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A global approach to point out priority problems out of experts' qualitative data

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Abstract. TRIZ methods have been developed and are widely used to solve problems. But one of the recognized limitations of these methods is the way to identify the priority problem to consider. This step of problem-solving process corresponds to the Analysis of Initial Situation, and has been developed as a part of the first versions of ARIZ, but then not pursued to be developed as an independent process. In this article, the authors aim is to develop a method enabling this identification of the priority problem, out of qualitative information, based on problem experts' interviews. The proposal is based on the exploitation of the OTSM-TRIZ Network of Problems in order to build a Network of Parameters. This second network is a graphical representation of all the influence relationships between the parameters of the system. This representation leads to a new understanding of the problematic situation, and to the identification of new directions for the problem solving steps. The proposed method will be illustrated on a case study related to plastics injection moulding process.

Keywords: Qualitative data, problem formulation process, network of parameters, priority problem identification.

1 Introduction

TRIZ methods have been widely used and recognized as a powerful mean to solve technical problems [1]. The TRIZ matrix and their 40 Inventive Principles are among the most used and known tool around the world [2], and ARIZ-85C the most generic method to analyze problems in order to search for solutions [3]. But both required to first state what is really the problem to be considered. The Matrix required to have already formulated technical contradiction, which, in the frame of TRIZ methodology imply having define the mini problem [4]. This mini problem that is also the entry point of ARIZ-85C.

Thus, the use of TRIZ methods imply to already know which problem to consider. And it is also recognized, not only for TRIZ-based approaches, that framing a problem as a key stake in problem solving process [5]. Several approaches have been proposed to tackle this step, among them the old versions of ARIZ [6], the network of problems defined by Khomenko [7], and different ways to hierarchize contradictions [8]. All

these approaches aim at formulating contradictions, at different levels and thus at identifying the main impacting contradiction, the one that could lead to more robust concept solutions.

In [9], the authors have presented a new way to formulate and consider the System of Contradictions (SoC), by a generalization enabling to: 1. always be able to identify a SoC for a problematic situation; 2. formulate SoC really representing the problematic situation, as real industrial problems do not rely on only two Evaluation Parameters (E.P.) and one Action Parameter (A.P.).

The classical TRIZ SoC is based on the consideration of the variation of one A.P. impacting two E.P.s, whereas first analysis of situations with experts is the comparison of different configurations of systems, each having their benefits and their limitations. And it is often difficult to reduce this formulation of pros and cons of different configurations to a classical SoC. The Generalized System of Contradiction (G.S.C.) is based on the elicitation of problems considering two states of a system, implying all the benefits and dissatisfactions of these two states. But the previous problem of the choice of the priority G.S.C. to be considered remains, as the number of possible G.S.C. is huge [10, 11].

In this article, the authors aim at presenting an approach to help in choosing the priority problem to consider when analyzing a problematic situation, which analysis is based on the extraction of qualitative knowledge with human experts (approaches based on quantitative data is presented in [12-14]). The article is built as an initial presentation of already proposed TRIZ-based methods for the Analysis of Initial Situation (A.I.S.); then a short presentation of the G.S.C.; a third part will introduce the proposed method to identify priority problem to consider; for which an application will be illustrated on a case study; before concluding and discussing the benefits and limits of the proposal.

2 TRIZ Based methods to analyze the Initial Situation

In this part will be presented different ways to identify the priority problem to consider and to help choosing which SoC has to be tackled first. The older versions of ARIZ, the OTSM-TRIZ network of problems, its use in I.D.M.

2.1 ARIZ evolution

The Analysis of Initial Situation has been present in TRIZ methods since the first versions of ARIZ [15]. But at the end, G. Altshuller considered that ARIZ has been well developed for the resolution of mini problems but that the way to choose this mini problem has to be developed independently from ARIZ, so the last classical TRIZ version of ARIZ [16] do not integrate anymore a part dedicated to the A.I.S. Indeed, TRIZ development lead to a set of methods based on a 5 steps process:

1. The analysis of initial situation
2. The definition of the problem
3. The definition of the ideal solution
4. The definition of a physical solution (generic concept of solution)

5. The definition of a technical solution (more specific concept of solution, with specification of the used resources)

But one can notice that the last Altsuller's version of ARIZ (ARIZ-85C) only fits the 4 last steps. The last version incorporating it is ARIZ-85A [17], and is still one key stake in problem solving process. The matter was the recognition that the proposed method for this step was not as developed as the methods inherent to the other steps, thus it was proposed to develop a specific program to tackle this analysis of initial situation.

Thus, the first part of ARIZ-85A can be referred as the last version of classical TRIZ A.I.S. It is a 9 steps algorithm aiming, by a set of questions to better frame the considered problematic situation, and to ensure that no trivial solution can be found, by the use of Vepole and patents analysis. But no real guide is proposed to help in hierarchizing problems.

2.2 OTSM- TRIZ network of problems

During TRIZ development, Altshuller proposed to tackle the following questions: "what should be the conical form for the description of the problem and what should be the canonical solution procedure?" [18]. The answers to these questions were developed within the framework of the 'General Theory of Powerful Thinking' (Russian acronym – OTSM) [19, 20]. The OTSM-TRIZ proposed 4 technologies: the New Problem Technology, the Typical Solution Technology, the Contradiction technology and the Problem Flow Technology.

In this part, two of these technologies could be highlighted as they contribute to the Analysis of Initial Situation. The Contradiction technology has been defined to help in solving problems, based on the use of the Ideal Final Result and by the analysis of the available resources. But one of the key benefits of OTSM-TRIZ related to the Contradiction analysis is the clarification of the link between Physical Contradiction (Contradiction of the Parameter in OTSM-TRIZ terminology) and Technical Contradiction (Contradiction of the System in OTSM-TRIZ terminology). This link leads to the model of System of Contradiction (detailed in chapter 3, cf. figure 5).

The New Problem technology aim is to clarify a problem and choose a problem to be solved. In the frame of this New Problem Technology, the Network of Problems has been proposed. The Network of Problems is an oriented graph representing the problematic situation enabling thus to analyze overall knowledge of the initial situation. Nodes of the Network of Problems are either problems, or Partial Solutions. Then, different kind of links exist: From a super-problem to a sub-problem; from a problem to a partial solution; and from a partial solution to a problem. These kinds of links are illustrated on figure 1. The benefit of the Network of Problem is to help in identifying, based on the architecture of the graph, the priority mini problem to consider, but the way this mini problem has to be formulated is not immediate. The IDM approach proposes a way to formulate Systems of Contradictions out of the Network of Problems.

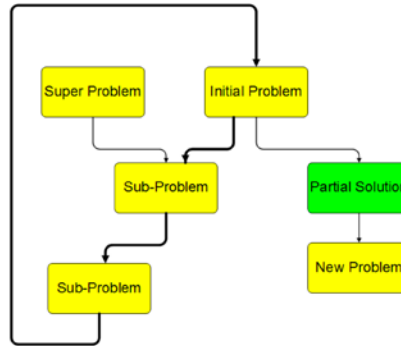


Fig. 1. OTSM-TRIZ Network of Problems [7]

Based on this NoP, a way to link several SoC has been proposed in [21, 22] to build a Network of Contradictions, as soon as a same A.P. (called Control Parameter) influences several Technical Contradictions, as illustrated on figure 2. This enables to classify A.P.s and E.P.s in regard of their implication in the all set of SoC. But, it does not take into account the potential influences between A.P.s.

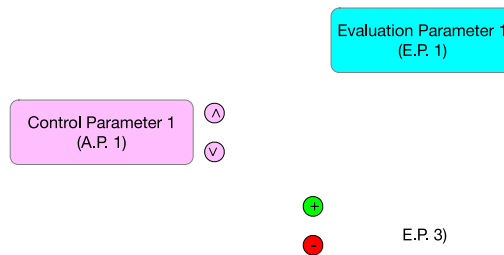


Fig. 2. Network of Contradictions [22]

2.3 IDM-TRIZ technical contradictions hierarchization

In Inventive Design Method (IDM), a step to extract the Systems of Contradictions out of the Network of Problems has been proposed [23]. This step is the elicitation of parameters inherent to the constructed Network of Problems. Thus, each identified Problem will be defined as Evaluation Parameters to be satisfied, and each Partial Solution will be defined as Action Parameters impacting the E.P. [24]; and each link of the NoP will represent an influence relationship between parameters. Based on this representation a new kind of contradiction has been proposed, the polycontradiction, that represents the influence of one Action Parameter on more than two Evaluation Parameters (as illustrated on figure 3), as it is limited in classical TRIZ SoC. Then the choice of the priority polycontradiction to be considered is made, based on: the weight on the influence of A.P., the strategic weight of the E.P. present in the polycontradiction, and also the number of polycontradictions based on the same A.P..

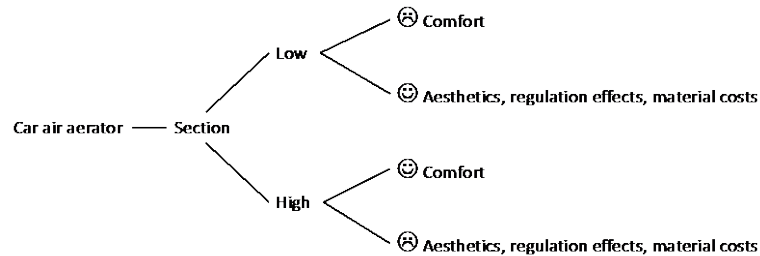


Fig. 3. IDM-TRIZ polycontradiction [23]

This approach enables to overcome one limitation of classical TRIZ model of SoC, the limit to two E.P.s, which does not seem reliable to well represent real industrial problems. But the IDM method do not consider these poly-contradictions for resolution, once the priority polycontradiction is chosen, it is decomposed in classical TRIZ SoC to enable the use of TRIZ inventive principles. Moreover, as for the previously presented Network of Contradictions, the potential influences between A.P.s are not considered in the modelization of the problem.

2.4 Cause-effect approaches

Another kind of approach to identify priority mini-problem is the use of Cause-effects chains [25, 26]. This enables to go from an identified problem to a more precise description of the root cause of this problem. This can be seen as a graphical representation of the 5-whys method, adding the information of potential contradiction, as illustrated on figure 4.

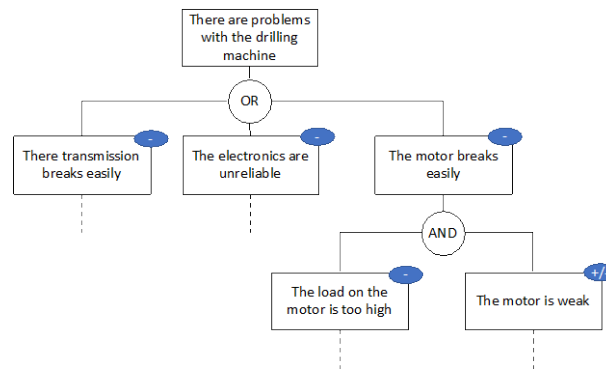


Fig. 4. Example of a Cause-Effect Chain Analysis [25]

This approach can lead to two drawbacks, as with previous approach, it only leads to the formulation of classical TRIZ SoC, but also, it does not provide a way to change the perception of the priority problem, as it decomposes it to identify its cause, but without providing a larger consideration of the system to identify, more objectively the real problem to be considered.

3 Generalization of the System of Contradictions

The formal limit of the OTSM-TRIZ SoC, has been highlighted by the authors (refs GSC), and they propose a Generalization of this SoC to be able to overcome these limitations. The Generalized System of Contradictions (GSC) is presented in figure 5, in comparison to the OTSM-TRIZ SoC.

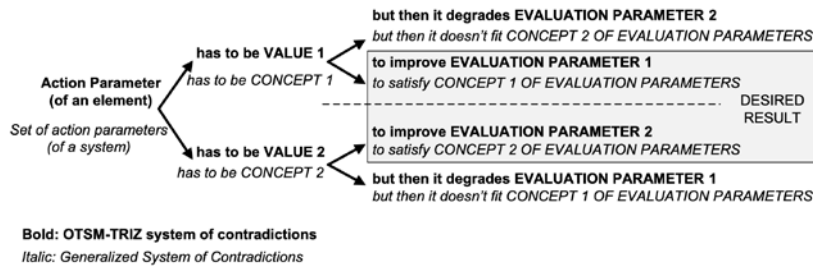


Fig. 5. OTSM-TRIZ system of contradictions and Generalized System of Contradictions [27]

This GSC model ensures the fact that in a given problematic situation, when no solution is known, a contradiction will always be possible to formulate. This equivalence between no solution and the existence of a contradiction is not formally true neither in OTSM nor in IDM models of contradictions. But the problem of choosing the priority GSC is even more complicated, as it has been illustrated that the amount of GSC that can be formulated in a given problematic situation is huge [10, 11]. Ways to automatically extract and to hierarchize GSC have been proposed in [14] for quantitative data, for example, based on the analysis of Designs of Experiments.

In this article, an approach based on quantitative knowledge, extracted from experts' domain interviews will be illustrated, as often, the problematic situation analysis first starts with this kind of interviews. Simulation, Design of Experiments or other quantitative data are not always available. And if the relationships enabling to link parameters with quantitative data are easy to obtain, working with qualitative data requires to elicit these relationships based on human knowledge. The next part of the article will illustrate the proposal to treat such problematic situation.

4 A method to point out priority problem

The proposed extraction of the knowledge (represented on figure 4) to build a model of the problematic situation and an analysis enabling to frame, step by step contradictions, is based, in first steps on the questions of AIZ-85A. Then a table of relationships is built in order to be able to understand all the design parameters of this system impacting the problem. These relationships enable a graphical representation through a Network of Parameter, which is then used to propose the priority GSC to consider. This process is then an eight steps process:

1. Determining the final goal of the searched solution, will mainly state the Main Useful Function of the considered system, and a first list of the more important Evaluation Parameters that will enable the recognition of the solution
2. The formulation of known (by experts) and existent (by patents analysis) solutions and of bypass approaches. This enable to choose explicitly the level on which the problem will be analyzed, and also to extract an initial list of Partial Solutions.
3. Based on these data a NoP is built, which will be completed by the discussion with experts, in order to have an exhaustive representation of the problematic situation, avoiding to restrict the formulation of the problem to the first a priori of experts.
4. The NoP will thus be analyzed the way proposed in IDM, i.e. each Partial Solution will be formulated as the modification of an Action Parameter, whereas each Problem will be formulated as an Evaluation Parameter to satisfy.
5. A table of relationships is then built in order to extract how A.P.s impact E.P.s, but also, to identify the influence between A.P.s. the way relationships are fulfilled is illustrated in table 1.

Table 1. Instantiation of relationships.

	Action Parameter 1	Action Parameter 2
Evaluation Parameter	②	-①
Action Parameter 1		-②
Action Parameter 2	①	

AP1 increase → EP1 is improved a lot AP2 increase → EP1 is degraded a little
 AP1 increase → AP2 increase a little AP2 increase → AP1 decrease a lot

In a DoE, A.P.s should be independent, but here, the way it is extracted, through discussion with experts, do not ensure this independence. And this influence could have importance when choosing the more impacting A.P. in the problematic situation.

6. The table of relationships is filled by human experts, considering parameters pairs by pairs. Some inconsistencies could be present in the global table, for example:
 - AP1 should be increased to improve EP1
 - AP2 increases when AP1 increases
 - AP2 should be decreased to improve EP1
 Such inconsistencies have to be analyzed and corrected to have a consistent table, on which conclusions will be built.
7. All these relationships are then represented graphically through a Network of Parameters, in order to point out the more impacting A.P.s
8. This Network of Parameters is then analyzed to identify the priority GSC to consider for resolution and for which the resolution steps will be performed.

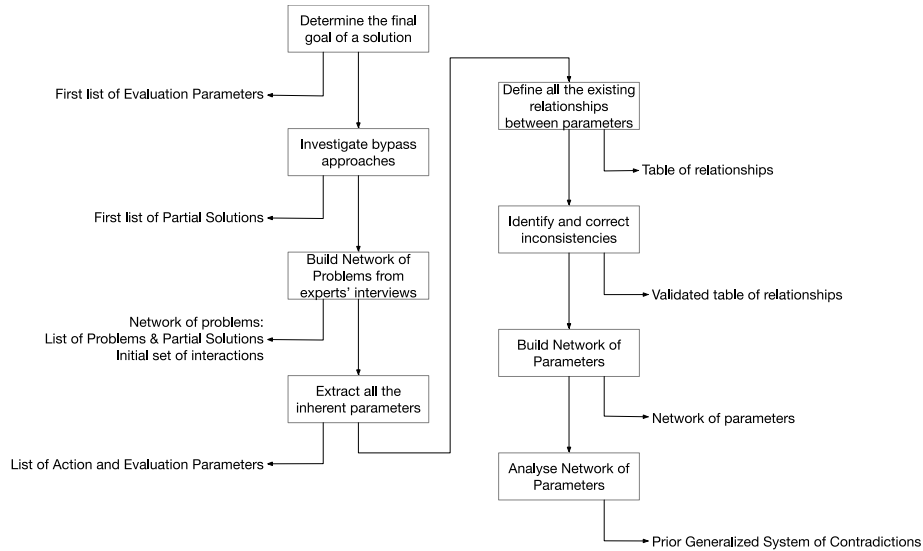


Fig. 4. Process to extract the priority GSC

The application of the method will be illustrated in the next part.

5 An application in injection moulding

The presented case study has been conducted with a group of 5 experts of the company Faurecia and two TRIZ experts from INSA Strasbourg. The initial presented subject was: “how to reduce the required clamping force for injection moulding process”. The previously presented process has been applied to identify key levers and to choose the priority contradiction to be considered. The global context of the study is given in this article, but, for intellectual property reasons, some parameters will be formulated a generic way.

5.1 The initial understanding of the problem

Not all the steps will be detailed in this article, but the key steps, and the evolving of understanding will be demonstrated. The human experts had a first understanding of the problematic situation, pointing out one E.P. (noted EP3) on which the study had to focus on, and considering as the main way to improve the situation to work on A.P.3 (Partial Solution 3). The NoP, step 3 of the previously presented method, was built using the PICC software¹, and lead to a list of 21 Problems and 14 Partial Solutions, as illustrated on figure 5, where the a priori most important problem to consider is circled in red.

¹ <https://www.picc-solution.com/>



Fig. 5. Network of Problems for injection moulding case study

Then the step 4 of the proposed method aims at analyzing the NoP in order to:

- Identify one E.P. for each Problem
- Identify one A.P. for each Partial Solution
- Weight the direct relationships: each arrow of the NoP represents a direct influence between two parameters, this influence is weighted, between -2 (high inverse influence) and +2 (high direct correlation)

This gave a first version of the table of influences which was the basis for analyzing and completing this initial situation analysis.

5.2 From table of influences to Network of Parameters

The table of influence did, at the beginning, only point out the direct links extracted from the NoP. But then, the influence of each A.P. on all the E.P.s has been considered, as has been considered the influence between all the A.P.s.

Thus, a second version of the table of influences was built, but the danger, when considering the influence pairs by pairs is to define inconsistencies, when fulfilling a table of 300 cases. An algorithm has then been built to check for these inconsistencies. Two main reasons explain the revealed inconsistencies:

- Simply an error when filling the table
- Two relationships concerning the same A.P. defined considering two different contexts, an influence could be true considering a version of a system, but false if considering a variant of the system. This implied that another parameter has

been modified between the two versions. And it thus leads to the addition of a new A.P. in the table of influences.

A new, corrected, version of the table has then been built, an excerpt is shown on table 2, and is the output of step 6 of the defined method. In this table, the E.P.s were also weighted, with their Strategical Impact (S.I.) representing the importance to satisfy the considered E.P., in the actual context of the problem.

Table 2. Corrected version of the table of influences.

	S.I.	AP1	AP2	Percentage of reaction oriented surfaces	Number of adjustments	Contact surface between mold sides	Milling technology	AP3	Tenacity (t/ha)	AP5	AP6	Complexity of mold shape
Evaluation Parameter 1	10	0	0	0	0	0	0	0	0	0	-2	0
Evaluation Parameter 4	10	-2	-1	-1	0	0	0	-1	0	-1	-2	-2
Evaluation Parameter 3	10	-1	-1	-2	0	0	-1	0	-2	2	-2	-1
Presence of burrs (numbers, mm)	10	1	1	2	2	0	0	1	0	2	1	0
***							***					
Injection machine number	1	0	0	0	0	0	0	0	0	0	0	0
Action Parameter 1			-1	0	0	0	0	0	0	0	2	0
Action Parameter 2		0		0	0	0	0	0	0	0	0	0
***							***					
Complexity of mold shape		0	0	0	0	0	0	0	0	0	0	

This table of influences then list all the Evaluation and Action Parameters and also all the relationships between these parameters. Analyzing such a table to choose a problem is not convenient, so a graphical representation of these relationships has been proposed (cf. figure 6). This Network of Parameters has been built using the software Cmap Tool².

One of the interests of this graphical representation is to have a direct vision of the SoCs. The figure 6 shows that different colors have been used for each A.P. to better see their influence in the global network. The A.P.s have been colored in grey, whereas the E.P.s have been colored in orange. Logically, all the E.P.s can be considered as sinks in the graph, whereas the A.P. are either sources, or intermediary nodes, depending on the fact that they are influenced by other parameters or not. Finally, the thickness of the arrows represents the weight of these influences.

² <https://cmap.ihmc.us/>

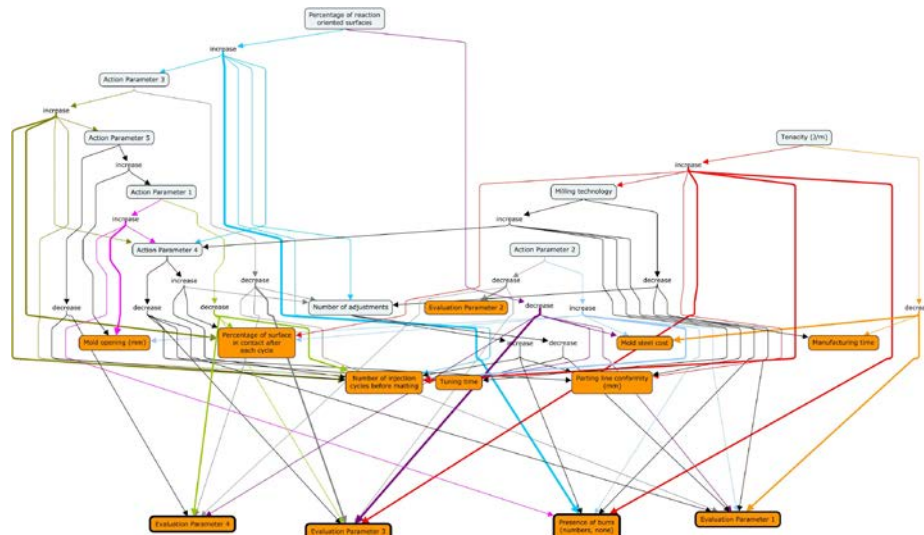


Fig. 6. Network of Parameters for injection moulding case study

5.3 Analysis of the Network of Parameters and definition of a strategy for resolution

One can consider the Network of Parameters represented on figure 6, and quite easily see that the first understanding of problematic situation by human experts (A.P. 3), even if influent in the net, is not the most promising parameter to consider. Indeed, two sources for the net lead to two SoC that have more impact on the most strategic E.P.s: the SoC based on the tenacity, and the SoC based on the percentage of oriented surfaces. This last proposed Soc totally changed the perception of the problematic situation, as the first understanding was on the way to design the mold, but the new understanding is on the way to control the flow of injected plastics. This new direction leads to the reformulation of a new mini problem, for which ARIZ-85C was applied and new promising concepts were proposed. The main benefit of this approach is that the global method seems logical, and even if, in the first statement of the new problem, experts are surprised, when reconsidering the logic of the way this statement has been built, based on their knowledge, they are forced to accept it, and recognize it as a potential new direction to consider.

6 Conclusion and discussion

The objective of this article was to present an approach to conduct the Analysis of Initial Situation when no quantitative data are available and aiming at being able to consider not only OTSM-TRIZ SoC, but generalized ones.

The benefits of this proposed method, illustrated through the case study is to enable, to have a more global understanding of the problematic situation and thus to build a strategy for resolution not based on a experts' preconceptions. Lot of information has

to be considered to enable this global understanding of the problem, but to be able to synthesize strategies, a simple way of analysis has to be proposed. The graphical representation of the Network of Parameters aims at proposing it. The influences appear clearly and the structure (what are the sources?) of the net help at building this strategy.

But some drawbacks still exist. The main one is linked with the fulfilling of the table of influences. A part of it can be made automatically, by the extraction of the elements available in the Network of Problems, but it is still necessary to consider all the pairs of A.P./E.P. and of A.P./A.P., and this is time consuming. Of course, this step could be shared among the experts participating to the study, but it more reliable to conduct it as a team group, to ensure that everybody agree with the quotations. A way that could be interesting to consider overcoming to this limit is to consider, once the parameters have been formulated the mechanical laws underlying the relationships; then the table could be, ideally, filled automatically. One limit to this proposal is the fact that considering the parameters without clearly defining the context may lead to wrong relationships.

Whatever, this step of eliciting the relationships and fulfilling the table of influences will be considered as the next step to be improved in the proposed method.

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