunroof and a V-6 engine.

Conjoint Analysis is a formal technique for examining these tradeoffs to determine an effective combination of attribute levels that will perform well in the marketplace. In short, Conjoint analysis is an approach for customer-based new product design. In particular, conjoint analysis is useful for deciding what attributes should be designed into a new product in order to maximize its expected market performance in the presence of existing competitors, and to determine which market segment(s) will find a particular product configuration to be most appealing. Many successful applications of this approach have been reported, including the design of the Courtyard by Marriott hotel (Wind, et al. 1989; see also Wittink and Cattin 1989).

There are three major commercial packages for designing and conducting conjoint studies. A recent detailed review in **JMR** has evaluated these packages (Carmone and Shaeffer 1995), namely, **Bretton Clark**, the **ACA package** available from **Sawtooth Software**, and the **CONSERV** package from **Intelligent Marketing Systems**. The packages differ along a number of dimensions, including whether they use the full-profile method or an "adaptive" approach to the selection of the specific product sets evaluated by customers, whether they include built-in editors for generating and modifying questionnaires, whether the questionnaires are administered to customers on a PC, the measurement scales on which customers evaluate the products presented to them, the algorithmic options (e.g., metric, non-metric) for computing the utility function, the approach they use to collect and merge background information on customers for purposes of segmentation, the set of criteria they offer for simulating market performance, the methods they use to "calibrate" the model to current market conditions and to assess the predictive validity of the model, etc. In addition to these standard products, knowledgeable analysts can conduct Conjoint Analysis using standard statistical packages such as **SPSS** and **SAS**. In SPSS, the **ORTHOPLAN**, **PLANCARDS**, and **CONJOINT** procedures are available under the Categories module. In SAS, the **TRANSREG** procedure may be used (see SAS Technical Report R-109).

In contrast to software used for idea generation, there is some published literature in marketing to assess the value of conjoint analysis, including the documented success of the Courtyard by Marriott hotels. There are also several academic studies that have explored the predictive validity of alternate ways to implement conjoint analysis. The interplay of academic research with program enhancements made by the software designers has led to continuous improvements in these packages since they were introduced in the mid-1980's. More software enhancements may be expected, including use of multimedia for presenting

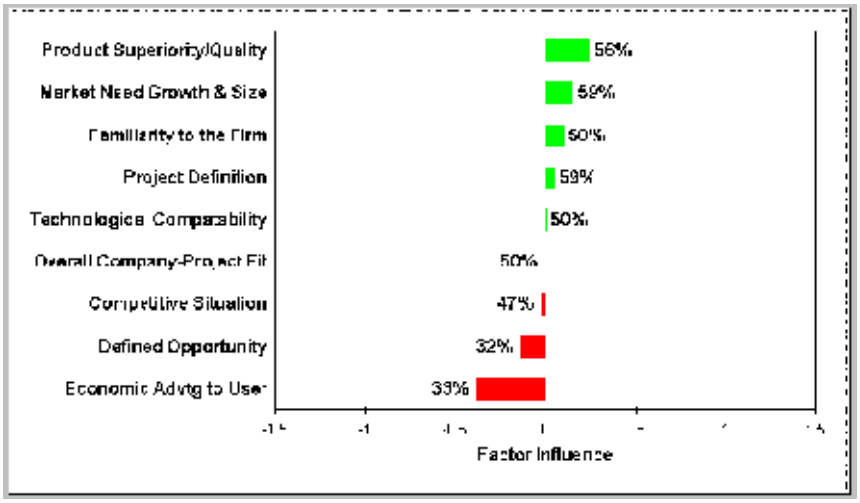
product stimuli (e.g., Sawtooth), data collection using web pages on the Internet. At the same time, new theoretical developments, such as the use of Bayesian analysis (Allenby, Arora, and Ginter 1995), foreshadow the availability of new types of software for conjoint studies.

A different customer-based approach for designing new products is the **BUNDOPT** model described in Green and Kim (1991), and available from **Intellicomm**. This model is particularly appropriate for deciding the optimal combination of features to be offered in a new product. For example, in designing a car, the manufacturer could incorporate a number of features/benefits such as cruise control, roof rack, hood air deflector, or trailer hitch. The number of available options could well be over 25, but most customers would probably not be willing to pay for more than 5-10 of these. However, each customer may have a different set of preferred features. An important question for the manufacturer is to decide which subset of the available features should be offered to ensure that the car will appeal to the maximum number of customers. The BUNDOPT model uses pick k/n data obtained from a sample of customers, and employs an efficient heuristic algorithm to identify the best combination of features. Other issues addressed by this model are the identification of segments that most prefer a particular set of features, and the desirability of a particular combination of features to a target segment.

Software for new product evaluation

NewProd: An important way to improve new product success rate is to conduct overall project evaluations to assess the business risks and rewards of the new product, and to determine the organizational resources that need to be devoted to improve its chances of success if the company decides to go forward with the new product. NewProd is a software developed from the research of Cooper (1986, 1992), who analyzed the determinants of new product success from 195 projects using 80 independent variables. The database has been updated and enlarged since the original study, and the software is based on the 30 of the 80 variables (reduced to 9 orthogonal factors) that were most instrumental in explaining the degree of new product projects.

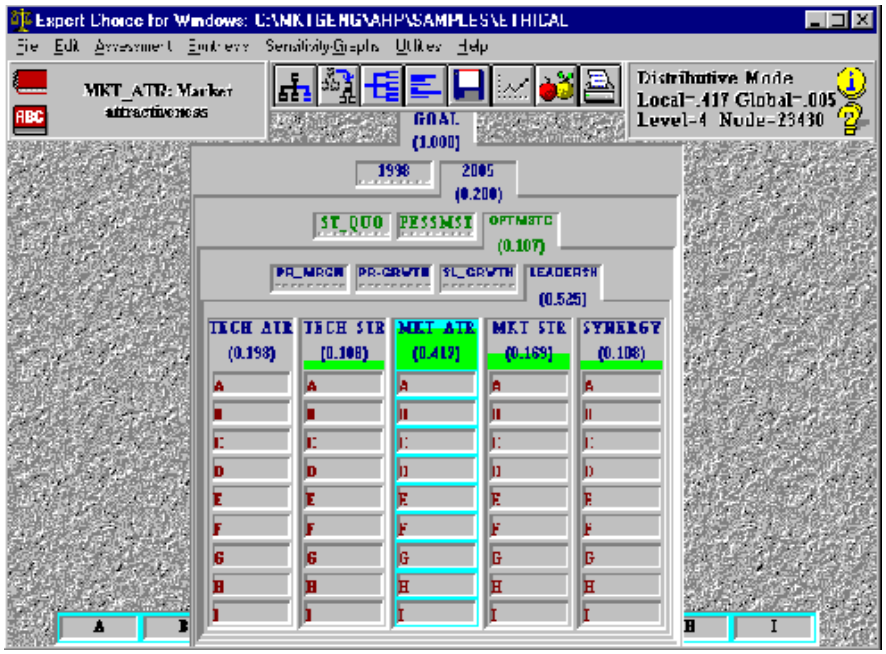
NewProd is used under the guidance of a trained facilitator. Project members independently provide data on the 30 variables identified in Cooper's research, and then meet to discuss differences in their inputs, repeating the process until there is general agreement about the in inputs. The NewProd program compares this input profile of the new product (summarized on 9 factors), to its internal database of factor scores to determine the percentile position of the new product as compared to the factor scores of products in the database. This evaluation may be customized by industry (e.g., consumer packaged goods, business markets, electronics and communications, etc.). Several reports help to determine whether the new product score on each factor is consistent with that of a successful or unsuccessful product, and to indicate what should be done to improve the new product's chances of success. This is shown in the following Screen display from the software.



Higher percentile scores on factors with high influence suggest higher probability of success.

In addition to monadic evaluation, this software may be used to simultaneously evaluate a number of products at different stages of development, thereby providing an assessment of a new product in the context of the entire portfolio of new products under development. This facilitates organization-wide resource allocation, as well as the identification of systemic problems in new product developments. NewProd is a simple, yet effective package for benchmarking new product projects. Further improvements to the model and software are bound to occur as more data becomes available about its impact on the NPD process.

Expert Choice: General purpose decision-aiding software can also be used for limited types of new product evaluation. One that has received some attention in marketing is **Expert Choice**, which implements the *Analytical Hierarchy Process (AHP)* (Saaty 1980). This software is particularly useful for choosing/prioritizing between several different new product projects based on user-proposed criteria and sub-criteria. The user first establishes a hierarchical structure of criteria and sub-criteria on which the new product projects will be evaluated, as shown in the example screen display below. Next, the user provides pairwise evaluations of the alternatives at each level on the hierarchy. The software synthesizes these evaluations across the entire hierarchy to come up with overall numerical scores that indicate the relative importance of each criterion/sub-criterion, and the overall relative attractiveness of each of the product options. The most useful aspect of the software is its feature for conducting sensitivity analyses visually. In particular, it is easy to see how changes in the relative importance of a criterion would alter the relative attractiveness of each of the alternatives. Although AHP is a somewhat controversial procedure because of the possibility hat it could lead to rank reversals [footnote: A rank reversal occurs, for example, when project A is preferred to project B before project C is introduced into the mix of projects being evaluated, but with the introduction of C, B becomes preferred to A.], it has seen wide application in the industry.



Hierarchy showing goals, subgoals, scenarios, and criteria on which 9 projects (A to I) are evaluated. Based on a real application supplied by Professor Jerry Wind.

Software for managing the NPD process

There are primarily two types of software to support the NPD process. The first is project management software which are designed to manage various aspects of project management such as project scheduling (e.g., through use of PERT charts), time management, resource management, task assignments, etc.

Microsoft Project is a good example of this type of software. The second is team management software designed to operate over a network and assist people in working together. Falling under the category, "groupware." these software packages support various aspects of team management such as electronic messaging and document transfer between team members, electronic conference between team members, and workflow automation. Increasingly, project and team management software are merging in response to the growth of matrix organizations. To illustrate these software and their impact, we will briefly look at two packages: GroupWorks and Lotus Notes.

GroupWorks is installed on the PC of all the team members, but the key files reside only on the PC of the "owner" (project leader) of the project. The PC's of the team members connect to the owner's PC as and when required. Each stage of a new product development may be set up as a separate project with its own "owner." For example, the team that makes the business case for the new product may be a different team than the one that sets up the product specifications, which in turn, may be different from the team that tests and implements the new product. These separate teams may all be linked together using this software. GroupWorks is designed to support small groups, and consists of four modules:

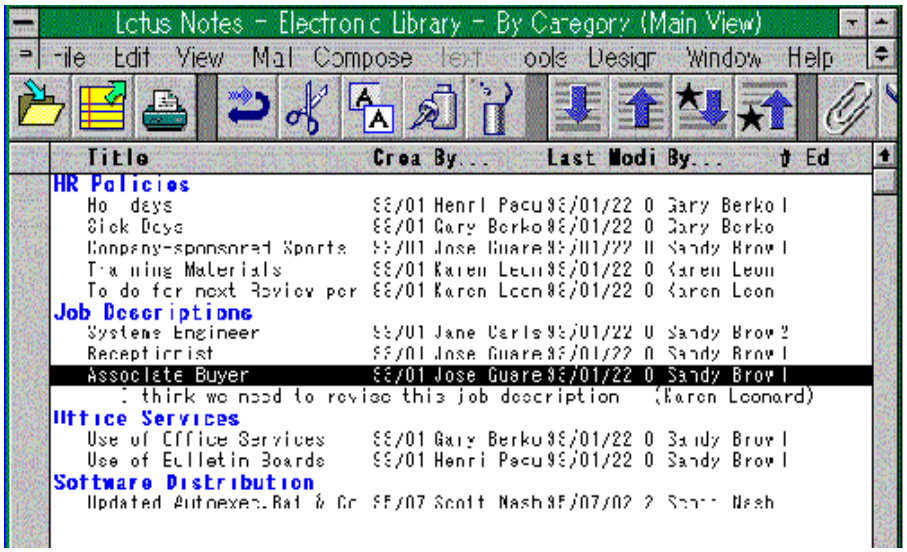
- **Overview:** Provides top-level project overview, and establish a common vision for the product among the team members. This module helps set up project preliminaries - e.g., project members, project objectives, start and end dates, etc.
- **Activities:** Helps set up and manage the activities associated with a project, such as assigning tasks to individual members, setting task priorities, tracking progress, etc.

This feature also allows users to attach documents/spreadsheet, etc. that can be worked on by all members of a team.

- **Discussions:** Enables members to initiate threaded (topic-specific) discussions with other project members.
- **Contacts:** Helps maintain project-related contact information. This can be kept private or distributed to other members.

According to a senior executive of **FTP Software, Inc.** (maker of **GroupWorks**), they do not yet have any clearly documented assessment of the impact of this software on NPD, as companies have just begun to use this software for this purpose. Early indications are that the quick access to project status information, and the automatic triggering of documents indicating impending deadlines and project updates have been of considerable value to these early adopters. We were able to obtain some information about the general impact of groupware products on NPD from Mr. David Coleman, an industry consultant. He states that currently, while only a few organizations have implemented groupware for NPD, those that have implemented groupware to manage hardware and software development projects are realizing a 25-35% improvement in productivity.

Lotus Notes is different from GroupWorks in two important ways: 1) it allows for company-wide implementation across different hardware platforms, which facilitates support for ad-hoc teams, and 2) it supports workflow automation for routine processes such as order fulfillment and billing. Since its introduction in 1989, Lotus Notes has become the premier groupware product. Several companies such as Price Waterhouse have installed thousands of copies of Notes to electronically link all company employees. This helps them to quickly put together ad-hoc teams to address specific problems and opportunities. The following screen display illustrates how a Lotus database is structured to facilitate document access between team members.



Database to organize, archive, and make accessible all project-related material. Allows multi-level access, along with controls such as "Reader," "Author," and "Editor."

A couple of examples will illustrate how companies are using Notes for NPD. Computer Language Research (CLR) is the leading firm in the tax software business - designing and

marketing hundreds of different software packages for managing audits and taxes for customers such as banks, accounting firms, and corporate tax departments. Due to changing tax laws, the firm has to be able to quickly make enhancements to existing products, as well as to develop new products for new customers in other industries. The use of Lotus Notes has helped CLR improve both the speed and quality of its new products. For example, team members can make some decisions online without having to arrange face-to-face meetings, which helps compress product development time. Likewise, new product quality is improved by providing project teams improved access to expertise available within the company, and through improved coordination in reporting and fixing problems before the new product is shipped.

Bristol-Myers Squibb is another company that has benefited from using Notes for NPD. The development of a pharmaceutical product is a complex endeavor that requires collaboration among many different types of people - scientists, engineers, marketers, attorneys, and senior executives. Lotus Notes provides a central database to maintain all project related information (e.g., market conditions, regulatory requirements, list of contractors and consultants, records of meetings, etc.), which is available to team members worldwide. This enhances the level of information sharing during the project. According to the Director of R&D, "we're better informed about what's happening outside our knowledge base ... in some cases, information obtained through Notes has helped us change our assumptions and make better decisions."

Concluding comments

In the immediate future, the Internet promises to have significant impact on NPD. The most interesting possibilities are the ability to more readily identify lead user communities and involve them in the NPD process, the ability to conduct online marketing research including concept testing and conjoint analysis, and the ability to establish "Intranet" to link widely dispersed project members and corporate databases over private networks, but using Internet tools. Newsgroups and Forums are now becoming part of the product development process. For example, the **Microsoft Forum** (available through online services such as Compuserve) provides the company with hundreds of ideas for enhancing their products. In some cases, forum members even post suggested solutions (patches) to enhance the company's software, which can then form the basis for product improvements. As another example, the educational division of Texas Instruments (TI) has used its web site (http://www.ti.com/calc/) to establish links with its customers in schools across the country. The development of the highly successful TI-92 calculator was significantly aided by the internet. TI posted on its web site the proposed specifications of the product and an online demo simulating its functionality, and invited feedback from members of various discussion groups devoted to education. The continuing feedback from the participants was instrumental in making many enhancements to the product. When the calculator was introduced, the final specs were also put on the web site. This offered a simple way for teachers to download documents to develop proposals to their school boards for purchase of these calculators.

There is also a newsgroup devoted solely to examining issues related to improving the NPD process (newprod@world.std.com). Likewise online marketing research is increasing. Sample biases are likely to become less of a problem as this mode of research becomes more accepted, especially in business-to-business markets. Finally, the growth of the Intranet promises to bring more flexible and less expensive "groupware" for supporting NPD.

In spite of the wide range of software that are now available for NPD, we know very little about whether, how, and why these software improve the process and outcomes associated with NPD. More careful measurements of impact are needed, especially in evaluating the effectiveness, not just the efficiency, associated with the use of these software tools. A related question is whether some aspects of NPD (e.g., project management) are inherently more amenable to software support. These "validation" issues are very important because software reviews in traditional computer magazines and journals seem to focus more on "ease of use" rather than on "impact on NPD." We also need research done by unbiased sources to examine the comparative performance of software that perform similar functions. To address this need requires closer collaboration between academic researchers and the makers and users of these software. We echo the comment of Carroll and Green (1995) that more research is needed on these "less-than-glamorous" but important issues. Perhaps if we start viewing the real-world as the laboratory, and the software as a research instrument, there may more interest in this type of research.

Finally, it is surprising that even after two or three decades after their introduction, there are no PC-based commercial software for such well-known models as the Bass model for new product forecasting, and the Assessor model for pre-test market forecasting. Although there have been a number of proprietary software implementations of these models within firms, there is a need for generic versions of these software. As a step in this direction, our book entitled **Marketing Engineering** (forthcoming, Harper Collins) contains software for several new product models including the Assessor and the Bass model. One way to increase the impact of models developed by academic researchers is to start viewing software as a technology transfer mechanism between academia and practice. Perhaps this view would lead to increased collaboration between academics and practitioners as well as more research on the effectiveness of marketing science methods.

References

Acknowledgments

The following companies provided full-function copies of their software for our evaluation:
Bretton-Clark, (201) 993-3135

- Expert Choice, Inc. (AHP software), (412) 682-3844, http://www.ahp.net/
- FTP Software, Inc., (GroupWorks), (800) 282-4387, http://www.hyperdesk.com/
- IdeaFisher Systems Incorporated, (714) 474-8111
- Inspiration Software, Inc., (503) 297-3004
- Intellicomm, Inc. (BUNDOPT software), (215) 387-3844, http://www.intellicomm.com/
- Mindlink Software Corporation, (800) 253-1844
- Sawtooth Software, (360) 681-2300, http://www.sawtoothsoftware.com/
- The Adept Group (NewProd software), (203) 929-9191
- The Namestormers, (214) 350-6214, http://www.namestormers.com
- In addition, we used **GroupSystems** ((800) 368-6338; http://www.ventana.com/) at the Team Decision Center at Penn State University. Finally, **Lotus Development Corporation** ((800) 343-5413; http://www.lotus.com/) provided a demo version of Lotus Notes, and examples of its use in new product development.