THE FUNCTION TREE ANALYSIS
FOR NEW PRODUCT DEVELOPMENT
& ITS APPLICATIONS

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Thesis Plan

PREFACE

TRIZ is a law of engineering systems evolution, but also it evolves itself. After Genrich Altshuller's studies, many TRIZ Masters and Experts have added new theoretical concepts and refined classical TRIZ tools. They also try to widen TRIZ area into business, software and also scientific areas, too.

One of the important directions of TRIZ evolution is how to model engineering systems. In classical TRIZ, there are few efficient analytical tools, so the initial problem should be formulated by engineer's intuition. Function Analysis was developed for the analysis of the system, and it provided much better formulated problem statements. TRIZ acquired its navigator to good problem statements that would help engineers to generate good solutions.

In 1999, I studied the analytical part of TRIZ processes and encountered a situation when it was necessary to predict a future system. Sometimes a new technical system (Paradigm Shifting System) is not based on the analysis of a previous system. For example, the LCD display has same function as the CRT display, but their components are totally different. Their functions are very similar, but the new system could hardly derive from the conventional system. In those situations, people usually use function oriented search or radical trimming, but the new system usually acquires new components and does not lose functions.

Sometimes, the function in the system was needed at the time when the system was developed, but technical evolution acts very fast. A function is gained at the first stage and transitional stage but the function' value can be seen in the different view in other box of the 9 screen operator.

Therefore my research was naturally focused on developing new problem analysis method for new product development. I found a new approach from hierarchical structure of Axiomatic Design and decided to modify the structure from TRIZ point of view.

After I left Yonsei University, I worked as TRIZ organizer in LG-Cable, Hyundai Motors and POSCO for 10 years. I met several TRIZ experts and technical engineers and learned from them. Fortunately I got a chance to apply and develop my theory through practical projects.

This hierarchical function analysis is called 'Function Tree' and it identifies more problems in the technical system. Unlike the situation when people focus one part or specific set of problems in the system, it provided the problems of future and past, super and subsystems.

This theory was published in 2001 (Graduation Thesis __ MS Degree), 2004 (ETRIA), and 2009(SAE and TRIZCON).

This thesis is a synthesis of my study through 10 years. It presents the main ideas of Function Tree and it conducts comparison with other modeling methods. As a case study, the development of new backlight unit of LCD-LED TV will be discussed as an example of Function Tree

Chapter 1. Issues of Technical Forecasting

1.1. Introduction

TRIZ is a law of technical evolution of engineering system. Many great inventions were developed by TRIZ. TRIZ tools are very powerful for (1) system improvement, (2) new product development, (3) cost reduction, (4) process innovation and (5) patent circumvention. Modern TRIZ process is composed of Analytical Stage for analyzing system and Creative Stage for generating concepts.

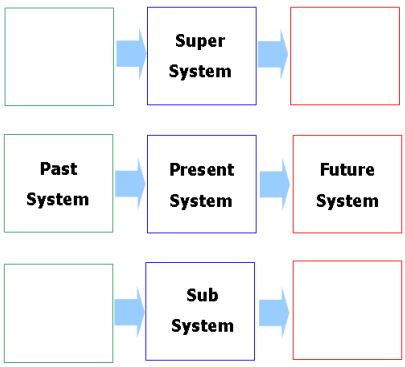
Usually Function Analysis is the most popular to describe the system. Even though it can build a function model of the system, it is not enough for new product design because it is usually models existing components of the present system.

For that, usually engineer picks up a leading system and changes it to system improvement project. Innovative Benchmarking tries to find a leading product in the different area of product..

In the system improvement project, usually engineer becomes focused on conventional tasks. Sometimes, it happens to get answer from outside of the technical system. Normal function analysis gives what functions exist among components, but it does not reveal why the conventional function in the system is needed. The problem engineers focus sometimes proves to be not the problem related to the key solution.

The function or problem of technical system is not permanent and varied with time. For the prediction of future system, the system should be modeled based on functions of the system, not components and described as a view of 9 screen system. (Fig. 1)

Fig 1. 9 Screen Analysis



Laws of Technical Engineering System Evolution is strong method for system evolution, but the laws are too macroscopic and could not be attached to conventional function analysis. In this chapter, the issues of technical forecasting are reviewed and the purpose of this study will be discussed.

1.2 Forecasting of the Future System

It is said that there are mainly 5 strategies for making profit of companies that is Base Retention, Share Gain, Market Positioning, Adjacent Market, and M&A.

In the past, the productivity and quality are considered most important. Nowadays market positioning is considered more important because it is critical to be in the dominant position in markets. For example, Hybrid Car of Toyota and I-Pod of Apple are good examples of market positioning in real cases.

Walkman (Sony) was the most developed music player. A competitor of SONY who has similar concept of product of walkman will fail to take the market share from SONY whose customers have loyalty to the #1 Brand.

APPLE developed new product, the I-pod. It changed paradigm and APPLE take over the market successfully from SONY. (Fig. 2)

How does Toyota take over the future market? They are the first provider of hybrid car in the markets. The system was impossible in the past, but one of the components evolved to 2nd Stage. Lithium battery was developed and the constraints were totally eliminated.

The paradigm of the system is jumping to new system. To be the winner in the market, it is needed to develop new products like internet, MS windows and Segway earlier than competitors and supply them to the markets ahead of their competitors.

Fig 2. New Paradigm of Product

1.3 Definition of New Product

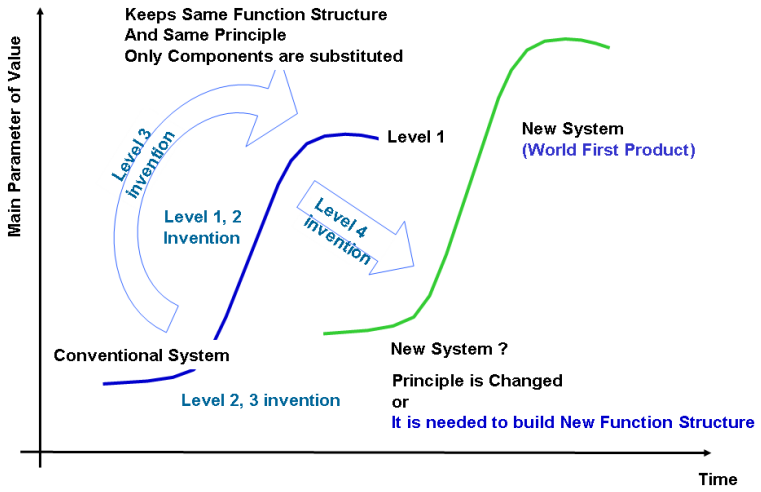
First of all, it is needed to define what new product is. According to a well known classification of the level of invention by G. Altshuller, Level 1 includes minor parameter change and most optimization. From level 2, the contradiction is resolved. Level 3 of invention starts to import technology from other industries. Level 4 keeps function but principle is changed. As shown in Figure 1, Inventions from level 1 to level 3 exist in same S-Curve and level 4 is based on new S-curve. Level 5 is totally new birth of S-Curve. (Fig. 3)

Innovation is moving upward on the S-curve with increasing functionality and decreasing cost. In this paper, new product means the invention corresponding to level 3 and level 4. It requires fundamental changes in the system.

The system result from patent circumvention usually keeps same position on S-curve. Cost reduction is also based on function modeling with existing components. System improvements can improve the functionality of one of components in the system or resolve a problem. In the case of new product development, it is needed to model the system with only functions extracted from the existing system.

For example, I-pod of Apple is new product in the area of music player. The past system was walkman of Sony. The components of walkman are totally substituted to the digital system but the main function structures remained same. For dramatic change of the system, it is needed to focus on restructuring functions in engineering system. Even though the components of future system are changed, the function structure of the future system is not dramatically changed and also some functions are eliminated totally. [1]

Fig 3. S-Curve and Level of Invention



1.4 Evolution in Nature

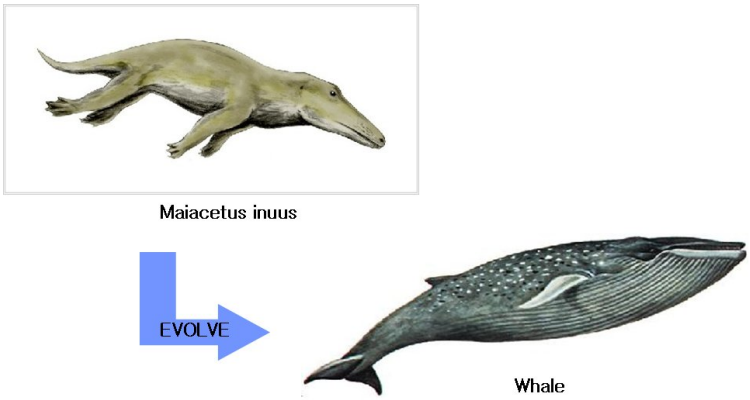
Like technical system, the animals and plants evolve. For example, the whale was a ground animal 47 million years ago. The fossil of ancestor of whale was found in 2008. The characteristic shows it had 4 legs like other ground animals. Why did it evolve like present form of whale? (Fig. 4)

It's because the functional requirements have changed. In the sea water, the hind legs are unnecessary. Supersystem had changed and the technical system followed and adapted the change of the system. If the ancestor of whale had not moved to the sea, they would not have needed fins and thick fat layer. Also they don't need legs anymore.

The technical system is same. If it is needed to resolve the problem in the system, it is enough to describe the components of conventional system.

When it is needed to change the system dramatically, the function should be modeled in advance of component modeling. The change of functional requirements will lead the existing system to the future system. Somebody said 'Necessity is the mother of invention' and it has the meaning of functional requirement leads to invention.

Fig 4. Evolution of Whale



Interestingly, it can be found in other example. It is well known the earth was rebuilt after dinosaurs had disappeared. Even though the ages are different but the shapes developed very similarly. Ichthyosaurus has no relationship with dolphin but they look very similar. It results from their needs of function in the same situation

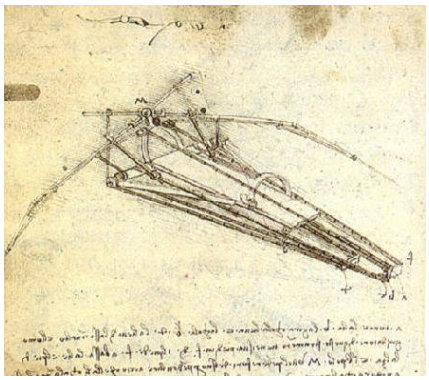
Fig 5. Similarities of Dolphin (R) and Ichthyosaurus (L)

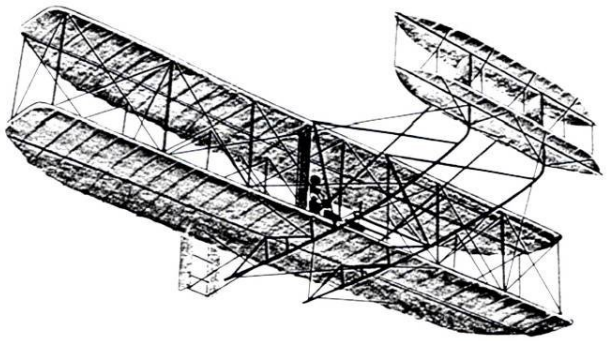
1.5 High Level Invention

High level invention means usually level 4 ~ level 5 inventions. Wright Brothers developed the first airplane. Leonardo Da Vinci also tried to invent Airplane but his invention did not realized. Why did Wright Brothers succeed to develop airplane and Da Vinci failed?

It's because Da Vinci's airplane did copied function of the bird but components of bird. Usually wing of the bird has a function of driving and lifting. Da Vinci tried to make same components the birds had.

Fig 5. The Airplane of Da Vinci (L) and Wright Brothers (R)





But Wright brothers copied only functions of the birds. They developed solid wings and separate propulsion with propellers. And it made successful result. Many of Da Vinci's inventions look like ones of a genius. If it is considered in the view of functions only, then it will make more promising future concepts.

They may build the structure of the function in their mind first and tried to find the proper components of the system. In their ages, there is no tool for generating ideas. Because they predicted the conceptive structure of future system, they could invent the product of high level. In his time, Leonardo could not benchmark any other system. He may have formulated the functions and made his systems.

However it is interesting to think how they could invent many interesting concepts. What is common in Edison and Wright Brothers? To make the real system, it is needed to build the model of the functional structure before the structure of the components.

1.6 Future System and Function Analysis

As discussed in previous chapter, FA is very popular and strong method for most types of projects like patent circumvention, system improvement, cost reduction and process innovation. The systems are usually modeled by Function Analysis. For cost reduction and patent circumvention, the power of Function Analysis is maximized because the strategies are usually based on existing technical system and removing some components for that. It is possible to find contradictions and function disadvantages in the existing engineering system. Function Analysis is the best modeling that describes existing system based on the components.

Altshuller mentioned that 95% of problem (Level 1 ~ Level 3) solved by the technologies used in the same industries. If the problem is found, new mechanism for performing the function or solving the problem can be found by function oriented search. Also radical trimming gives the chances to change system dramatically. But there are more cases of invention which can not be explained by pure radical trimming or function oriented search.

But the cases of level 4 or 5 inventions like the first airplane need more explanation how the system was developed.

There are 9 screens of technical system in Fig 10. Function Analysis usually describes system of present domain of the product. New product locates in right parts.

Function Analysis is a strong tool for finding problems from existing system. If you want to keep existing system and improve it, it will provide clear and efficient scheme of engineering system.

But if engineer wants to develop some other system, the model of function analysis can constrain thinking about the existing system.

Usually New product has kept same functions as present system but the components are changed. For example, the data storage devices have evolved from tape recording to optical or magnetic drive system. The components are totally changed but functions remained like Walkman and MP3 player.

Also New system is influenced by Technical System Evolution Law of TRIZ including the development of subsystem and supersystem. Therefore it is needed to overview evolution of supersystem and subsystem together. For example, electric vehicle had poor performance due to limit of battery capacity. Because the capacity of battery is increased by lithium battery (according to supersystem and subsystem evolution), it started being used in the car industry. To develop new product, it is needed to see subsystem and also supersystem.

Function Tree Modeling is modeling based on functions of existing system and it gives more chance to formulate problems from different views. It gives chance to overview the

whole system including supersystem from the hierarchical modeling. It is based on Axiomatic Design, that can be seen in the following explanation.

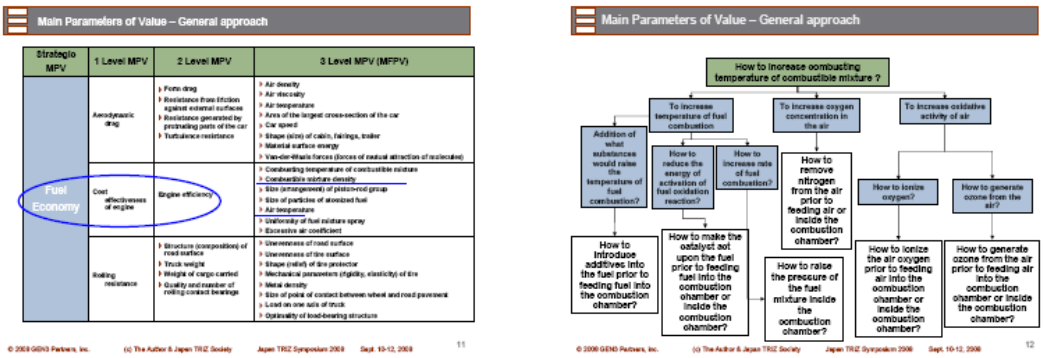
1.7. Future System and MPV Analysis

MPV analysis is a methodology to find MSPV (Main Strategic Parameter of Value)) attributing customer's behavior in the market and change it to the MFPV (Main Functional Parameter of Value). It is also trying to search latent MPV, too. It differs from Axiomatic Design because Customer Needs and Functional Needs are in the same hierarchy.

MPV starts from generic terms but starts to guide the parameter to the Main Functional Parameter of the value. Similarly Hierarchical Structure of Axiomatic Design starts form Customer's Needs and leads it to Functional Needs.

As seen Fig. 6, it becomes a specific functional problem and forms a CECA structure. After that, it tries to find methods to satisfy given problems.[5]

Fig 6. Example of MPV Analysis (TRIZ Symposium Japan 2008, Dr. Sergei Ikovenko)



These methods start from customer needs and MFPV begin to find the reason of upper hierarchical MSPV. It is very similar to effect chain of scientific effects.

It starts from customer requirements and is good for strategic planning. Also have similarity to CECA (Cause Effect Chain Analysis) which is used for finding key disadvantages or reformulating main function.

MPV analysis is a method to deliver MSPV to MFPV, but it starts from very generic terms as Leonardo Da Vinci or Edison did. MFPVs derived from Customer's Needs are very diverging and it makes lots of branches. Also it usually starts from the Top of the hierarchical system; therefore it does not fit into system descriptions.

To predict future system in a guided direction, it is needed to build the system model from the conventional technical system. It's because the technical evolution is commonly

occurred in the level of sub components in the system not only at higher levels of the system.

1.8. Function Tree and Function Synthesis (From paper of Dr. A. Kislov)

Function Synthesis is developed for the synthesis of engineering systems (ES) that do not have analogous prototypes by Dr. A. Kislov, According to his thesis, the algorithm has some assumptions as follows. [6][7]

- Any ES can be considered as a device and as a process (technology).
- Any ES is designed only for performing some functions (actions). That is why it is psychologically easier to start the synthesis looking at the ES as a process.
- To profoundly understand how an ES works there is a powerful tool – function modeling.
- The synthesis of the ES can be considered as the very beginning of its development. At this stage the components of the ES have minimal functional load. The choice of the carrier of the function (a system component) is done individually for every necessary action (function).
- The output of the synthesis should be a function model of the ES.

and In the above chapters, it is revealed that it is needed to focus on functions of the system to develop a new product and also the conventional analytical methods are reviewed.

FA and FOS were main tools of system modeling and CECA and MPV analysis is kind of new. But to predict the future system, it is needed to find better problems for deriving ideas. If conventional system is very strong, then it is also hard to escape the paradigm and generate idea of the new system. MPV analysis is good for revealing new requirement from customer but it starts from a very broad concept.

There are 8 steps as follows.

Step 1. To identify the Main Product – an object for what the system is designed. To formulate the main function of the Engineering System (ES) that is under investigation.
Step 2. To identify parameters of the Main Product before the main function is performed on it.
Step 3. Build the ideal functional model of the process, and to show how to perform the main function of the Process. To do that we need to formulate functions that directly creates the Main Product (productive functions) without specifying the carriers of these functions.
Step 4. To build Flow Model of the process:
Step 4.1. Assign a technological operation for every productive function that we have identified at Step 3.
Step 4.2. Specify states of the product in the beginning and at the end of every operation.

Step 4.3. Specify/check the flow of states of the product from one Operation to another.

The output of Steps 1-4 is a function model of the process (flow sheet) at the very top hierarchal level Steps 5 and 6 allow developing the ES in more detail.

Step 5. Build a function model of the process at the second hierarchal level. To do that it is necessary to formulate functions of every operation from Step 4 without specifying carriers of the functions.

Step 6. Repeat Step 4 for the second hierarchal level.

Note; Each lower level hierarchy adds more details to the development of the ES. How low in the hierarchy we should go depends on the objectives of the project. If necessary, repeat Steps 5 and 6 to get to a lower level of hierarchy. If not, go to Step 7.

Step 7.Build a component model of the device. To do that, for every operation from the previous step, we should design a component that can perform the function of the operation.

Step 8. Build function model of the device. To that it is necessary to formulate functions of the components introduced at Step 7.

Fig 7. Fig, 1 Flow Chart of Synthesis of the ES

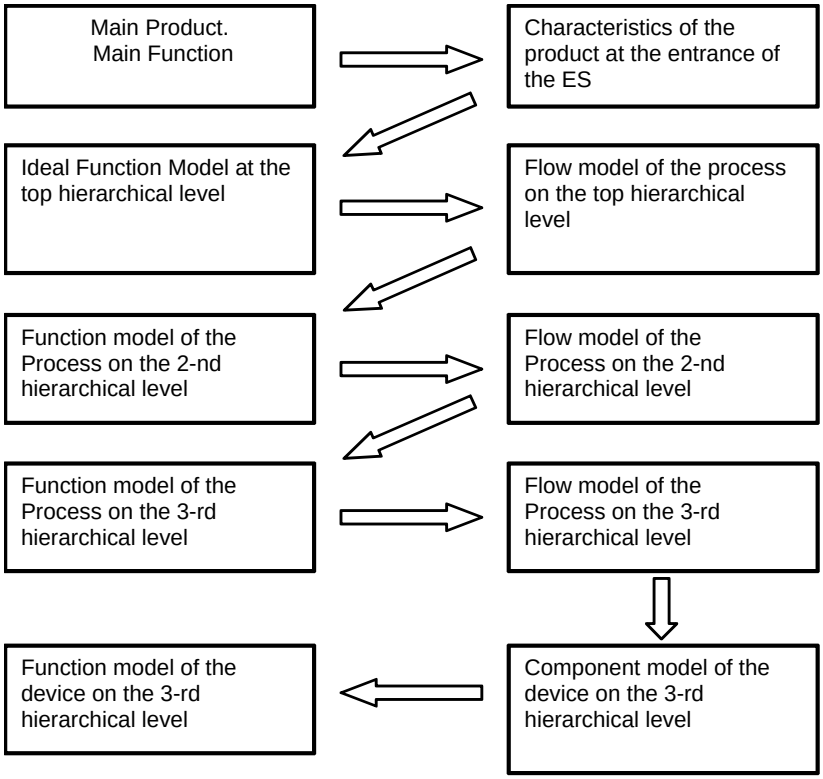


Fig. 7 shows the flow chart of Function Synthesis. The main idea is to describe new system from highest hierarchical level from main function. It's new approach and similar to MPV analysis which start from MSPV.

1.9. Conclusion

In the above chapters, Function Analysis is based on conventional system. The new system developed from Function Analysis will have same functional structure or trimmed structure from original system. (Giraffe can't be developed from analysis of elephant : businessweek 2009)

If we start from main function(function synthesis) or MSPV (customer requirement), the new product will have more variants but VOC (Voice of Customer) is kind of dangerous to predict future system. Function synthesis is more like to describe process modeling for new product development.

In this thesis, it will be discussed new modeling method based on hierarchical structure called function tree. It is a system modeling method for new product development. It starts from conventional technical system and it will extract function from it to develop new product.

Therefore new analytical method should have the characteristics as follows.

1. Function Based Modeling
   - The modeling is separate modeling of functions and designs(component/parameter).
   - The modeling is composed to function tree and design tree.
   - If the diagram is complex, it is very hard to analyze what is important function and what is auxiliary functions. The modeling should show the main composition of functions in the system very easily.
   - New ranking method will be suggested. (In the past, the rank of engine was kind of lowest in the function modeling.
   - Radical trimming is occurred at the 3rd stage of system development, but usually in the 1st stage, the system earns new functions. This modeling will provide more convenience to add new functions.
2. System Describing Modeling
   - It should reveal all the functions in the system
   - The modeling is usually from some technical system, not zero base.
3. 9 Screen Modeling
   - It should reveal super system functions and subsystem functions together. Also the functions could be revealed for specific moments in time..

New modeling will provide 2 main advantages.

From macro view
1. New Development from analysis of overviewing old system.
From micro view
2. Derive more problems for dramatic change. (reformulating functional structure)

In the next chapter of the thesis anew modeling method called function tree will be proposed.

Chapter 2. Function Tree Analysis

2.1. Introduction to Function Tree

The requirements shown in Chapter 1.8 and the area of new product analysis cover the following:

1. System should be modeled with functions
2. System should be modeled as a hierarchical structure.
3. Each function should have specific relationships.

Function Tree is oriented from hierarchical structure of Axiomatic Design and also it derived from the conventional function analysis. Hierarchical Structure of Axiomatic Design provides the structure of the system and it looks like the hierarchical modeling of axiomatic design, elements of which are substituted with functions from Function Analysis.

Axiomatic Design was invented by Professor Nam Suh, but lots of theories are under development. The development of axioms is quite well defined but no exact theories are not existing for hierarchical structure. I worked for 11 years to make useful tool after 1999 and the development of this thesis is quire original.

Usually the hierarchical structure is built from highest functional requirement in the Axiomatic Design, but Function Tree started to arrange the functions from the engineering system to the hierarchical structure.

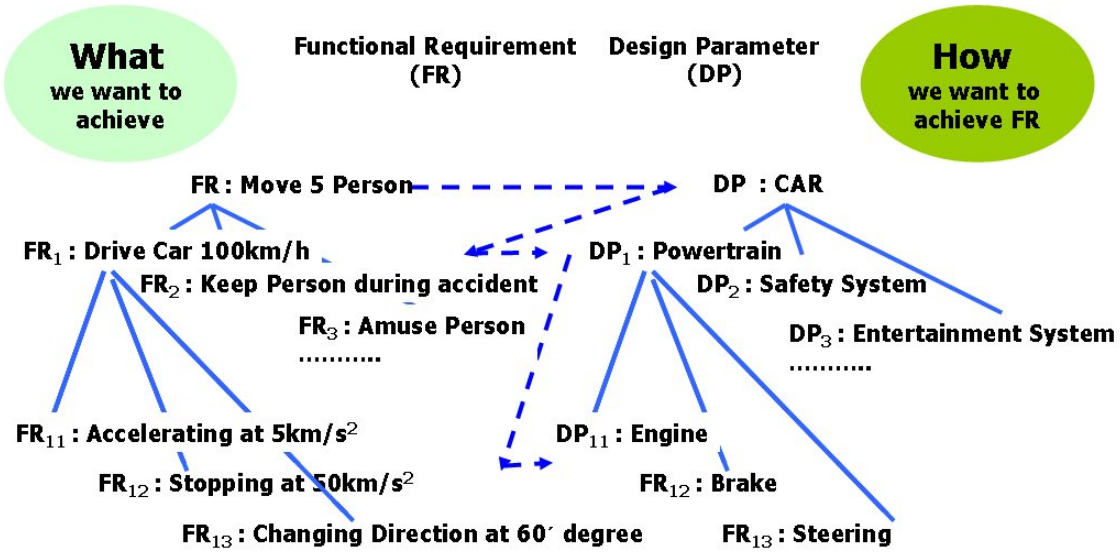
This method also builds hierarchical structure of design parameter (Components). But main advantages of this analysis are in the modeling of functions.

This is a method to describe the structure of Functions in technical systems. FA is horizontal modeling to describing existing system and Axiomatic Design and MPV Analysis is a vertical modeling. Function Tree can show multiple level of component/functions.

2.1.1. Hierarchical Structure

Axiomatic Design describes Function & Components in one screen. This hierarchical structure is describing system. It describes function and component in the different domain. Each of domains is built by hierarchical structure of Function Requirement(FR) and Design Parameter(DP) from Top-Down directions.
At first, it starts from highest FR and then it selects DP to achieve the function. And again it selects the lower level of FRs and DPs. It is called zigzagging.[2]

Fig 8. Hierarchical Structure of Axiomatic Design



Function Tree differs from Axiomatic Design because it starts from base system as Function Analysis. And it builds the hierarchical structure form Down-Top directions. It is called Reverse Zigzagging of Function Tree. Also instead of parameter, Design Component locates in the right domain.[3][13]

2.1.2. Function Requirement

Every system consists of functions. Function Requirement (FR) is a function with a required level of performance defined by designer. Function Tree is composed of sets of FRs and shows the relationships among functions in the system.

FR is a kind of target, so the function in the system could fulfill FR or not. Usually people's FR is increasing continuously and it is the reason of technical evolution. All the technical evolution is oriented to human needs. If the functions satisfy FR by 100% and FR keeps stable, the increasement of technical property becomes slow, too. For example, the brightness of lamp keeps same level because people only want certain range of brightness.

Function Requirement is little bit different from so called function. Function requirement is a target of function which is required in the system. Usually performing a function is overcoming functional requirement. If the function doesn't meet functional requirement, it usually has supporting and correcting functions.

There are lower-level functions for its main function. Also there are maintaining function and corrective functions which does not relate to the principle function directly. The functions help sub functions but does not relate to directly primary function. The functions are in the same level of Function Analysis, but they could be in the different

level in Function Tree and also very low level of function can not be seen in the Function Tree.

2.1.3. Functional Ideality

Ideality in TRIZ is expressed by Function/Expense. The formula is very abstract but it could be estimated to relative numbers. Usually Function doesn't need an infinite amount. Chair support people as much as the weight of person. Lamp irradiates light as much as humans need.

If one FR is satisfied, it meets 100% of function requirement at the moment, but desire of people usually keeps increasing. The ideal system in the past becomes less ideal due to increase of function requirement and it results in system evolution.

FRs are not fixed term and some functions are newly added and others can disappear if they are not much important. It's because the system components at that time couldn't do the function because infrastructure of the system (super system) has not evolved much.

For example, chair meets already 100% of functional requirements of human needs on "Support 150kg to vertical direction". In this case, system starts to get other functions for human which is the target of chair. For example, people moves chair, then it will get new function "chair move itself".

Each Function Requirement of Function Tree has its own S-curve, For example, old mouse pad had function of "moving ball" but optical mouse pad new function "reflect light". The function of move ball has been disappeared. It allows engineers to determine where they should concentrate. It is possible to make new generation of system even if there are no scientific revolutions, Also it could help to predict future systems based on super system evolution. (Mouse evolution leads to Mouse Pad evolution)

2.1.4. Design Component

Design Component is the method for satisfying given FR and it has many variants. It coincides with Components in Function Analysis, but design parameter is the parameter which influences to FRs. It usually is described by certain parameter of a specific component.

After Function Tree is built, Design Parameter is also forming a hierarchical structure. It is called Design Parameter Tree.

Function Analysis describes Function & Components in one screen. A main different characteristic of Function Tree is describing function and component in the different domains. Each of domains is built by a hierarchical structure called Function tree and Design Parameter Tree.

Usually Function Analysis shows all the functions and components. But Function Tree my not reveal all the functions but it categorizes functions and components. It provides easy understanding of system than Function Analysis.

2.2 Process of Function Tree

Function Tree is built by a certain process to describe a structure of Functions in technical system. The steps are shown as below. [16]

2.2.1 Extract Functions from Existing Engineering System. (STEP 1)

In MPV Analysis or Axiomatic Design, designer usually started to build the hierarchical structure from the upper level due to personal experiences or intuition. But Function Tree Modeling starts to build the hierarchical structure from lower level. First of all, it is needed to extract the functions from Function Analysis of product as shown in Fig 9.

Fig 9.Extract Functions from Function Analysis (Pencil)

Functions	Designs
Move carbon core	Cylinder
Move Cylinder	Hand
Hold Carbon	Paper
Abrade Carbon	Paper

Other Functions
Knife cut Cylinder
Clothes hold Carbon

Rules

- **1.1 : Don't extract Harmful Functions**

Recommendation

- **1.1 : Extract 10~15 functions from Function Modeling**
- **1.2 : Extract functions related in Operation Stage.**
- **1.3 : To add more functions in the system, Extract functions in all the stages.**

2.2.2 Categorize Functions (STEP2)

The diagram of function modeling sometime looks complex. But every system has its own main purpose and the functions can be grouped by the purposes. Some of extracted functions have their own lower level functions which help their actions. If the function acts insufficiently or generates harmful effects, they should have lower level functions for correcting it.

After functions are arranged in the tree, they should be grouped as high level Function Module as shown in Fig. 10.

Rules

Recommendation

- **2.1 : Chain functions (Ex, A moves B, B moves C) are usually grouped together**
- **2.2 : The functions which has common target can be grouped together.**

Fig 10.Function Module (Pencil)

Function Module	Functions	Components
Position Pencil	Move carbon core	Cylinder
	Move Cylinder	Hand
Deliver Carbon	Hold Carbon	Paper
	Abrade Carbon	Paper

2.2.3. Changing Functions to Function Requirements (STEP 3)

The function module in the system is described as a form of verb + object usually. For developing new product, it should be turned to form of a Function Requirement. (Fig. 11)

Function Requirement has its own adjectives and embodied and limited by them. It gives engineer to think more objectively and gives more chance to improve the system.

Commonly there are 3 adjectives; Time, Space and Condition.

Fig 11.Functional Requirements (Pencil)

Function Requirements	Function Module	Functions	Components
Positioning Pencil in X-Y Plane	Position Pencil	Move carbon core	Cylinder
		Move Cylinder	Hand
Deliver Carbon On Paper	Deliver Carbon	Hold Carbon	Paper
		Abrade Carbon	Paper

2.2.4. Arrange Function Requirements (STEP 4)

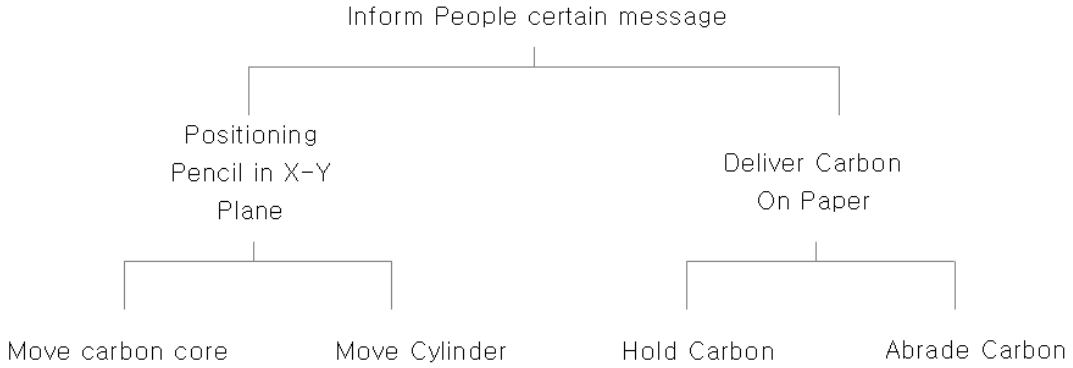
After categorization and modification, it is needed to put Function Requirements to proper positions. Function Requirement of the system is located at the top of Function Tree. The functions are transformed to Function Tree as shown in Fig. 12.

Fig 12. Build Hierarchical Structure (Pencil)

2.2.5. Expand Function Tree (Optional, STEP 5)

Function Tree can be expanded according to the situation. If it is needed to find more resources, then it expands to the upper level direction. If it is needed to find control factor of a system, it makes lower level branches.

Fig 13. Extension to the upper level (Pencil)



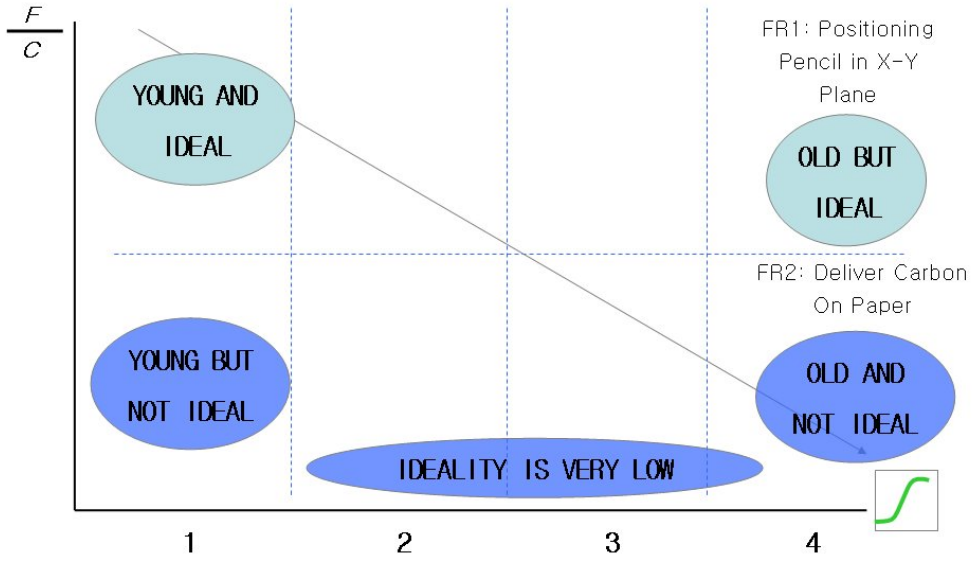
2.2.6. Analyze Function's Performance. (STEP 6)

After Function Tree is built it is possible to look the system more objectively. It's because Function Tree shows only main philosophies of the system. This method is not focused on the resources near the system and it only tries to find what function should be improved and what function does not act well. Also it usually focused on the functional evolution of the system. Every level of function has its own S-Curve and F/C ratio in Fig.15 and Performance Table in Fig. 14. They help to understand on what function we should be focused for new product development.

Fig 14. Performance Table (Pencil)

Functional Requirement	Operation Time	Operation Space	Performance	Cost
Deliver Carbon On Paper	Writing Period	On Paper	Have some Undesirable Effects	Cheap
Positioning Pencil in X-Y Plane	Writing Period	On Paper	Good	Cheap

Fig 15. Ideality-Stage Mapping (Pencil)



2.2.7. Select Scenario for Function Tree. (STEP 7)

It is needed to select Target Functions to be developed in Function Tree by using performance table shown in Fig. 14. It is usually useful because the model clarifies the function structure of engineering system. If Function Tree Modeling is completed, it is needed to decide what level of function will be developed. The least ideal function usually selected as Target Function to develop. Also the graph of ideality and stages of development helps to select possible scenario to develop Function Tree (Fig. 15)

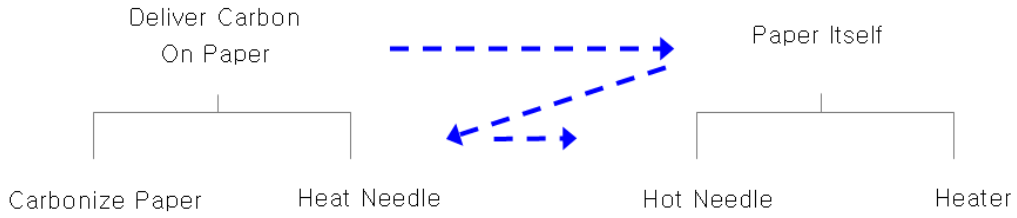
In the case of Pencil, carbon core is run out after using it. It is needed to buy new pencil after some period. Therefore, FR2 is selected as target function to develop.

The comparison is relatively compared. The importance factor can be applied for each criteria.

2.2.8. Build new Function Tree (STEP 8)

After considering the extracted functional structure and selecting target in STEP 7, it is required to rebuild a new FR structure using zigzagging algorithm. Also it is needed to build Design Tree, too.

Fig 16. Function Tree and Design Tree (Pencil)



Functional Requirement is more abstract than function. And it shows the desired state of the system and initial system. Description of Functional Requirement provides more chance to change technical system.

In the case of pencil, it found new functions of carbonize paper and heat needle. It leads to use new component of needle and heater instead of carbon core (Fig. 16).

Rules

Recommendation

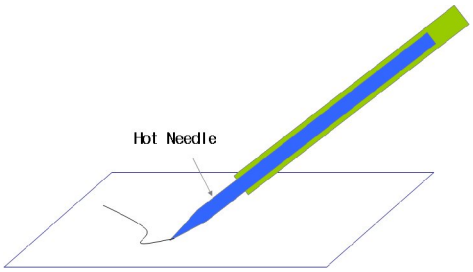
- **8.1 : The question to find new lower functions is**
  "How to achieve FR by using DC (there will be several candidate of Design component)"

2.2.9. Evaluate New Design

After new Functional Requirement is selected, it needs to find the Design Parameters which satisfy the Functional Requirements.

If the solution is not satisfying, go to the step 2.2.7 and repeat the process again. If the concept is good, then develop the new concept. If the solution is good, it is needed to produce the new product and launch it to the market (Fig. 17)

Fig 17. Hot Needle Pen (Pencil)



2.3 Characteristics of Function Tree

2.3.1 Overview of the System

Function Tree has several characteristics to differentiate it from other modeling tools. One of the advantages is that FA is system modeling to describe an existing system. Function Tree is better to overview how system works. The details are shown as bew.

According to the rules of design, the essence of design process exists in the hierarchical structure. It starts from the highest FR(Functional Requirement) and finding the DC(Design Component) which meets the FR.

After that it makes the lower level of FRs and DCs sequentially make detail design. The structure describes the super-system and sub-system of the engineering system. Also it can describe the future system and the past system together. But some of the functional requirements are too early to develop. Therefore more practical FRs and DCs are selected.

The functional structure usually becomes more complex than the past system, or sometimes becomes simpler than the previous system. It depends on the designer's decision on the functional requirements.

Function Tree only shows needed functions and could see the function of far from the original system. The upper level of functions and lower level functions can be viewed in one screen.

Through this hierarchical structure it is possible to view the functional structure of whole system. And it leads to the new development of the product.

2.3.2 Rank of the Function

In Function Analysis, the most important function is the basic function and the least important was the function farthest from basic function. It had modified to rank 3 to basic function and 2 to additional function and 1 to auxiliary function. Function Analysis is sometimes too complex and hard to understand what function exists for what purpose. [18]

Function Tree categorize functions to Function Module, therefore it is easy to see what function is important.

But there could be important function in the system even though the component is far from the target. Function Tree helps to overview the function though usually important functions are located at the upper level. Engineers can identify and concentrate on more useful functions because the functions are grouped by Function Module.

2.3.3 Function Tree and System Evolution

Function Tree can be seen as a sequence of Time. If we see the development of functional structure, it could be possible to identify what will be the next function structure (Fig. 18)

Also most of evolution law is based on functions not components. It is easy to apply the laws to function tree. If the system is not mature, it could be predicted it will get the function of supersystem. For example, I-Phone took the function of Nintendo, MP3 Player, and Camera together.

For the evolution of components, the evolution law in the Dynamics helps for the innovation. But for the evolution of the system, it is convenient to use this Function Tree to apply the evolution laws to the system and add new function in the system.

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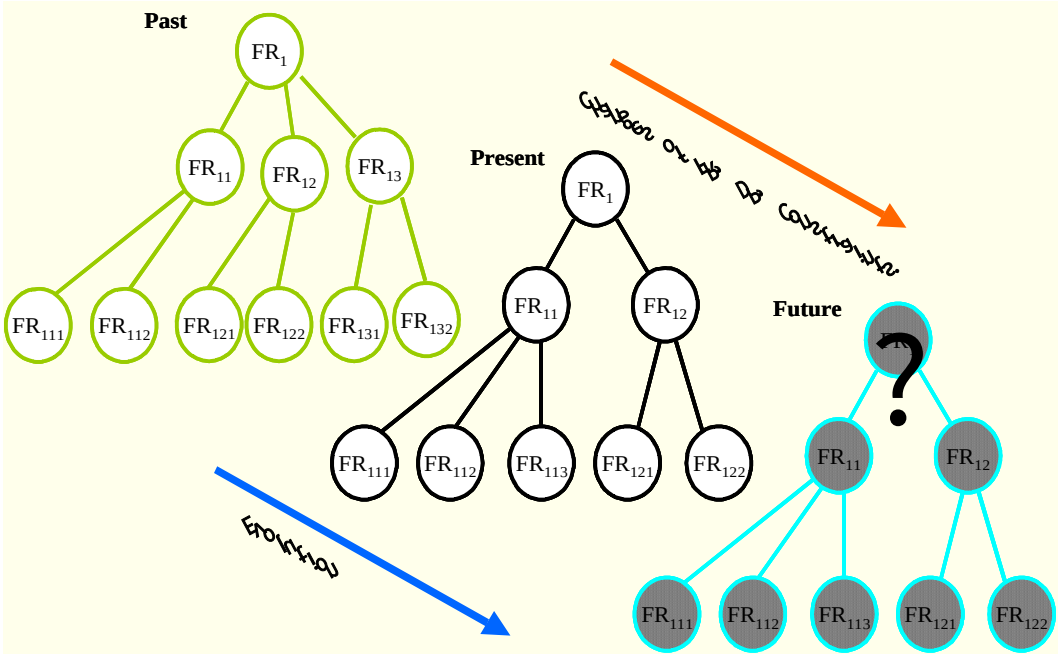
Fig 18. Function Evolution



2.3.4 Function Tree and Contradiction

In Function Analysis, usually engineer misses the function of supersystem. It happened usually when we model a huge system or a process like a centrifugal chiller or manufacturing devices.[15]

Function Tree can describe more widely the functions that are far from system (Chapter 2.3.1). Therefore it could make it easy to analyze and find contradictions.

Also it provides a chance to circumvent the contradiction by bypassing (Delete the contradiction at upper level of function

2.3.5 Function Tree and Chemistry & S/W

Nowadays there are lots of new industries like internet, programming, biology, electronics and business management. But most of cases of TRIZ are based on mechanical engineering. It is needed to model the structure of codes and molecules. But it is hard to identify components.[10]

One of the main difficulties of Function Analysis is that it starts from component analysis of the system. But it is very hard to find component in the chemical composition.

Function Tree can model them as the structure of function because it could be built only with functional requirements.

2.4. Comparison between Function Tree and Other Tools

Function Tree has several differences from other analytical tools. In this part, it will be discussed what main differences are.

2.4.1 Function Tree and Function Analysis

Main difference of Function Tree and Function Analysis is that Function Tree forms hierarchical structure. It starts from Function Analysis but it extracts functions and changes it to the functional requirements. And arrange it in the hierarchical structure.[9]

Basically Function Tree can generate more problems to develop future system. Function Analysis provides radical trimming and function oriented search based on functions that already exist, but function tree can lead to function oriented search based on the functions that do not exist now and restructuring function structure for future system.

2.4.2 Function Tree and MPV Analysis

MPV analysis starts from MSPV and it turned to MFPV. After MFPV is defined, it starts to build hierarchical structure based on CECA.[5]

Function Tree starts from the conventional system. It builds hierarchical structure to down-top direction and it could not reach the customer's requirements. Also Customer requirements are located in different domain in Function Tree. Function Tree can build hierarchical model of small part of the system.

Because it is based on the conventional system, it models all the functions in the system basically. Also the relation between top and down level is different too. Function Tree relation sometimes doesn't have any relations of why-how between top and down level of functions.

2.4.3 Function Tree and Function Synthesis

Function Synthesis is based on substituting functional relation with a flow model. Every engineering system could be modeled as flows. If the modeling starts from upper level, it starts to find the process models of the bottom level. Function Tree's lower level is the

Functional Requirements for upper Functional Requirements. The components and purposes of Function Synthesis and Function Tree are much different. In Function Tree, new Functional Requirement can be added and the structure could be modified because it is not just describing the system.[8]

2.4.4 Novelty of Function Tree

Function Tree is a system modeling method and differs from MPV analysis or Function Synthesis because it starts from base system.

It divides the system to Function Module and translates it to Functional Requirements. From the Functional Requirements, design can be varied more dramatically compared to the conventional Function Modeling.

Even original Axiomatic Design does not have detail methods and algorithms to build hierarchical structure. As known well, Axiomatic Design is not completed methodology and still under development. (Function Tree is oriented from my thesis in 2001)

This research can contribute on TRIZ as well as Axiomatic Design. Not only new product, it can be used to reformulate functions in the technical system. Also, even based on zero base projects which do not have any prototype, it can predict the future system's functional structure without benchmarking. After modeling of Function Tree is fixed, TRIZ can provide lots of tools for generating concepts for the questions derived from Function Tree.

2.5. Conclusion

New product development is most significant area of TRIZ. To develop new system, it is needed to model future system and problems. Function Tree is building hierarchical structure based on conventional systems.

There are 9 Steps and templates for building Function Tree and it has also its own several characteristics.

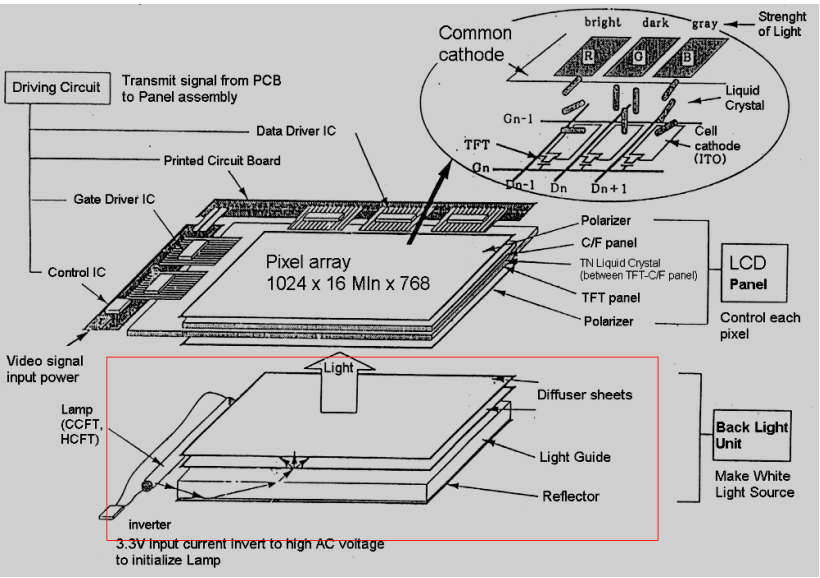
Also it is totally different from other analytical method and provides more possibilities for future system.

Chapter 3. APPLICATION OF FUNTION TREE FOR DEVELOPING NEW BACKLIGHT UNIT (Scientific Case Study)

3.1. Introduction of Problem

LCD Display is the most popular system for the display. It has a component called backlight unit (red box of Fig 19. The function of the system is to make planar light to the LCD panel. The backlight unit was most expensive part and complex. It is required to develop cheaper and elegant system. [9]

Fig 19 LCD Display

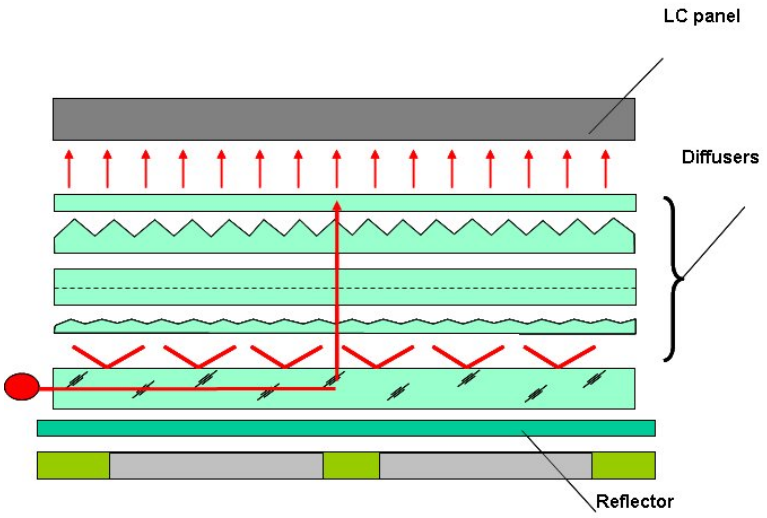


The main function of backlight unit is to generate planar beam to the orthogonal direction of screen. As shown in Fig 20. Backlight Unit is composed of mainly 5 components. Lamp generates the light from the edge of backlight unit. The beam should be turned to 90’ degree to make uniform planar light. Reflector reflects beam to the orthogonal direction but there is a problem. The angle of reflector is very low and it could not reflect light to the screen. It is the same problem of making linear beam into planar beam.

Therefore 3 components are added to fix the problem. Prism-1 refracts the light to the X-orthogonal direction and Prism-2 refracts the light to the Y-orthogonal direction. But still some part is too bright and the other part is so dark. Diffuser makes the difference of the brightness uniform.

At least 3 films are needed to resolve the problem and it make the system very expensive. To make new backlight unit is a very important for LCD display system to survive in the competition with other display system.

Fig 20 Backlight Unit

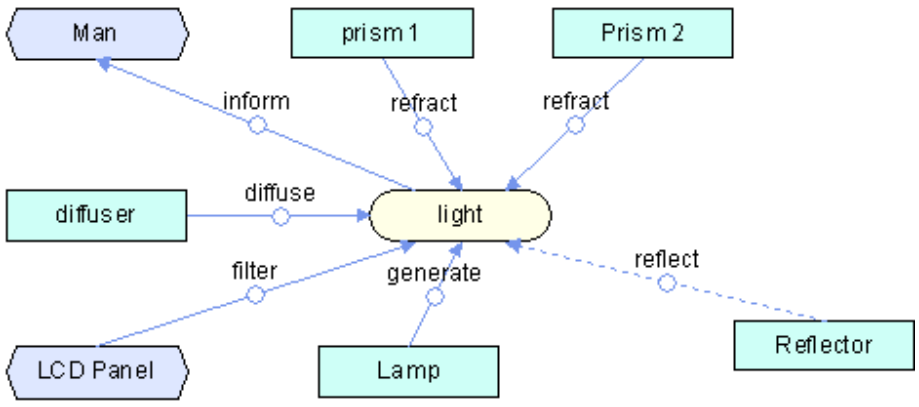


In this chapter, it will be disclosed the conventional approach to develop new backlight unit and also the approach with Function Tree.

3.2. Conventional Approaches & Solutions

The conventional approaches were tried and developed many solutions but not much ideal or without problems in manufacturing. The conventional approach started from Function Analysis. (Fig. 21)

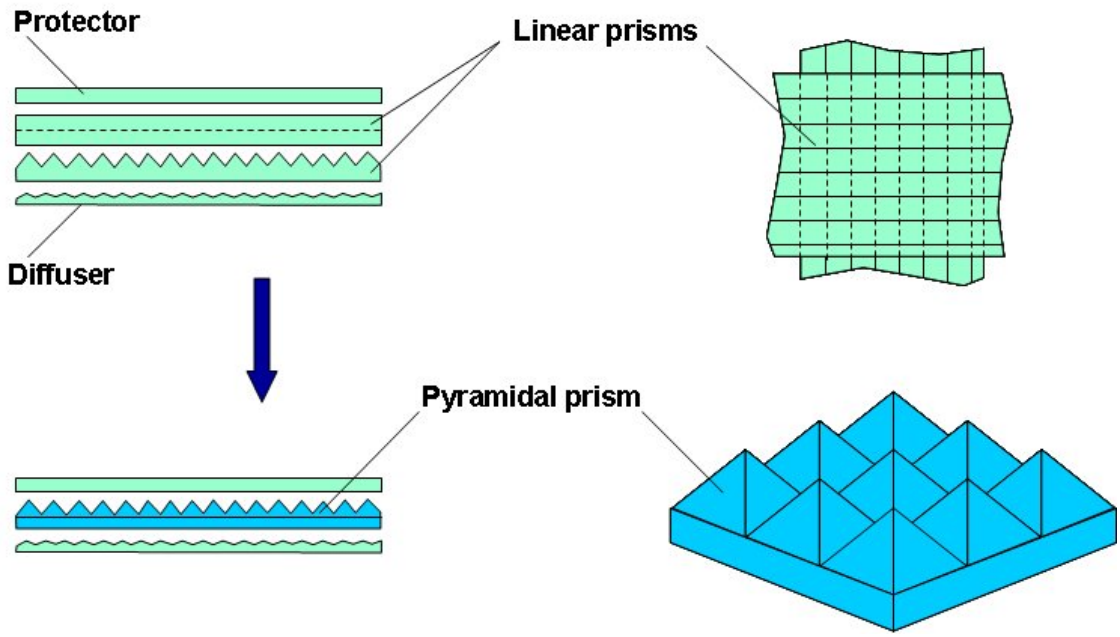
Fig 21. Function Modeling of Backlight Unit



It is a conventional spider web shape and various ideas are developed from the modeling

IDEA-1 : Trimming Scenario - 1

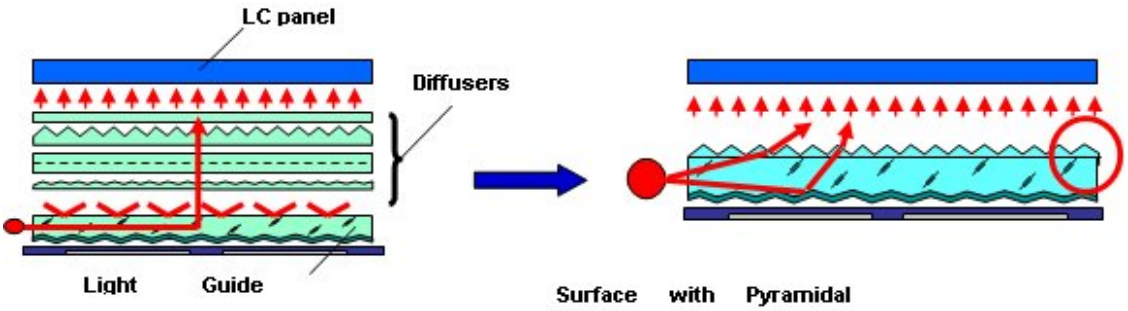
Fig 22. Pyramid Prism Sheet



The first idea is to trim one of the prisms and make it into one prism (Fig. 22). It can reduce one of the prism sheets but it makes problem of making a new pyramid film. It requires to develop new technology to make it.

IDEA-2 : Trimming Scenario - 2

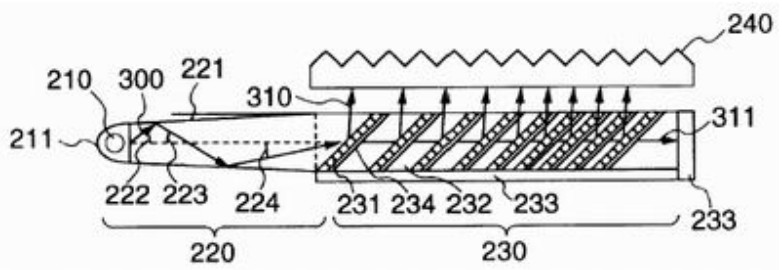
Fig 23. Merging all film into lightguide



The 2nd scenario is to put the components of diffuse and prisms into lightguide. But it is more difficult to make separate films and assembles them.

IDEA-3 : Function Oriented Search

Fig 24. Merging all film into lightguide



The third idea is found in competitor's patent using polarizing beam splitter. But there are 2 problems. One is it is already patented by competitor and the other is to use polarizing splitter is less ideal than to use 3 films on the light guide.

Several ideas are blocked by competitor's patents and sometimes trimming scenarios makes the system more complex in the view of total manufacturing process. It is needed to develop totally new and ideal system.

3.3. Functional Tree Analysis

In previous system, trimming led the system to combine 2 or 3 components together and deliver the functions to one component. Those approaches are good for some projects but there could be other possibilities to invent a new system. Also Function Oriented Search requires leading science or technical system in other industries. However there may not be a leading science or technologies.

Function Tree gives more chances to develop a new system. It will be disclosed how Function Tree contributed to develop new product differ from previous ideas.

3.4. Formulate Problems

Following the process shown in 2.2, it is possible to extract functions from Fig. 21. It is common spider web type Function Modeling and the functions are extracted as follows.

STEP1.
- Prism 1 refract light to Y-orthogonal direction
- Prism 2 refract light to X-orthogonal direction
- Diffuser diffuse light
- Lamp generate light
- Reflector reflect light

Each function is of basic rank and it should be at same level. But in the view of Functional Requirement, diffuser and Prism 1 and 2 are correcting function of reflect light. (Fig. 25) The functions are transformed to Functional Requirements. Functions Requirements are arranged in the hierarchical structure as Fig. 26 as below.

Fig 25. Function Relation in Backlight Unit

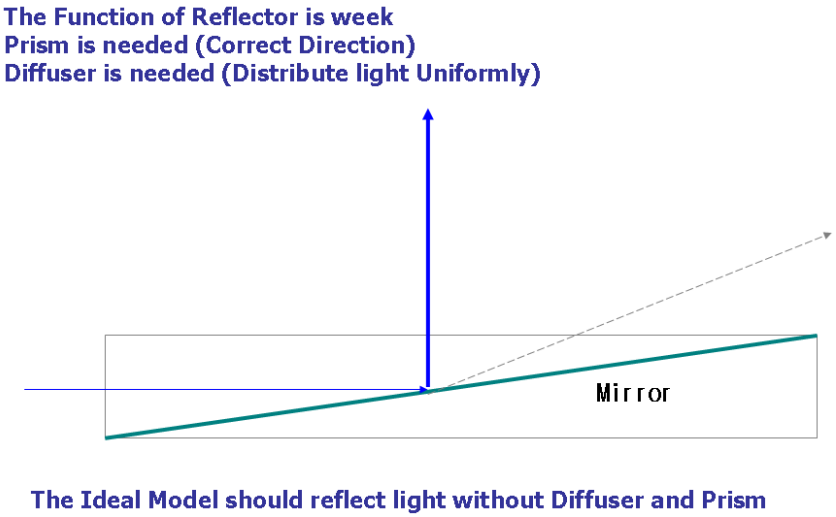
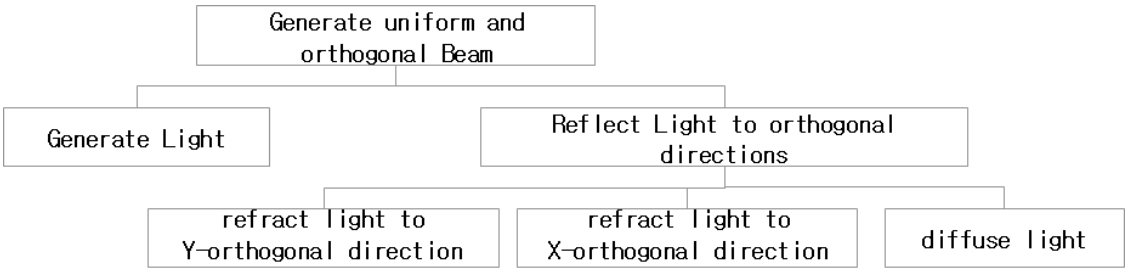


Fig 26. Function Arranged in the Hierarchical Structure

STEP 4



In the tree, it is possible to find the function of reflect light to orthogonal direction requires most expensive and less ideal part as shown Fig. 27. (STEP 6) To develop a new system, it is needed to find a new system for the Functional Requirement.

Fig 27. Performance Table

Component	Operation Time	Operation Space	Performance	Cost
lamp	All the period of operation	In Light Guide	Sufficient	Normal
reflector	All the period of operation	In Light Guide	Insufficient	Normal
Prism 1	All the period of operation	In Light Guide	Sufficient	Expensive
Prism 2	All the period of operation	In Light Guide	Sufficient	Expensive
Diffuser	All the period of operation	In Light Guide	Sufficient	Expensive

3.5. Substitute Problems

To develop a new system, it is needed to substitute problems. If it is possible to make sufficient functional sets for Functional Requirement of “reflect light by 90 degree”, it will automatically make the sub corrective functions of “Refract” and “Diffuse”

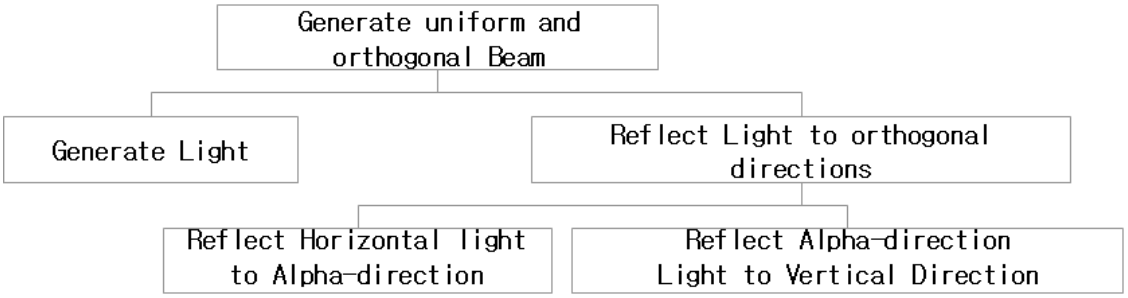
The Function Requirement is unbind as below because Recommendation 2 says to divide one function to two identical functions. Therefore, insufficient reflecting function can be transformed 2 reflecting functions

Reflect the light by 90’ degree
= horizontal input light → vertical output light (1 function)
= horizontal input light → Alpha-direction light → vertical output light (2 functions)

It could be possible to add one more component to transmit the light more efficiently.

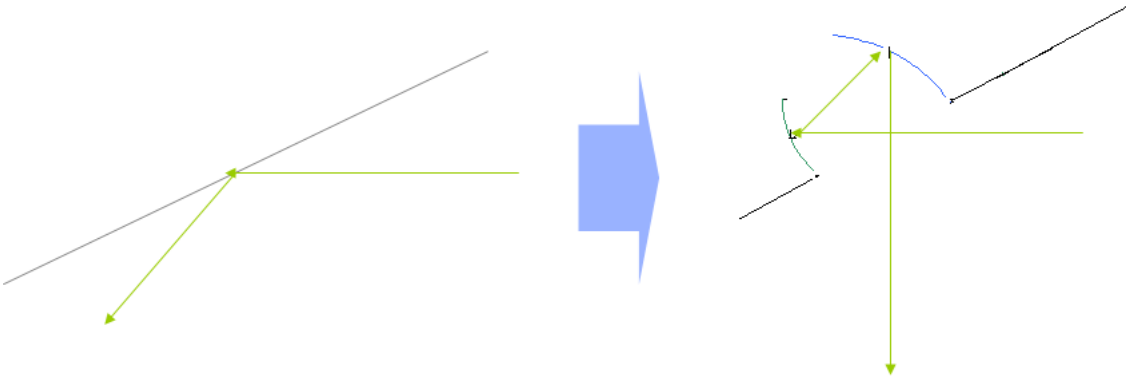
New Function Tree is substituted as Fig. 28

Fig 28. New Function Tree



The Design Parameter of function “reflect” is reflector(Fig. 29 left). Therefore it is possible to use 2 reflectors to do the functions for making planar light. (Fig. 29 right)

Fig 29 MULTI-REFLECTING Surface

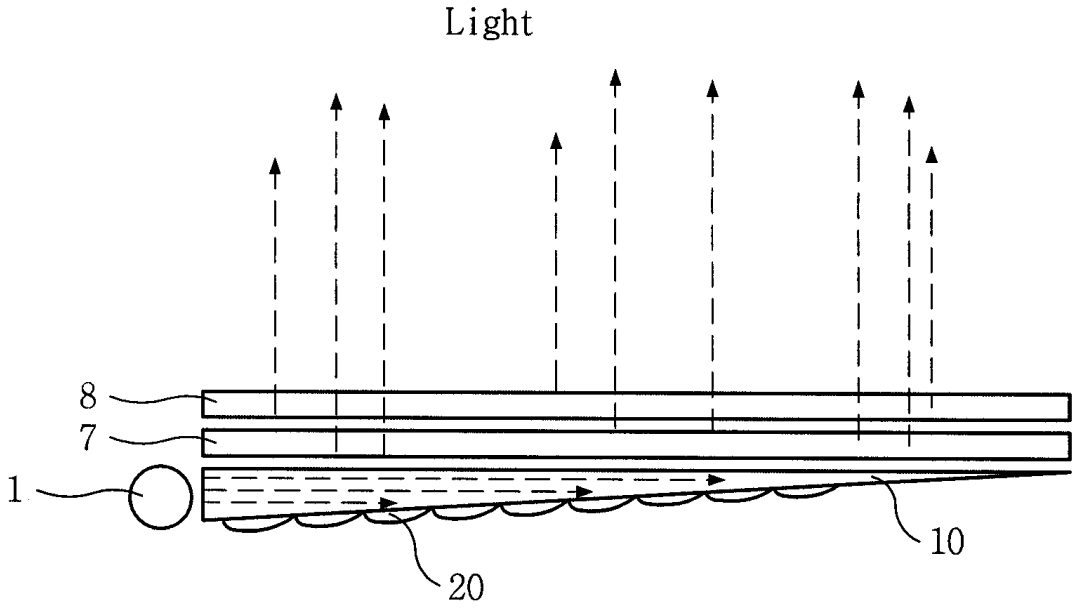


3.6. Deriving Concepts

The conventional approaches were tried and developed many solutions but not much ideal or without problems in manufacturing. The conventional approach started from Function Analysis. (Fig. 21)

The reflector has already patterns on its surface. Therefore it is much cheaper than conventional ideas and doesn't make any additional problems. The idea is generated in 2005 and patented in PCT (WO06107138A1) and several countries.(Fig. 30)

Fig 30 MULTI-REFLECTING BACKLIGHT UNIT (Whole Part)



3.7. Conclusion

This problem is well known and famous problem in the LCD-LED Display industes. Still many companies tried to develop new film for their backilight unit and it still cost very high.

Using this multi reflecting backlight unit provides additional advantages of reducing process, and enhancing brightness of BLU. It leads to decrease the number of LED and reduce energy consumption.

Chapter 4. Conclusion

Concept generation is one of the most important parts of engineering system improvement. For concept generation, many tools are developed in TRIZ but for modeling of future system, many TRIZ experts and Masters try to develop new one.

As Function Modeling is imported from Value Engineering, Function Tree has its origin in Axiomatic Design, but it is still incomplete theory under development. I participated as one of the researcher to improve Axiomatic Design, and finally I mixed concept of function & component of Function Analysis and Hierarchical Structure of Axiomatic Design. Function Tree models system as hierarchical structure of Functional Requirement and Design Component.

This trial to build hierarchical structure with Functional Requirements is studied from 1999 [13] and it is tested through real application in the industries.

Function Tree can help engineer to develop new system from scratch (function can be benchmarked from other system) and dramatically change conventional system because it provide problems from other point of view (not present system but super/sub system)

Function Tree can overview the system more intuitively because it starts from very few functional requirements (Function Module) and also can rank the function more effectively. From the overview, it is possible to investigate the development of function tree of the system. (Components are changed very rapidly but functions are slowly changed) Also contradiction is found easily and can be adapted to S/W industries which doesn't have any components.

With applying Function Tree, TRIZ will be effectively used to solve undiscovered problems and the area of technical forecasting part can be analyzed more systematically.

In this paper, new idea for Backlight Unit and the process for developing new idea are discussed. Function Tree is changed to new one and new Design Parameter was selected. Finally Multi-Reflecting Backlight Unit is created by the theory in Function Tree.

It is promising that Function Tree can contribute to TRIZ development of new product development without prototype. And it is expected more examples will be discovered in Function Tree.

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APPENDIX 1. Process of Function Tree

STEP 1 Extract Functions from Existing Engineering System.

Rules

- 1.1 : Don't extract Harmful Functions

Recommendation

- 1.1 : Extract 10~15 functions from Function Modeling
- 1.2 : Extract functions related in Operation Stage.
- 1.3 : To add more functions in the system, Extract functions in all the stages.

STEP2 Categorize Functions (STEP2)

Rules

Recommendation

- 2.1 : Chain functions (Ex, A moves B, B moves C) are usually grouped together
- 2.2 : The functions which has common target can be grouped together.

STEP.3. Changing Functions to Function Requirements (STEP 3)

Function Requirements	Function Module	Functions	Components

STEP. 4. Arrange Function Requirements (STEP 4)

STEP 5. Expand Function Tree (Optional, STEP 5)

STEP 6. Analyze Function's Performance. (STEP 6)

Functional Requirement	Operation Time	Operation Space	Performance	Cost

STEP 7. Select Scenario for Function Tree. (STEP 7)

STEP 8. Build new Function Tree (STEP 8)

Rules

Recommendation

- 8.1 : The question to find new lower functions is

"How to achieve FR by using DC (there will be several candidate of Design component)"

STEP 9. Evaluate New Design