Root Conflict Analysis (RCA+): Structured Problems and Contradictions Mapping

Valeri Souchkov ICG Training & Consulting The Netherlands

valeri@xtriz.com

*Original paper was presented at the ETRIA Conference **TRIZ FUTURE 2005**, Graz, Austria, November 11-13, 2005*

INTRODUCTION

When solving an inventive problem, we usually face different initial situations:

1. A system or its certain components produces a negative effect: either it fails (or might fail) to deliver its function, or it does not provide required behavior during operation, or it causes negative side effects, and we need to solve a particular problem to prevent the negative (undesired) effect from occurrence.
2. A system performs well and meets most of requirements, but we would like to improve its performance or controllability.
3. A system performs well, but we need to cut costs attributed to its complexity, manufacturing, maintenance, support, etc.
4. We have no system or a system component to deliver a specific function, thus new functionality has to be created.

Most cases which are presented in classical TRIZ fall to the first and the second categories: elimination of a negative effect or improvement of the existing positive function or effect. The second category of problems which is often described as “insufficient” effect. For example, if breaking a bicycle tire during the ride can be undoubtedly considered as a negative effect, then unsatisfactory degree of polishing a glass surface during production process can be considered as insufficient effect.

An inventive problem usually differs from a “standard” problem due to presence of a cause of the problem which creates a conflict. In inventive problem, the same cause might result in both negative (or insufficient) and positive effect. If a “standard” problem can be solved by locating and eliminating a cause which is a source of the negative effect, in the inventive problem, a cause which leads to a negative effect may not be directly eliminated since it also leads to a positive effect. For example, the cause of easy breaking of the bicycle tire is that the material of the tire is soft. On the other hand, the material should be soft to provide comfort of the ride.

Today we know how to eliminate such conflicts with the TRIZ tools, but to do it, first we need to properly identify and formulate such conflicts (which are also called "contradictions"). The difficulty is that often such conflicts are not explicitly visible, or a problem can be caused by several conflicts.

This paper presents an approach based on cause-effect mapping to analyze why negative and insufficient effects happen and to extract underlying conflicts. It is called "Root Conflict Analysis" (abbreviated as RCA+) and is based on problem decomposition and establishing causal relationships between causes and effects. The approach was extensively tested during last several years of numerous applications in technology and business and has proven its effectiveness.

EXISTING TECHNIQUES FOR INVENTIVE PROBLEM ANALYSIS

Although classical TRIZ provides proven techniques to solve inventive problems, it used to lack a clear and structured way to identify and properly formulate problems. ARIZ-85C [1] forces us to select a contradiction in the very beginning of the problem analysis which might be a quite troublesome task, especially for TRIZ specialists with little experience, and sometimes lead to selecting a wrong contradiction. Another analytical technique, Function Analysis [2] is a robust tool to map actual physical relationships in a system but fails to reveal causal dependencies that lead to negative effects since the technique does not include a process model. I-TRIZ methodology provides causal mapping of situations, but is quite informal and might leave critical issues behind the resulting model [3].

There have been attempts to integrate TRIZ with other problem analysis techniques, like Quality Function Deployment (QFD), but there are certain problems with building a formal bridge between these techniques and TRIZ that would provide a smooth transition to the problem solving process.

CAUSE-EFFECT MAPPING

An idea of studying and mapping causal relationships for identification of underlying causes of problems (or accidents) has been explored in science and technology for several past decades. Several alternative methods are known, among them are Ishikawa Diagrams (also known as Fishbone Diagrams) [4], Root Cause Analysis [5], Method of "Five "Why's" [6,7], Current Reality Trees in Theory of Constraints [8].

However, a common drawback of these methods is that while they help finding causes of problems, they do not provide means to solve problems and require deep analysis of causes of negative effects in order to find a root cause. In some cases, revealing a "hidden" cause makes it possible to solve the problem by just eliminating the cause. However it is not always the case, since the same cause might contribute to both positive and negative effects as mentioned above. In TRIZ terms, in such situations we have a conflict, or a contradiction.

Second, most of these methods do not contain interface with problem solving tools, so it is often not clear how to deal with causes identified, especially when the problems are difficult and contain contradictions.

The methodology presented in this paper is based on the ideas first proposed by the TRIZ experts of the Dutch company DSM which addressed problems in chemical industry. They used the Root Cause Analysis technique which has been quite popular to extract "hidden" causes of accidents occurring at chemical plants in order to develop preventive measures. After observing this process, it became obvious that RCA, or at least some of its ideas can be integrated with TRIZ. In my professional opinion, the approach to analyzing causal relationships can greatly help with performing the first phase of problem analysis: area, which has used to be traditionally weak in classical TRIZ.

Quite close to our method is a technique presented in [9], and called "Root Contradiction Analysis". It correctly identifies a general problem with a classical Root Cause Analysis and proposes a method of finding a root contradiction instead of a root cause. While our idea is similar, we introduce a more formal and extended approach which is also expanded to combining tree and network approaches for conducting analysis and problem mapping.

RCA+: ROOT CONFLICT ANALYSIS

The essence of the method which is being presented in the paper is to map all causal chains of causes and effects that contribute to a problem, which is represented as a general negative or insufficient effect, and then identify conflicts that within the model produced can further be resolved with TRIZ.

The RCA+ cause-effect diagrams are presented as trees, with nodes stating for effects/causes. They are usually built in a top-down manner, starting with a general negative effect and then moving downwards by describing a chain of causes that lead in the general negative effect until a conflict is reached. Both "in-depth" and "in breadth" strategies should be explored. In addition, networking of parallel causes and effects is also possible.

Any specific cause of any negative effect itself might be regarded as a negative effect, and therefore we need to identify other underlying cause for this effect thus completing a chain of causes and effects.

There are might be two types of situations:

1. Situations where all causes of an effect are interrelated and refer to a particular case. This addresses to those situations which result in a specific problem caused by certain conditions relevant only for this type of problem. For instance, an accident with a car occurs due to a leakage of the oil in the braking system. Here we deal with a specific situation, a specific car design, and do not consider other possible variants of the braking system failure.

2. Situations where alternative causes might potentially contribute to a problem. For instance, a boat can capsize and sink due to different causes, which are in some cases interrelated, but in some not. For instance, "a hole in a hull" cause is not interrelated with a cause "overweight of the boat". Both causes can lead to capsizing independently of each other.

The starting point of the RCA+ is defining a general negative or insufficient effect. It might be a very general expression, like "computer crushes". Next steps are being performed to build a logical tree of causes the computer to crush. Here we should decide if we want to conduct a general analysis of all potential contributing factors which lead to the crush of the PC or we want to analyze a specific case.

"*WHAT IS A CAUSE*?" INSTEAD OF "*WHY*?"

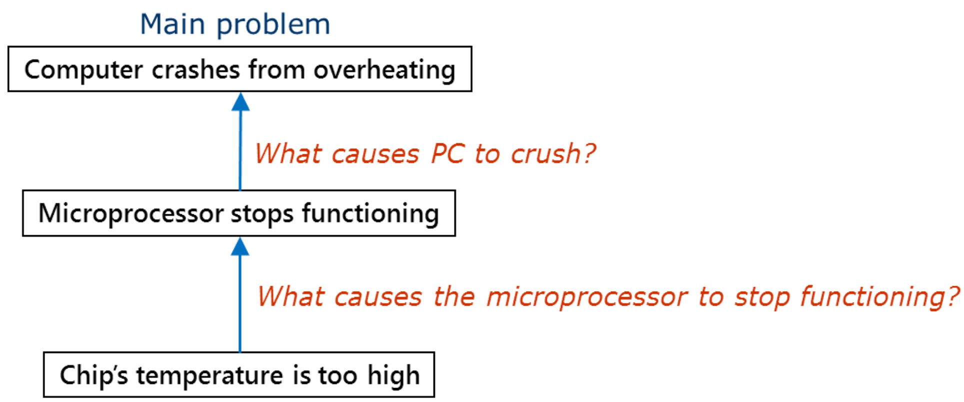
One of the key differences between RCA+ and other cause-effect analysis methods is that main question which is asked during RCA+ process is "*What is a cause*?" or "*What causes an effect to occur*?" This question is different from the classical RCA question "*Why?*". It is very important, since when we answer to question "*why?*' we might indicate both a real cause as well as a goal. But to properly understand the underlying causes of a problem we should not explore goals. For example, if to ask, "*Why a person goes to a supermarket?*", many would answer "*To buy food*". But it is not a cause, it is goal. If now to ask question, "*What is a cause that a person goes to supermarket?*", the correct answer will be "*Because the person does not have food at home*".

In addition, answers like "low reliability" or "low quality" are not acceptable for RCA+. When answering this question, we have to identify exactly what object and what its feature are responsible for producing the negative effect. It should not necessarily be an object, but some physical parameter identified with an object or a flied, like "temperature" and its relative value. Action as well might serve as a cause. This makes considerable difference with classical Root Cause Analysis or Ishikawa Diagrams. We must identify a specific feature or active condition which contributes to producing a negative or insufficient effect. A cause is always written as a single sentence which specifies either:

1. Condition of an attribute (a parameter) of a system or system's component leading to negative effect. Examples: a) temperature is too high, b) speed is too low.
2. Action leading to negative effect. Examples: a) water is cooled down, b) a car is moving
3. Radical change of a system or a system's component leading to negative effect. Examples: a) ice melts, b) currents is switched off.

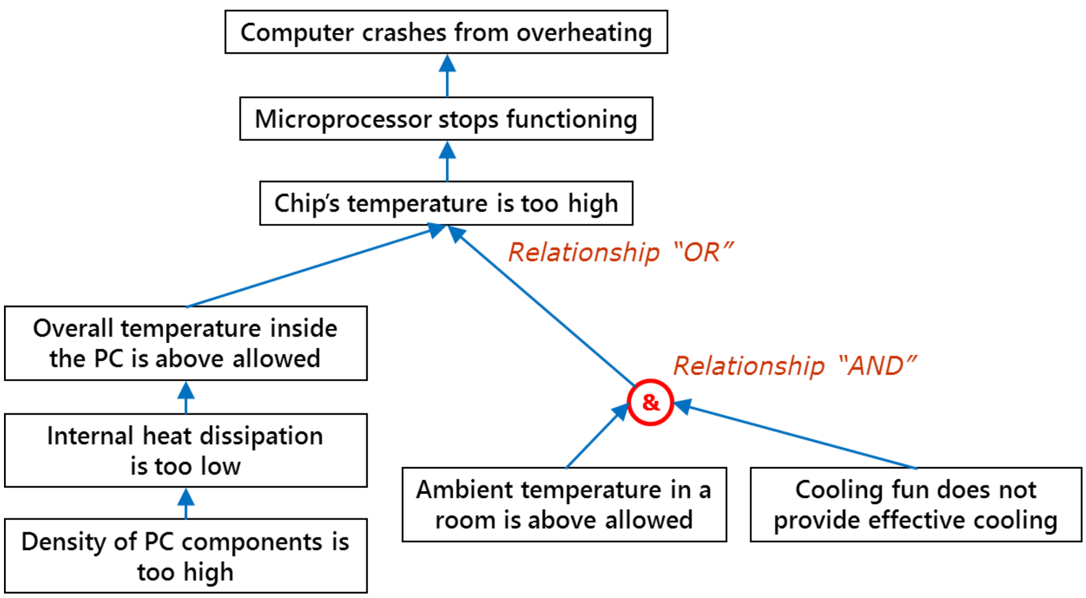
BUILDING RCA+ TREES

The simplest causal chain can look as follows:



The degree of details presented at this diagram is low. We can add more specific causes to the diagram.

RCA+ has a number of rules and checklists to perform in-depth and in-breadth analysis of a problem. The following diagram attempts to reveal several possible causes for overheating of the chip (to avoid complexity, we omit other causes that contribute to the problem):



This diagram presents causal relationships which contribute to the general negative effect. Note, that at the diagram there are two types of relationships: "**AND**" and "**OR**". Thus, the causes "*Ambient temperature in a room is above allowed*" and "*Cooling fun does not provide effective cooling*" must act together to produce the negative effect "*Chip's temperature is too high*". If any of these two causes is eliminated, the negative effect will not occur. It leads us to the following conclusion: whenever we identified a cause of a negative effect, we should always check if it is enough to produce the negative effect or it must act together with some other yet unidentified cause.

The question often arises when to stop the chain of a certain branch of a tree. Usually we stop exploring the chain when we reach a cause which is either:

- a cause is a demand or requirement that is impossible to change, for instance, it is a policy requirement or a part of technical specifications;
- a cause that contributes to both positive and negative effects (see the next section). This is what we call “a root conflict”; however it might be as well useful in certain situations to continue analysis further to investigate the underlying causes of the conflict as well.

Once the cause-effect diagram is completed, it must be analyzed against logical consistency and missed intermediate causes. In most situations, the diagrams undergo modifications during the validation process.

MAPPING CONTRADICTIONS

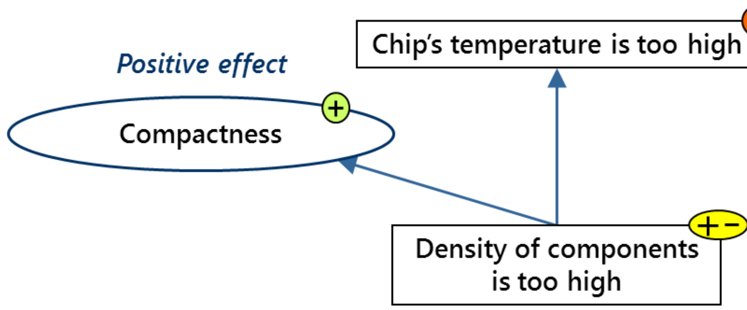
Technical and physical contradictions can be formulated on the basis of evaluating the cause-effect diagram against positive effects which are provided by causes of negative effects.

During building the RCA+ diagram, it is important to investigate if there any positive effects which are provided by the causes specified in the boxes. Certainly, the condition which results in a positive effect is “density of packing components is too high” because in this case we can produce compact chip, which is crucial for designing notebook and handheld PCs.

Thus, we can have for types of causes/effects in the RCA+ diagram:

1. Negative “-“ : the cause/effect only causes negative result (effect).
2. Positive “+“: The effect from a specific cause is positive; there is no need to change it. Usually positive causes do not exist alone inside of the chain, otherwise there would not be negative effects resulting from them.
3. Combined negative and positive (source of a contradiction) “+-“: the same cause results in both positive and negative effects.
4. Unchangeable “--“ : a cause which may not be changed or influenced to solve a problem.

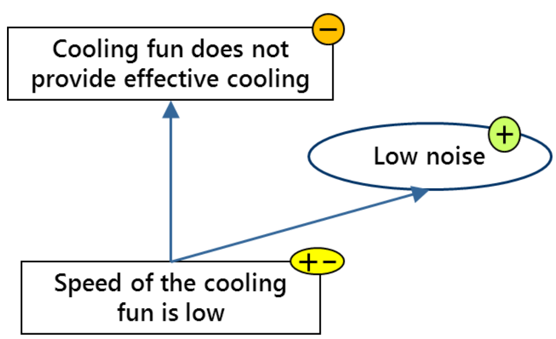
Now, we can tag each cause/effect in the RCA+ diagram with an appropriate symbol:



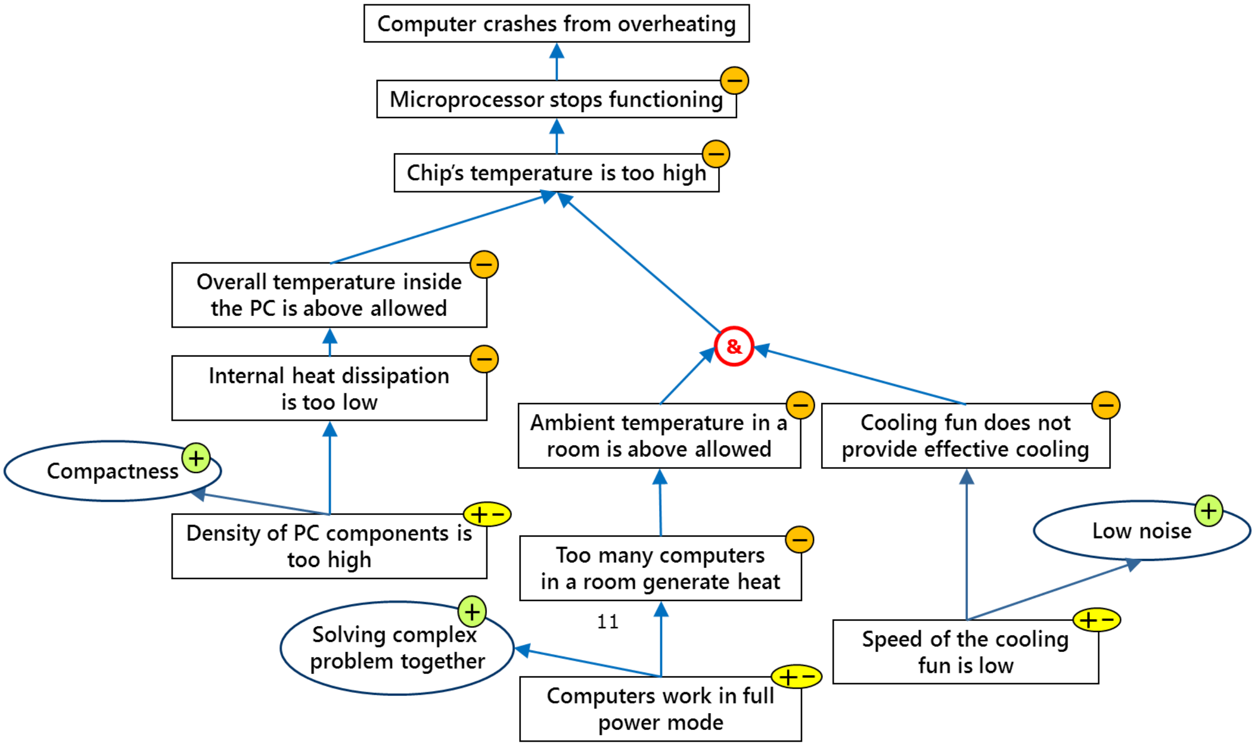
At this diagram, we can see that while the high density of components in a computer is positive to provide compactness, at the same time it is also negative since it produces overheating of the microprocessor chip. Such a "triad" model gives us a direct indication of both technical and physical contradictions which are present in the system:

- **Technical contradiction:** "*Compactness*" versus "*Chip's temperature is too high*". In classical terms or TRIZ, this technical contradiction is that by increasing the compactness of electronic components inside a computer, we increase the temperature of the microprocessor chip.
- **Physical contradiction:** "*Density of components should be high to provide compactness of the computer design and low to avoid overheating of the components*".

Similarly, another pair of contradictions presents in this diagram (due to the fact that the cooling fun has low speed to produce less noise):



The overall RCA+ diagram for the presented case with "tagged" causes:

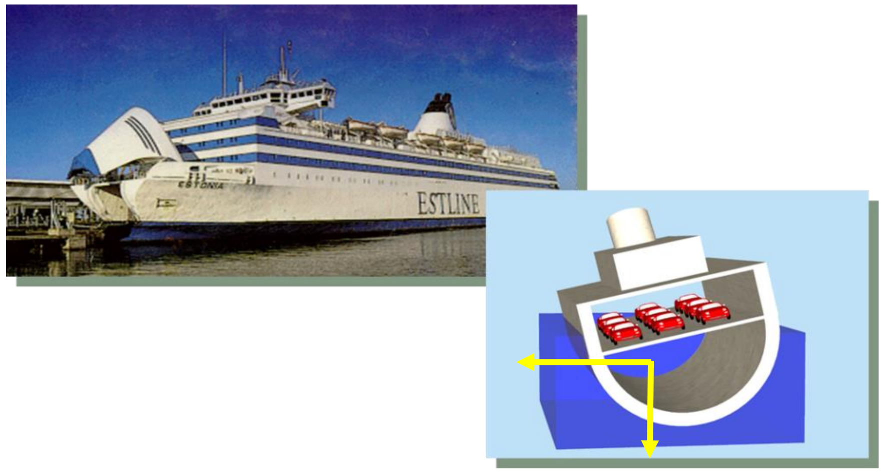


After the RCA+ model of a problem is completed, a table of revealed problems is created, and selection of a particular conflict to solve is made on the basis of the desired changes in the system.

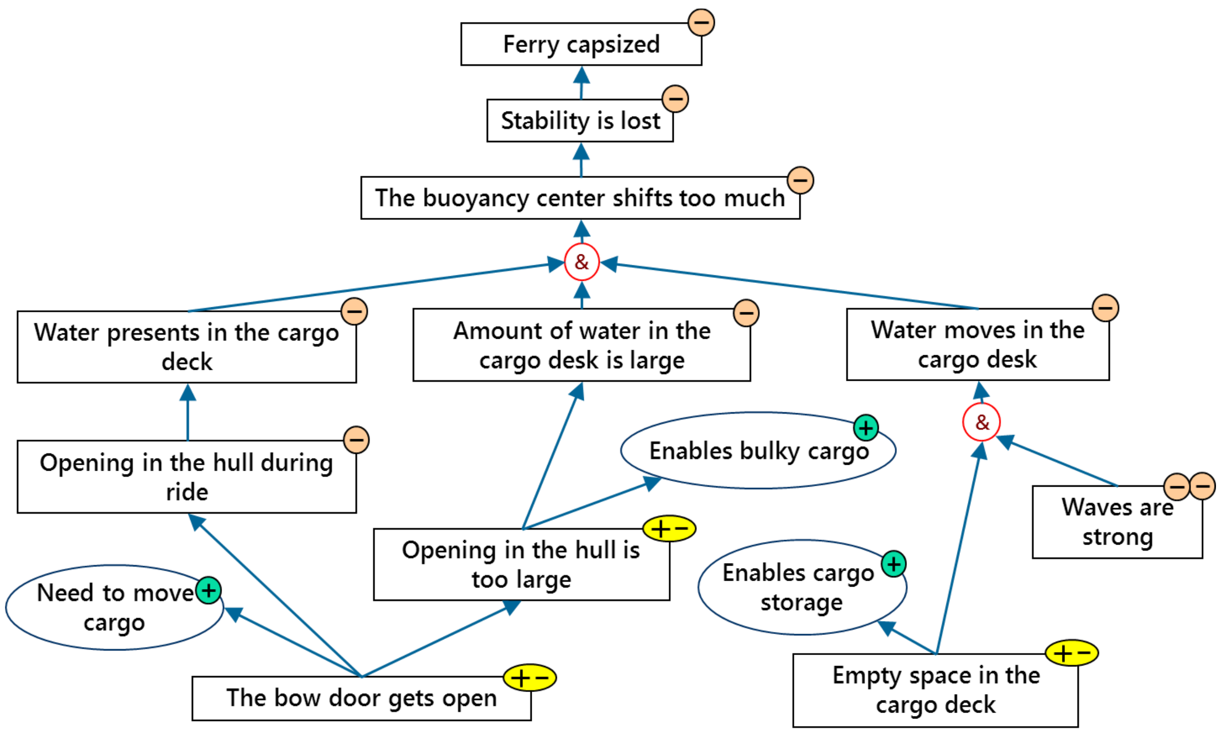
Performing RCA+ in real practice also requires checklists after each step and following specific rules that are omitted in the paper.

LINKING RCA+ AND TRIZ: A CASE STUDY

To illustrate the concept presented above, let us analyze a case which is in detail presented in [9]. A problem is an accident during the sea ride of the ferry Estonia which happened in 1994 and about 850 people lost their lives as a result of the accident. The accident happened due to the fact that the bow door opened during the ride, and sea water poured to the cargo deck. The amount of water was not enough to make the ferry sink, but since the waves were strong, the accumulating water started to move in the cargo desk. As a result, it caused the loss of stability of the ferry which led to the capsizing of the ferry.



The following diagram presents the model of the described case (a fragment of a total RCA+ model is shown):



Note, that to eliminate a general negative effect “Ferry capsized” in order to prevent the re-occurrence of that specific situation, it would be enough to eliminate any single cause presented in the diagram. It is possible because all causes and branches of the RCA+ tree are connected through “AND” relationships.

Let us identify which causes are the sources of conflicts:

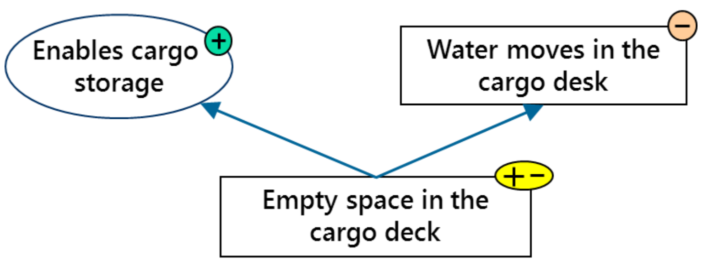
Cause	**Problem Formulation**	**Negative/Positive**
Ferry lost stability	How to control stability of the ferry during an accident?	N

The buoyancy center shifted too much	How to prevent the buoyancy center from shifting?	N
Water presents in the cargo desk	How to prevent water from being present in a cargo desk?	N
Opening in the hull	How to prevent a possibility of opening?	N
The bow door gets open	How to make sure that the door does not get open during the sea ride?	N+P
Amount of water in the cargo desk is large	How to reduce amount of water?	N
Opening is large	How to decrease sizes of the opening while keeping it large for loading/unloading bulky cargo?	N+P
Water moves in the cargo desk	How to prevent water in the cargo desk from moving?	N
Empty space in the cargo desk	How to ensure that open space is present but does not allow water to move?	N+P

The cells in the table which are marked as “N+P” indicate that the conflict takes place. Further, the problem can be solved in two ways: by trying to eliminate only “N”-marked causes, or by trying to resolve the conflicting causes marked as “N+P”.

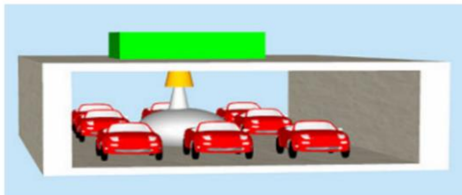
To select a right problem, we use a set of rules which help to filter out problems that would be too difficult to solve and focus on solving such a contradiction, solution to which would not require too much changes of the existing system .

Suppose, we selected the following problem:

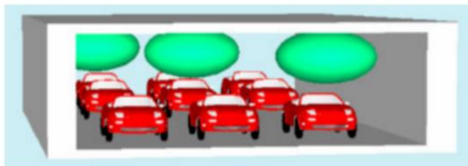


A physical conflict can be formed on the basis of this triad as follows: “Open space must be in a cargo bay to enable loading/uploading of bulky cargo and must not be there in order to avoid movement of water during an accident”.

Solving this problem formulation with ARIZ-85C and using the principle of separating conflicting properties in time led us to the following solution concepts:



Containers with liquid plastic foam which solidifies after being spayed in case of emergency



Airbags which are deployed in case of emergency

Compared to the problem solving process presented in [10], we see that now the problem becomes highly structured and clearly visible as a result of logics behind RCA+.

SUMMARY

AS has been proved by numerous case studies, causal decomposition of problems has appeared to be very effective in different situations. RCA+:

- Structures problem space.
- Helps to identify all sub-problems that contribute to a general problem.
- Establishes and shows logical relationships between the sub-problems.
- Helps to identify causes producing conflicts and contradictions.
- Makes it easier to conduct problem analysis process in TRIZ, helps to automatically present and extract contradictions.
- During teamwork, helps to come to consensus and develop a common perception of a problem situation, which results in reaching better agreements regarding goals and action plan.
- Provide visual understanding of a problem by someone who sees the problem for the first time.

Another advantage of using RCA+ is that it helps in the training and educational processes. It has been always difficult for novices to understand and learn the concept of the contradiction: both technical and physical, because standard teaching does not put contradictions within the context of any logical analysis. With the RCA+ diagrams the contradictions are shown in a natural way.

We investigated the applicability of RCA+ method in 2003-2005 to analyze and solve a broad range of problems within both technological and business systems. In each case, the conclusion was that RCA+ produced better results to logically structure problem and identify and structure conflicts in systems that any other method. Also, apart from the identification of conflicts in a problem, we found several extra benefits from using RCA+, such as selection of a key contradiction and direct input to at the University of Twente (The Netherlands) and several universities.

Acknowledgements

I would to express my thanks to Patrick Hendriks and Wim van den Elschout of DSM Research, who first applied the Root Cause Analysis for analyzing inventive problems and for very useful talks with them which significantly contributed to this paper. Special thanks to Desmond Ebenezer and André Boder of LEM Ventures for their useful comments and proposals during trial-out applications of RCA+, as well as Nikolai Khomenko of the Technical University of Strasbourg and Don van Sonsbeek of D Sight B.V. for their useful input.

References

1. Altshuller, G. “Algorithm of Inventive Problem Solving ARIZ-85C”, In the training materials “Methods for Solving Scientific and Engineering Problems”, St. Petersburg, 1985, in Russian.

2. Gerasimov, V. & Litvin, S. “Laws of Technology Development in VEA of Technological Processes”. In Practice of Value Engineering Analysis in Electrical Engineering, M.G. Karpunin (ed), Moscow, Energoatomizdat, 1987, In Russian.

3. Ideation International. Inventor’s Workbench software.

4. Ishikawa K., Guide to Quality Control, Asian Productivity Organisation, Tokyo, 1991.

5. ABS Group Consulting Inc, Root Cause Analysis Handbook: A Guide to Effective Incident Investigation, ABS Group Consulting Inc, 1999.

6. Apte P., Shah H. & Mann D., "5W's and an H" of TRIZ Innovation’, The TRIZ Journal, September 2001.

7. Khomenko N., Private discussions on OTSM-TRIZ, 1997-2004.

8. Goldratt E.M, Theory of Constraints, North River Press, 1999.

9. Mann D., “Analysis Paralysis: When Root Cause Analysis Isn’t The Way”, The TRIZ Journal, May 2002.

10. Killander A & V. Sushkov V, “Conflict-Oriented Model of Creative Design”, in “Computational Models of Creative Design”, J.S. Gero, M.L. Maher & F. Sudweeks (eds), Queensland, Australia, 1995, 369-397.