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TRIZ Master Thesis

A Method for Cause Effect Chain Analysis Based on Multi Screen Thinking and State-Interaction Model

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Table of Contents

Preface

Every technical system is under spontaneous deterioration like corrosion, erosion, and unexpected severe conditions. Degradation causes poor performance and sometimes catastrophic failures. Besides, a certain design decision often results in unexpected undesirable events. Undesirable events tend to happen beyond our foresight. Engineers have attacked those undesirable events as 'target disadvantages' since technical systems were invented. However, no matter how effective the prevention ways are, undesirable events happen. That is one of the main reasons for engineers to try to find root causes for higher reliability of technical systems[1]. In Fig.1, A schematic diagram of Ishikawa method, or Fishbone method, one of the most frequently adopted method for finding root causes is shown.

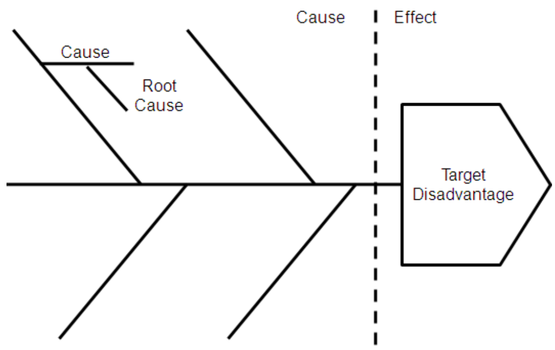

Fig.1. A schematic diagram of Fishbone method for identification of root causes of a target disadvantage

In Fishbone method, all potential root causes are presented individually on the branches of relatively exclusive cause groups. It doesn't show any interrelationship among potential root causes. However, the word, 'root' of the root causes means that they are the cause of other causes. The applicant believes that in order to identify the cause of other causes systematically, a certain diagram of Root Cause Analysis had better show the interrelationship between the root causes and other ones.

In modern TRIZ field, there are several methods to formulate 'key disadvantages' which are to be prevented for elimination of a target disadvantage[2,3,4]. The methods of TRIZ field are different from each other in aspect of some characteristics but they have an important common parameter that the undesirable events as causes must be arranged in the structure of Cause Effect Chains like one shown in Fig.2. The arrow indicates that the preceding event is the cause of the following event.

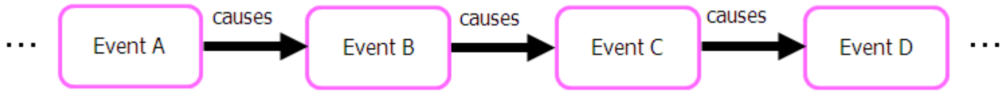

Fig.2. A diagram of a Cause Effect Chain

Comparing to other ways for Root Cause Analysis like Ishikawa method and logic tree method, construction of Cause Effect Chains has several benefits. First, it offers a well-organized interrelationship among disadvantages from a target disadvantage to root causes while Ishikawa method or logic tree method shows only plausible root causes as factors independent of each other. Secondly, Cause Effect Chains provide structured diagrams to identify key disadvantages while Ishikawa method and logic tree method just deploy the potential root causes without any systematic explanation about how to decide the key disadvantages. As explained in Fig.3, the first causal events are root causes in the diagram of Cause Effect Chains.

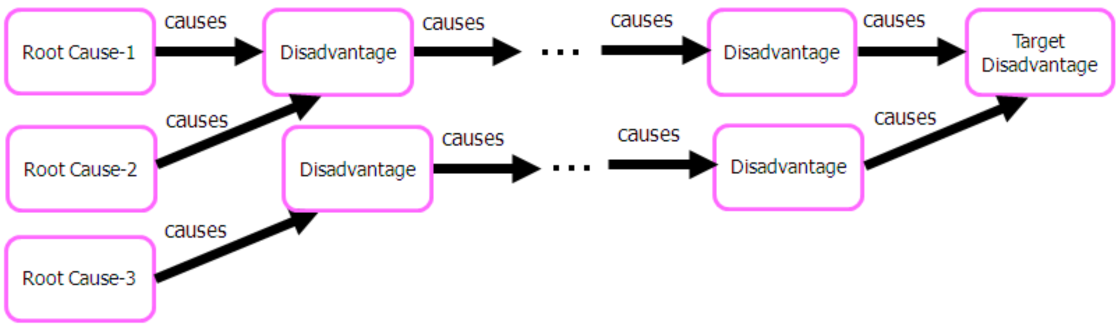

Fig.3. A schematic diagram of interrelationship among target disadvantage, root causes, and other disadvantages

Just like any other thinking method, Cause Effect Chain Analysis has some demerits out of its own merits. Most of all, it is not so easy to build Cause Effect Chains when we face the target disadvantage first time. To construct Cause Effect Chains, we must identify the disadvantages as causes of the target disadvantage and arrange the disadvantages according to the interrelationships among them. However, it may be difficult not only to arrange disadvantages related to a target disadvantage but also to identify them. In another perspective of TRIZ application, Cause Effect Chains must serve a set of problem models to be used for solution idea generation with TRIZ tools. Even though elimination of root causes is probably the best, it is not always easy to eliminate or prevent root causes. When root causes are not susceptible to prevention, the other causes become candidates to be prevented. The more comprehensive the coverage of causes is, the higher opportunity Cause Effect Chains offer to prevent the target disadvantage. Therefore, we need 'theoretically' as exhaustive a set of causes as possible. The set of problem models from Cause Effect Chains should offer comprehensive directions to prevent the target disadvantage. This is strongly related to completeness of Cause Effect Chains.

In order to improve Cause Effect Chain Analysis from the above viewpoints, the applicant suggests some new thinking ways. Summarily, the two new methods will be suggested and discussed with others' related researches on them.

The suggested new method 1 : Multi Screen Thinking with Time-Condition Axis, Function Analysis and Parameter Analysis for easier and more systematic building Cause Effect Chains

The suggested new method 2 : State-Interaction Model as a guide to find missing hidden causes for the more exhaustive set of causes

Chapter I. Multi Screen Thinking with Time-Condition Axis, Function Analysis and Parameter Analysis

1.1 Introduction

In order to build Cause Effect Chains more easily and systematically, since 2005, the applicant has been applying Multi Screen Thinking with Time-Condition Axis, Function Analysis and Parameter Analysis. The essence of this method is doing Function Analysis for Multi Screen Thinking according to parametric changes 'BEFORE' the construction of Cause Effect Chains.

During preparing this dissertation, the applicant was informed about similar approaches. To clarify the uniqueness of the applicant's method, first, the similar approaches will be discussed. Serge Pesetsky, etc.[5] and Leonid Batchilo, etc.[6, 7] introduced Multi Screen Approach as a way to improve Root Cause Analysis. They believed traditional cause-effect diagrams (called as Ishikawa diagrams or fishbone diagrams) have two major disadvantages.

First, it may be difficult to identify a cause during construction of a cause-effect diagram. Second, it may be hard to resolve the newly identified problems.

Therefore they adopted Multi Screen Thinking (they also called it TRIZ nine screens approach) to turn a general question like "What is a cause of a problem?" into a more specific question like "Resources of what screen are a cause of a problem?".

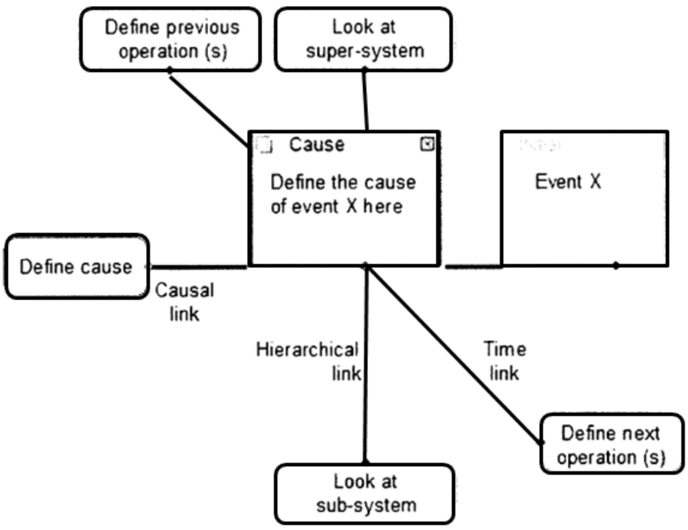

Fig.4. The schematic overview of Multi Screen Approach introduced by Leonid Batchilo, etc.[6]

As Fig. 4 shows us their approach, their version of Multi Screen Approach is composed of three axes, Cause-consequence axis, Operation axis, and Hierarchy axis (i.e., System Scale Axis).

Cause-consequence axis reflects causal links between the events preceding and following the initial problem situation. This axis is to reveal the root causes.

Operation axis is the sequence of operations that the object of the problem undergoes. This axis is helpful to reveal at what stage the undesirable effect occurs and discover the potential contribution of resources in the operations for solving the problem.

Hierarchy axis shows the interactions betweeen sub/supersystems and the technical system under consideration. This axis is for finding out how the problem can be solved by using the resources of the sub/supersystems.

An example from Leonid Batchilo, etc.[6] shows that, first, Cause-consequence link is built and then for each disadvantage, Hierarchy axis is applied to find out the solution ideas related to a certain resource among subsystems and in the supersystem.

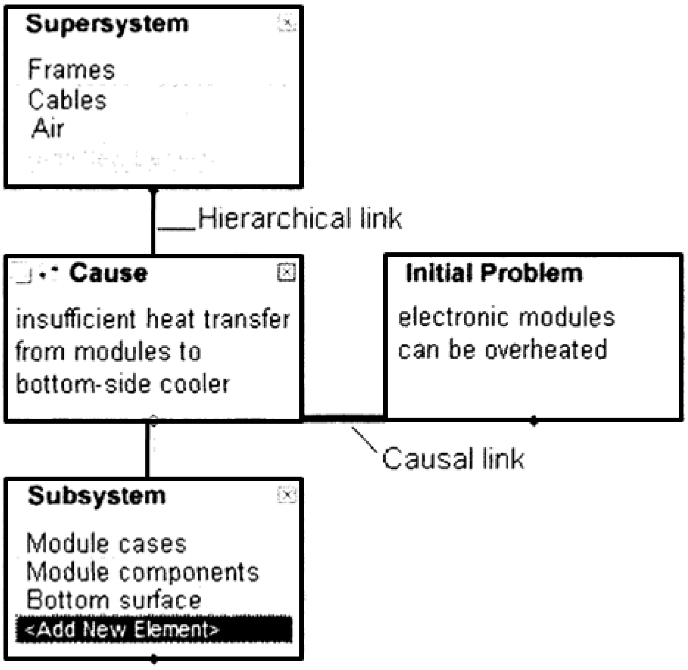

Fig. 5. An example of the Cause Effect Diagram with Hierarchical Link (i.e., System Scale Axis) introduced by Leonid Batchilo, etc.[6]

As another similar approach, Functional Why-Why Analysis[8] suggested by Aleksey M. Pinyayev should be examined. In his method, a solver does the functional analysis of the why-why contradictions as the next step to the completion of the why-why diagram which is a kind of Cause Effect Chain Analysis. The solver ends up doing many small functional analyses instead of a big one. His paper says that the functional model is only slightly more complex than the problem model on the level of a why-why contradiction. His approach is for making the functional analysis much simpler and more focused which makes the concept generation easier and more effective.

From the next section, we will discuss the differences between the above similar approaches and the applicant's method. Detailed explanation of the applicant's method will be followed subsequently.

1.2 Time-Condition Axis and a general axis-by-axis procedure of Multi Screen Thinking

Compared to the approach of Serge Pesetsky and Leonid Batchilo, etc., the applicant's method has the common suggestion that Multi Screen Thinking should be adopted for easier Cause Effect Chain Analysis.

As the first different point, the applicant suggests Time-Condition Axis which is an adapted version of the traditional Time Axis.

Next, the method of the applicant includes Multi Screen Thinking for getting an overall picture of the problem situation 'BEFORE' building Cause Effect Chains while the approach of Serge Pesetsky and Leonid Batchilo, etc. suggests doing Multi Screen Thinking 'AFTER' identification of causes in a 'cause-by-cause' way.

Additionally, while the approach of Serge Pesetsky and Leonid Batchilo, etc. doesn't suggest which axis must be examined prior to different axes, the applicant insists that each axis should have its own sequent order according to the thinking process.

First, the applicant developed 'Time-Condition Axis' from a notion that a certain time stage of Multi Screen Thinking should be determined not only along a time flow but also along conditions with the parameter value change of resources. Very often, we have to think about super/subsystems according to certain conditions which are determined by the change of parameter value of certain resources instead of a simple time flow.

The premise of 'Time-Condition Axis' is that in physical world, a certain event happens under a specific condition and the specific condition is determined by a particular parameter of something related to the event, NOT just along the Time Axis. Especially, an undesirable phenomenon is very often NOT a kind of designed event but a spontaneous harmful event. At that case, it is not one of our operations which are designed to complete a process. Therefore, we should check the value of parameters of some resources. The main two kinds of parameters to determine conditions are evaluation parameters exposed in the target disadvantage and control parameters of certain resources.

The applicant found a very classical example of this notion of 'Time-Condition Axis' in G.Altshuller's time analysis explained in ARIZ-85C[9]. In Part 2.2 for the problem of a lightning rod and an antenna, Altshuller analyzed time resources, i.e., 'Operational Time'. Altshuller divided Time Axis into two time stages, 'the time of a lightning stroke' and ' the time before the next lightning stroke'. The applicant thinks his analysis of time resources was not only according to Time Axis (for example, before a certain moment or after the moment) but also according to certain conditions determined by value changes of parameters of something (i.e., existence of a lightning stroke or no existence of it).

For another example, let us suppose that we have to reduce or prevent Galvanic corrosion of a coated steel body. When we apply Multi Screen Thinking to this problem situation, we have no designed time spans among time stages. We cannot get necessary time stages along Time Axis if it is purely and simply about time flow. We have to conduct a hypothetical imagination about what has happened before the target corrosion according to the conditions from the specific problem situations.

As for this example, if we have no knowledge about galvanic corrosion, we could suppose that the degree of corrosion development as an evaluation parameter for the target disadvantage should be considered for condition changes. We could divide Time-Condition Axis according to the degree of corrosion like the following:

Time-Condition 1 - no corrosion state → Time-Condition 2 – corroded but coating layers are kept → Time-Condition 3: corrosion in steel body is exposed.

If we know the general mechanism of galvanic corrosion as shown in Fig. 6 and want to get the particular Cause Effect Chains about our specific situation, we might add more Time-Condition stages according to the salt concentration in water as the control parameter of the corrosion like the following:

Time-Condition 1 - no corrosion state with high humidity of air around object → Time-Condition 2 – not yet corroded but water penetration with zero salt concentration through coating layers / Time-Condition 3 - not yet corroded but water penetration with high salt concentration through coating layers → Time-Condition 4 - a closed galvanic corrosion circuit with no salt / Time-Condition 5 - a closed galvanic corrosion circuit with a lot of salt.

Through examination along this Time-Condition Axis, we can identify specific interactions among resources. Without condition specification, it is hardly completed to analyze a certain situation.

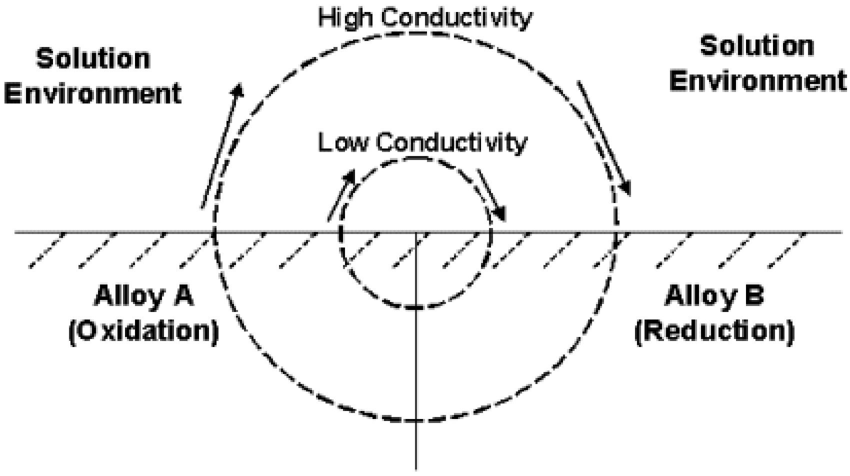

Fig.6. Galvanic Corrosion Mechanism[10]

Next, let us go over a general axis-by-axis procedure of Multi Screen Thinking. In doing Multi Screen Thinking, resources of super/subsystems are examined for further understanding of a problem situation. At this stage, a mostly forgettable fact is that resources of super/subsystems are not constant. They are different according to relevant conditions of the super/subsystems. Suppose that we have to build a Cause Effect Chains about an undesirable event related to a tree. The resources of super/subsystems of a tree are totally different according to seasons which are the relevant conditions. In spring, one of the subsystems of a tree is a flower. But, from summer to winter, there is usually no flower among subsystems of a tree. The color of a leaf of a tree may be another example. The color of a leaf as a parameter of a subsystem is not constant. Therefore, when we try to identify which resources of super/subsystems might be causes of a disadvantage, we cannot select a certain resource immediately without identifying the relevant condition of the super/subsystems 'first'. Based on this discussion, Time-Condition Axis must be considered prior to System Scale Axis (i.e., Hierarchy Axis). Next, it is apparently obvious that building Cause Effect Chains cannot be done before resource analysis according to System Scale Axis of Multi Screen Thinking because every cause is from resources related to the target disadvantage. Based on this viewpoint, the applicant suggests the axis-by-axis procedure of Multi Screen Thinking like the following:

identification of Time-Condition Axis → examination of resources according to System Scale Axis → next steps for exploration of Cause Effect relationships based on the previous results

This procedure will be updated after the following discussion.

1.3 Function Analysis with Parameter Analysis at each Time-Condition stage in Multi Screen Thinking

The applicant supposes that Cause Effect Chains should be built on assumptions about causal relation from mainly four kinds of viewpoints.

- Assumption in time viewpoint: a specific cause must happen before a specific result of it. We might face a viscous circle which shows a cause is caused by a result of it. However, even in that case, at each cause effect link, a specific cause is prior to the result of it and then the result causes the next specific cause.

- Assumption in parameter viewpoint: every disadvantage must show an undesirable value or change of the value of a certain parameter of something

- Assumption in resource viewpoint: every disadvantage must be caused by resources.

- Assumption in causality viewpoint: in engineering problems, every cause effect relation must be valid according to physical laws and principles

In order to build Cause Effect Chains easier, we need more information about the above four viewpoints of time, parameter, resources and causality. The applicant found Multi Screen Thinking is the right thinking frame of the integration of all those information from the time viewpoint. Based on understanding the problem situation through Function Analysis, we can easily conduct Parameter Analysis. Consequently, if Multi Screen Thinking is finished with Function Analysis and Parameter Analysis 'BEFORE' construction of Cause Effect Chains, we may build Cause Effect Chains more easily and efficiently.

As explained in section 1.1, the approach of Serge Pesetsky and Leonid Batchilo, etc. and Functional Why-Why Analysis of Aleksey M. Pinyayev are talking about the analysis of interactions, in other words, functions among resources in super/subsystems.

Therefore, we will discuss the differences of the applicant's method and theirs in the viewpoint of adoption of Function Analysis for Cause Effect Chain Analysis.

Interestingly, their two different researches have the same characteristic: a Function Analysis for a certain undesirable event as a cause of Cause Effect Chains, i.e., the cause-by-cause approach. Compared to their ways, the applicant's approach involves Function Analysis for getting the overall comprehension on interactions among resources of super/subsystems at each time stage of the whole Multi Screen Thinking. That is the first difference between the applicant's method and theirs about Function Analysis in Multi Screen Thinking. The applicant thinks that the overall Multi Screen Thinking can increase easiness of building Cause Effect Chains much more than the cause-by-cause approach. We will examine this point through a practical example in Chapter 3.

Secondly, the applicant insists Parameter Analysis should be done with Function Analysis. With Parameter Analysis, Function Analysis becomes clearer. It will be explain in detail in Chapter 3.

Last but not least, there is difference in the time of conducting Function Analysis. The others' methods mainly deploy analysis about interactions 'AFTER' getting a certain disadvantage as a cause or starting point: a single Function Analysis for a single causal event 'AFTER' identification of one disadvantage at least.

On the contrary, the applicant suggests that Multi Screen Thinking including Function Analysis with Parameter Analysis should be done 'BEFORE' any single cause-effect link is built.

All the above discussion is summarized into the schematic overview of building Cause Effect Chains based on Multi Screen Thinking in Fig. 7.

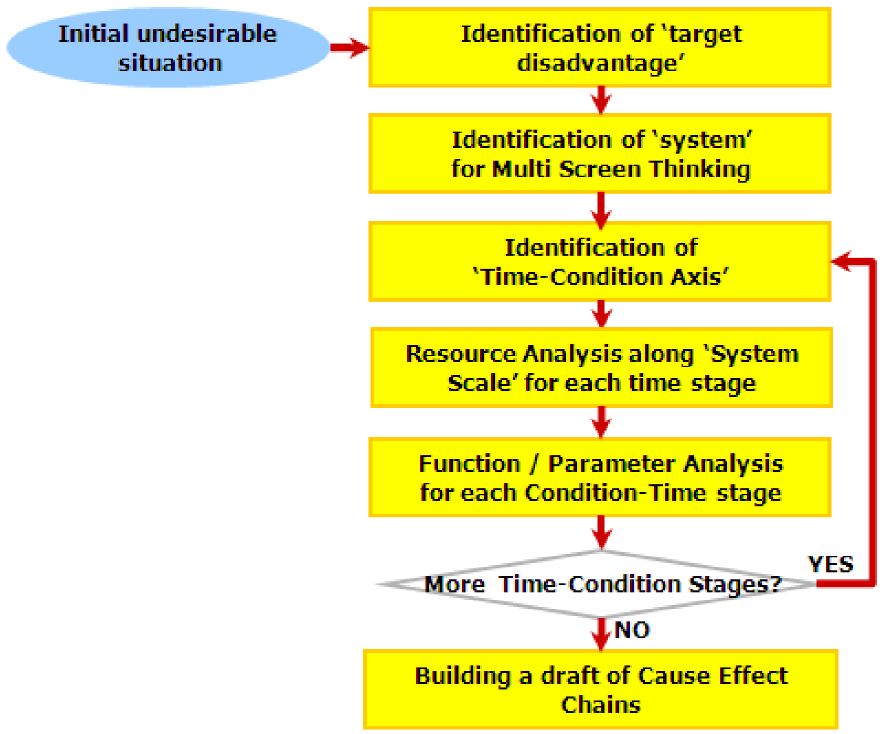

Fig.7. The schematic overview of building Cause Effect Chains based on Multi Screen Thinking

Chapter II. State-Interaction Model for Revision of Cause Effect Chains

2.1 Introduction

As discussed in Chapter 1, we need as exhaustive a set of causes as possible after Cause Effect Chain Analysis in order to increase the possibility to prevent the target disadvantage. Therefore, the applicant suggests revision of Cause Effect Chains according to 'State-Interaction Model' to find missed disadvantages. Aleksey M. Pinyayev also suggested an interesting way to find hidden whys for an improvement of completeness of Root Cause Analysis[11].

Pinyayev suggested a way to discover 'hidden whys' which mean lost causes. The way is to stare an imaginary blank between two consecutive whys to find out the lost cause. He noticed that most of the hidden whys could be found by analysis of the sequence of events or considering the process on a micro-level. In summary, 'time zooming' and 'micro-level analysis' were suggested for more exhaustive set of causes. 'State-Interaction Model', the applicant's suggestion is for the same purpose but based on a totally different approach. Pinyanyev's way and the applicant's way are not against each other but can be used independently.

2.2 Notion of State-Interaction Model

‘State-Interaction Model’ is that one ‘state description’ ‘SHOULD’ follow one ‘interaction description’ and vice versa. The ‘state description’ is ‘entity + parameter of it +evaluation of the parameter’ like ‘water container’s temperature higher (lower) than 100 ˚C’.

It must be notified that only a parameter cannot be a description of a state. Every state is the state of a certain entity. Therefore, the applicant introduced the term 'State' instead of 'Parameter' for the description of ‘entity + parameter of it +evaluation of the parameter’. The ‘interaction description’ is ‘entity + function model (+ evaluation of the function)’ like ‘water container heats water in it (insufficiently)’. In this case, the applicant introduced the term, 'Interaction' instead of 'Function' simply because every interaction description must manifest two 'Entities' of a certain interaction. But, a function model gives only the action and the target.

The premise of ‘State-Interaction Model’ is that in physical world, interactions among entities happen only if certain state conditions are reached among them and certain states among entities are achieved only by certain interactions. Only states cannot result in different states. Through interactions, a certain state causes another state. As for interactions, any interaction cannot result in another interaction without a certain state condition fulfillment. Built based on this presupposition, a Cause Effect Chain is shown in Fig.8.

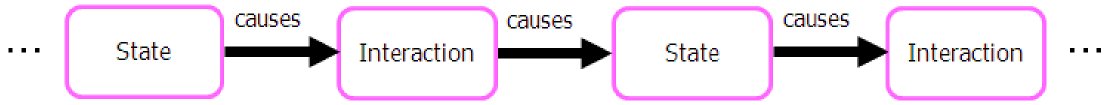

Fig.8. A Cause Effect Chain built based on 'State-Interaction Model'

If the rule of description is kept strictly, 'State-Interaction Model' also helps us to find which resource must be examined to identify causes or find missing causes. As shown in Fig.9, if one disadvantage is described in the form of 'Tool +Action+ Object', or interaction form, the cause of the disadvantage might be a certain state of 'Tool' and if needed, the state of the direct interaction between 'Tool' and 'Object'. The disadvantage as a result might be the state of 'Object'.

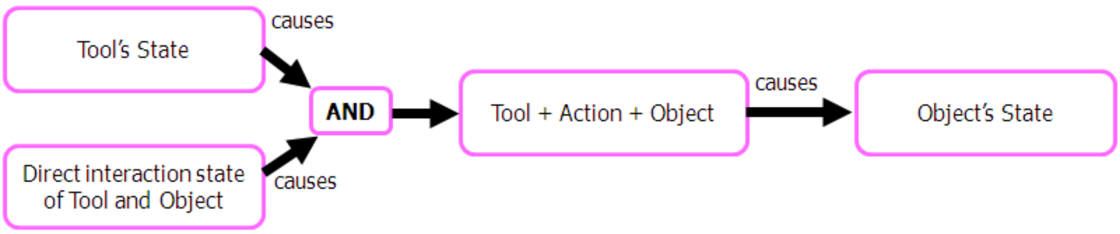

Fig.9. The basic relationship among resources according to 'State-Interaction Model'

For example, let us suppose that there are two solid bodies, A and B in contact with each other. Under what condition does the solid body A heat B in conduction mode? : Only when the temperature of the solid body A is higher than B and A contacts B directly. If there is no temperature difference and direct contact between them, there cannot be no heat conduction. Therefore, we can make the following Cause Effect Chain in Fig 10.

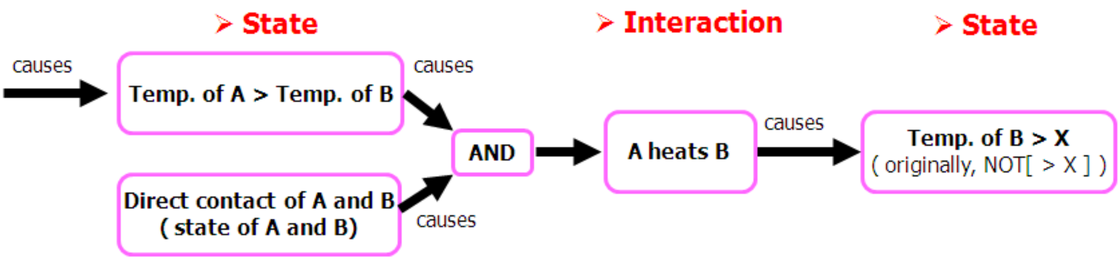

Fig.10. An example of a Cause Effect Chain built based on 'State-Interaction Model'

Based on the explained reasoning, the applicant suggests the following ways to find hidden causes with ‘State-Interaction Model’.

(1) Finding hidden causes by revising the forms of description of causes
(2) Finding hidden causes by checking whether or not the interaction is ‘Direct Interaction’.
(3) Finding hidden causes by introducing missing interactions or states

It must be notified that 'State-Interaction Model' is NOT for judging if the Cause Effect Chains are wrong or right BUT for finding hidden causes and making Cause Effect Chains more comprehensive.

2.3 Use of State-Interaction Model

From now on, how to use 'State-Interaction Model' is explained in more detail. Let's suppose that we have just finished the first version of Cause Effect Chains. The 'State-Interaction Model' can be used typically through the following examinations for every link of one cause and one result.

- **Finding hidden causes through revision of each description form of causes**
  Check if 'State' description is expressed in the form of 'Entity + a certain parameter of it + value of the parameter' and 'Interaction' description is expressed in the form of 'Tool + Action + Object'. If not, first of all, the description must be changed according to the requirements. Through correction, we might find missing hidden causes. For example, let's suppose a pair of Cause-Effect is described as only nouns, ‘fan’ and ‘noise’ like shown in Fig.11. According to 'State-Interaction Model', we have to identify at least two causes related to ‘fan’ and ‘noise’, one is the state of the fan as a cause and another is the cause as the interaction between the fan and other resources.

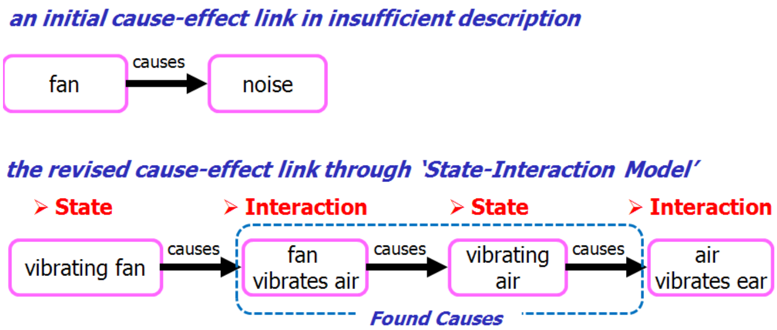

Fig.11. Application of 'State-Interaction Model' to insufficient descriptions of causes

- **Finding hidden causes through identifying 'Direct Interactions'**

  If the link of one cause and one result is a pair of 'State' description and 'Interaction' description shown in Fig.8, check if the 'Interaction' is being done directly between 'Entity' of 'State' description and another 'Entity' as 'Tool' or 'Object' of the 'Interaction' description. ‘Direct Interaction’ means there is no intermediate transmitter to deliver the interaction between the entities. Fig. 12 explains typical cases about that.

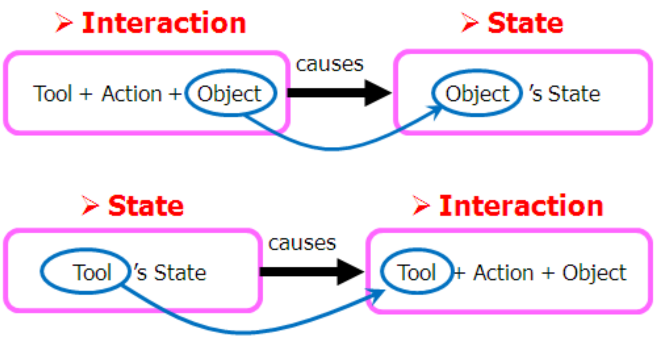

Fig.12. Typical relations of a Cause Effect Link based on the descriptions of direct interaction

If the 'Interaction' is 'NOT' being done directly between 'Entities', that means there should be some 'hidden causes' between the initial two causes. Go back to Multi Screen Thinking and find 'Entities' which directly interact with each other between the initial Cause event and Effect event. Through this procedure, we might find some hidden causes.

- **Finding hidden causes through finding missing ‘States’ or ‘Interactions’**

  If the link of one cause and one result is 'NOT' a pair of 'State' description and 'Interaction' description shown in Fig.8, there are several cases.

  a. a pair of 'State' descriptions like the case A shown in Fig.13-a.
     In this case, we have to find what kind of interaction happens between two objects appeared in the initial Cause Effect Link. The missing interaction should be the hidden cause. It is a matter of course that we should also check ‘Direct Interactions’ after doing this way to find missing causes.

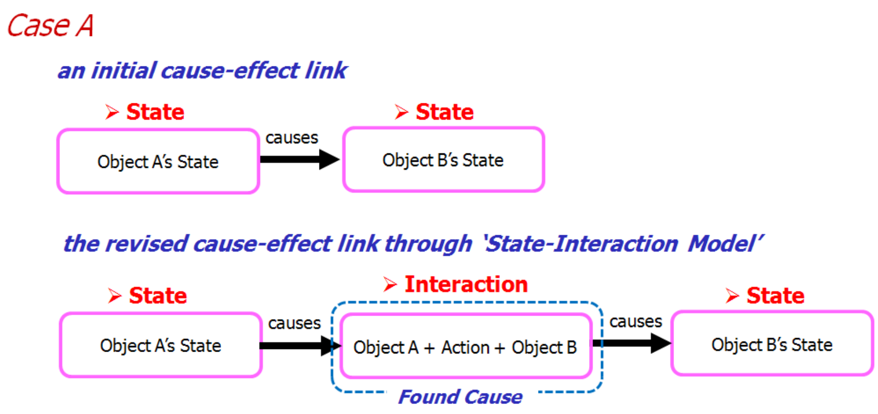

Fig.13-a. The case of a pair of 'State' descriptions

b. a pair of 'Direct Interaction' descriptions like the case B shown in Fig.13-b. As for this case, we have to find what state of 'Object B' is required for the former interaction to result in the following interaction appeared in the initial Cause Effect Link. The missing state of 'Object B' should be the hidden cause.

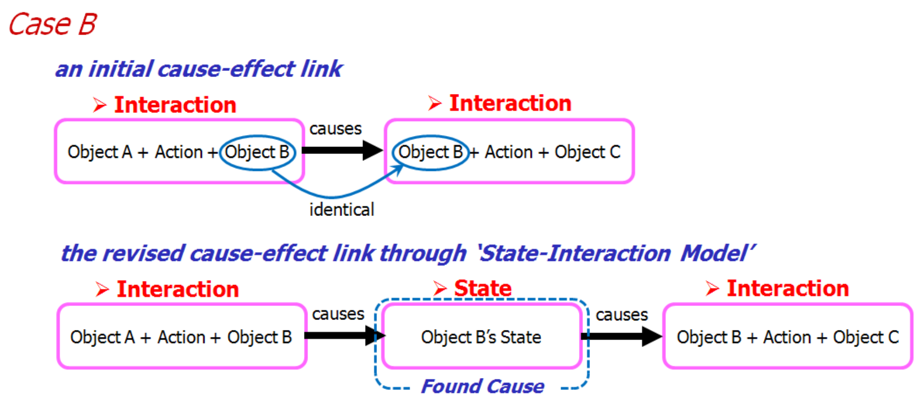

Fig.13-b. The case of a pair of 'Direct Interaction' descriptions

c. a pair of 'Indirect Interaction' descriptions like the case C shown in Fig.13-c. Concerning this case, we have to find missing 'State' and 'Direct Interaction' of 'Object B', 'Object C' and if any, other intermediate entities between them. This case is treated by following repeatedly the guides for the cases explained previously.

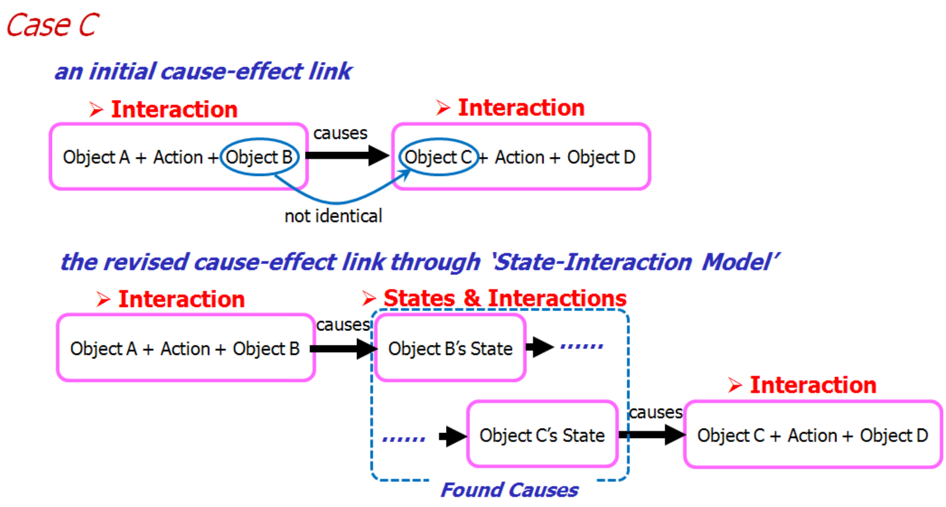

Fig.13-c. The case of a pair of 'Indirect Interaction' descriptions

Checking the Cause Effect Chains according to 'State-Interaction Model' should follow the previous procedure which was explained in Chapter 1. In conclusion, the final procedure for Cause Effect Chain Analysis Based on Multi Screen Thinking and State-Interaction Model is suggested as shown in Fig. 14.

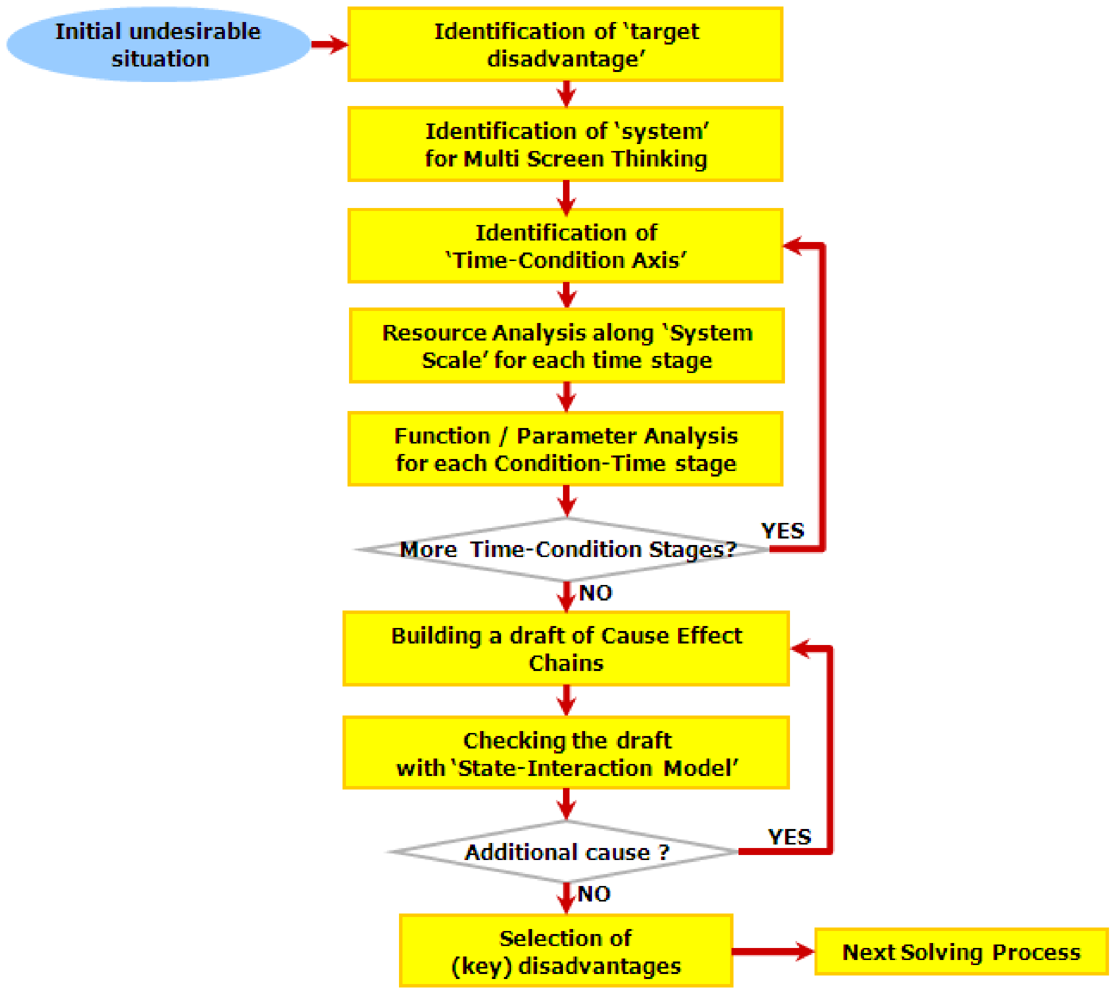

Fig.14. The schematic overview of Cause Effect Chain Analysis Based on Multi Screen Thinking and State-Interaction Model

Chapter III. The Detailed Procedure of Cause Effect Chain Analysis Based on Multi Screen Thinking and State-Interaction Model

In this chapter, we will explore the detail procedure of the suggested methods through an example. The example is about how to reduce moisture condensation on the inner side of a lens of a vehicle lamp. Fig .15 shows a conventional vehicle lamp.

The traditional vehicle lamp typically has the light bulb inside an enclosed housing of the lamp for several purposes like aesthetic appearance, prevention of water, dirt and the like from contact with the bulb. It also has the reflective surfaces, and the light transmitting surfaces of the lamp. The problem situation is that upon thermal cycling during the bulb use, thermal cycling due to changes in the environment, or thermal cycling as a result of vehicle operation, moisture condenses on the interior of the housing, especially on the inner side of a lens and hinders light output from the lamp[11]. We want to reduce moisture condensation on the lens. At this example, the lamp is tested after complete drying treatment.

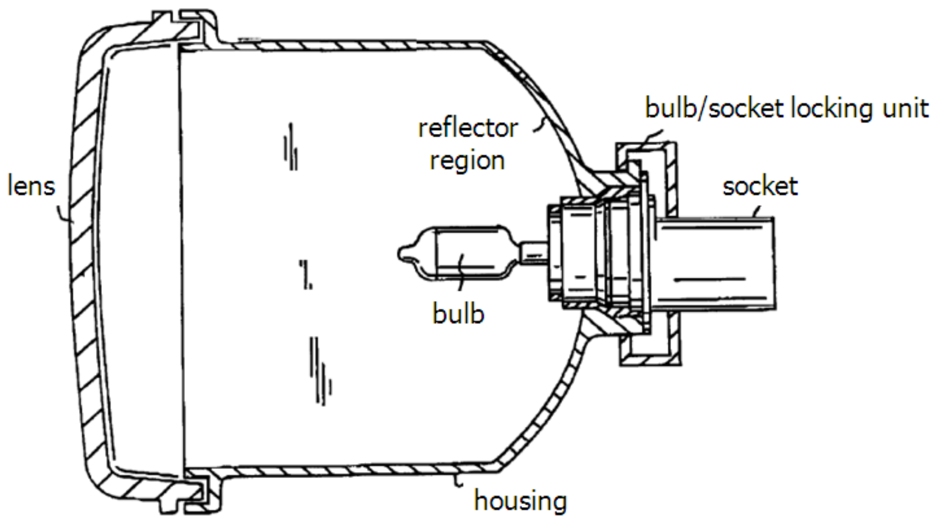

Fig.15. A traditional vehicle lamp

(1) Identification of ‘target disadvantage’:

a. Identify the undesirable event from the initial undesirable situation. The undesirable event is probably related to the goals of the project like Main Parameters of Value.

<Example>

In this example, the target disadvantage is ‘moisture condensation on the inner side of the lens of the vehicle lamp’.

b. According to the target disadvantage, identify 'System' of Multi Screen Thinking which is related to the target disadvantage.

<Example>

The vehicle lamp system is related to the disadvantage of ‘moisture condensation on the inner side of the lens of the vehicle lamp’. Therefore, we finish the first step for Multi Screen Thinking shown in Fig. 16.

Time-Condition Axis / System Scale Axis	Time-Condition
(Components of) Supersystem & Environment	
System	*Vehicle Lamp*
Subsystems	

Fig.16. Multi Screen Thinking after identification of ‘System’

(2) Identification of ′Time-Condition Axis’:

'Time-Condition Axis' is usually overviewed according to a series of several stages which are related to the system of the target disadvantage. The 'Time-Condition Axis' of Multi Screen Thinking can be deployed according to change of a certain parameter of the causal objects. We should examine what might happen before the target disadvantage appears according to the change of conditions. You should suggest several time stages if there are recognizable changes of some parameters through which a situation at each stage is different from one of the very previous and next stages individually. The deployment of 'Time-Condition Axis' cannot be done just by one trial. 'Time-Condition Axis' must be updated through the whole process of Multi Screen Thinking.

<Example>

Moisture condensation in a vehicle lamp is not an intended phenomenon. Consequently, there are no such operations of a designed process. We have to imagine the hypothetical conditions according to the change of the evaluation parameters or some control parameters if we know about the general laws related to the target disadvantage. As for our example, the evaluation parameter is 'moisture condensation observed at a certain situation'

Time-Condition 1: no moisture condensation

Time-Condition 2: during moisture condensation

Time-Condition 3: finding condensed water droplets

	no moisture condensation	**during moisture condensation**	**finding condensed water droplets**
(Components of) Supersystem & Environment			
System	***Vehicle Lamp***	***Vehicle Lamp***	***Vehicle Lamp***
Subsystems			

Fig.17. Multi Screen Thinking after identification of 'Time-Condition Axis'

(3) Function Analysis with Parameter Analysis for each stage of Time-Condition Axis on Subsystem – System - Supersystem Screen:

At each stage of Time-Condition Axis, you can identify subsystems and supersystem components and conduct Function Analysis with them. As you know well, Function Analysis must be done according to the current problem situation and the data regarding to it. You should examine the current situation from the viewpoint of energy conductivity and energy flow from one element to another element. It might be better to start from the time of the target disadvantage to the past time stages. However, you should check all Function Analyses from the early to the later and vice versa several times.

<Example>

We don't examine the change of conditions. In this case, we realize that Function Analysis cannot be finished because we cannot identify interactions among resources. For example, we cannot decide whether or not the bulb is on. If the bulb is on, the light out of it heats components of the lamp. As for the condensed moisture, we cannot display the interaction to cause phase change of the inside moisture. Without examination of conditions, no practical Function Analysis can be done. This first result of Function Analysis with Parameter Analysis in Multi Screen Thinking is presented in Fig. 18.

As shown in Fig.18, practically, we can hardly conduct Function Analysis in Multi Screen Thinking without the overall viewpoint. In order to identify interactions among resources, first of all, we have to know the conditions under which resources are given. That is why the applicant suggests the overall Function Analysis in Multi Screen Thinking. This point is the important difference of the applicant's methods from similar approaches[5,6,7,8].

There is one more thing to remember. During conducting Function Analysis for each stage, the changes of values of parameters of subsystems, system, and components of supersystems must be inspected and the Time-Condition Axis can be updated according to the inspection. If some parameters' values changes result in different result of Function Analysis, an additional time stage must be added to the Time Axis.

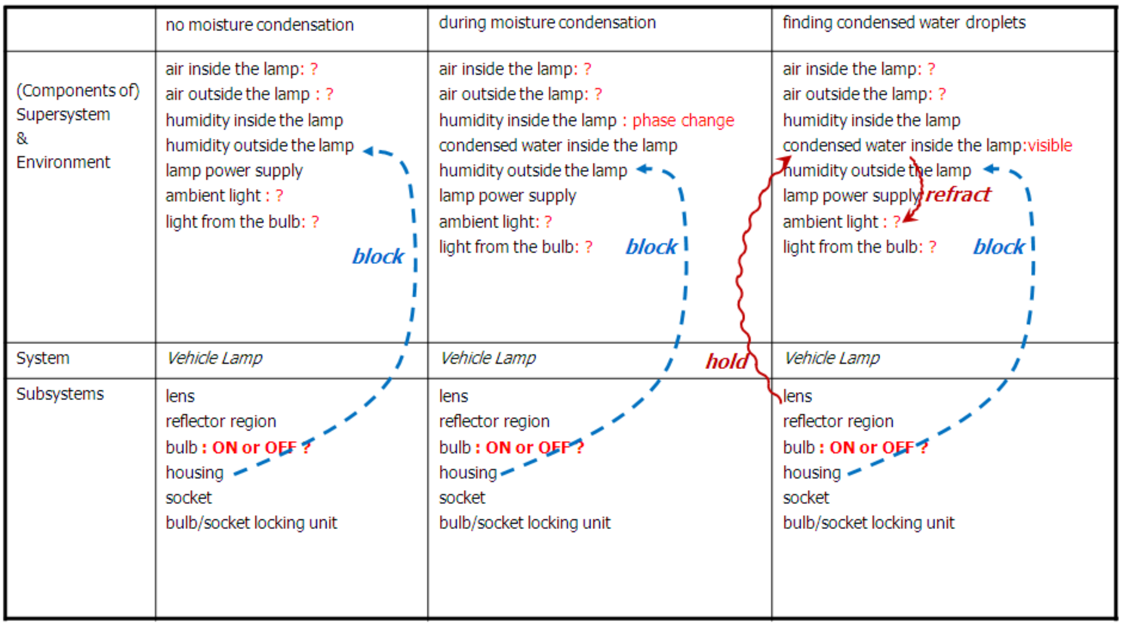

Fig.18. The first result of Function Analyses in Multi Screen Thinking

If we check the values of parameters of resources which are changed through Time-Condition Axis, we can get each result of Function Analysis for each Time-Condition stage. As for this example, a certain test condition is adopted. The part of the final result of Parameter Analyses with Function Analyses is shown in Fig.19

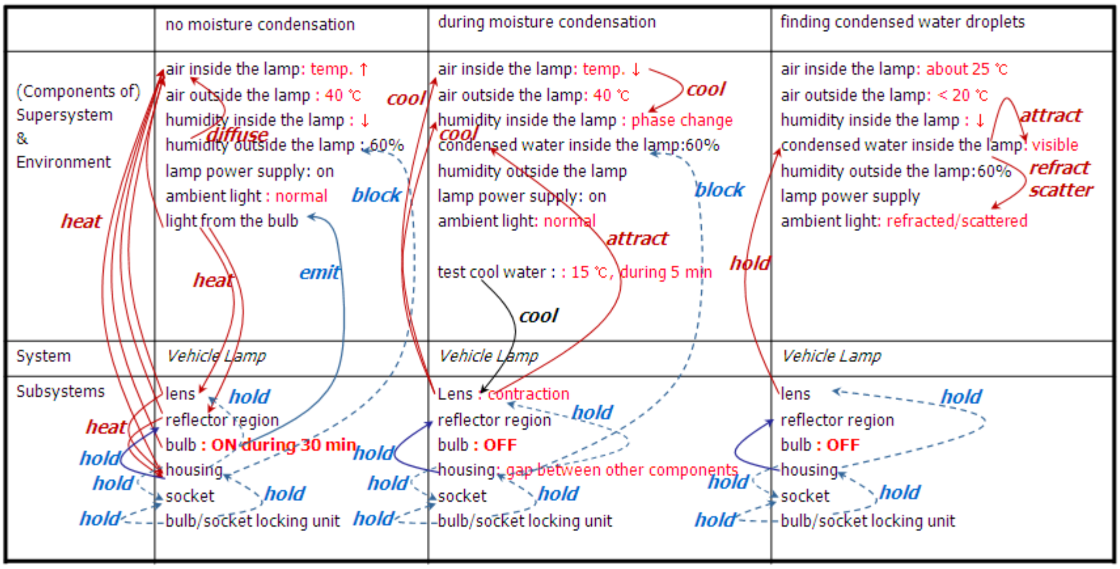

Fig.19. Multi Screen Thinking after Function / Parameter Analysis for each stage

(4) Construction of Cause Effect Chains according to the result of Multi Screen Thinking and 'State-Interaction Model'

a. Construct the initial version of Cause Effect Chains according to the Multi Screen Thinking which has been built with Function Analyses and Parameter Analyses:

Starting from the latest stage and ending up to the first stage of Multi Screen Thinking, identify interactions and important changes of values of parameters of objects and connect them as cause-effect relation. At the last stage, we can identify the target disadvantage. The next disadvantage can be defined from interactions and states of resources which have direct relationships with the resources of the target disadvantage.

<Example>

For clear explanation of revision according to 'State-Interaction Model', the initial Cause Effect Chains for the example is built intentionally with only interactions examined in Multi Screen Thinking as shown in Fig. 20.

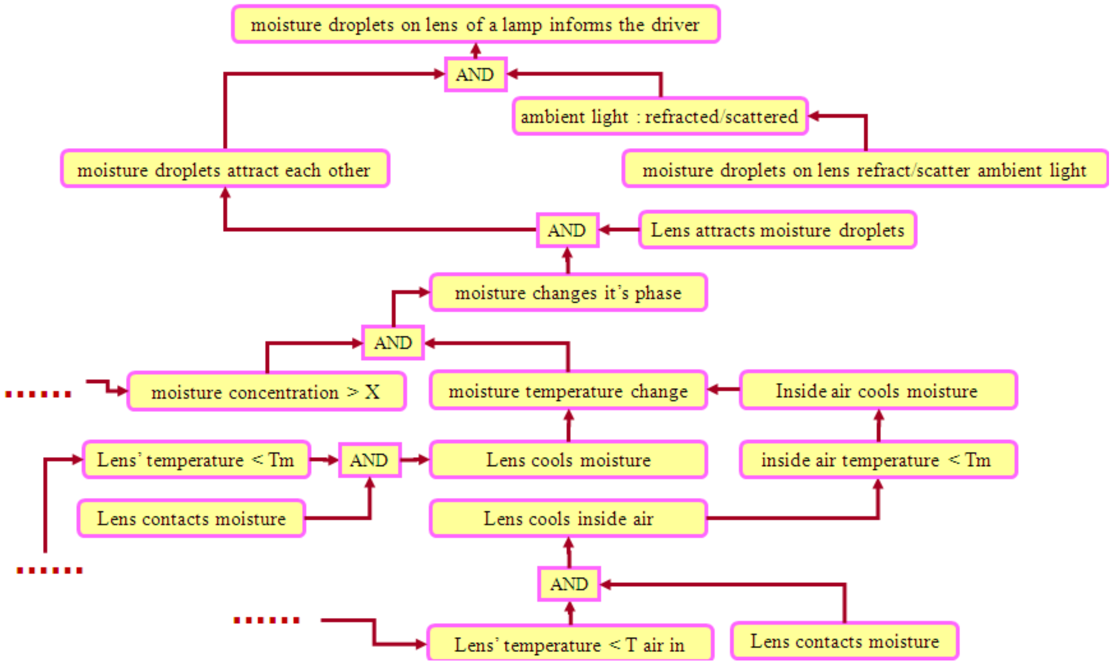

Fig.20. Cause Effect Chains built as the initial version

b. Revision of the initial version guided by 'State-Interaction Model':
Every causal link should be checked if it follows 'State-Interaction Model'. If there is any missing 'State description' or 'Interaction description', we have to think about it according to the result of the previous Multi Screen Thinking.

<Example>

Let us revise one link from the initial Cause Effect Chains presented in Fig. 21. The disadvantage, 'lens attracts moisture droplets' causes 'moisture droplets attract each other'. This link is composed of only two interactions like the case B explained in Fig. 13-b. According to the guide to find the hidden cause for the case B shown in Fig. 13-b, there might be possibility to find some missing disadvantage as 'State description' about the state of moisture droplets which are necessary conditions for the resultant interaction because the 'Object' of the interaction disadvantage, 'Tool + Action + Object' as a cause is the 'Tool' of the resultant interaction disadvantage.

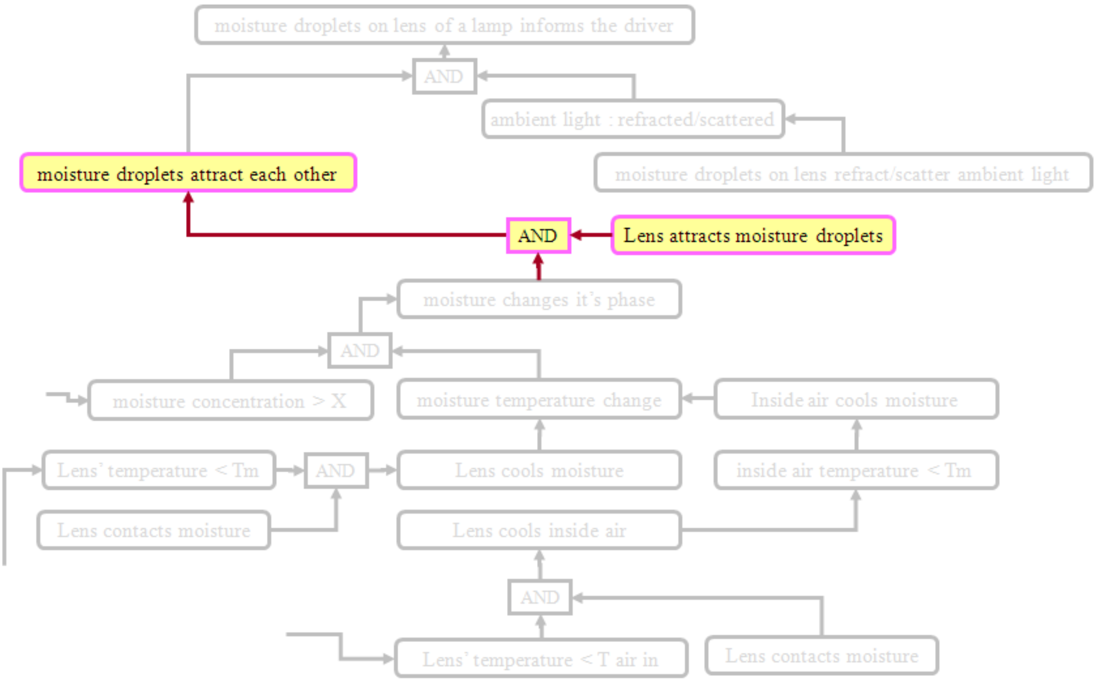

Fig.21. One link selected to revise it according to ‘State-Interaction Model’

Think about what state conditions of moisture droplets are required to make the resultant event, "moisture droplets attract each other" happen. By reviewing Multi Screen Thinking, the resultant state of ‘droplets’ which is ‘Object’ of ‘Interaction Description’ of the previous causal interaction, ‘Lens attracts moisture droplets’ is ‘closeness of each other on the lens’, which means the moisture droplets are located as closely each other on the lens as the attractive force among them can have influence effectively. That is a hidden 'State' cause from the given situation. Additionally, checking the related physical laws for aggregation of liquid particles or the resultant interaction, ‘moisture droplets attract each other’, makes us identify the source of the attractive force among water droplets. This leads us to the fact that molecular polarity of water molecules. That is another missing 'State' cause. Therefore, the missing disadvantages can be described like '(amount of) moisture droplets on lens (> a certain value)' and ' High polarity of water molecules' like highlighted by bold red lines shown in Fig. 22.

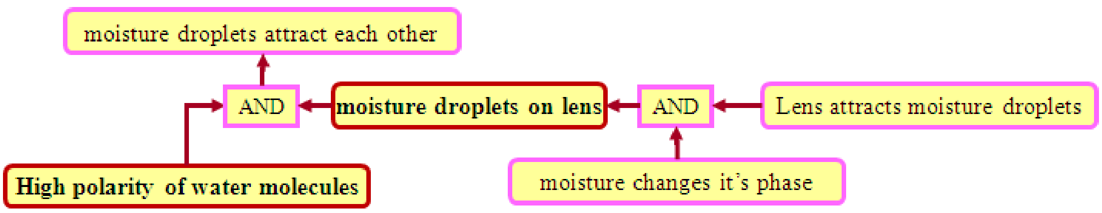

Fig.22. An example of revision of a causal link according to ‘State-Interaction Model’

Subsequently, we can continue to do the same revision as many causal links as necessary. Fig.23 presents part of the whole Cause Effect Chains after revision with ‘State-Interaction Model’.

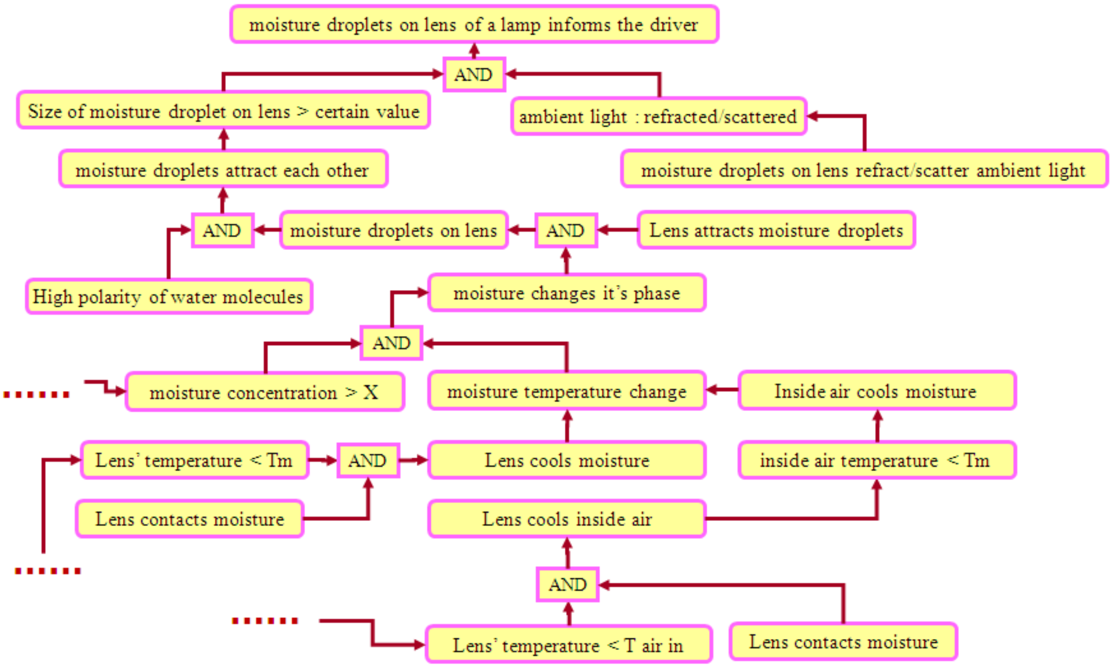

Fig.23. A part of the whole Cause Effect Chains after revision with ‘State-Interaction Model’

Chapter IV. Conclusion

1. A new method is suggested for easier and more efficient building Cause Effect Chains with Multi Screen Thinking. It introduces 'Time-Condition Axis' which is for replacement of the traditional Time Axis of Multi Screen Thinking.

Multi Screen Thinking along Time-Condition Axis and System Scale Axis can give us an overall comprehension according to Parameter Analysis with Function Analysis which deploys interactions among resources and conditions of them which are necessary information of building Cause Effect Chains.

2. An absolutely new guide of cause-effect chains is the ‘State-Interaction Model’ which is composed of one by one series of ‘entity + parameter of it +evaluation of the parameter’ and ‘entity + function model + evaluation of the function’. Checking Cause Effect Chains according to ‘State-Interaction Model’ leads us to find missing causes.

The developed methods have been very successfully used in various projects for different leading corporations worldwide since 2005, especially for Samsung Electronics, Samsung SDI, Samsung Mobile Display, LG Display, POSCO, Hyundai Motors, Hyundai Mobis, and Amore Pacific, etc.[12, 13]

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