APPLICATION OF AXIOMATIC DESIGN FOR ENGINEERING PROBLEM SOLVING AND DESIGN USING MECHANISM-BASED SOLUTION DESIGN: PART 1

Sung-Dai Moon
msdqqq@gmail.com
CEO, R&D Center of MSD
Rm, 401 EOS Hall, KIT, Yanghodong,
Gumi, Gyeongbuk 730-701, KOREA.

ABSTRACT

All companies wish to avoid issues such as expensive recalls, costly product reworks, and unexpected delays in product releases. Major contributing factors for these issues are the inability to troubleshoot problems and the lack of decision-making processes in design. Under present design processes such as Design for Six Sigma (DFSS) or Axiomatic Design (AD), design engineers are often left to deal with crucial requests in uncertain conditions, which make it difficult to predict failure mechanisms and customer demands.

This paper proposes a different method in the decision-making process called Mechanism-based Solution Design (MSD). MSD proposes a transparent way to determine "Desired Results" through a three step process: defining issues, analyzing the mechanisms, and determining the solutions in every domain in AD. This process is ideal for troubleshooting and design because designers can reduce ambiguity and iteration easily with MSD. Therefore, MSD is an essential tool for design engineers who want to achieve design creativity and positive results when faced with difficult problems.

Keywords: design process, Design for Six Sigma, Axiomatic Design, Mechanism-based Solution Design.

1 INTRODUCTION

Engineers are the leaders of social innovation in developing new technological solutions. Design engineers apply scientific knowledge, mathematics and ingenuity when developing solutions for technical problems. They are tasked with designing materials, machine structures and systems within the limitations imposed by practicality, safety and cost. During the engineering design process, an engineer's responsibilities include defining problems, narrowing research boundaries, analyzing criteria, finding solutions, and making decisions. Design engineers may also follow products and make requested changes and corrections throughout the life of the products, which is referred to as "cradle to grave" engineering. The product design process has influence on the overall performance of the system, development cost and time [Park, 2007]. It is generally accepted that most design engineers are not utilizing systematic design approaches to reach "good designs". The present stereotypical design process is fairly inefficient and time-consuming because there is too much feedback during the process [Lee *et al.,* 1996]. A lot of resources are wasted by design problems which were absent or unpredicted in the design process. Therefore, many design engineers struggle to find proper solutions for identified problems with their own know-how or present problem-solving processes. W. Edwards Deming states, "If you can't describe what you are doing, as a process, you don't know what you're doing" [Deming, 1982].

The Mechanism-based Solution Design (MSD) process is the first contribution in this paper for a clear way to setup an efficient decision making process in Axiomatic Design. Therefore many design engineers can effectively access the solutions of each domain in Axiomatic Design. Part 1 of this paper proposes the 1st step which defines issues through the identification of the current states to develop the desired results and defines the issues. Part 2 of this paper proposes the 2nd step which analyzes the mechanisms by checking the hypothesis on the issues and verifying the hypothesis and defining the mechanism model. Finally, the 3rd step determines the solutions by refining the desired results, optimizing the design solutions, and performing new design validation. This process is ideal for troubleshooting and new designs are also adaptable because designers can reduce ambiguity and iteration easily with MSD.

2 REVIEW OF PRESENT DESIGN PROCESSES

Many design projects should be able to execute the four steps of the design process as follows:

- Step 1. Definition of functional requirements (FRs).
- Step 2. Ideation or creation of ideas.
- Step 3. Analysis of the proposed solution.
- Step 4. Inspection of the fidelity of the final solution to the original needs.

The Axiomatic Design (AD) approach to the execution of the above activities is based on a four key concepts.

In the first step, the functional requirements (FRs) are defined to satisfy the original perceived needs. The appropriate set of design parameters (DPs) to satisfy the FRs must then be defined via a physical entity. The proposed solution is analyzed using design axioms and other applicable physical laws and principles to ascertain if the solutions proposed are rational. Finally, the reliability of the final solution to the original perceived needs must also be established. Each step often involves iteration, which may involve the redefinition of FRs, the creation of new ideas, and the modification of the proposed solutions.

In AD, the functional requirements (FRs) are generated from the given customer needs (CNs). Defining the needs of the customer and the determination of FRs is very difficult without professional experience because the customers' demands are often unclear, unfeasible, and inconsistently delivered to design engineers. Design engineers can be given with too much data to follow up on. The results of AD are sometimes hard to control because a huge design matrix can cause some engineers to narrow the scope of analysis without considering the system and be satisfied with partial optimization. In the end, insufficient solutions for the system may be presented by the design engineers.

Many design engineers who I have spoken with, including many professors of mechanical engineering, have experienced problems in the past by not properly defining functional requirements and the problems in a system. However, most of the AD solutions display sharp insights of the issues. The Axiomatic Design analogy (FRs from CNs, FRs and DPs obtained through the 'zigzagging' processes, DPs that check the manufacturability from the PVs) provides sharp insights and a deep understanding of the system that are essential to design engineers. Unfortunately, it is rare that well-trained professional engineers are in the field. Thus, a process is needed for engineers to more easily access the solutions of each domain in Axiomatic Design.

Mechanism-based Solution Design (MSD) offers a clear way to establish the "Desired Results" through a three-step process from defining issues to the determining mechanism-based solutions, in which the "Desired Results" mean a properly defined marketing strategy, functional requirements, design parameters and production variables as the design solutions of each domain in Axiomatic Design.

3. MECHANISM-BASED SOLUTION DESIGN

MSD provides a clear process for solving problems and design in the Axiomatic Design framework. Figure 1 shows the process of Axiomatic Design using MSD.

If we know the functional/physical mechanism of a target system then it is helpful to suggest a creative solution. A creative problem solving ability will depend on deep involvement to devise the theme of the issues. In-depth knowledge of a problem will often bring better alternatives than intelligent insights. However, if we do not have the necessary knowledge and insight, the designer should provide a logical overview of the system. Additionally, we must identify the 'essence' of the critical issues. Bigger and more important issues need a focus on the "root mechanism" in order to best find solutions. MSD proposes a three-step process as follows:

- Step 1: Define the issues.
- Step 2: Analyze the functional/physical mechanism.
- Step 3: Determine the design solution

The process of MSD is shown in figure 1. It starts with a function/effects analysis from "current states" to "desired results", which confirms the gap between "desired results" with the "current state" for defining issues, performs a mechanism analysis of defined issues, and determines the design solutions with systematic thinking.

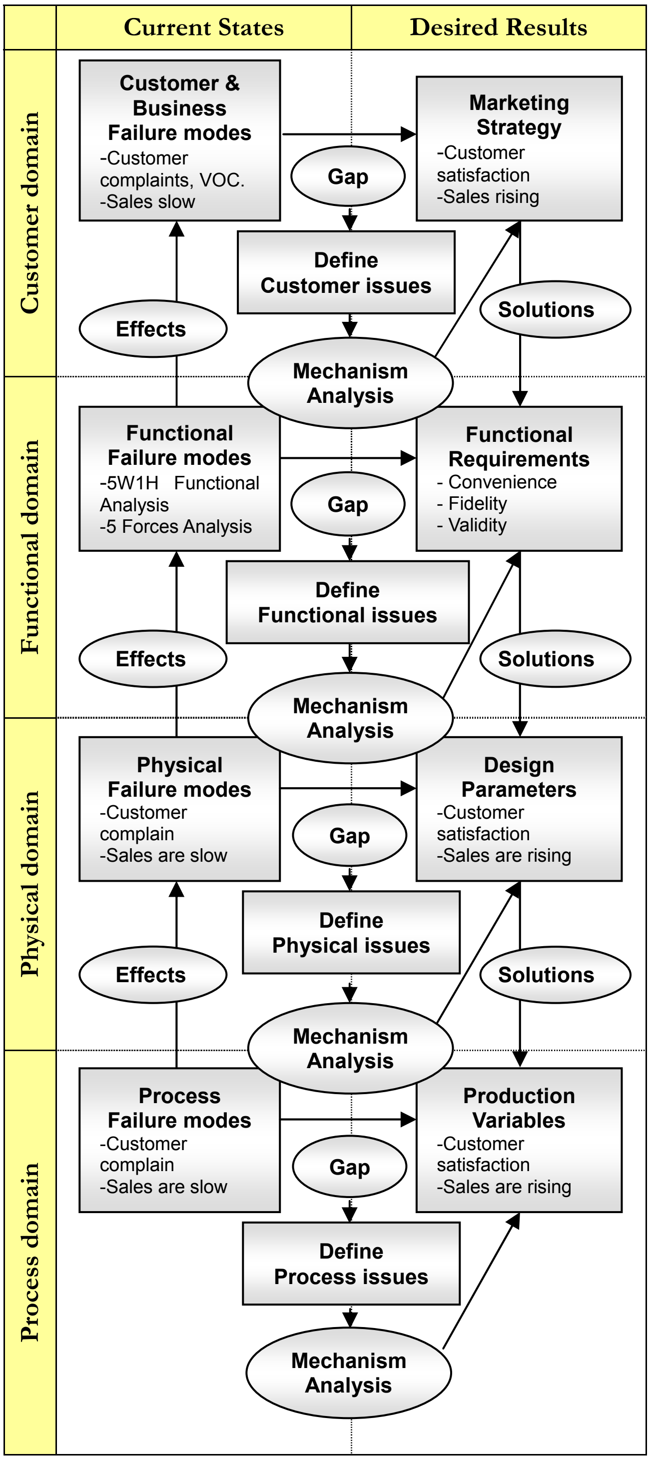

Figure 1. Axiomatic Design using MSD method.

3.1 DEFINE THE ISSUES

Defining the issues of the target system focuses on "what are the problems to be solved". In this paper, issues are defined as the set of defined problems which constitute the gap between the "current state" and the "desired results" viz. the challenges. One caveat here: in recent years, product reliability has been emphasized in the early stages of design, and engineers often face extreme external pressure in providing credibility of a new design idea to a board and others. Hence, they often place too much focus on reducing risks in their decisions instead of setting a challenging goal as a desired result. This makes obtaining creative design solutions more difficult. In order to achieve more creative design results, figure 1 illustrates the proposed process for defining the issues in MSD.

The defining the issues can be applied to all the domains in AD, as follows in these three phases:

- Phase 1: Identify the current states.
- Phase 2: Develop the desired results.
- Phase 3: Define the issues.

3.1.1 IDENTIFY THE CURRENT STATES

The purpose of this phase is the identification of current states with the analysis of present work. The identification of functional failure modes (FMs) and failure effects (FEs) analysis is the function and effects analysis process which helps to define "Where we are standing" by researching the current state of art and the demands of the customers. It should be developed using a *fact base*, *critical thinking*, and *outside the box* thinking. Also, an existing worked failure mode and effect analysis (FMEA) or fault tree analysis (FTA) can be helpful for the analysis of present FMs [HEO *et al.,* 2007]. However, in the early phases of the design process, engineers simply cannot foresee all potential failure mechanisms. Thus, as [HEO *et al.*, 2007] describes, it is rare to get a complete FTA of the target system. Therefore, we need another reasonably simple approach for the functions and effect analysis of a system which should follow the *Mutual Exclusivity and Collective Exhaustion* (MECE) principle [B. Minto, 1996].

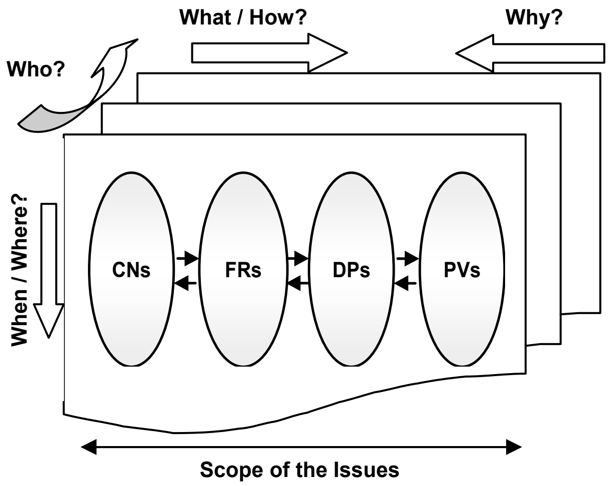

Figure 2. The 5W1H function and effect analysis.

This implies a similar philosophy to the *independent axiom*. *Mutual exclusivity* avoids the risk of redundant issues, and *collective exhaustion* avoids the risk of missing issues. This concept is desirable for the purpose of systematic design thinking. Thus, this paper suggests the concept of 5W1H functions and effects analysis for the analysis not only of current states but also of new designs based on the MECE principle shown in figure 2. In order to apply the 5W1H method for analysis of the system, first of all, we should define the scope of the analysis. Next is the classification of the current states as follows. "Who" means the characteristics of the customer. "When, Where" means the situational operation. "What" means functional requirements. "How" means design parameters. And "Why" means the mechanism of functions and effects; for example, the functional failure modes received from the post sales service data and the 5 forces analysis results as market competitors' technology trends. Finally, we should map from the FMs in the functional domain to the failure effects (FEs) in the customer domain and define the scope of the issues. The results of the identification of current states process are denoted as follows in Table 1 where CCFL is a Cold Cathode Florescent Lamp, and LED is a Light Emitting Diode.

The example takes a look at an external electrode fluorescence lamp (EEFL) back light unit (BLU) for an LCD TV Company. They are the supplier of EEFL BLUs for an LCD Panel Company.

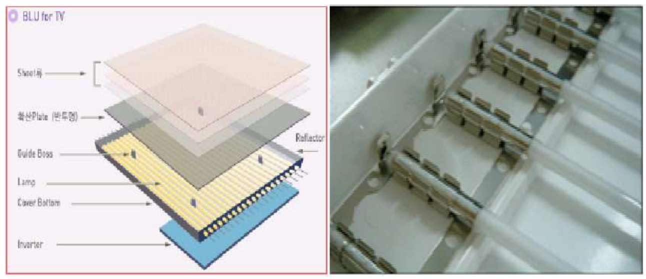

Figure 3. The layout of BLU and EEFL into BLU.

The operating mechanism of conventional EEFLs is shown in figure 6. These lamps are driven under very sever conditions: AC1200V ~ 2000V /60 kHz with temperatures up to 260°C. The inner side of lamp glass wall is coated with R.G.B. phosphor materials, and it contains Hg, Ar and Ne gases with vacuum conditions. Plasma is discharged on both inner sides of the external electrode by the driving conditions.

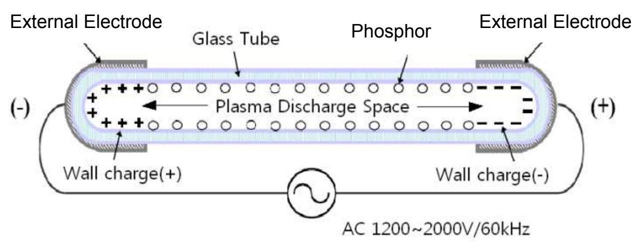

Figure 4. The operating mechanism of conventional EEFLs.

Table 1. Functional failure modes and effects analysis.

Current Functional Failure Modes	Effects/Trends in Customer/Business
Functional complaints /Customers' demands 1) Need to reduce price of BLU 2) Need to increase luminance of BLU 3) Need to reduce power consumption about 50%	**Functional complaints effects** 1) Customer reduces our orders and increase orders to low price company. 2) Performance of LCD TV cannot upgrade, looking for LED BLU company.
Post sales service data 1) Luminance decreased by aging 2) The lamp colour coordinates changed by aging	**Post sales service effects of business** 1) Brightness of LCD TV degrades, required to the quality improved BLU and reduces our order.
Etc. functional VOC 1) The luminance quality dispersion of each lamp is too wide.	**Etc. functional VOC effects of business** 1) Customers require to the quality improved samples and reduce our order.
5 Forces Analysis	**Effects/Trends in Customer/Business**
Competitive rivalry within an industry 1) W company's new developed EEFL BLU reduce the cost 10% and increase luminance 5%	**Competitive effects of customer/business** 1) Customer reduces our orders and increase W company orders.
Bargaining power of suppliers 1) BLU parts suppliers refuse the price cuts 2) Japanese phosphor company don't improve quality.	**Suppliers bargaining effects of customer and business** 1) Cannot reduce the manufacturing cost of BLU 2) Colour change by aging degradation don't improved
Bargaining power of customers 1) If we do not make the target price, customer will reduces our orders.	**Customers bargaining effects of business** 1) Maximize customers profit 2) Deficits our business
Threat of new entrants/technology 1) LED BLU market increased to 20% in 2011	**New threat effects of customer/business** 1) The growth of EEFL BLU market seems to be stop.
Threat of substitute products/technology 1) S company reduces lamps from 16 to 8 and save power consumption about 30% for 42"LCD TV CCFL BLU	**Threat of substitute effects of business** 1) EEFL BLU lose market to the CCFL BLU

In order to analyze the failure mechanism, we will require a mapping between domains. Current business states (CBSs) are influenced by CFRs, CFR are influenced by current design parameters (CDPs), and CDPs are influenced by current production variables (CPVs). In this paper, we define the relationship between domains as a "mechanism" which is also adaptable to every domain of the "Desired Results site".

The relationship between **CFR** & **CBS** is:

$$\{CBS\} = [CBM] \times \{CFR\} \tag{6}$$

where the current business mechanism matrix **CBM** is given by:

$$[CBM] = \begin{bmatrix} CBM_{11} & \cdots & CBM_{1n} \\ \vdots & \ddots & \vdots \\ CBM_{m1} & \cdots & CBM_{mn} \end{bmatrix} \tag{7}$$

Eq (6) is a current business states equation of H-Company,. The relationship matrices of each domain are defined by the mechanism matrixes in MSD. For the easy analysis of mechanisms of businesses, the [CBM] is either diagonal or triangular in order to satisfy the Independent Axiom.

For example, the current business states of H-Company can be classified as the following process.

CBS1 The profit of our company decreases because the customer reduces our order

- **CBS11** Customers increase orders of W-Company's newly developed BLU and decrease our order.
- **CBS12** Customers consider adapting S-Company's CCFL BLU.
- **CBS13** Customers looks to LED BLU Company for a new design.

CBS2 Customers require improved quality samples

- **CBS21** Customers require "the luminance decreased by aging" to be improved in samples
- **CBS22** Customers require "the lamp colour coordinates are changed by aging" to be improved in samples
- **CBS23** Customers require "the luminance quality dispersion of each lamp is too wide" to be improved in samples

The current functional states can be classified as the following process:

CFR1 Customers require the BLU performance to be upgraded and cost reduction.

- **CFR11** W-company's newly developed EEFL BLU reduces the cost by 10% and increases luminance by 5%.
- **CFR12** High current operating CCFL BLU reduces lamps from 16 to 8 and saves the cost and power consumption by about 30%.
  At 12mA operation of EEFL can achieve high luminance and efficiency as CCFL but pinhole failure occurs at the external electrode side within 30 minutes. It is fatal error in LCD TVs but very many professional engineers in the BLU market could not resolve pinhole failures for about 3 years.
- **CFR13** Customers want to reduce power consumption about 50%. Only LED BLU satisfies the demand. But it has heat sink problems.

CFR2 Customers require improved quality samples.

- **CFR21** The characteristics of 50% luminance decreased by aging. Most BLU assure 60000h reliability of the 50% luminance decreased by aging at 7mA operation but assure 50000h/8mA, 25000h/12mA at CCFL.

CFR22 The lamp colour coordinates changes by aging. Especially a blue colour is changed quickly.

CFR23 The luminance quality dispersion of each lamp is about 8%. "It is too wide."

Therefore the current business mechanism of H-Company's EEFL BLU is denoted as follows:

$$\begin{Bmatrix} CBS11 \\ CBS12 \\ CBS13 \\ CBS21 \\ CBS22 \\ CBS23 \end{Bmatrix} = \begin{bmatrix} X & X & & X & X & X \\ & X & & & & \\ & & X & & & \\ & & & X & X & \\ & & & & X & \\ & & & & & X \end{bmatrix} \begin{Bmatrix} CFR11 \\ CFR12 \\ CFR13 \\ CFR21 \\ CFR22 \\ CFR23 \end{Bmatrix} \quad (8)$$

And current design parameters can be developed as follows:

CDP1 The numbers of lamps in a EEFL BLU is 16 for a 42" LCD TV. The number of lamps in a CCFL is going to 8 and our cost of manufacturing is high into market.

CDP11 The dielectric constant influence to increase luminance. For cost reduction and luminance improvement, the glass tube material changes from borosilicate glass to alkaline glass.

CDP12 We know that the core parameter that influences pinhole failure is current density [Cho *et al.,* 2004]. The area of electrode should be enlarged, but the length of electrode is limited by the width of LCD TV bezel. So they try to increase the diameter of electrode part as shown in figure 5.
Lamp diameter also influences pinhole failure but they don't want to enlarge the lamp diameter because of cost reduction.
Matsushita [2005], Cho *et al.* [2004] claim that high-voltage discharge or surge affects the pinhole failure.

CDP13 Competitive LED array layout design for heat failure free LED BLUs.

CDP2 The market middle class quality BLU.

CDP21 A symptoms of Hg gas turning to amalgam by aging. Other gases also chemically degrade.

CDP22 The phosphors characteristics degrade by aging. The blue colour phosphor degrades especially quickly.

CDP23 The phosphors characteristics dispersion and accuracy of phosphors mixture ratio influence the luminance quality dispersion of each lamp.

$$\begin{Bmatrix} CFR11 \\ CFR12 \\ CFR13 \\ CFR21 \\ CFR22 \\ CFR23 \end{Bmatrix} = \begin{bmatrix} X & & & & & \\ & X & & & & \\ & & X & & & \\ X & & & X & & \\ & & & & X & \\ & & & & & X \end{bmatrix} \begin{Bmatrix} CDP11 \\ CDP12 \\ CDP13 \\ CDP21 \\ CDP22 \\ CDP23 \end{Bmatrix} \quad (11)$$

Figure 5. Electrode enlarged EEFL [D.-H. Gill, 2005].

And current production variables can be developed as following process

CPV1 The number of the EEFLs goes from 16 to 8 then the cost of the BLU decrease by 30%.

CPV11 The lamp alkaline glass contains a significant amount of Na which will chemically react with the Hg gas. It will reduce the life of the lamp.

CPV12 The process variable of resolving pinhole failure is the lake of engineer's passion.

CPV13 The process variable of LED array manufacturing.

CPV2 The market top class quality BLU.

CPV21 The lamp alkaline glass includes Na which will have a chemical reaction with Hg. Most lamp companies eliminate the inner glass protection coating process to reduce cost and improve luminance.

CPV22 We require characteristics of the phosphors to be upgrade by a Japanese phosphor material company. But it shows no improvement.

CPV23 We require characteristics of the phosphors to be upgrade by a Japanese phosphor material company. Our process of phosphors mixture is very well controlled.

Therefore the current physical mechanism of H-Company's EEFL BLU is denoted as follows:

$$\begin{Bmatrix} DP11 \\ DP12 \\ DP13 \\ DP22 \\ DP21 \\ DP23 \end{Bmatrix} = \begin{bmatrix} X & & & & & \\ & X & & & & \\ & & X & & & \\ & & & X & & \\ & & & & X & \\ & & & & X & X \end{bmatrix} \begin{Bmatrix} CPV11 \\ CPV12 \\ CPV13 \\ CPV22 \\ CPV21 \\ CPV23 \end{Bmatrix} \quad (12)$$

A more in-depth analysis runs into a similar process. The exact scope of the analysis is limited to the EEFL issues in this paper because considering all of the parts of the BLU is too large a sample to explain the purpose of introducing the MSD process. The author notes this to obtain benefits for the case.

3.1.2 DEVELOP THE DESIRED RESULTS

The development of the Desired Results (DRs) in MSD means the process of defining the Marketing Strategies (MSs), the Functional Requirements (FRs) and Constrains, DPs and PVs for each domain. This starts with the classification of the current states effects analysis data. For example, the planning of MSs for customers/businesses is the development of "What are the customers' demands" through the effects analysis of the customers' "needs, wants and validity" as follows in table 3.

Table 3. Analysis of customer demands

		Needs	Wants	Validity
		- Classified basic requirements	- Classified secondary requirements	- Classified implicative requirements
Functional analysis results	-Effects/Trends of customer/business	**FN analysis** "Reliable BLU for LCD TV"	**FW analysis** "Chip, high luminance and low power consumption BLU for LCD TV"	**FV analysis** "Reliability" "Cost" "Luminance" "Save power" "Customer's profit"

It is very important to develop MSs for the success of the business. This will be developed by customer requirements analysis and SWOT analysis process in MSD. The SWOT analysis method is a well known process for planning business strategies. Table 4 shows the example to develop the marketing strategies of H-Company using a SWOT analysis process.

Table 4. SWOT analysis for marketing strategies

EEFL BLU		**Strength**	**Weakness**
		1. EEFL BLU is chipper than CCFL BLU 2. Life cycle of EEFL is longer than CCFL.	1.Pinhole failure occurs at 12mA operation 2.Increase noise and heat in BLU
Opportunity	1. Low cost 2. At 12mA operation high efficiency and luminance of lamp 3. Study MSD process	**OS strategies** 1. Low price, high efficiency and long life EEFL BLU develop with MSD process	**OW strategies** 1. Resolve Pinhole failure with MSD 2. Reduce noise and heat with MSD process
Threat	1. CCFL BLU reduce lamps 16 to 8 2. CCFL BLU save 30% power consumption 3. Dispersion of the quality 4. Degradation of quality	**TS strategies** 1. EEFL BLU also reduce lamp 16 to 8 2. EEFL BLU save 30% power consumption 3. Find out the mechanism of quality dispersion 4. Find out the mechanism of quality degradation.	**TW strategies** 1. Reduce No. lamps without pinhole failure 2. Increase luminance of lamp without influence of noise and heat failures.

In order to achieve the desired results, as marketing strategy is important in business, the establishment of a conceptual design and the determination of FRs is very important in the engineering side planning. The conceptual design is the development process of the ideal solutions to achieve the desired results of each domain "What to do/How to improve customer satisfaction". The development of high-levels of FRs, DPs and PVs are conceptual design processes in MSD which follow the process of "zigzagging" from MSs to PVs. The framework of the 5W1H with the MECE principle provides for customer satisfaction of well-designed products. To determine the design concept is to seek the "fidelity" and the "convenience" for customers demands, and both should be investigated in the backdrop of a "zero base" and an "outside the box" way of thinking. The suggested design concepts are described as "SMART" which stands for specific, measurable, achievable, relevant and following a logic tree structure of functional hierarchy. Finally, design engineers should have the ability to differentiate the functional requirements and constraints from MSs. The FRs have target values but the constraints follow the characteristics of the smaller/larger the better such as cost, performance etc.

The relationship between **MS** & **FR** is:

$$\{\mathrm{MS}\} = [\mathrm{CSM}] \times \{\mathrm{FR}\} \tag{13}$$

where the consumer satisfaction mechanism matrix **CSM** is given by:

$$[\mathrm{CSM}] = \begin{bmatrix} CSM_{11} & \cdots & CSM_{1n} \\ \vdots & \ddots & \vdots \\ CSM_{m1} & \cdots & CSM_{mn} \end{bmatrix} \tag{14}$$

Each element of the consumer satisfaction mechanism matrix **CSM** and MSs & FRs are given by:

$$CSM_{ij} = \frac{\partial MS_i}{\partial FR_j} \tag{15}$$

$$MS_i = CSM_{ij} \cdot FR_j \tag{16}$$

Eq (10) is a marketing equation of business. For a successful business, the [CSM] is either diagonal or triangular in order to satisfy the *Independent Axiom*. Therefore, the goal of the marketing equation (13) is to determine each FR to satisfy the MS with the requirements of equation (17).

$$\sum_{j=1}^{i} CSM_{ij} = \text{Functional cost of } MSi \tag{17}$$

Where, i is an arbitrary row of [CSM]. Equation (17) is able to use the index of functional cost of MSs. It is similar concept of *Information Axiom* in the Axiomatic Design.

For example, the marketing strategies of H-Company can be classified as following process.

MS1 Customers increase our order and the profit of the company will increase.

MS11 Customers increase their orders for our cheaper and better luminance BLU.

MS12 Customers adapting newly developed EEFL BLUs of H-Company instead of CCFL BLUs.

MS13 Customers develop LED BLUs with H-Company.

MS2 Customers require other companies to improve the quality as much as H-Company.

MS21 Customers require other companies to improve the "luminance decreased by aging" quality as much as H-Company.

MS22 Customers require other companies to improve the "the lamp colour coordinates are changed by aging" quality as much as H-Company.

MS23 Customers require other companies to improve the "luminance quality dispersion of each lamp is too wide" quality as much as H-Company.

And functional requirements (FRs) can be developed as the following process:

FR1 H- Company decreases the price of BLU 15% and the cost of BLU decrease 30%.

FR11 Reduce the number of EEFL from 16 to 8 and increases the luminance of EEFL about 120% 1100cd.

FR12 Decrease the power consumption of EEFL BLU about 30%.

FR13 Develop competitive concepts of LED BLU.

FR2 Achieves the top class quality of BLU into the market.

FR21 Achieves 60000h reliability the 50% luminance decreased by aging quality.

FR22 Achieves the "lamp colour coordinates changed by aging" quality as world top class.

FR23 Achieves quality variance less than 5% of the luminance dispersion of each lamp.

Therefore the desired marketing mechanism of H-Company's EEFL BLU is denoted as follows:

$$\begin{Bmatrix} MS11 \\ MS12 \\ MS13 \\ MS22 \\ MS21 \\ MS23 \end{Bmatrix} = \begin{bmatrix} X & & & & & \\ X & X & & & & \\ & & X & & & \\ X & & & X & & \\ X & & & X & X & \\ X & & & X & X & X \end{bmatrix} \begin{Bmatrix} FR11 \\ FR12 \\ FR13 \\ FR22 \\ FR21 \\ FR23 \end{Bmatrix} \quad (18)$$

Other domains also run into a similar process.

The determination of desired results in each domain is composed of the same conceptual mechanism matrix viz. design matrix of each domain to the desired results site are defined as desired mechanism matrixes in MSD.

And design parameters (DPs) can be developed as the following process:

DP1 The number of the EEFLs drops from 16 to 8 then the cost of BLU decrease by 30%.

DP11 Pinhole failure frees EEFLs to operate up to12mA.

DP12 The power consumption is about 30% decreased for EEFL BLUs.

DP13 Competitive LED array layout design for heat failure free LED BLU.

DP2 The market top class quality BLU.

DP21 60000h reliability of the 50% luminance decreased by aging achieved BLU.

DP22 The reliability of phosphors achieved EEFL.

DP23 The luminance quality dispersion of each lamp quality variance is less than 5%.

Therefore the desired functional mechanism of H-Company's EEFL BLU is denoted as follows:

$$\begin{Bmatrix} FR11 \\ FR12 \\ FR13 \\ FR22 \\ FR21 \\ FR23 \end{Bmatrix} = \begin{bmatrix} X & & & & & \\ X & X & & & & \\ X & & X & & & \\ & & & X & & \\ & & & X & X & \\ & & & X & X & X \end{bmatrix} \begin{Bmatrix} DP11 \\ DP12 \\ DP13 \\ DP22 \\ DP21 \\ DP23 \end{Bmatrix} \quad (19)$$

And production variables (PVs) can be developed as the following process:

PV1 The numbers of the EEFL from 16 to 8 then the cost of BLUs decreases 30%.

PV11 The current density influence to pinhole failure.

PV12 The power consumption about 30% decreased EEFL BLU.

PV13 New competitive conceptual LED BLU.

PV2 The market top class quality BLU.

PV21 60000h reliability of the 50% luminance decreased by aging achieved BLU.

PV22 Contact to other phosphor company.

PV23 Contact to other phosphor company.

Therefore the desired physical mechanism of H-Company's EEFL BLU is denoted as follows:

$$\begin{Bmatrix} DP11 \\ DP12 \\ DP13 \\ DP22 \\ DP21 \\ DP23 \end{Bmatrix} = \begin{bmatrix} X & & & & & \\ X & X & & & & \\ X & & X & & & \\ & & & X & & \\ & & & X & X & \\ & & & X & X & X \end{bmatrix} \begin{Bmatrix} PV11 \\ PV12 \\ PV13 \\ PV22 \\ PV21 \\ PV23 \end{Bmatrix} \quad (20)$$

All of the design matrixes or mechanism matrixes comply with the requirements of the independent axiom. This means that the EEFL problem can be solved easily but LCD researchers couldn't solve this problem in a short time. Part 2 shows the core process of MSD such as defining the issues, examining the functional/physical mechanism by verification of hypothesis, refining the desired solution, optimizing solutions and reliability assessment.

4. CONCLUSION

The MSD (Mechanism Solution Design) process gives a more in-depth way to solve design problems with a three-step process. In this paper part 1 defines "What are the issues". MSD suggest defining the issues process as that is gap between "desired results" and "current states".

This paper shows the "current states" site failure mechanism-based effects analysis, and the conceptual design in the "desired results" site and which are adaptable to every domain in AD. This helps to define the issues clearly for newly suggested problem definition and functional requirements evaluation. As a measure of customer response and functional cost function, a CSM (Customer Satisfaction Mechanism) matrix is introduced to evaluate the proposed FR.

As an example, the actual problem of an EEFL BLU for LCD TVs is introduced which is analyzed by the sight of common engineer with AD. Part 2 shows the MSD process of defining the issues, examining the failure/functional mechanism by hypothesis, refining desired solution, optimizing solutions and reliability assessment.

As mentioned above, MSD proposes a new evaluation method of FRs, a new definition method of critical issues and analysis method of mechanisms which are clear to help design engineers avoid mistakes. It can also reduce iteration in the design process. Therefore, MSD helps design engineers achieve both cost reduction of development and creative results of design.

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