THE HOLISTIC MODEL OF NEW PRODUCT DEVELOPMENT PROCESS

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ABSTRACT

New products are emerging all the time at a high speed of development. This is due to dynamic forces such a globalization of market, rapid technological development, greater customer demands, etc. With the changes in manufacturing and service industries, the new product development process and quality methods should be integrated to meet the current and future customer needs. Therefore, the holistic approach is introduced in this paper. The application of this model is also illustrated.

***Keywords**: new product development, quality tools, holistic model*

1. INTRODUCTION

In business and engineering, new product development (NPD) is the term used to describe the complete process of bringing a new product or service to market. Improving and updating product /business is crucial for the success for any organization. Failure for an organization to change could result in a decline in sales and with competitors racing ahead. The process of NPD is crucial within an organization. Products go through the stages of their lifecycle and will eventually have to be replaced. There are six main phases of new product development: (0) Pre-concept; (1) Concept Development; (2) System Level –Design; (3) Detail Design; (4) Testing and Refinement; (5) Production Ramp up (Ulrich and Eppinger,1995).

Many companies will implement the Six Sigma method to help them design and develop new products, services and processes. We will begin by drawing up a business strategy that will include the improvement of products and systems and will ultimately result in overall customer satisfaction. DMADV (Define, Measure, Analyze, Design, Verify) differs slightly from the overall Six Sigma approach because it starts at the beginning of the design phase of a new product, service or process. DMADV is about new, not fixing what is already completed. The DMADV methodology is geared towards creating new products and business practices.

Design for Six Sigma (DFSS) is the application of Six Sigma principles to the design of new products and their manufacturing and support processes. DFSS is a methodology to make the introduction of new products and services more efficient, reliable, and capable of meeting customer expectations or requirements (Anthony, 2002). DFSS is driven by “Critical to Quality” (or CTQ) factors, the quality characteristics critical to the customer. It is important to note that some companies may use a variation of this method known as IDOV, where the acronym stands for Identify, Develop, Optimize, and Validate (Creveling *et al.*, 2003).

In ‘*lean thinking’* value is defined as “a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer.” An immediate difficulty presents itself when attempting to define value solely in the context of NPD. At the end of the NPD process, value has only partially been realized. The design may eventually satisfy the end user, but it must pass through production, operations, sustainment, and possibly upgrades before life-cycle value can be assessed. Aspects of “value” can include a producible, low cost design; a design that is expected to satisfy customer requirements with an acceptable level of risk; or a supplier infrastructure which supports production as well as the operations and sustainment. All of these contribute to a successful product. There is also value which flows to future developments (e.g. human capital preservation and experience, synergies to other products, etc.). The NPD process also pulls in value from organizations or tasks that do not at first appear to be in the direct value stream, (e.g. research groups, internal information infrastructure and tool creation groups, etc.) (Yang and El-Haik, 2009).

TRIZ is a popular, scientifically based inventive problem solving process. TRIZ practitioners aim to create an algorithmic approach to the invention of new products or systems, and the refinement of old ones. It is based on the idea that there are universal principles of invention that are the basis for creative innovations that advance technology. Once these principles can be identified and codified, they can be used to make the process of invention more predictable. TRIZ is widely used today to improve and develop products, services, and systems. It greatly reduces the time to produce breakthrough ideas and inventions (Yang and El-Haik, 2009).

The right product is defined as one that adds value to the new product development which leads to the end-user. For the end-user, value added may be perceived values, which are ultimately measured by customer satisfaction indices. Quality management and its performance can be considered as a performance measure for development result. Therefore, quality performance has been considered as the criterion for the new product development.

2. THE PROPOSED HOLISTIC MODEL

The holistic relationship among DMADV, DFSS, Lean, and TRIZ are presented in Fig. 1 below.

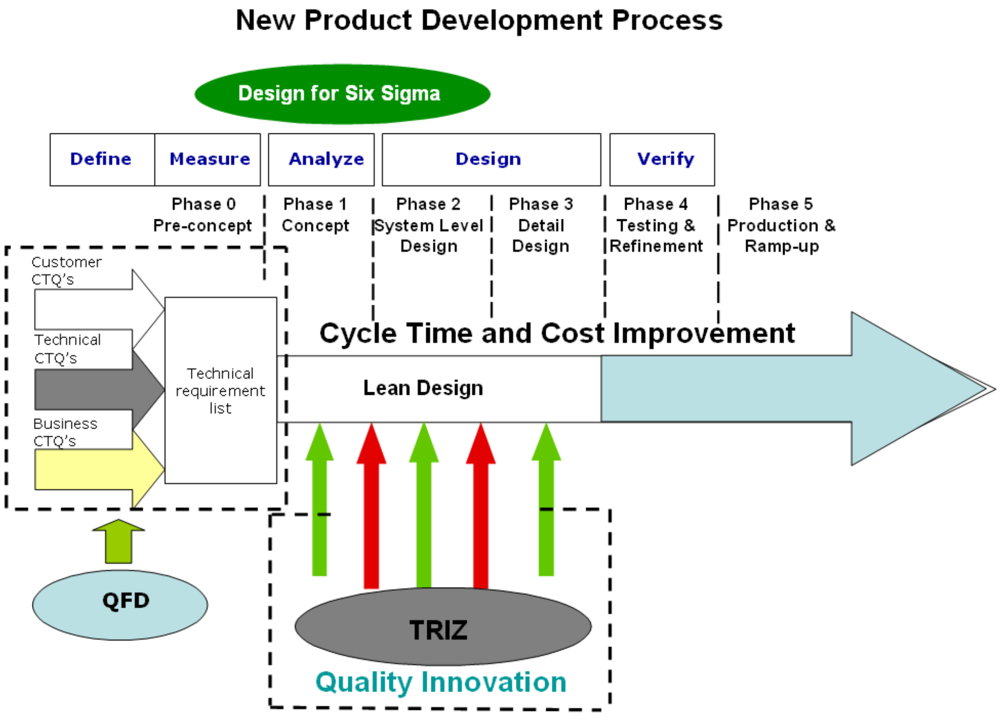

Figure 1. The proposed holistic model of new product development

Each of the phases in the NPD process represents something completely different. Starting with the pre-concepts phases, this phases consists of define and measure steps of DFSS. In define step, we spell out the purpose of the project, the importance, scope, deadlines, and available resources. This may seem tedious as you will have numerous meetings to discuss planning for future products and services. During the measure process we learn to understand the voice of the customer. This includes customer research, benchmarking, and technical research to arrive at CTQs (Critical to Quality Characteristics). Data collection, planning, and translating customer needs into technical design requirements are essential. QFD method helps us to generate technical requirements list from customer needs.

The concept phase will look back on the CTQs from previous phase and use them as your cornerstone for new ideas and design. Each idea or concept is evaluated and the best concept or design will be chosen. During the evaluation it is important to have customer feedback and input. During this phase there will be a lot of creativity, prototyping and support from the design team. TRIZ helps development engineers to overcome psychological barriers in this phase. In the system level design and detail design phase, development, testing, building, budgeting and many others will be included. During this time you will be involved in reviewing simulations, process modeling, risk analysis, and process charts. Finally, you have reached the Verify stage. This last step helps all teams involved transition the product, process, or service to the customer.

The lean design strives to optimize an organization's production process by reducing costs during new product development. Lean considers the value of a product from a customer's perspective, and questions the necessity of all costs associated with product development. Three types of waste: *muri*, which refers to wasteful design; *mura*, which refers to wasteful implementation; and *muda*, which refers to wasteful activity. Significant costs may be attached to each of these types of waste, and these costs are likely to be passed on to customers, thus decreasing a product's value. Thus, while lean design is able decrease production waste, DFSS is able to implement DMADV procedures to increase product quality.

3. THE APPLICATION OF THE HOLISTIC MODEL

In order to give better understanding of this holistic model, the case study taken from Kohnhauser's paper about 'Mouse-Trap' developing process is provided.The modified Ulrich and Eppinger's generic model and DFSS phases in new product development was applied.

Phase 0: Pre-Concept

- **Define Stage**

The purpose of this stage is to clearly identify scope and deliverables for the development project and to form the development team. The process begins with identifying the problem. The problem is how to develop 'mouse trap' based on customer needs. It is inevitable for the realization of efficacious products that the customer needs and requirements are identified and understood. Therefore, those people who must later process the consumers' information should be tied up in the procurement of information. After all they know best what kind of information is essential for developing new 'mouse trap'. For the data gathering of customer needs, diverse information channels can be tapped (see Table 1).

Table 1. Diverse Information Channels

questionnaires	data banks
customer interviews	customer forums
advertising events	expert talks
presentation of prototypes	specialist periodicals
fairs	claims
Benchmarking	trend research
lifestyle planning	and so forth

- **Measure Stage**

The purpose of this stage is to pinpoint critical to quality (CTQ) factors to focus design efforts. The output of this stage is a determination of customer needs and specifications through benchmarking competitors.

It is the development team's task to translate customer demands into actual product characteristics. This performance can be assisted by QFD. The QFD is accomplished in interdisciplinary teams, which guarantees the integration of all concerned departments from the beginning. Intense discussions occasion all project members to think about what the product must look like to transform customer requirement as good as possible.

It must also be noted that the consumer requests meet the current situation. In the mouse-trap example following customer requirements could exist (see Table 2).

The development team's effort now lies in converting these consumer demands into the technical characteristics of the mouse trap. In a next step the degree of the customer demands' realization that can be achieved with the technical parameter is rated. For the mouse-trap following characteristics were derived:

Table 2. Customer Demand/Requirement

Customer demand	sign	Customer demand	sign
Safe for fingers	5	foolproof	1
kills fast	5	bait is easy to place	1
effective lure	5	easy activation	1
safe for children and pets	5	killing signal	1
non soiling	3	quiet operation	1
low cost	3	non-skidding	1
reliable	3	proper size	1

Table 3. Technical characteristics

Technical characteristics	
radius of effectiveness	security standards
size	operating sound
ratio dead/trapped	slide resistance
MTBF	number
audible visible	size
number of baits	striking force
activating resistance	sales-price

When constructing a mouse-trap that meets all customer requirements it appears that some parameters affect each other negatively, e.g. the customers want the trap to be safe in handling and quick in killing the mouse. To kill the mouse immediately the trap needs as much striking force as possible. But an increase in drive also raises potential hand injuries.

So there are two customer demands "safe for fingers" and "kill immediately" which are hardly compatible. The ranking indicates, though, that the realization of both requirements is of high relevance to the customer. At the same time the QFD shows how our competitors are rated and maybe we realize we must improve. The calculated ranking of the separate technical parameters signals that the striking force is of high significance to the product.

Phase 1: Concept Development

This phase has the same objectives as the analyze stage of DFSS: generate solutions and then prioritize solutions. Typically, the problem solving is generating all possible solutions. The objective is to produce as many solution ideas as possible and then evaluate them. The purpose is not to find a single good idea, but to develop a pool of good ideas by evaluating, modifying, and improving. Once a wide variety of solution ideas is produced, evaluation begins with a list of manageable ideas and the promising ones are held up for scrutiny.

TRIZ helps development engineers to overcome psychological barriers in the this phase. With TRIZ, though, all imaginable ways for the solution of a problem are surveyed. This enlarges the expenditure for the development of new concepts, but it also ensures that all potential solution possibilities are taken into consideration. Hence the best concept will be realized. TRIZ consists of several different tools that can be used to solve technical problems. There is no fixed order which must be followed in the problem solving process. Rather, the TRIZ users' knowledge and experience direct what tools are to be used in connection with the particular problem.

Using TRIZ, the problem was handled with the "40 principles" to solve technical conflicts. A conflict is given when the improvement of one parameter leads to deterioration of another parameter. In our case, the "user friendliness" decreases as the "striking force" increases. For this conflict, TRIZ offers so called solving principles that can be drawn from the conflict-matrix. For our problem following principles were set out:

- ✓ Grouping/ segmentation (1)
- ✓ Replace mechanical systems (28)
- ✓ Local characteristic (3)
- ✓ Self-sufficiency (25)

Each of these principles must be worked over to develop adequate concepts.

TRIZ suggests, e.g., to apply the "grouping/segmentation" principle to the mouse-trap. It advises to split the trap into several parts. This means as follows: a special holding device is constructed which cuts out the risk of finger injury during the commissioning of the trap. Is the trap ready, it is set and the holding device is removed? A further principle is the replacement of mechanical systems with an optical, acoustic, or electric field. In the mouse-trap example, electroshock could serve as a substitute for the mechanic guillotine in killing the mouse.

All solution possibilities given by TRIZ must be examined step by step, till all imaginable solution concepts are elaborated. If the acquired solutions are non-satisfactory, further TRIZ tools must be applied. The preceding QFD guarantees that those problems which hinder the realization of customer requirements are treated first.

Phase 2: System Level Design

This phase is part of design stage of DFSS. To not only satisfy the customers but also enthuse them with product innovations it is not enough to simply fulfill the set of requirements. TRIZ offers the possibility to simulate future developments of technical systems. The basis for this is the classical s-curve model. Previous experience was used to derive laws of evolution of technical systems. By means of these laws scenarios on how the mousetrap will further be developed can be worked out. Here is a list of the mouse trap concepts that these examples of the technology forecasting pattern of "Flexibility" suggest. The basic function of the mousetrap is "killing the mouse". This function is performed by the guillotine (see Fig.2).

Phase 3: Detail Design

In this phase, a detailed design for the product is developed and optimized. The robustness of the design is ensured to minimize the impact of variation on performance of the product. After deciding in favor of one distinct solution concept all conceivable shortcomings that occur with the realization must be given thought. For that, an FMEA can be made. The potential shortcomings are assigned to the corresponding causes of fault. TRIZ assists this search for causes of fault by means of the so-called "subversive failure analysis".
A potential weakness in the mouse-trap case could be that the mouse gets the bait without setting of f the trap. To eliminate this deficiency it is essential to know all causes for the failure. How does the mouse manage to steal the cheese? For subversive failure analysis the problem must be inverted. The idea is formed that the mouse-trap holds a valuable diamond instead of cheese. The task now is to get the diamond without triggering the trap off. This is one problem like many others. TRIZ is a means to reach for solutions. Each solution found constitutes a potential cause for failure. For the mouse trap there could be the following solutions:

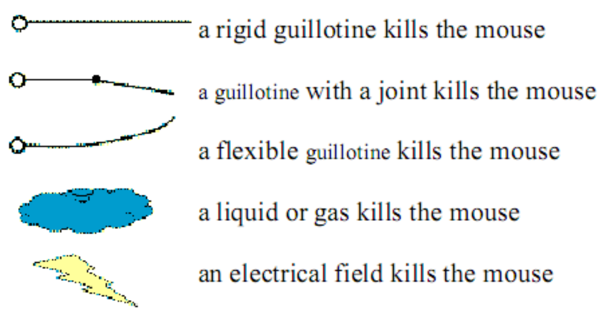

Figure 2. The basic function of the mousetrap: "killing the mouse"

- ✓ the mouse can touch the mousetrap in such a way that the trigger is activated, but the mouse itself is not in the "right" position.
- ✓ the mouse fixes the mousetrap with one of it's paws, so that the bait can't move down.
- ✓ the mouse waits until corrosion fixes the mousetrap.

With all potential failures to the developed concept identified and eliminated, the optimization of the product parameters should be carried out prior to series production. Especially with substantial changes at the product the risk of unwelcome side-effects which were not sufficiently reflected occurs.
The mouse-trap example shows how optimization can be achieved by simple means. To optimize the parameters it is especially significant to consider not only the main effects but also the corresponding interactions between the parameters. An interaction for two factors is given when one factor's influence on the target size depends on the adjustment of other factors. In this example this means that along with the optimization of the length of the guillotine it is necessary to consider the spring strength used and the size of the base-plate. For this, the development team works out those parameters that are being optimized in the course of test planning. In the mentioned case following 4 factors were chosen:

- ✓ Length of guillotine
- ✓ Spring strength
- ✓ Bait

- ✓ Base-plate

For each of these parameters two levels were determined which served the parameter optimizing (see Table 4).
Since the bait does in no way interact with the other parameters, an experimental plan can be made. The – and + symbolize the respective parameter adjustments. The number of mice caught per wee k is target size Y.

Table 4. Four chosen factors with 2 levels

Parameter	-	+
guillotine length (B)	6cm	7cm
springstrength (S)	0.8 Nm	0.5 Nm
Bait (K)	cheese	bacon
base-plate (P)	A	B

Table 5. The number of mice caught for each combination of parameters

	B	F	P	K	Y
1	+	+	+	+	4
2	+	+	-	-	3
3	+	-	+	-	5
4	+	-	-	+	2
5	-	+	+	+	4
6	-	+	-	-	2
7	-	-	+	-	3
8	-	-	-	+	5

In this case 8 tests were done. The last column shows the number of mice caught for each combination of parameters.

To find out whether bacon or cheese is more suitable to catch mice, following calculation must be accomplished. The sum of all K (13) divided by the number of tests (4) amounts to the average number of mice caught with cheese (3.25). Then, the average number of mice caught with bacon is calculated and entered to the diagram. Next, the two points are connected. In this case, an average of 3.25 mice was caught with cheese and 3.75 with bacon. Bacon is the better bait to catch mice.

To enable the consideration of the interaction between parameters they must be converted into a graphic as well. The calculation pattern is exactly the same as before. To work out point F+B+, the average for caught mice is formed from the respective combinations of parameters. The average (3.5) of test 1 and 2 is computed.

Concerning the relation between guillotine and spring strength the diagram clarifies that with a long guillotine the springiness doesn't affect the number of caught mice, whereas in combination with a short guillotine more strength is advantageous. The graphic of all parameters and their interaction

allows a fast and simple analysis of the series of tests. In the above example the decision was made in favor of long guillotine, high spring strength and base-plate B. Bacon is the preferable bait.

In this way, all other parameters of the mouse-trap can be evaluated. This process leads to optimal performance of the mouse-trap even before series production starts. It might happen, of course, that new problems occur with the test run. These problems must again be properly described and consequently worked on by TRIZ.

Phase 4: Testing & Refinement

This phase is analogous to verify stage of DFSS. In this phase, the generated designs are verified and validated using simulation and other approaches. While the purpose of the verify stage is to assure that the resulting design conforms to specifications and validates the performance previously identified in CTQs

Phase 5: Production & Ramp-up

In this phase, we evaluate early production output and then begin operation of entire production system of mouse trap.

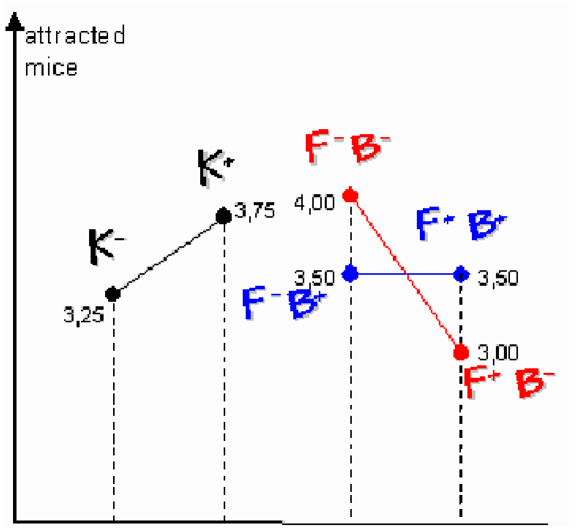

Figure 3. The interaction between parameter

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