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► **To cite this version:**

Marek Mysior, Sebastian Koziolk. Hypotheses Analysis as a Development of the System Operator Method Used in TRIZ. 22th International TRIZ Future Conference (TFC), Sep 2022, Warsaw, Poland. pp.154-162, 10.1007/978-3-031-17288-5\_14 . hal-04449803

**HAL Id: hal-04449803**

**<https://inria.hal.science/hal-04449803v1>**

Submitted on 15 Feb 2024

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# Hypotheses analysis as a development of the System Operator method used in TRIZ

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**Abstract.** The purpose of this work was to formulate a novel method of problem definition and to apply this method as an extended version of the System Operator. In TRIZ, System Operator is used to describing context of the problem in time and space, which is of vital importance in many problem-solving approaches and forecasting applications. However, this known method concentrates on a single technical system and its alternatives and does not take into account other systems, that directly interact with each other. The proposed approach takes into consideration not only sub- and supersystems in the past and future but also the outcome of the problem and phenomena occurring in relation to the identified problem. The method is organized in a systematic way through a dedicated diagram and also utilizes a heuristic approach to identify and describe the context of a problem. The proposed method was applied to identify drivers and barriers to the development of vehicles and biogas distribution solutions. It was shown, that the proposed approach represents a significant and novel development of a System Operator that improves problem definition in the problem-solving approach.

**Keywords:** System Operator, TRIZ, Problem-solving, Inventive Engineering.

## 1 Introduction

In modern design problems, there is an increasing importance of proper problem identification and its description, which is often regarded as the most important part of conceptual design [1, 2]. In an ever-changing world around us, the capability to cope with the evolution of technical systems and technological processes often determines the ability of companies to remain on the market and compete with each other [3]. Concentrating our efforts on solving a problem that is not significant consumes available resources of time, information, material, energy, and space, giving no to little improvement. It was shown, that lack of understanding of customers' needs is one of the key issues in modern design approaches [4].

Proper identification of the outcome of the problem as well as its causes is thus of vital importance in an effective problem-solving approach. There are already existing approaches available that concentrate on problem modeling and identification of the root cause of the problem. In TRIZ, such tools as Contradiction Matrix [5], including analysis of the contradiction clouds [6], Cause-Effect Chain Analysis [7] and System Operator (also known as the 9 boxes) [8, 9] are commonly used. Those approaches are effective in defining the correspondence between different components of the problem but are not directed toward the quantitative description of the problem neither in the scope of its outcome, nor its cause.

Contradiction Matrix is an effective tool used to find potential solutions to the problem by modeling contradictions existing within a technical system or a technological process. But without a proper understanding of parameters describing the system or a process, there is a risk of solving a contradiction, that does not affect the outcome of the analyzed problem. Such a situation contributes to increased resources usage and limited usefulness of the outcome, decreasing the ideality of the design process.

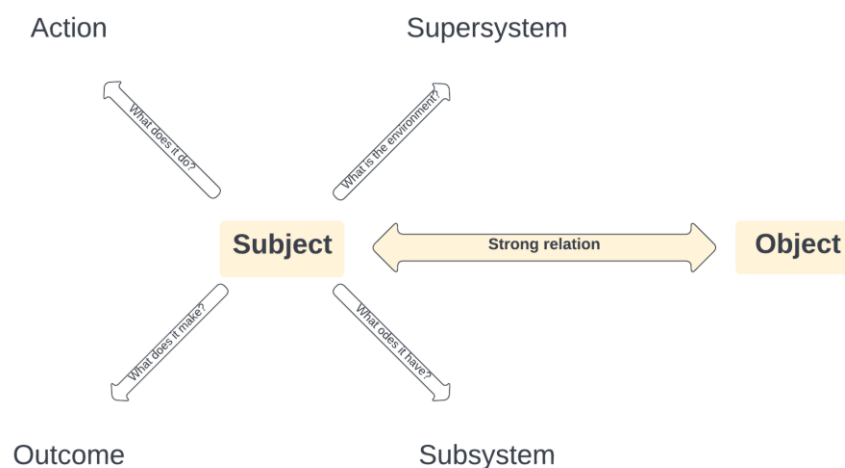
In Cause-Effect Chain Analysis, a problem is analyzed in the form of the creation of a cause and effect relationship. This analysis is usually performed heuristically, without an emphasis on the design of a measuring system that can verify the potential dependence between various layers of the problem.

A more broad approach is used in the System Operator Analysis, commonly known as the 9 windows analysis, in which a problem is being analyzed in the time domain (before-at-after the moment of problem occurrence) as well as the space domain (subsystem, system, super-system level). This is a very efficient approach in technology forecasting since it combines past, present, and future descriptions of technical systems and technological processes at different contextual levels [10, 11]. Although by taking into account space and time dimensions, there is still a lack of a systematic approach in the identification of parameters that directly describe the surrounding of the problem to be solved at different levels with the possible examination of their mutual dependence.

Having roots in Inventive Engineering by combining several TRIZ concepts into a single problem modeling tool, Hypotheses Analysis makes it possible to formulate hypothetical dependencies between various parameters describing the problem directly and indirectly. Each of those dependencies can possibly indicate the quantitative influence of the source parameter on the one resulting in the outcome of the problem. This in turn allows establishing distinct limits for the parameters to be designed to solve the problem, leading to the formulation of the technical specification of a technical system or a technological process. In the next chapter, a detailed description of the process of creation of the Hypotheses Map is shown. The following chapters present examples of Hypotheses Maps for various examples and a selected example of the application of the analysis as an expansion tool for the Contradiction Matrix.

## 2 Materials and methods

Hypotheses analysis is primarily used to establish a set of parameters, that directly and indirectly contribute to the outcome of the problem. This leads to the formation of the measurement system, in which the mutual influence of parameters is examined, determining causal relations. Knowing this influence, one can identify the source of the problem and define quantitatively the expected outcome of the problem-solving approach. The first step in the creation of the hypotheses map is to identify parameters that describe the outcome of the problem. If there is more than one key parameter describing the outcome of the problem, hypotheses analysis should be performed for each one of them separately. Each problem refers to the particular object, that is being directly affected by the problem. The presented approach is based on the assumption, that the problem to be solved exists due to the existence of a strong relationship between the subject and the object. The subject is a technical system or technological process that is directly connected with the problem to be solved. This stands in agreement with the principles of functional analysis used in TRIZ [12, 13]. From the point of view of the subject, there is an ambiguity in its selection, because at this stage it is unknown, which system directly influences the outcome of the analyzed problem. One can select the subject at different levels, depending on the area in which the problem-solving approach is being conducted. The subject is being analyzed from the point of view of its function (*what does it do?*), supersystem (*what is its environment?*), subsystem (*what does it have?*), and outcome of the function it performs (*what does it make?*). Let us consider the exemplary problem that is the bicycle accident. In this case, there will be a strong relationship between the Bicycle (*Subject*) and the Cyclist (*Object*), since the Cyclist is directly affected by the outcome of the problem. The selection of the bicycle as a subject creates a hypothesis, that the problem can be solved within that Technical System. The scheme of the hypotheses map at this stage is shown in fig. 1.

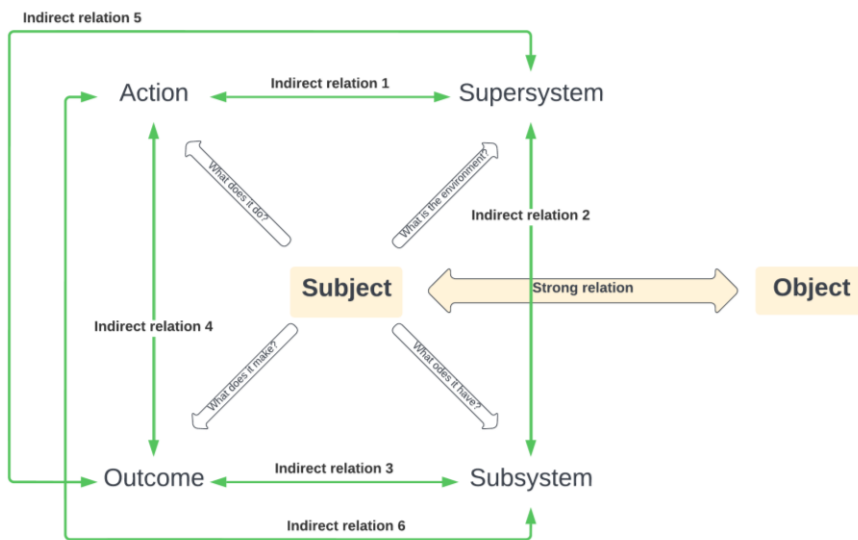


**Fig. 1.** Scheme of the hypotheses map, strong relation

The following process involves the definition of 6 relations in the form of physical phenomena that exist in conjunction between each of the four elements of the hypotheses map, as shown in fig. 2. Those relations, existing between:

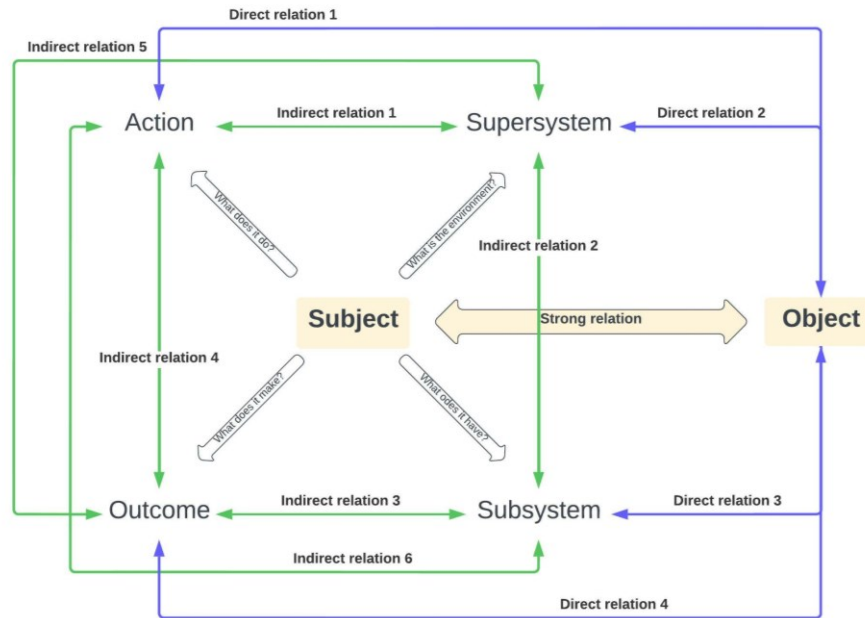
- Action and Supersystem,
- Supersystem and Subsystem,
- Subsystem and Outcome,
- Outcome and Action,
- Supersystem and Outcome,
- Subsystem and Action,

are regarded as indirect relations, thus not directly corresponding to the subject and outcome of the problem to be solved. Each of those relations can be described by a set of measurable parameters, that can potentially form a direct cause and effect relation with the outcome of the problem, reinforcing or weakening it.



**Fig. 2.** Scheme of the hypotheses map including relations

At the final stage of the process, 4 direct relations are being defined between the object and the Action, Supersystem, Subsystem, and the Outcome. Those are the relations that are directly related to the outcome of the analyzed problem and can represent a set of measures describing it in a quantitative way. Usually, those relations are described in a similar way to those indirect relations, being physical phenomena that occur in conjunction with relating elements. A measure of those direct parameters contributes directly to the outcome of the problem and may represent a measure of the significance of the problem for the customer, A complete scheme of the hypotheses map is shown in fig. 3.



**Fig. 3.** Scheme of the complete hypotheses map

Performing Hypotheses Analysis at different levels makes it possible to identify many potential solutions to the problem, forming a set of potential solutions. Each one of them is then analyzed from the point of view of ideality or innovativeness, leading to the selection of the ideal/most innovative solutions.

### 3 Examples of hypotheses maps

In this chapter, several exemplary diagrams are presented to demonstrate the idea behind the formation of the Hypotheses Map. The first problem to be analyzed is connected with preventing of accidents occurring on motorbikes. The outcome of the problem, which can be measured by the number of accidents every year, is directly affecting motorcyclists. The area, in which this problem can be solved can be oriented towards the motorcycle or the protective equipment he/she is wearing. This forms two relations:

1. Motorcycle – Motorcyclist
2. Protective equipment – Motorcycle

On fig. 4, a hypotheses map of the first relation is shown, and on fig. 5 of the latter one.

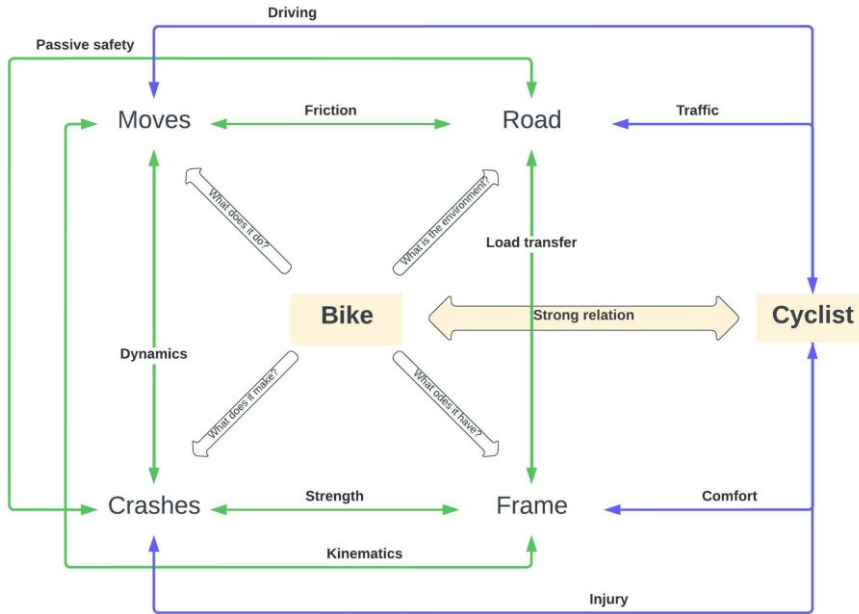


Fig. 4. Hypotheses map of a bicycle crash problem, point of view of the bike.

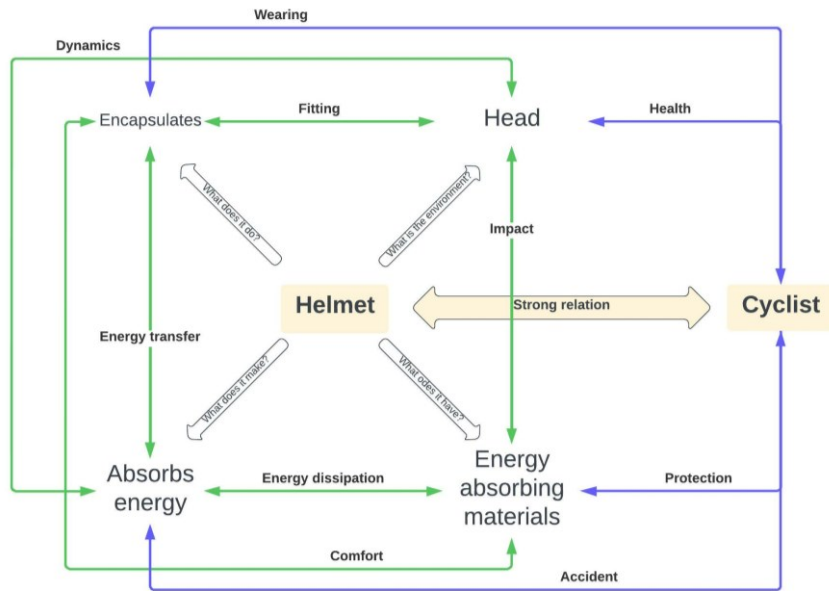
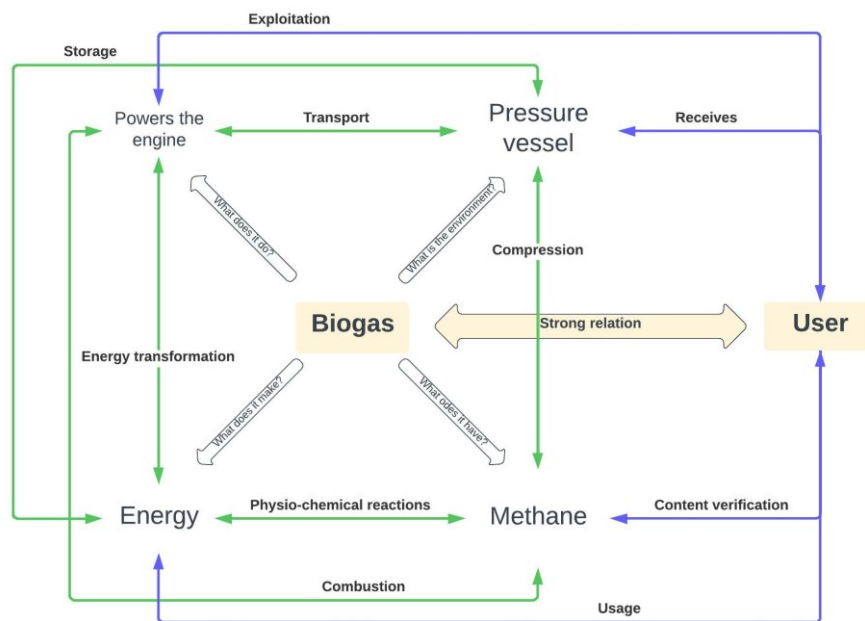


Fig. 5. Hypotheses map of a bicycle crash problem, point of view of the helmet.



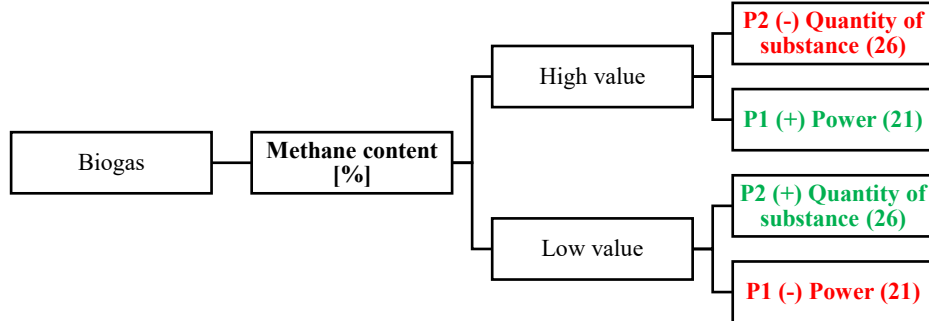
#### 4 Applications of the method in problem solving

Development of gas delivery systems are of huge interest currently. One of the solutions to meet growing demand on energy obtained from green, environmentally friendly sources is located in Biogas. This opportunity is of growing concern worldwide [9, 14–16]. Applying a Hypotheses Analysis to this problem results in the following map, as shown in fig. 6. The strong relation is defined between the biogas (as a potential source of energy) and the user that will consume it.



**Fig. 6.** Hypotheses map of a biogas delivery system, based on [17].

For each relation shown on the map, a set of parameters can be defined that directly (shown in blue) or indirectly contributes to the outcome of the problem. Examining those parameters can uncover contradictions existing within the analyzed Technical System or Technological Process. An example of such contradiction for “combustion” that exists in conjunction with Methane and powering of an engine is described in fig. 7.



**Fig. 7.** Contradiction model based on the parameter describing relation of “combustion”

From this point, there is a possibility to use Contradiction Matrix and 40 Inventive Principles to find potential solutions to the problem, in this case:

- (4) assymetry;
- () discarding and recovering;
- () periodic action.

## 5 Discussion and summary

The proposed approach represents a significant development in the problem-solving approach and expands the application of the System Operator known in TRIZ to be utilized as a tool for measuring system design. Working with conceptual design is difficult due to very limited access to measurable that are of vital importance in innovativeness assessment [18]. Hypotheses analysis makes it possible to identify a broad set of parameters related to many different Technical Systems or Technological Processes associated with the analyzed problem. The goal of this approach is to identify those parameters, that affect the outcome of the problem the most and concentrate the problem-solving approach on alternating the value of the said parameter, improving it. Additionally, identification of parameters influencing the outcome of the problem, it is very common to define technical and physical contradictions, which makes it possible to use other TRIZ tools like Contradiction Matrix and 40 Principles to seek the solution. As compared to the System Operator, Hypotheses Analysis concentrates not only on the context of the Technical System or Technological Process from the point of view of scale and time but also manifests causal relations within the surrounding of the problem. By applying this approach to the problem of green energy generation from methane, it was possible to identify the set of solutions based on solving contradictions between the Volume of the stationary object (8) and Strength (14). The quantitative feature of this tool is of great importance in the formulation of contradictions.

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