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Clarifying the gap between how cause finding tools are described in literature and how they are used in real life

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Over the past couple of years the importance of fast product development has been increasing. This led to the fact that solving problems and creating more innovative ideas became imperative to do at a high speed. Many tools have been designed to help in this process, examples of this are cause finding tools. However, there is currently still a difference between how tools are described and how tools are used in organisation. This research focuses on indicating those differences and determining what still needs to be changed in the current cause finding tools. The conclusion of this research was that the biggest gap between theory and current usage is the need to include a method to structure all necessary information beforehand. This should include the stakeholders, the problem scenario, and information on the product and its functioning.

Evaluation, Design Method, Cause-finding Tool

1. Introduction

It is undeniable that there are requirements of product development these days. One of the key elements is that designing and producing new products need to be done at a fast pace[1]. Included in a fast development is the need to have the ability for fast problem solving. More importantly, there is a need for the ability of problem solving without making mistakes. Making fewer mistakes means that less time is wasted and fewer parts of the analysis have to be done again. Resulting in a faster product development [2].

To keep up with fast problem solving, a high degree of creativity is needed[3, 4]. To help the creative process and making innovative solutions, many different tools have been designed. Because of the large variety of tools, it can be difficult to determine which tool is best suitable for which situation. Important is that preferences of the tool are often dependent on the personality of the user [5, 6]. One such type of personality is structuralists; people who create the most creative ideas when they are working with a structured method. This type of personality was used to focus this research. This type was chosen because they place higher value in the use of tools, to help structure the process and in the end help generating solutions [5].

To help increase fast problem solving, many different cause-finding tools have been created over the past few years. Important is that all tools are also in need of constant improvement. However, often there is a difference between how tools are explained in research and how the tools are actually used in organisations. To help visualize the important aspects of a cause finding tool a research has been done comparing different cause finding tools against each other, but also comparing these tools with the opinion of experts in the field. This will give an overview of aspects that need to be considered when improving different cause finding tools.

This research consists of a literature review which is explained in part 2 and executed in part 3. In part 4, the conclusions of the literature review have been compared to expert opinions. These have been gathered through multiple interviews with different experts and through a survey. In part 5 the conclusion of the research is stated, which is followed by a discussion on the research in part 6.

2. Cause finding tools

For this analysis, a total of six different tools are compared. These tools have been chosen based on the main goal of the tool and on the availability of sufficient scientific articles addressing these tools. The chosen tools were found in articles that were also based on comparing different cause finding tools. The five tools that appeared 3 or more times were the *cause-and-effect-diagram* (CED), *Root Cause Analysis* (RCA), *Interrelationship Diagram* (ID), *Current Reality Tree* (CRT) and the *5 Why's* [7-11]. Lastly, the Root Conflict Analysis (RCA+) tool has been included in the research. This tool was included because of the focus of this study. This study focuses on structuralists, for this type of people it is highly recommended to use TRIZ, a Russian methodology focusing on improving products through abstraction of the problem and relating the problem to similar examples. These examples can be used to find solutions. The RCA+ is one of the TRIZ tools focusing on cause finding, therefore it is included. Below a short description is given on each of the tools.

2.1. Cause-and-Effect Diagram

The Cause-and-Effect Diagram is also known as the fishbone- or Ishikawa diagram. Officially this is a quality control tool, however, it can also be used to find causes of a problem [12]. The idea behind the tool is to describe causes of a problem, using different types of categories. Commonly used categories include: *man, machine, material, method* and *measurement*. Each category is placed on a different branch. Causes are collected by a team, these causes are related to one of the categories and added to that specific branch. If additional details are needed on one cause, more subbranches are added. Placing all the information on the branches creates the shape of a fishbone, hence the use of this term [13, 14].

2.2. Root Cause Analysis

Searching information on the Root Cause Analysis (RCA) is not easy, since the RCA can be interpreted as both a tool and a term

that describes all tools based on root cause finding. Therefore, a more specific tool was chosen, the lightweight RCA, also called the ARCA [15-17]. The ARCA focuses on group meetings, talking about the problem and possible causes, instead of doing a lot of research on the problem, looking through data and statistics. Because the focus of this tool is based on group discussions, the effort required is relatively low on the side of participants. However, the person responsible for the group meetings has a much higher work load. The tool uses a tree structure to describe all possible causes related to a problem. In this structure it is also possible to indicate relations between different causes [17].

2.3. Interrelationship Diagram

The Interrelationship Diagram (ID) is designed to clarify the intertwined causal relationships of a complex problem in order to identify an appropriate solution. To accomplish this, all causes related to a problem are noted down. By placing arrows between different causes, relations between different causes become visible. This makes it possible to determine which causes are affected by each other. By comparing arrows going in and out of causes, key factors of a problem can be found. Figure 1 shows an abstract example of such a diagram. As can be seen, there is no real structure to the placement of causes, this can lead to a chaotic overview [13, 18].

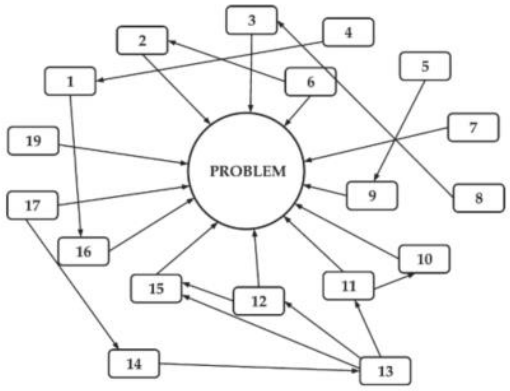

Figure 1.; An abstract example of an Interrelationship Diagram.

2.4. Current Reality Tree

The Current Reality Tree (CRT) has the goal to show how a system is currently functioning by displaying all effects, including undesirable effects (UDEs). In the diagram all negative effects must be explained. By defining system boundaries, UDEs, and relations between effects, a root cause can be found. The overview itself uses a tree structure, where relationships between different causes are indicated using arrows [13, 19].

2.5. 5 Why's

This tool is familiar and often used in organisations. One of the reasons for its popularity is that the tool is fast and the steps are easy. According to a study at Toyota, by asking five times the question: "Why?", a root cause can be determined [9]. This tool is mainly based on expertise of the user. The results are highly related to the expertise, tendency and willingness of the experts [20].

2.6. Root Conflict Analysis

This tool is related to TRIZ. The main purpose of the RCA+ is similar to the CRT: finding causes of a problem by looking at effects and how these are related to other causes. A difference however is that this tool focuses on finding contradictions instead of root causes. This is in line with TRIZ. A contradiction is when there is a cause that has both a positive and a negative effect. The RCA+ also uses a tree structure, similar to the CRT or ARCA.

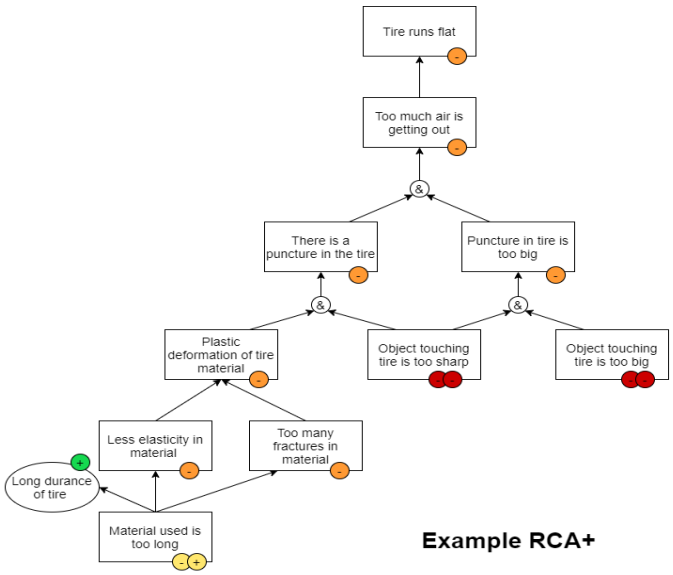

Figure 2.; An example of a Root Conflict Analysis.

3. Comparison of the tools

For the comparison of different tools, articles were gathered based on aspects that should be considered in a tool. From the articles, seven categories could be defined with which six tools are compared [21-26]. These categories are: transparency, planning, complexity of the tool, requirements, results, project teams, and influences.

It is important to note that information found in the articles about different cause-finding tools does not cover all categories. Therefore, the categories above have been grouped into four generalized groups. These groups are:

1. Information gathering;
2. Considered resources;
3. Readability & amount of information;
4. Evaluation of results.

Information gathering focuses on how information on a problem is collected. *Considered resources* is about the type of information that should be included in an overview. *The readability & amount of information* concerns the amount of information that should be implemented for a complete overview, while still keeping a comprehensive overview. Lastly, *evaluation of results* is about evaluating the correctness and completeness of the final results of an analysis.

3.1. Information gathering

Articles on the aforementioned tools all mention the use of brainstorming for creating an overview of the problem, where information is gathered through discussing different topics [13, 14, 17, 18, 27]. The amount of information retrieved from the methods mainly depends on the knowledge of the people present in a project. Although most papers only mention the use of knowledge through brainstorming, some papers state that information should be evaluated and supported by theoretical information and data [8, 17, 28].

According to the CED, ID, 5 Why's and RCA, information is found using the question: "Why?" In contrast to the RCA+ and CRT, which

specifically mention the use of "What causes?" A reason given for this is that the interrogative word "why" can be interpreted in multiple ways, which should not be possible with the words "what causes" [13, 20, 29].

3.2. Considered resources

Categories are mostly used to assure that the complete product problem is considered. Which categories should be used differs per tool. The RCA+ mentions the use of *time, space, material, functionality, supersystem* and *energy and forces* [30, 31]. The CED mentions that it is dependent on the preferences of the user, however, commonly used categories are *man, machine, material, method* and *measurement* [13]. The CRT bases their categories on the UDEs, which should be determined by the user, similar to the CED[27]. However, the RCA, ID and 5 Why's do not mention the use of specific categories. Still, all tools mention that the information in the analysis should be based on the complete product development[14, 17, 19, 32].

3.3. Readability and amount of information

Readability of the diagram is important, because if there is a lot of chaos in the overview it is possible to miss important relations or parts that influence the problem. For readability, most tools use a tree structure diagram, as mentioned for the RCA, CRT, RCA+ and 5 Why's [9, 12, 13, 15-19, 31]. The CRT, RCA and RCA+ also incorporate the dependencies of different causes. This is important when a product part should be redesigned. By knowing which other parts are related to that specific part, it is less likely that the importance to the other parts is not forgotten[13, 19, 31].

Another way to prevent users to create an overly complicated and chaotic overview is by implementing stopping guidelines. This is currently only implemented in the RCA+, CRT and 5 Why's. For the RCA+ an analysis is done based on the type of causes. If there is a contradiction, the branch is complete. If all branches have either a contradiction or non-changeable effect, the complete analysis is done. For the CRT the analysis is done when all UDEs are connected. The 5 Why's has as guideline that after asking "why" five times, the most important root cause is described [13, 17, 31, 33].

3.4. Evaluation of the results

According to the found literature, only the CRT and CED specifically mention the use of evaluation criteria. The CRT has included a checklist, which should be used to check all causes that have been noted down. The CED does not include a checklist, this method focuses on evaluating the chosen results by considering the data or performing additional tests. All the other tools did not include the evaluation parts in the tool. Clarification for this is that most researchers mention that the results of such an analysis is highly dependent on the executer, which can make a preconstructed checklist irrelevant, lacking or difficult to use [13, 14, 17, 27, 31, 32].

4. Expert opinions

Oftentimes, the way in which methods and tools are meant to be used is not how they are used in an organisation. Tools are adjusted to match corporate strategies and essential elements of current production. So that would be a necessity for fast product development. To determine the differences between how these tools are supposed to be used and how they are actually used, a comparison was done. For this comparison, methods as formulated in part 3 were compared to opinions of experts in the field. These opinions were gathered through a survey and a variety of interviews.

4.1. Information gathering

Similar to literature, experts also mention brainstorming as the main source of gathering information. However, where literature only rarely describes some form of analysis beforehand, most experts mention that this should be done. This information should take into account the stakeholders and product functioning. A tool specifically mentioned was the functional analysis (FA), a tool where the relations of all product parts are made visible, including the type of relation these parts have (positive, neutral or negative).

4.2. Considered resources

Expert opinion holds that which categories should be considered is dependent on the problem situation. This is in line with the theory behind the RCA, ID and 5 Why's. Categories should therefore be adjusted as the executer of the tool sees fit. Effort should be made to make sure that the analysis is still done properly, since it is of importance that the problem description is complete and understood by all people participating in the analysis. To do this, three aspects were suggested for consideration. These were type of problem, the scenario in which the problem occurs and lastly, the stakeholders of the problem.

4.3. Readability and amount of information

Most experts did not state a clear opinion on their preferred structure of the analysis itself. However, there were opinions related to the types of causes and the amount of details to include. It was stated that there should be a 20/80 ratio on the needed amount of information. Meaning that around 20% of all information in the analysis is useful, while the other 80% is not. Details give experts the assurance that there is a complete overview. Furthermore, it was mentioned that root causes should be physical or mechanical limitations, since this would, according to them, lead to the most innovative solutions.

4.4. Evaluation of the results

Literature showed divided results, where the CRT and CED included evaluation criteria and the other tools did not. Most experts stated that determining when an analysis was done and complete is based on gut feeling and experience. However, it was mentioned that the impact and controllability of the causes need to be considered and that the root causes need to be related to the problem description. Also, experts mentioned that final conclusions should be tested with data, this is similar to the CED.

5. Conclusion

Comparing what is written in literature and what is said by experts in the field there are several similarities but also differences. Both literature and experts mentioned the use of brainstorming as the main functioning of information gathering. Where papers mention that information is mainly based on knowledge, experts mention that although mostly knowledge is used, the knowledge needs to be constructed beforehand. Structuring this knowledge is mostly done with the use of pre-existing tools like the FA. Although some literature refers to the use of specific resources to help with the structure, most experts mention that the necessary resources are dependent on the type of problem that is analysed.

From the aforementioned categories it can be concluded that the experts think it is necessary to have a complete overview and

understanding of the problem situation. This overview needs to contain information on the problem scenario, the stakeholders and the product (parts) and its functionalities.

Improvement of cause finding tools should include more focus on the process before starting an analysis, with the focus of structuring information. An option for this could be some form of a template that includes all the aspects mentioned in the previous paragraph. By focusing more on structuring information, probability of an accurate and complete analysis is higher. Furthermore, it will help connect the different types of information and help prevent missing relations that can be vital for overcoming a problem and designing innovative solutions.

5.1. Further recommendations

Currently, not much is done for the evaluation of an analysis. Experts say it is mostly based on experience. This is in line with most tools, which don't include steps to evaluate at all. However, doing such an evaluation can help prevent designers from making mistakes that influence the design project negatively. Therefore, it could be useful to execute further studies on this subject.

Interestingly the economy and how companies should operate is focused on creating new products and improving products at a fast pace. However, most experts have mentioned that for them it is important that as much detail as possible is included in the analysis. This leads to excessive information included in their analysis, which takes more time and ultimately slows down the product development speed. Therefore, it would be interesting to further investigate what type of information is necessary compared to what type of information is preferred by people working in organisations.

6. Discussion

These conclusions were made based on information from the interviews with experts. Moreover, a survey was sent to various people in the TRIZ community. The goal of this survey was to gain an overall view of the opinions on the current state of the RCA+.

Unfortunately, the survey did not receive many responses. In order to still draw valid conclusions, at least 20 to 30 experts had to be participating - however, only 7 responses were recorded. Because there were so few responses, no conclusions could be made that represented a larger voice within the TRIZ community.

Instead, expert interviews were held. This allowed insights into more specific and detailed information. There are many similarities between the results from the interviews and the survey. All in all, more responses to the survey would have been preferred, this would make the opinions more representative of the needed improvements to the RCA+. However, since the results of the survey and the interviews show many similarities, the interviews probably still give a good representation of the opinions in the TRIZ community in general.

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