ICED13
INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED13
19-22 AUGUST 2013, SUNGKYUNKWAN UNIVERSITY, SEOUL, KOREA

COLLABORATIVE PRODUCT DESIGN AND DEVELOPMENT FOR COMMERCIALIZATION OF INVENTION

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ABSTRACT
In this paper, the framework and process of product design and development and commercialization of an invention are discussed. A method developed by the author, the 3P Approach (i.e. People-Product-Process), has been successfully used in design and development of innovative products. The 3P Approach connects the definition of people-centric and objective-driven design intent, identification of an ideal design direction and application of collaborative product design and development phases, in order to achieve an optimized design solution. In the paper, the author uses a case study to discuss the key concepts and methodology of the 3P Approach in the design and development of a patented product.

Keywords: collaborative design, new product development, invention, innovation, commercialization

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1 INTRODUCTION

The primary objective of product design and development is to provide a design solution that improves people's life. The initial idea for product design and development may come from improvement of an existing product (i.e. innovation) or a breakthrough of technology or process (i.e. invention). On the other hand, an invention may arise from technological research or from the product design and innovation.

A design solution is one that solves the people's problems or meets the people's needs. An outstanding design is one that exceeds people's expectations. It is, therefore, vital to define the design specifications and design direction clearly and ensure that they meet the desirability of the people. In addition, a design solution must be feasibility in terms of materials, technology and manufacturability.

The business perspective, which includes costs of manufacturing and all downstream activities, is another critical factor; and this is commonly known as viability. Desirability, feasibility and viability form the primary approach in Design Thinking (Brown, 2009).

Figure 1 illustrates the relationship between products and customers in the context of commercial scenery. It should be noted from the figure that besides external customers, internal customers and partners, relevant people in external companies which produce competing products constitute the fourth group of stakeholders.

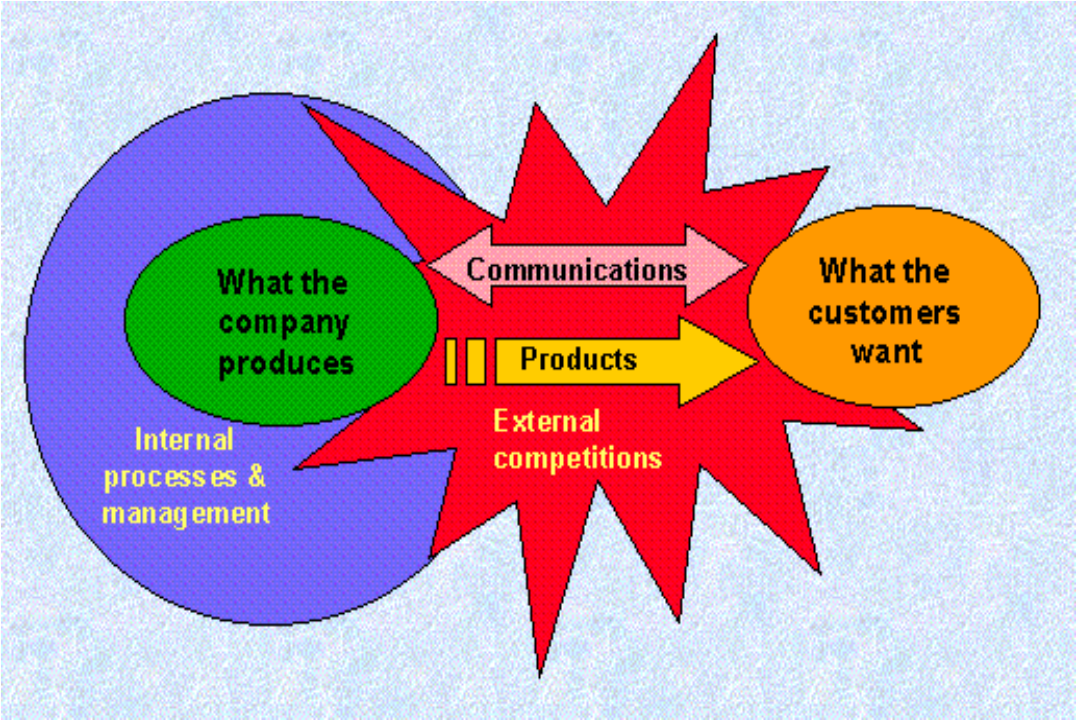

Figure 1. Product design and scenery

One of the most challenging areas for companies to succeed in an ever competitive market place is to plan and implement an effective product design and development process that connects the vision of a good or excellent product to the requirements based on all the stakeholders. There are many ways to represent design and development process, and there are various names given to phases in design process (Ulrich and Eppinger, 2003). Table 1 shows an example of a design and development process from the product lifecycle and business management perspectives, and with particular emphasis on product information.

Typically, an invention happens during the technology development or the product design or prototype testing phase of the product design and development process. In order to protect the invention, a patent is filed before the production design phase of the invention. In this paper, a novel product design and development process, called the 3P Approach, was described in the context of commercialization of an invention which was granted a patent before the phase of production design.

Table 1. Product design and development process

Phase	Typical task content and product information output
Product Idea Definition	The tasks here include identification of a good product idea and critical analysis of the idea from the corporate position. The product idea can be for a new product or a new model of an existing product. The idea may originate in a number of possible ways such as from new technology, new market, customers' feedback, new corporate strategy, new product features, employee suggestions, etc. The decision to proceed with a new product idea is normally made at the corporate management level with consultations with relevant personnel in the company. Product information output: Product Strategy -- which includes product direction, market identification, preliminary business plan, preliminary product specifications, resources requirements, etc.
Design Research	These tasks include planning the market research, benchmarking, preparing survey questionnaires, conducting the market survey, analysis of the survey results, and making conclusions and recommendations. Product information output: A complete market study report, which is a vital piece of information for subsequent business decisions and the formulation of the actual business plan for the product.
Product Design	These tasks include preparation of the Design Brief, concept generation, concept evaluation and refinement, detailed design and communication of the design results. Product information output: A Design Brief or a set of Design Specifications, proposed concepts in sketches, concept evaluation results, selected design, detailed design drawings and specifications, 3D mock-ups and models, engineering analysis and results, market and user trials, considerations and decisions on aesthetic and ergonomic features, evaluation and feedback on the product functions.
Prototype Testing	The tasks in this phase include building a fully working prototype, conducting comprehensive tests on functions, aesthetics, ergonomics, manufacturability, reliability, packaging and maintainability, and preparing production requirements. If necessary, different versions of working prototypes may be built for further testing. Product information output: A thorough prototype testing report and a complete set of design drawings and specifications ready for production.
Production	These tasks include production and process planning, procurement of components, design and development of tooling, production control and management, assembly, quality assurance, packaging and logistics management. Product information output: Product system and documentation, and completed products ready for delivery to the distributors, retailers and customers.
Marketing and Sales	The tasks here include product pricing, preparation and implementation of marketing plan, sales and promotion, delivery and customer services. Product information output: Marketing and sales system, and timely delivery of product to the customers.
Market Feedback	These tasks include gathering feedback from customers, distributors and retailers, analyzing the feedback and making recommendations. Product information output: Timely reports on market feedback for immediate and future plans.
New Model Planning	The tasks here include synthesis of market feedback and reports and all relevant information in the entire product development process, in order to prepare the product direction for subsequent models. Product information output: A report on recommendations for the new model product direction.

2 AIMS AND METHOD

A big challenge in product design and development process is how to ensure that the final design solution is eventually able to meet the users' needs or solve the users' problems. Design Thinking Design Thinking (Lockwood, 2010) emphasizes the importance of empathy, which is the initial phase of design with observation, experiencing and interviewing, in order to fully understand the needs or problems faced by the target user group. The subsequent phases of Design Thinking comprise defining the needs and problems of the users, generate solution ideas, making a prototype of a chosen idea, and then testing the design using the prototype with the target users. Though Design Thinking plays the crucial role of getting designers and encouraging everyone to empathize with the users in order to provide a matching design solution, the importance of setting a set of design specifications or specifying a potentially ideal design solution was not elaborated.

Quality Function Deployment (QFD), originally developed in 1960s, is a "method to transform user demands into design quality, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process" (Akao, 1994). QFD aims to transform customer and user needs into technical or engineering characteristics for a product or service, prioritizing each product or service characteristic while simultaneously setting development targets for product or service using charts and matrices. QFD combines combined quality assurance and quality control points with function deployment used in value analysis or value engineering (Fowler, 1990). One disadvantage of QFD is that the use of charts and matrices is time consuming and not efficient. A better approach is using collaborative database via the Internet or an intranet system.

The author has developed a method to manage the information produced and communicated in product design and development. The method, called Product Information Management System (PRIMAS), is particularly useful in product design and development team design so that the customer and user needs are classified, managed, integrated and shared using a developed database system among the team members (Tan and Bonollo, 2001) (Tan, 2009). Figures 2 and 3 show the structure and operational system of PRIMAS respectively. The PRIMAS method has been applied in several product design and development projects that the author was the project leader or member. The findings from these projects have shown that PRIMAS is effective in dealing with the design information in collaborative and team projects. Nonetheless, it has been discovered that there is a need to constantly relate the user needs to the ideal design solution via an effective design and development process. Hence, the author developed an approach called the 3P Approach to address this issue. The 3P Approach has been implemented in product design and development projects and significant results have been found.

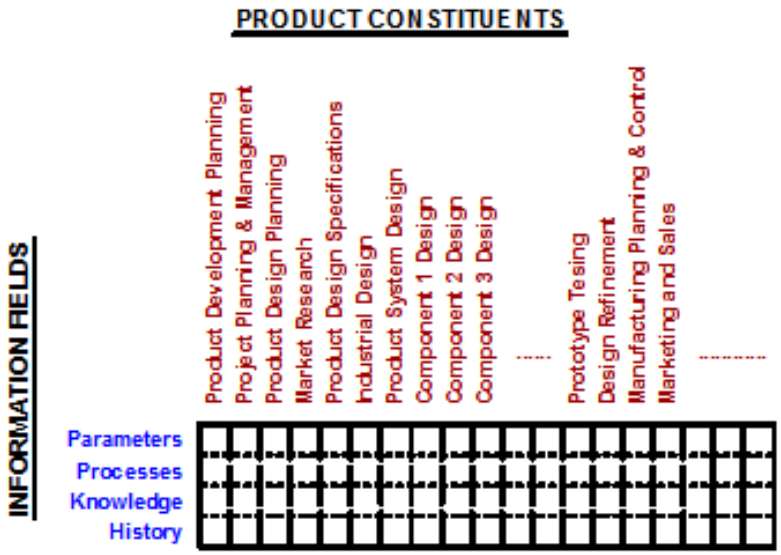

Figure 2. Structure of Product Information Management System (PRIMAS)

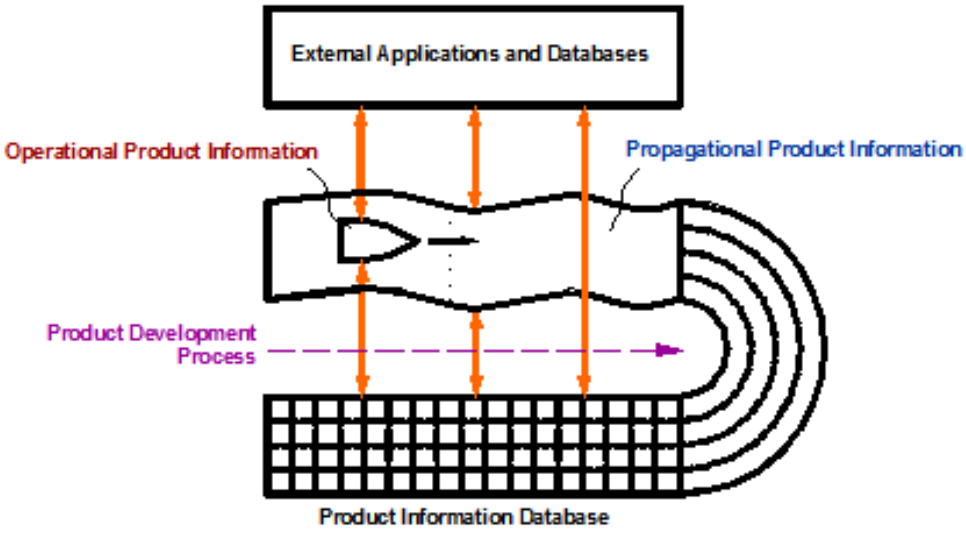

Figure 3. Operational System of PRIMAS

This paper first describes the fundamental principles of the 3P Approach, follows by a case study on how the 3P Approach has been applied in a product invention and commercialization project. A discussion on the findings from the project and conclusion follow subsequently.

3 THE 3P APPROACH

The 3P Approach (People-Product-Process) for product design and development developed by the author connects people's problems and needs to the characteristics of a good product via a well planned and executed design process. The goal is an innovative design solution that meets the needs of all stakeholders and is developed in an integral and effective way. A basic model of the 3P Approach is shown in Figure 4. It is iterative in nature, similar to any typical design process.

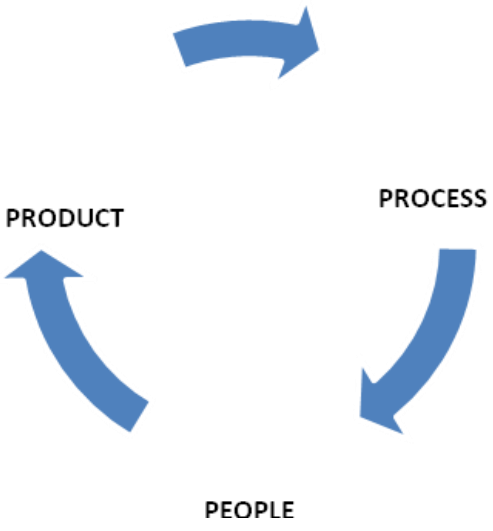

Figure 4. The 3P Approach

The starting point for an innovative product design and development project is the *People* phase, in which the questions pertaining to "who are the people", "what are their problems and needs", "why, where and when they have these problems and needs" and "how they deal with the problems and needs currently" drive the tasks and objectives. The mission of this crucial people-centered phase is to get a full understanding of the users and other stakeholders, and then carry out detail research into what their

problems and needs. It involves observations, surveys, interviews, comparative studies, etc, and the culmination is a set of design findings; that is, from design brief to design research report.
A design solution is normally meant for a certain target user group and not for everybody. For instance, a multipurpose vehicle is designed primarily for large-family users who need space, whereas a sports car is for relatively younger single or double users who need speed and strong form in the design. Therefore, the importance of the *People* phase in establishing the criteria and direction for a good design outcome can never be underestimated.
The *Product* phase is when the stakeholders' problems and needs are translated into "what product can solve their problems and meet their needs", "what are the characteristics of the product" and "how will it solve the problems and meet the needs". Essentially, this phase involves setting the vision for a good design solution, defining the design specifications for an intended ideal design outcome – the design utopia.
The three attributes of design are Function, Form and Efficiency (Figure 5). The functional aspect of a design is the combined feature of utility functions, ergonomic functions, esteem functions, etc. Form represents the collective property of a design pertaining to the human five senses, i.e. visual, hearing, tactile, smell and taste. The configuration or organization of parts in a design affects the efficiency of a design in aspects such as lower production costs and environmental sustainability.
In the *Process* phase of the 3P Approach, the aim is to devise a suitable project management plan in order to accomplish the mission of designing and developing a design solution that meets the needs of the stakeholders. Depending on the nature of the project, an adapted version of the product design and development process in Table 1 is used to realize a good design as specified in the *Product* phase that connects intimately to the *People* phase.

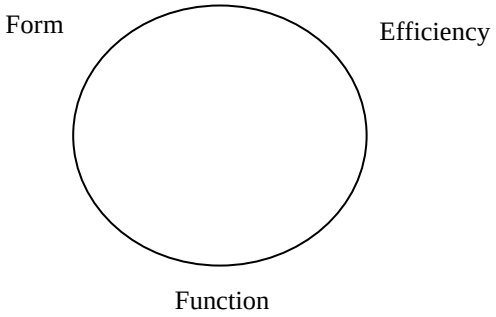

Figure 5. The three attributes of design

The arrows shown in Figure 4 imply that the 3P Approach is fundamentally iterative in nature. Whenever necessary, the design team needs to review the results and repeat the tasks of the People, Product and Process phases. Revised and refined versions of the design brief, research report, design specifications, concepts, detail design, prototype, etc, are generated iteratively. This process can be managed with the help of the Product Information Management System (PRIMAS) developed by the author such that an optimized design solution with win-win characteristics for each of the stakeholders identified is eventually achieved.

4 CASE STUDY ON PRODUCT INVENTION AND COMMERCIALIZATION

The author has applied the 3P Approach in several industrial collaborative product design and development projects. In this section, a case study on one of such collaborative projects is described with particular emphasis on the attempt to apply creativity in the major phases in the project.
The author led a team of designers and engineers in the design and development of a breathing apparatus, called the Mask-Aid device. The project began when some nurses and doctors complained about the discomfort of breathing over a prolong period of using a N95 and HEPA respirator facemask. The enquiry came to the author on whether it would be possible to design and develop a solution that could make breathing easier for nurses and doctors when using such facemask.
A design team comprising a product designer, a mechanical designer, an electrical design, and a couple of prototype making technicians was formed, with the author as the project leader. The team started the *People* phase of the 3P Approach. They met the nurses and doctors and spent several days

observing nurses and doctors using typical respirator facemask. Necessary photographs and videos were taken. They worn the respirator facemask themselves to experience and understand the problems the nurses and doctors faced. Many rounds of focus group survey and discussion with the nurses and doctors were conducted and useful information was collected and studied. The team also studied other respirator facemask users, e.g. workers in factories and shipyards who need to wear respirator facemask to protect against airborne fine particles. This was followed by a preliminary study on the desirability-feasibility-viability and the people-product-process prospective of the project.

The team proceeded to carry out research on the needs of other stakeholders related to the product, including people involved in manufacturing, marketing and sale, packaging and delivery, servicing and maintenance, retirement and disposal of the product. The research also include other aspects relevant to the project, including existing products (e.g. powered air purifying respiratory used in chemical industry), technology and materials (e.g. methods of air filtering), performance requirements (e.g. minimum air flow rate and filtering efficiency), costs of materials and manufacturing, etc.

Following several rounds of brainstorming and discussions, applying both creative and critical thinking, the team identified the problem statement as:

> "The discomfort of wearing a respirator facemask lies with the fact that the amount of carbon dioxide and moisture exhaled from the user accumulated inside the dead space of the respirator facemask, and the user will face breathing difficulties when the proportion of oxygen in the dead space drops to a certain low level usually after 20 minutes of continuous use of the respirator facemask. The discomfort can cause fatigue in the users and lower the quality of the performance in their work."

The design intent of the project was:

> "To provide a design solution such that users of N95 and HEPA respirator facemask can breathe more comfortably over prolong continuous usage of the respirator facemask up to a shift work of 8 hours."

The team subsequently proceeded with the *Product* phase of the 3P Approach by performing a series of experiments and technical investigations to establish the required air flow rate, acceptable noise level from the product, internal component requirements, study on the form or aesthetics for the product, size and weight of the product, easy of manufacturing and assembly, etc. This function-form-efficiency study for a utopia design led to the first version of the design specifications for the product.

One important design feature for the product is to provide maximum flexibility for the users when using the product, i.e. *design for users' creativity*. For example, the design specifications stipulated that the Mask-Aid device would allow the users to wear it at the waist, at an arm, hung from the neck or place it in a handbag or carrier. It also permits the users to adjust the air flow rate at a comfortable level. The users would be able to add features such as fragrance to the filtered air, microphone and speaker for communication when used by doctors during surgery operations. The device would be produced with different color and surface texture for different preferences of the users.

In the *Process* phase of the 3P Approach, the team went on to brainstorm for design ideas and concepts in accordance to the design specifications. A large quantity of divergent ideas was initially generated. These ideas were evaluated using criteria specified in the design specifications, and suitable ideas were developed into design concepts guided by the principles underpinning the desirability-feasibility-viability of the design thinking philosophy. An example of concepts generated is shown in Figure 6.

Applying creative and critical thinking, the concepts were evaluated and refined, and several working prototypes were produced for testing and evaluation. Figure 7 shows one of the prototypes produced. A patent search was then carried out and a patent was then filed for the novel technical process invented.

The design team subsequently worked with the technology innovation office in the organization to look for an industrial partner to develop the invention further for commercialization. Consequently, a collaboration agreement was signed with a company which manufactures medical products, and a joint product development team with the company was formed to carry out the tasks involved.

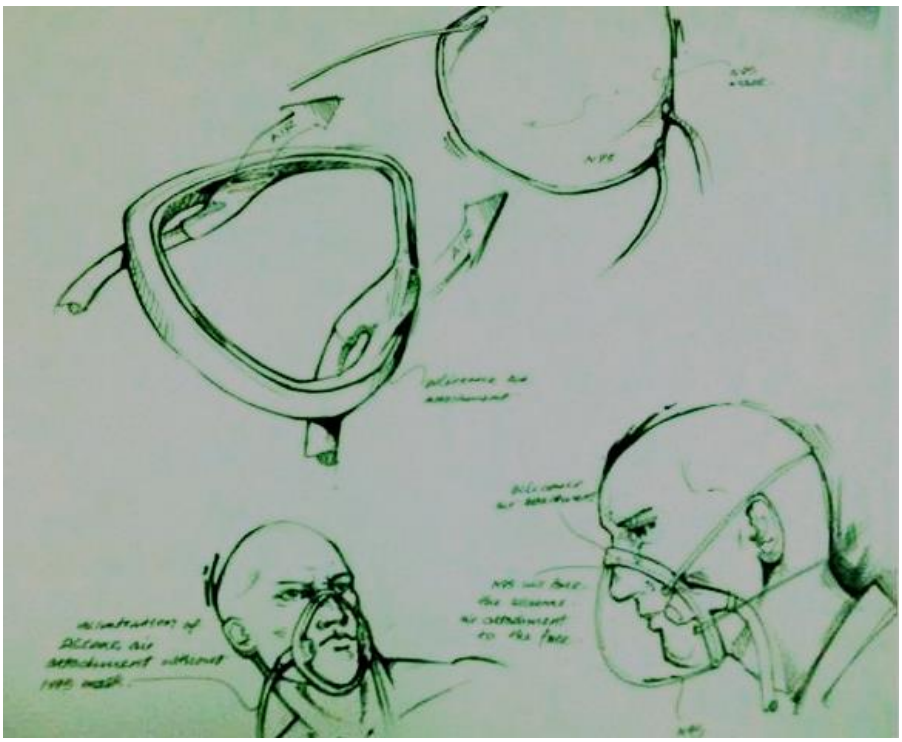

Figure 6. An example of concept generated

Figure 7. A working prototype

The joint development team produced a refined design within a couple of weeks. With a few sets of working prototype based on the refined design, user trials were carried out by nurses and doctors. Figure 8 shows a refined prototype.

With the feedback and information obtained from the user trials, the design was further refined and a production design was finally developed. Regulatory requirements for the product category were studied and necessary features on materials and other requirements were included.

Throughout the process of the product design and development project, especially in the collaborative commercialization of the product with the company, creative project management skills were needed. Win-win strategy and strong interpersonal skills were key success factors.

Figure 8. A refined working prototype

5 DISCUSSION AND CONCLUSION

The 3P Approach has been applied in designing and developing innovative products, including inventive products which are patentable. It has proven to be a useful methodology that sets the priority of setting a clear design direction by first looking into *People* aspects of design. Identifying the design specifications from the perspective of design utopia or the ideal *Product* to match to the findings of the problems and needs of the stakeholders is the second stage of the 3P Approach. The *Process* phase completes the integral link and connects the product to the people, providing an optimized and win-win design solution.

One of the key findings from the implementation of the 3P Approach is that when this approach is used together with PRIMAS, they provide an impetus to constantly check the evolutionary design specifications derived from the continuous *People-Product* definition pursue so that the *Process* phase in product design and development will not derail the fundamental objectives of the project mission. Further research work includes developing PRIMAS and the 3P Approach into a robust system with sustainable empowerment for product design and development.

REFERENCES

Akao, Y., (1994), *Quality Function Deployment: Integrating Customer Requirement into Product Design,* Productivity Press, Portland.

Brown, T. (2009), *Change by Design,* Harper Collins, New York.

Fowler, T., (1990), *Value Analysis in Design,* Van Nostrand Reinhold, New York.

Lockwood, T., (2010), *Design Thinking: Integrating Innovation, Customer Experience and Brand Value,* Allworth Press.

Tan, A. K. (2009), "An Integral and Strategic Approach in Product Development and Management", *2009 International Conference on Advanced Management Science*, Singapore, 17-20 April 2009.

Tan, A. K. & Bonollo, E. (2001), "Integrated Genome-like Product Database and Management System", *American Society of Mechanical Engineers International Design Engineering Technical Conferences and Computers and Information in Engineering Conference 2001,* Pittsburgh, Pennsylvania, USA, September, 2001.

Ulrich, K. & Eppinger, S., (2003), *Product Design and Development,* McGraw-Hill, New York.