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# Integrating the Generalized Table of Parameters and Contextual Database in an Inventive Design Method to Extract Problems to be Solved

*Numerous TRIZ-based methods to extract the core problems to be solved within the inventive problem-solving process are released. Nevertheless, one acknowledged limitation of these methods is how to select the most important problem, "contradiction," to be solved. One of the interesting developed tools to model the system parameters is the Generalized Table of Parameters (GTP). However, the GPT has not yet been integrated as an essential tool within TRIZ-based methods. In this article, we aim to develop a method to integrate the GTP in the inventive design process to extract the most important contradictions to be solved. To illustrate the presented method, the authors would apply the method to extract the prioritized problem to be solved of a mechanical shock absorber based on lattice structure within a particular mechanical field context.*

***Keywords:*** *Generalized Table of Parameters, Contextual Database, Contradiction, TRIZ, Lattice Structure, Energy absorption.*

## 1. INTRODUCTION

In the frame of problem-solving methods, there are two types of problems: first, those problems that can be solved by using optimization methods (Routine met–hods), and others that cannot be solved by optimization methods (Inventive methods) [1]. Searching for a solu–tion by using routine methods is an effective approach in many situations and for many problems, but it is not an effective approach when it comes to an inventive problem that requires adding new variables and new relationships between these variables. Since routine methods search for potential solutions within the stated problem space, then there is a probability of finding a final global solution. Otherwise, inventive design theories and methods propose changing the stated problem space and, therefore, defining a new space of the problem. One of the inventive design problem-solving methods is the iterative inventive design method [2,3], shown in Figure 1.

The iterative inventive design problem-solving method that is intended to be enhanced in this work is composed of an iterative process step, which is based on four main phases: Analysis of the initial situation, which is the first phase in the inventive design problem-solving method. During this phase, the objective is to understand the administrative contradiction and, hence, understand the system itself. The context of the problem has to be understood at this level, such as the initial problem, constraints, requirements, and final goals. To achieve this goal, pertinent information is collected and derived from sources like literature reviews, expert insights, experiments, patents, internal company records, and other relevant data concerning the topic.

The second phase is one of the important phases in the inventive design method. In this phase, the system is modeled by its parameters and their interactive relati–onships. Modeling the problem can be implemented by using different approaches [4]: Experimental approach, Numerical approach, Analytical approach, and Quali–tative approach.

For developing the first two phases, [5] proposed the Generalized Table of Parameters (GTP), which is linked to the Contextual Database (CDB) to enhance the mo–deling of the system and facilitate analysis of the initial situation by providing a comprehensive, organized syn–thesis of relevant system information, enabling efficient problem formulation.

The third phase is optimization, which is a systematic refinement of system parameters to achieve better designs. Inputs to this process encompass system models generated through various approaches, such as regression modeling, while outputs yield optimized design solutions and/or partial solutions. Some research work exploits optimization methods and related developed ones for both single-objective [6] and multi-objective problems [7,8]. At this level, if objectives are achieved, then the loop is left. Otherwise, there are two scenarios: either the compromise of solutions is accepted, or the model has to be changed.

Moving to the fourth phase, which is the model changing, this phase is composed of two sub-phases. Through the first sub-phase, the core problem of the system should be formulated through the contradiction model. The second phase in model changing is to solve this extracted contradiction. The inventive design theories and methods propose changing the stated problem space and, therefore, defining a new space of the problem. Some inventive methods are based on TRIZ theory [9] (Theory of Inventive Problem Solving),

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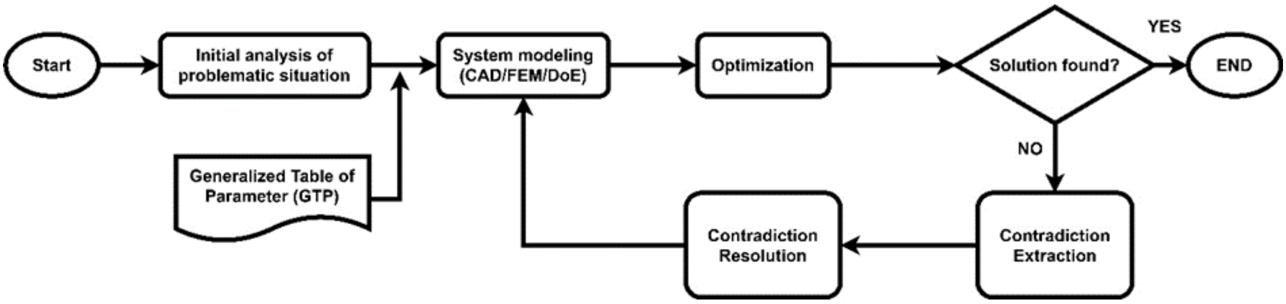


**Figure 1: The iterative inventive design method**

and others are not based on TRIZ. Some examples of the non-TRIZ-based methods used for the inventive process are C-K theory [10], Axiomatic design [11], Function–Behaviour–Structure (FBS) Framework [12], and Brainstorming [13]. In this article, the focus would be more on developing the prioritization of the design problem by extracting the most important problem to be solved, also called a generalized system of contra–dictions (GSC), out of the generalized table of para–meters within a TRIZ-based method.

To illustrate the proposed method, a case study was presented. This case study focuses on designing an energy absorber with a primary component being a lattice structure, aiming to enhance industrial mecha–nical energy absorbers in applications like helmets or packaging. Utilizing lightweight polymer materials for the lattice structure, the primary objective is to create a system that excels in mechanical energy absorption, rigidity, and lightness, which is crucial for improving industrial applications in the mechanical field when optimizing these three characteristics is paramount.

In this article, we aim to develop a method to exploit the generalized table of parameters GTP within an inventive design process to extract a generalized system of contradictions GSC. The new method has to be a systematic approach, which is not loaded heavily with users' level of experience. Hence, using the proposed approach has to be possible by non-experts in the domain of the treated design problem. To illustrate this method, the authors would apply the method to extract the prioritized problem to be solved of a mechanical shock absorber based on lattice structure within a particular mechanical field context.

## 2. BACKGROUND

### 2.1 Generalized table of parameters (GTP)

As a part of receiving information to be processed, ana–lyzing the problem situation first starts with intervi–ewing experts [14]. Some pieces of work tried to represent the design parameters to model the design problem or for further needs. In [15], the authors sug–gested a graph-based representation to model the rela–tions between design parameters. In [16], the authors proposed modeling the design problem by representing design parameters and the interrelation between them based on a graph network model. This last model took around three sequential interviews with experts to build only the network of parameters, and at each time, the network was enhanced. Consequently, authors may need more interviews to develop this network further with time. In [14], the authors proposed a method to model the problem situation based on qualitative information from experts. This method suffers from some limitations. First, the established table of influences considers design parameters and their influences (AP/AP) and (AP/EP), but it neglects the context from which these parameters are extracted. Second, this method does not explicitly show the multi-physical model of the design problem.

To develop previous approaches and overcome some of their limitations, Abdellatif et al., in [5] proposed a systematic approach to building, which is called "Gene–ralized Table of Parameters GTP". This table is based on the observation that some information for problem formulation is specific to the system or family of systems under study and represents only a small portion of the information contained in the domain's biblio–graphy. This information is largely common to the design prob–lems concerning these systems and can, therefore, be extracted independently of the specific problem and in advance of its treatment (at least with the design process described in Figure 1). Thus, our first proposition is to accomplish a part of the work that the designer must undertake in advance by creating a Generalized Table of Parameters (GTP) for the system, encompassing various relevant information about the system and frequently expected performances. It represents the different parameters cha–racterizing the system or the process, including physical, qualitative, or quantitative variables, as well as variables reflecting expected performances. Identifying and understanding these parameters and their relationships within the system enable a better understanding of standard and inventive design constraints and opportunities. Indeed, comprehending these interconnections can help identify dependencies and interactions among parameters that may influence the system and, consequently, better model the problem to be addressed. The table synthesizes and organizes vast literature review documents, expert perceptions, and reports of CAD/FEM trials on the specific domain under study. In this thesis, the studied behaviors are in the mechanical domain concerning rigidity, energy absorption, deformation, weight, and cost of lattice structures. The sources can include research articles, books, case studies, patents, numerical simulations (FEM models), CAD models, and other resources providing in-depth information on con–cepts, methods, and standard solutions proposed in the field. It can also be enriched by the opinions and knowledge of domain experts, who can offer unique perspectives, valuable advice, and recommen–dations based on their experience.

Furthermore, each cell of the table cross-referencing system parameters is linked to a set of source infor–mation that explains, validates, or extends its content. This source is called "Contextual Database (CDB)" in our study. The generalized aspect of the table and its accompanying database is crucial, allowing easy en–richment with new information, studies, or research results. However, the update and maintenance aspects of the database are not addressed in this thesis. Extracting contradictions from the database by analyzing the links between parameters, their weights, and significance helps highlight conflicts within the system and, consequently, extract contradictions. This guides the search for inventive solutions and contributes to effective problem resolution in the industrial context.

### 2.2 Generalized system of contradictions (GSC)

In the theory of TRIZ, three types of contradictions were proposed [17]: Administrative, technical, and physical. These contradictions represent the problem of a treated system in different stages of understanding the available and possible means to act on the treated system in order to solve its problem [9]. OTSM-TRIZ [18] kept only two types of contradiction: technical and physical. The administrative contradiction was not kept because it represents an objective with no solving tool. Khomenko et al., in [19], linked both models of tech–nical contradiction with the model of physical contra–diction. The author stated that "Many physical cont–radictions may be linked to a given pair of technical contradictions". This implies the definition of the system of contradictions. This system of contradictions explains that the physical contradictions are the main and root reason for the technical contradiction.

The Generalized System of Contradictions (GSC) was proposed initially in [17] and [20]. This model was proposed to fit the axiom of equivalence between a problem's presence and a contradiction's formulation. The GSC is expanded to consider not only two pairs of EPs but two sets of EPs for the technical contradictions. Unlikely the classic TRIZ model of contradiction, the GSC takes into account two states of several action parameters Aps instead of two states of one AP. In [20], the Generalized System of Contradictions is linked to the design of the Experiments model (DoE), and the concept of GSC is based on the automated search for contradictions in digital data. In [3], the limitation of the classical TRIZ and OTSM-TRIZ system of contra–diction was revealed. Thus, there was a need to generalize the system of contradictions. An algorithm was developed by [21] for identifying and extracting generalized technical contradictions (GTC) from experiments as a part of the Generalized System of Contradictions (GSC). Another algorithm was deve–loped by [22] to identify and extract the Generalized Physical Contradictions (GPC) from experiments as another part of the generalized system of contradictions (GSC). Hence, it automates the entire process of the extraction of the Generalized System of Contradictions (GSC). However, one of the downsides of this extraction is the huge number of extracted GTC and GPC; thus, the same second obstacle of the classical-TRIZ system of contradictions, which is the selection of the contraction model to be treated by TRIZ. For this reason, the concept of choosing optimum solutions was developed. The concept will be detailed in the next section. This study will contribute to helping designers select the most relevant contradiction "conflict" to be solved. Another further limitation is solving the core cause of the design problem in its form, GPC.

Figure 2 illustrates the difference between the two systems of contradictions, the classical TRIZ one and the other generalized. As shown in this figure, the system of contradictions in TRIZ theory is based on contradictive design parameters. For this reason, studies implemented in the frame of TRIZ theory have to search for contradictive parameters. For this importance of design parameters, one should be very careful in the selected design parameters, and this is one of the objec–tives of the Generalized Table of Parameters (GTP).

### 2.3 Synthesis

The literature review outlines a systematic approach to inventive design, directly addressing the research problem articulated in the introduction. The Generalized Table of Parameters (GTP) emerges as a tool for mo–deling the studied system and helps in problem selec–tion, collecting diverse information to understand sys–tem characteristics comprehensively. While enhancing problem modeling, the GTP and its linked CDB are presented to treat the limitations, including neglecting contextual nuances and the absence of explicit multi-physical models. However, challenges persist, notably in selecting the most relevant contradictions for reso–lution. To overcome this main limitation, this article would propose a systematic method to exploit the generalized table of GTP parameters within an inventive design pro–cess to extract the most important problem to be solved. Extracting such problems would help in dedicating efforts to solve this core problem later on, which is important for addressing inventive design problems.

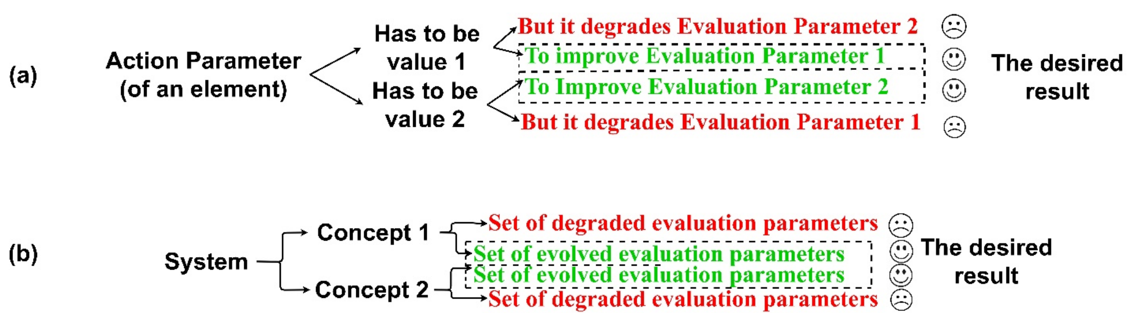


**Figure 2: (a) Classical TRIZ system of contradictions, (b) Generalized System of Contradictions (GSC)**

## 3. METHODS AND MATERIALS

### 3.1 Presenting the case study

After analyzing several studies on the desired performance for lattice structure [25–27], we propose an energy absorber as a case study that can serve several applications in the mechanical domain. It focuses on the design of an energy absorber whose main component is a lattice structure. The challenge is to design a solution based on lattice structures to improve industrial mechanical energy absorbers found in various systems such as helmets or packaging. The "absorber" system will be manufactured using a lattice structure made from lightweight polymer materials. The main objective is to create a system that meets the criteria of shock resistance, rigidity, and lightness. This system would be a crucial component in industrial applications in the mechanical field, aiming to improve these three characteristics simultaneously. The main function of an energy absorber is to efficiently absorb the kinetic energy generated during deformation while preserving the structural integrity of systems. The central question here is how to create a lightweight, rigid system that excels in crashworthiness.

The following aspects fall within the scope of this case study:

**Domain of application**: for this case study, the focus will be dedicated only to industrial applications within the mechanical domain.

**Initial problem**: Energy absorbers have compromised results between crashworthiness capabilities, rigidity, and lightweight for many industrial mechanical systems, such as helmets, packages, and other applications, which require improving the three characteristics together, as indicated in Figure 4.

**Fabrication technology**: the energy absorber under consideration should be fabricated using additive manufacturing technology.

**Used material**: the energy absorber should be made from polymeric materials.

**Deformation**: the structure of the absorber would be subjected to a static deformation, which is uniaxial.

**Possible industrial applications**: this case study aims to fabricate an energy absorber that could be a part of one or more industrial systems, i.e., products. The tackled design problems are common between a set of industrial systems such as helmets, car bumpers, packaging of precious objects, safety equipment, sports protection, shoe equipment, and bullet-proof vests, as shown in Figure 4. To address this case study, a systematic method using the previously proposed GTP is proposed in the next section.

### 3.2 Proposed method and its application

In this section, we propose a 10-step method to exploit the GTP for extracting generalized systems of contradictions (GSC) [28] underlying a given inventive problem, as illustrated in Figure 3. This section presents the proposed method, while the next section will present the application of this proposal to the case study mentioned in section 3.1.

### 3.3 Applying the method to the case study

The illustration of the method, mentioned in section 3.2 on the lattice case study, will be detailed within the next lines.

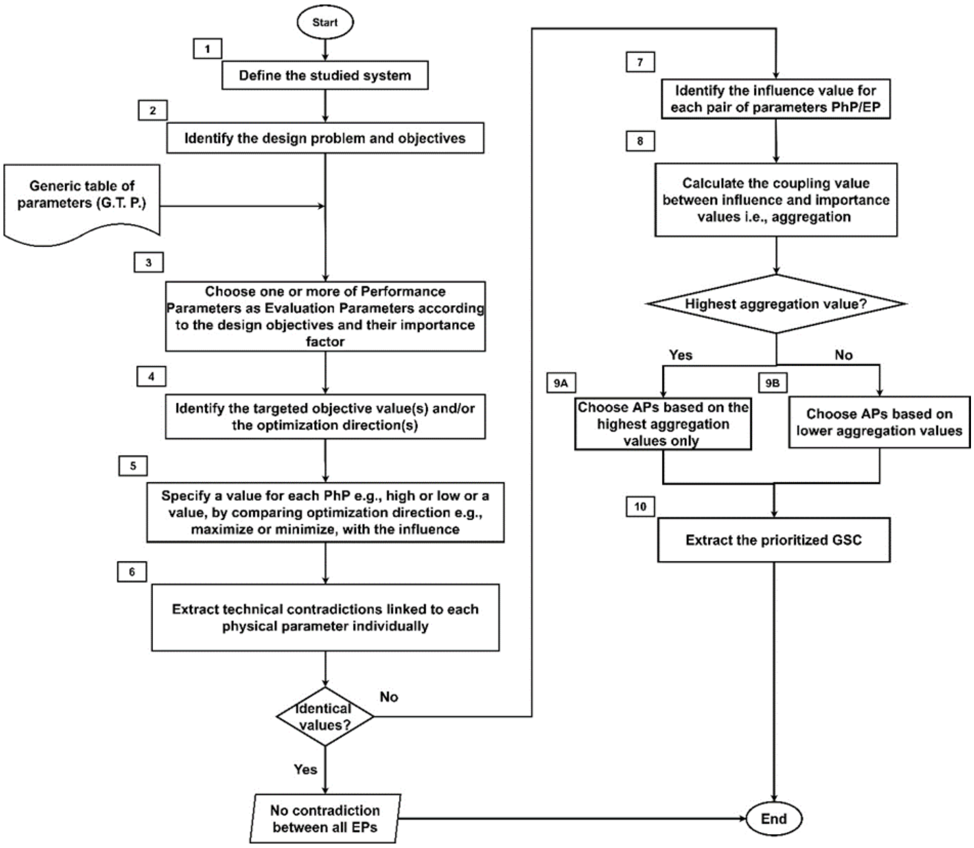


**Figure 3: Proposed inventive design method to identify and solve the GSC from the GTP**

*Step1:* Define the studied system

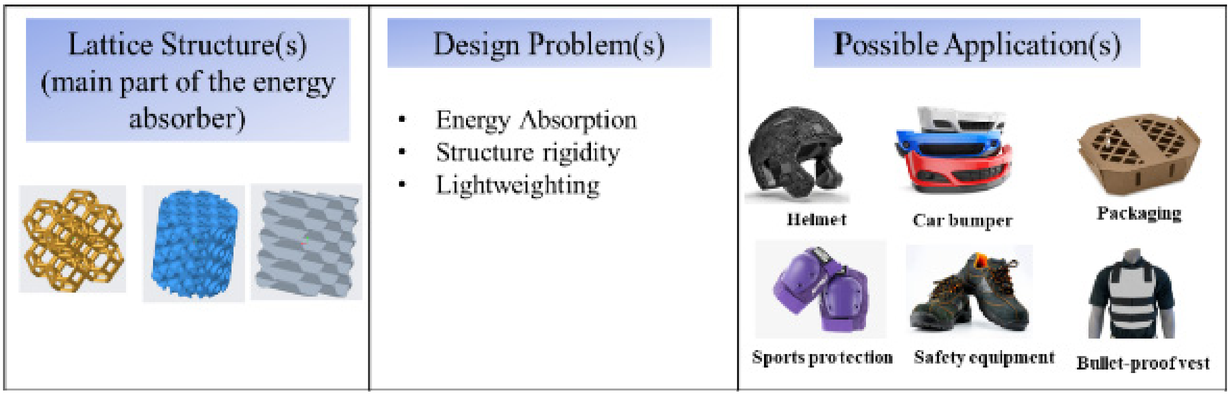


**Figure 4: The core part of the designed energy absorber, its inherent design problems, and their relevant possible industrial**

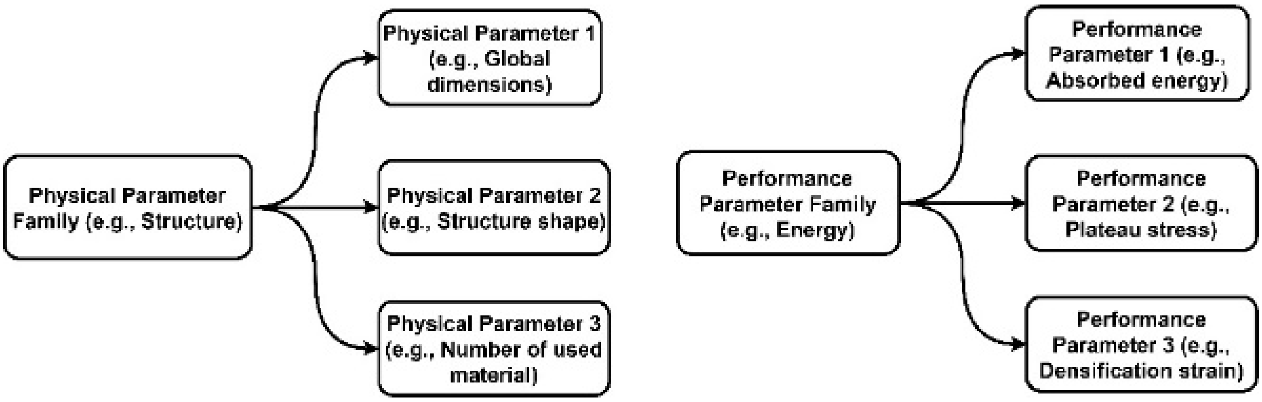


**Figure 5: An indication of the parameter family applications of this energy absorber**

In this step, the studied system is first defined as a product or a process. In this study, the focus is on developing products. Hence, the system is a product of our study. The full definition of the studied system is detailed in section 3.1.

*Step 2:* Identify the design problem and objectives

The additive manufacturing technology should fabricate the structure

- It should be made of polymeric materials
- The structure is made of a specific material, not a composite structure
- This structure might be subject to static load, i.e., deformation
- The selected problems to be covered by this table are three: Energy, structure strength, and lightweight
- The concerned field is the mechanical field

The design objective of this case study is to enhance the lattice structure's ability to absorb mechanical ener–gy arising from external solicitations, such as pressure, displacement, or applied force. The enhanced mecha–nical energy absorption capacity will render the lattice structure suitable for utilization as an energy absorber in a wide range of applications, including protective pads, car bumpers, and helmets, within a broad context. Furthermore, the structure must maintain both rigidity and lightweight characteristics. These objectives gain significance due to the challenges associated with conventional design and fabrication methods.

The initial problem is that energy absorbers have compromising results between crashworthiness capabi–lities, rigidity, and lightweight for many industrial mec–hanical systems, such as helmets, packages, and other applications, which require improving the three charac–teristics altogether.

*Step 3:* Choose one or more of Performance Para–meters (PrPs) as Evaluation Parameters (EPs) according to the design objectives and their importance factor

In this step, one or more Performance Parameters can be selected from the Generalized Table of Parameters (GTP) according to the design objectives. In this method, experts are asked to assign a value of im–portance to each Performance Parameter (PrP). Hence, the most important PrPs can be considered Evaluation Parameters (EPs) in the context of the design problem since they are modeling the design problem.

The choice of EPs can be facilitated by using the GTP by referring to the so-called “Parameter family”. The one -parameter family is grouping one or a set of parameters, as indicated in Figure 5. In this case, specialists and non-specialists can refer to these families to select the appropriate EPs and/or APs. An example of these families is the family of energy, which contains parameters of energy absorption per unit volume, densification strain, and other parameters that can model problems of mechanical energy. For example, if the design problem is around (energy), then the family (energy) would be taken into consideration as a priority.

In this step, on the other hand, an "importance" factor within the range of 1 to 10 is given to each EP to help the decision-makers prioritize the problem to be solved. These values are given by stakeholders in the field of the ongoing problem, i.e., lattice structures or cellular structures.

According to the design objectives to be measured, five PrPs have been chosen to be considered as Evaluation Parameters EPs in the context of the design problem based on the importance values determined by experts in our case. These chosen EPs are related to specific families: energy, lattice structure rigidity, and Lightweighting. Moreover, the importance factor was determined for each chosen EP, as indicated in Table 1.

**Table 1: The chosen EPs from the GTP and their relevant families, and importance factor**

| Evaluation Parameter (EP) | Importance factor of each EP | Parameter Family |
|---|---|---|
| Energy absorption per unit volume | 10 | Energy |
| Modulus of elasticity of lattice structure | 10 | Energy |
| Plateau stress | 7 | Energy |
| Densification strain | 7 | Rigidity of lattice structure |
| Mass | 10 | Lightweight |

*Step 4:* Identify the targeted objective value(s) and/or the optimization direction(s)

This step translates the objectives into expected values for the evaluation parameters and the optimization direction of each EP. Two situations are distinguished:

- The target values are known. For example, the mass of the system designed must be less than 50 grams to limit weight; the range of target values is between 0 and 50.
- Target values are not (yet) known. In this case, objective values are defined in terms of mini–mum or maximum. For example, the mass of the de–signed system is to be as low as possible.

**Table 2: The chosen EPs from the GTP and their relevant optimization directions**

| Evaluation Parameters (EPs) | Optimization direction of each EP |
|---|---|
| Energy absorption per unit volume (MJ/m$^3$) | Maximize |
| Modulus of elasticity of lattice structure (MPa) | Maximize |
| Plateau stress (MPa) | Minimize |
| Densification strain | Maximize |
| Mass (g) | Minimize |

In this case study, an optimization direction was determined for each chosen EP according to the desired targeted objectives, as indicated in Table 2.

*Step 5*: Specify a value for each PhP, e.g., high or low, or a value by comparing optimization direction, e.g., maximize or minimize, with the influence.

In this step, a new corresponding table is estab–lished. Each cell of this table contains information about the decision taken to change a Physical Parameter to satisfy one Evaluation Parameter and meet the opti–mization direction. As shown in Table 3, for this case study, some values, e.g., high, low, or a specific value, were specified for each physical parameter in order to satisfy each evaluation parameter individually.

*Step 6*: Extract technical contradictions linked to each physical parameter individually

In Table 4, PhP1 must be as high in value as pos–sible to satisfy EP1 (in red) and must be as low in value as possible to satisfy EP2 (in yellow). This means that there will be a technical contradiction between both parameters EP1-EP2. Otherwise, there is no technical contradiction, as indicated in the same figure. By checking the identification of the value necessary for each PhP, the technical contradiction between EPs could be highlighted, as explained previously. The specific extracted table of parameters was checked to highlight the possible contradictions between EPs. This resulted in Table 4.

*Step 7*: Identify the influence value for each pair of parameters PhP/EP

To identify the influence weight of each pair of parameters, we need to present the definition of this term first. The definition of the term "influence weight" can be presented as follows:

*Influence weight*: it is the degree of intensity of change (null, low, moderate, high) on a parameter, e.g., evaluation parameter EP, that results from changing the value of one parameter, e.g., physical parameter PhP. The influence (null, low, moderate, high) is coded with three values:

- if the influence between parameters is high, the weight is 3
- if the influence between parameters was moderate, then the weight is 2
- if the influence between parameters was low, then the weight is 1
- if there is no influence between parameters, then the weight is 0

**Table 3: An excerpt of the specific table that indicates the specific value for each PhP for each EP with respect to the objective direction**

| index | | 15 | 15.1 | 15.2 | 16 | 17 |
|---|---|---|---|---|---|---|
| | | Evaluation Parameters (EP) | | | | |
| | Optimization direction | maximize | minimize | maximize | maximize | minimize |
| | | Energy absorption per unit volume | Plateau stress | Densification Strain | Modulus of elasticity of lattice structure | Mass |
| A | Relative density of lattice structure | high | low | minimize | high | low |
| B | Global dimensions | low | high | low | high | low |
| .. | .. | .. | .. | .. | .. | .. |
| ZZ.1 | Type of base material | ABS | PLA | PLA | ABS | ABS |

**Table 4: An excerpt of the specific table which highlights the possible contradictions between EPs for each AP**

| The contradictions table | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| index | | | 15 | 15.1 | 15.2 | 16 | 17 | |
| | Parameter type | | Evaluation Parameters (EP) | | | | | |
| | | Optimization direction | maximize | minimize | maximize | maximize | minimize | Contradictions |
| | | | Energy absorption per unit volume | Plateau stress | Densification Strain | Modulus of elasticity of lattice structure | Mass | |
| A | Physical Parameters (PP) | Relative density of lattice structure | high | low | low | high | low | Contradiction |
| B | Physical Parameters (PP) | Global dimensions | low | high | low | high | low | Contradiction |
| .. | .. | .. | .. | .. | .. | .. | .. | .. |
| ZZ.1 | Physical Parameters (PP) | Type of base material | ABS | PLA | PLA | ABS | ABS | Contradiction |

The influence weight can be determined by different techniques. Those techniques are as follows:

- *Expert's feedback*

The expert, as a referring source of knowledge, can be interviewed to give his/her own opinion on the value of influence.

- *Equation*

The equation represents a mathematical model of a set of parameters, inputs, and outputs.

- *Graph*

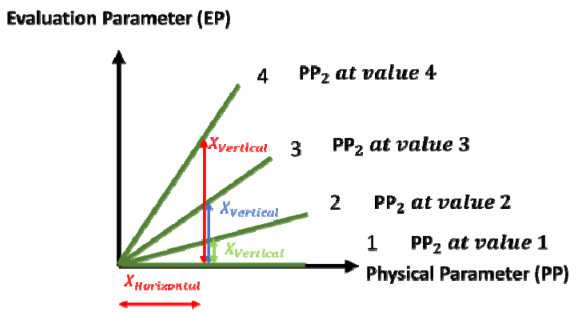


**Figure 6: Indicative representation of the extracted information from a graph**

The results can be represented graphically by plotting the observed results. These graphs can be read and analyzed to extract information about the relation between two parameters, as shown in the interaction between two parameters and a third parameter, as shown in Figure 6.

For this case study, the influence weights were collected from two experts, one in cellular materials and another in mechanical design. An excerpt from the table of influence weights (IW) is indicated in Table 5.

*Step 8:* Calculate the coupling value between inf–luence and importance values, i.e., aggregation

The aggregation value is the summation of multi–plying the importance factor (IF) of the most important EPs (highlighted in green and grey in Table 6, multi–plied by the corresponding influence weight (IW) and identified by calculated aggregation (highlighted in yel–low and orange colors), in the same table. The aggregation is following the formula of equation (1):

**Table 5: An excerpt of the table used to identify the influence weights (IW)**

| The influence weight (IW) table | | | | | | | |
|---|---|---|---|---|---|---|---|
| impact factor | | | 10 | 7 | 7 | 10 | 10 |
| | Parameter type | | Evaluation Parameters (EP) | | | | |
| | | Optimization direction | maximize | minimize | maximize | maximize | minimize |
| | | | Energy absorption per unit volume | Plateau stress | Densification Strain | Modulus of elasticity of lattice structure | Mass |
| A | Physical Parameters (PP) | Relative density of lattice structure | 3 | 3 | 3 | 3 | 3 |
| B | Physical Parameters (PP) | Global dimensions | 1 | 1 | 1 | 1 | 3 |
| .. | .. | .. | .. | .. | .. | .. | .. |
| ZZ | Physical Parameters | Strut shape | 1 | 2 | 2 | 3 | 3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (PP) | | | | | | | |
| ZZ.1 | Physical Parameters (PP) | Type of base material | 3 | 3 | 3 | 3 | 3 |

**Table 6: The calculated aggregation values for each EP in the specific table. This table will lead to the selection of Action Parameters APs out of the entire set of Physical Parameters PhPs**

| | | | AP1 | PhP2 | PhP3 | PhP4 | PhP5 | $PhP_n$ |
|---|---|---|---|---|---|---|---|---|
| | | | Relative density of lattice structure | Global dimensions | Shape of structure | Number of used materials | Gradience | … |
| EP1 | 10 | Energy absorption per unit volume | 3 | 1 | 3 | 3 | 2 | … |
| EP2 | 7 | Plateau stress | 3 | 1 | 0 | 3 | 2 | … |
| EP3 | 7 | Densification strain | 3 | 1 | 0 | 3 | 1 | … |
| EP4 | 10 | Modulus of elasticity lattice structure | 3 | 1 | 3 | 3 | 1 | … |
| EP5 | 10 | Mass | 3 | 3 | 2 | 2 | 3 | … |
| | | | 90 | 50 | 80 | 80 | 60 | … |

$$\text{Aggregation} = \sum_{n=1}^{N} IF_n * IW_k \text{ for each } K \tag{1}$$

By applying this rule to the study case, Table 6 will be obtained. In this step, the choice of Action Parameters APs is based on choosing those ones with an aggre–gation more than or equal to 90 (highest aggregation value). This led to prioritizing 3 APs out of 32 PhPs in total.

*Step 9:* Choose APs based on the highest aggre–gation values

In this step, the choice of APs is based on choosing those ones with an aggregation of more than or equal to 90. This led to prioritizing 3 APs out of 32 in total. The chosen APs are illustrated in Table 7.

**Table 7: The chosen APs with their aggregation values**

| | | | AP1 | AP11 | AP32 |
|---|---|---|---|---|---|
| | | | Relative density of lattice | Cell size | Type of base material |
| EP1 | 10 | EP1 | 3/(high) | 3/(low) | 3/(ABS) |
| EP2 | 7 | EP2 | 3/(low) | 3/(high) | 3/(PLA) |
| EP3 | 7 | EP3 | 3/( low) | 3/(high) | 3/(PLA) |
| EP4 | 10 | EP4 | 3/(high) | 3/(low) | 3/(ABS) |
| EP5 | 10 | EP5 | 3/( low) | 3/(high) | 3/(ABS) |
| | | | 90 | 90 | 90 |

| Value | Explanation |
|---|---|
| 3/(high) | Influence weight/value of action parameter to satisfy the evaluation parameter |

*Step 10*: Extract the prioritized GSC

The proposed method specified APs linked with a chosen EPs. This may result in a potential system of contradictions based on the previous *step*. In this step, the prioritized generalized system of contradictions (GSC) could be extracted from the Generalized Table of Parameters (GTP). The contextual GSC is shown in Figure 7.

This GSC is true under the context of having ABS as the type of material. States that the system of lattice structure needs to be in two concepts. The first concept is to have a lattice structure with a high relative density and low cell size to satisfy the energy absorption and modulus of elasticity. The same structure should have a relative density and a high cell size to provide a lightweight structure.

## 4. FEEDBACK DISCUSSION

This feedback discussion of the used method is demonstrated based on two main questions: first, what is the positive feedback observed about the proposed method? Second, what are the potential limitations that are determined because of the application of the proposed method?

Answering the first question could be resumed in the following bullet points:

- Presenting a systematic, inventive design met–hod is less dependent on the user's experience level and can reduce subjectivity in the decision-making process.
- The proposed approach could give a holistic vision of the core problem of the system and contribute to re-formulating the design problem to facilitate solving this problem.
- The method could reveal some design parameters related to the design conflict. These parameters and their relation to the design conflict were not well-explained by the interviewed experts. This shows the strength and robustness of the proposed approach.
- In contrast with some existing methods, e.g., the IDM method[29], our method is inclusive of all design problems in one conflict model, i.e., the GSC model. Moreover, it presented feasible and applicable direct solution concepts that are very coherent to the design problem and less dependent on the experience of users

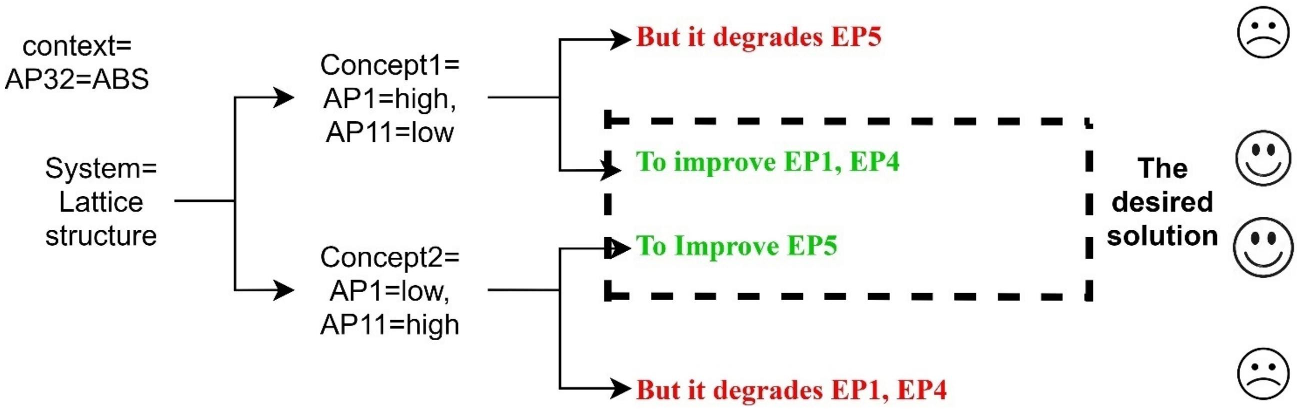


**Figure 7: The formulated contextual GSC out of the table of parameters**

- From the perspective of this method, solving the Generalized Physical Contradiction could be possible by using units of parameters, such as anticipating the parameter(s) that can substitute a set of APs by multiplying or dividing the units of these parameters. Hence, this approach could be developed more in the light of more complex contradictions.

The proposed method is a systematic approach, which is not loaded heavily on the level of experience of users; hence, using the proposed approach can be possible by non-experts in the domain of the treated design problem.

Answering the second question, this proposal is promising, even though it suffers from some limitations. The influence weights and importance values given within this method are still partially based on the experience of the user, and, therefore, this could be a subjective step in the process of decision-making. However, the authors argue that different techniques, such as analyzing graphs or equations, can determine the influence weight, which could give more objective values. Authors attribute the use of importance value for giving an optional step to experts' opinions. However, this step is not obligatory, and in case of the absence of importance value, all EPs of one family would be treated at the same level of importance. For example, if it is desirable to design a strong lattice structure to bear loads, then it would be preferred to select 'Rigidity' family from the GTP as EPs to evaluate the perfor–mance of the system. Hence, the entire family with all linked EPs would be taken into consideration for further steps.

## 5. CONCLUSION

In this article, we present a method to exploit the built generalized table of parameters GTP in the inventive design process to extract and prioritize the generalized system of contradictions (GSC). The new method is presented as a systematic approach, which is not loaded heavily with users' level of experience. Hence, using the proposed approach can be possible by non-experts in the domain of the treated design problem and decrease the subjectivity in the decision-making process. A case study was treated to illustrate the strengths and limitations of the proposed method. This case study was to fabricate an energy absorber with a lattice structure as a core component. This structure must have high crashworthiness and rigidity and be lightweight. As a result of applying the method, one prioritized GSC was extracted to be solved. Finally, in the next article, developments will be proposed to present specific solutions to the technical-system problems within a specific context by applying the experimental approach (DoE-based).

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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| *GTP* | Generalized Table of Parameters |
| *FEM* | Finite Element Modeling |
| *CAD* | Computer-Aided Design |
| *TRIZ* | A Russian acronym, translated into English as "Theory of Inventive Problem Solving" |
| *DoE* | Design of Experiments |
| *CDB* | Contextual DataBase |
| *PhP* | Physical Parameter |
| *PrP* | Performance Parameter |
| *IF* | Importance Factor |
| *IW* | Influence Weight |

## ИНТЕГРИСАЊЕ ГЕНЕРАЛИЗОВАНЕ ТАБЕЛЕ ПАРАМЕТАРА И КОНТЕКСТУАЛНЕ БАЗЕ ПОДАТАКА У МЕТОДУ ИНВЕНТИВНОГ ДИЗАЈНА ЗА ИЗДВАЈАЊЕ ПРОБЛЕМА КОЈЕ ТРЕБА РЕШИТИ

**М. Абделатиф, Х. Чибане, С. Дубоа, Р. Де Гујо**

Објављене су бројне методе засноване на ТРИЗ-у за издвајање кључних проблема које треба решити у оквиру инвентивног процеса решавања проблема. Ипак, једно признато ограничење ових метода је како одабрати најважнији проблем, „контрадик–

цију“, који треба решити. Један од занимљивих развијених алата за моделирање параметара система је Генерализована табела параметара (ГТП). Међутим, ГПТ још увек није интегрисан као суштински алат у оквиру метода заснованих на ТРИЗ-у. У овом чланку, циљ нам је да развијемо метод за интеграцију ГТП-а у инвентивни процес пројектовања како бисмо издвојили најважније контрадикције које треба решити. Да би илустровали представљену методу, аутори би применили метод како би издвојили приоритетни проблем који треба решити механичког амортизера заснованог на структури решетке унутар одређеног контекста механичког поља.