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

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Abstract

Every technical system is under spontaneous degradation which causes poor performance and sometimes catastrophic failures. Besides, unexpected undesirable events tend to happen beyond our foresight. Engineers have attacked those undesirable events as 'target disadvantages' since technical systems were invented. For efficient prevention of target disadvantages, engineers try to find root causes for higher reliability of technical systems. There have been developed several ways of Cause Effect Analysis from Ishikawa method to variable ways in the structure of Cause Effect Chains. In modern TRIZ field, the different methods of Cause Effect Analysis have an important common attribute that the undesirable events as causes must be arranged as Cause Effect Chains. The adoption of Cause Effect Chains 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. 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. 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, the set of problem models from Cause Effect Chains should provide 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.

First, the applicant introduces 'Time-Condition Axis' which is for replacement of the traditional Time Axis of Multi Screen Thinking. Along Time-Condition Axis and System Scale Axis, Multi Screen Thinking with Parameter Analysis and Function Analysis can give us an overall comprehension about interactions among resources and conditions of them which are necessary information of building Cause Effect Chains.

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. 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 case, 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 which concerns water and salt concentration of it 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. In order to identify interactions among resources, first of all, we have to know the conditions under which resources are given. Therefore, if we do not get the overall viewpoint according to the condition specification, we can hardly conduct Function Analysis in Multi Screen Thinking. That is why the applicant suggests the overall Function Analysis 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.

The dissertation will show a practical example of a vehicle head lamp problem about which a certain test condition is adopted.

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

‘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.1. In Fig.1, the arrows mean 'the left event causes the right one'.

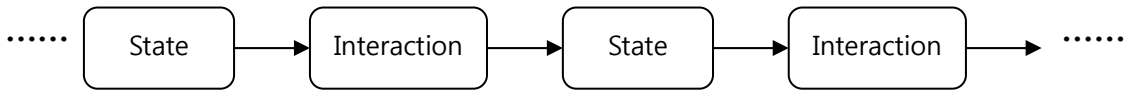


Fig.1. A Cause Effect Chain built based on ‘State-Interaction Model’

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.2, 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'.

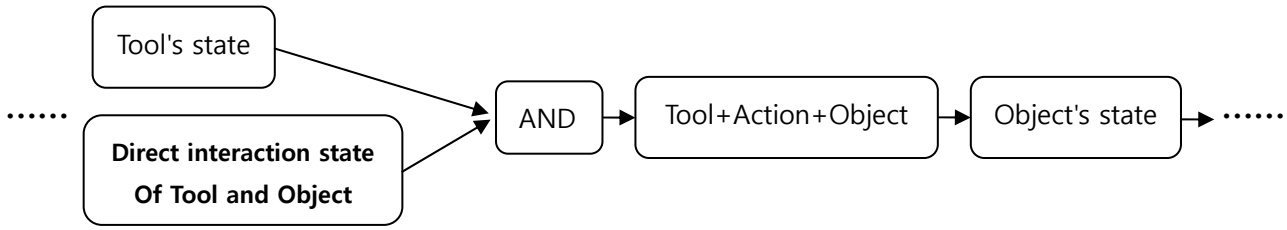


Fig.2. The basic relationship among resources according to ‘State-Interaction Model’

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.

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.3. 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.

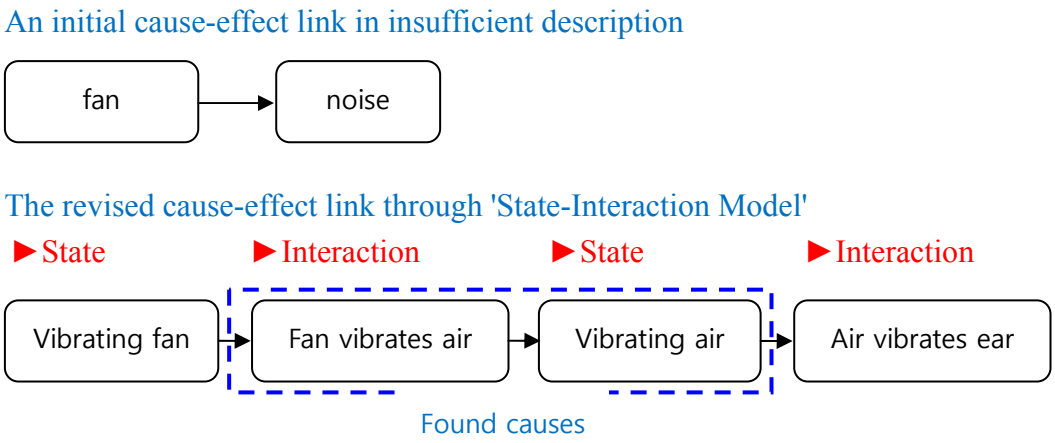


Fig.3. Application of 'State-Interaction Model' to insufficient descriptions of causes

- **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. 4 explains typical cases about that.

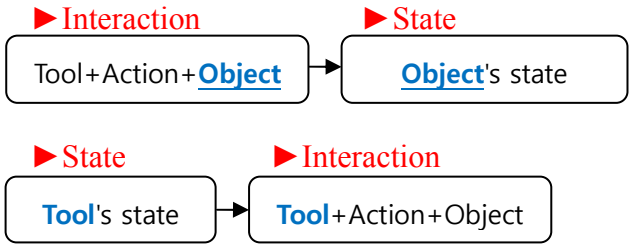


Fig.4. Typical relations of a Cause Effect Link based on the descriptions of direct interaction

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.5-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.

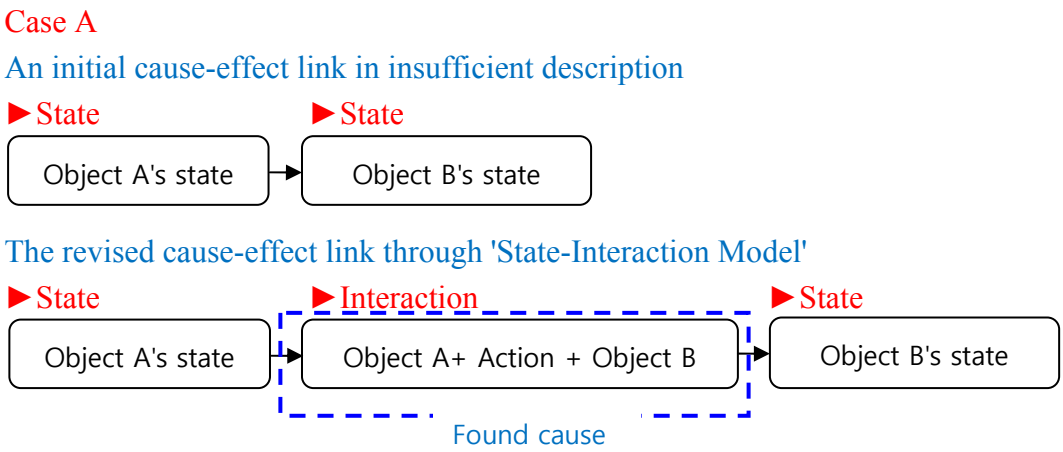


Fig.5-a. The case of a pair of 'State' descriptions

b. a pair of 'Direct Interaction' descriptions like the case B shown in Fig.5-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.

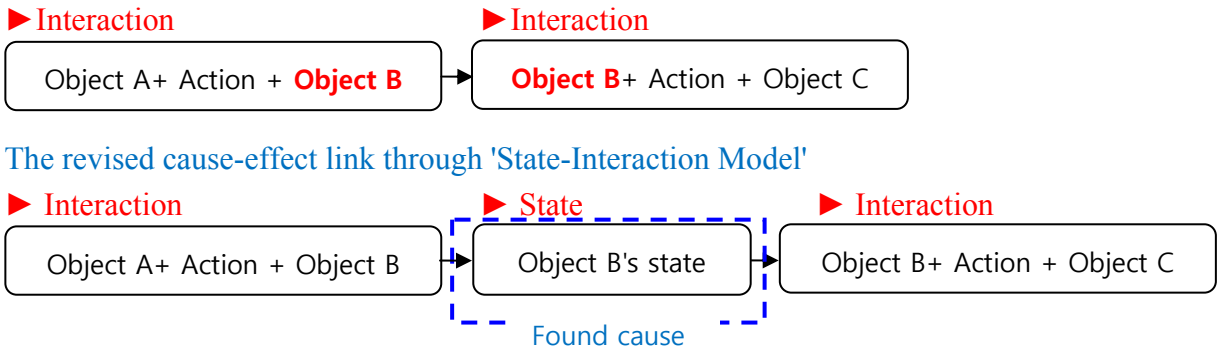
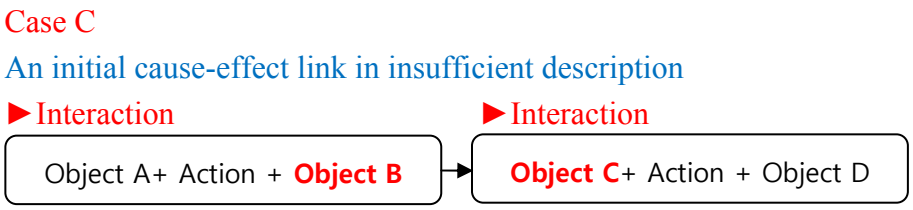


Fig.5-b. The case of a pair of 'Direct Interaction' descriptions

c. a pair of 'Indirect Interaction' descriptions like the case C shown in Fig.5-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.



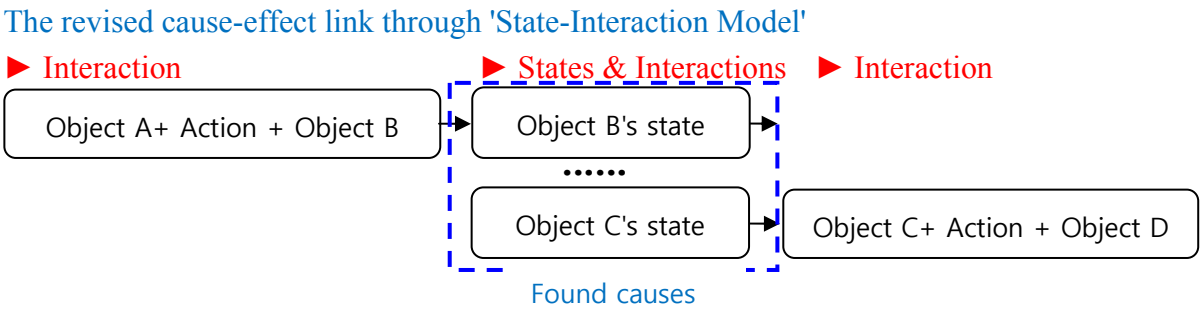


Fig.5-c. The case of a pair of 'Indirect Interaction' descriptions

The above 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.