21ST INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED17
21-25 AUGUST 2017, THE UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER, CANADA

FROM SIMULATION TO INVENTIVE PROBLEM RESOLUTION, A GLOBAL METHOD

Dubois, Sebastien (1); De Guio, Roland (1); Rasovska, Ivana (2); Ben Moussa, Fatima Zahra (3); Benmoussa, Rachid (3)
1: INSA Strasbourg, France; 2: University of Strasbourg, France; 3: ENSA of Marrakech, Morocco

Abstract

In order to formalize and automatize the use of TRIZ based patterns, and in particular, the use of contradictions, a Generalized System of Contradictions (GSC) has been proposed. The model has been defined to always satisfy the existence of a GSC for unsolvable problems. It has also been stated that for a given problem, many systems of contradictions can be formulated. And so the question of the choice of the GSC to consider for resolution has to be tackled. In this article, a method will be proposed to illustrate that classical TRIZ contradictions do not exist systematically, but that in this case, Generalized Contradictions could be formulated. The hypotheses to hierarchize the contradictions will be proposed. The problems related to the use of the GSC will be detailed and a method to go from simulation until inventive problem resolution will be proposed. Finally, the existence of particular contradictions, contextual contradictions, will be illustrated, as they enable the application of TRIZ resolution principles.

Keywords: Design methods, Innovation, Optimisation

Contact:
Dr.-Ing. Sebastien Dubois
INSA Strasbourg
LGECO
France
sebastien.dubois@insa-strasbourg.fr

Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 4: Design Methods and Tools, Vancouver, Canada, 21.-25.08.2017.

1 INTRODUCTION

TRIZ-based methods have been widely used in multiple industries to solve problems and to find inventive solutions. The robust ability of these methods to formulate problems and help people think differently is recognized (Jafari et al., 2013; Chechurin and Borgianni, 2016; Chang et al., 2016). These patterns have been proposed for use by experts to fit cognitive descriptions of problems. Several approaches have also been proposed to automate the instantiation of these patterns from texts (Souili et al., 2015; Li et al., 2014). For this purpose, ontologies have been proposed to better formalize the models (Cavallucci et al., 2011), in particular, the case of contradictions. Nevertheless, one problem has been identified: this model is not robust, as it considers the required specs only in pairs, and thus, a problem implying two-spec solutions can be formulated (Dubois et al., 2009) for which no solution is known to satisfy all of the specs. Thus, a generalization of the patterns of contradiction has been proposed to overcome this limitation. This Generalized System of Contradictions has been presented, along with the fact that for a given problem, many systems of contradictions can be formulated. Now, questions remain on how to choose the prior system of contradictions for consideration for resolution. In (Dubois et al., 2015), a parallel was drawn between contradictions and the Pareto frontier, as the contradiction represents the limit that can be reached by optimization approaches, and their resolution aimed at finding solutions based on new working principles, which are thus beyond the Pareto frontier. In this article, a method is proposed to illustrate that classical TRIZ contradictions do not exist systematically, but in this case, Generalized Contradictions can be formulated, thereby showing the existence of particular contradictions, contextual contradictions, that enable the application of classical TRIZ resolution principles.

The first part of this paper introduces the state of the art regarding different models of contradictions, including the classical TRIZ system of contradictions, polycontradictions, and Generalized System of Contradictions (GSC). Then, the problems related to the use of the GSC will be detailed, and a method to go from simulation to inventive problem resolution is proposed. Application of this method is then illustrated, before discussing the results and conclusions.

2 TRIZ BASED MODELS OF CONTRADICTIONS

TRIZ is a theory used to develop methods of problem resolution in the design of technical systems. It is centered on formulating and solving problems. TRIZ addresses so-called solution less problems, where "the problem is unsolvable" means that there is no way to simultaneously create a satisfying value for each parameter of the specs. In TRIZ, several models of problem formulation are proposed, each of which corresponds to a different level of abstraction. Some of the models are used to enable resolution by the use of shaped databases of generic solutions; some of the models are only intermediary steps in the problem formulation process. The objectives of the different models are to enable a progressive understanding of the limits of the considered system and how it is possible to act on it to make it evolve. TRIZ is defined as a dialectical approach, as among these different models, one can recognize two models of contradictions. These models have been developed to help humans think efficiently and thus must fit human cognitive limitations (Belski and Belski, 2008). In particular, the contradictions model has been defined in accordance with the restriction that the human mind cannot simultaneously consider, in short-term memory and thus in information processing, more than seven pieces of information (Miller, 1956). Thus, when aiming at the automation of contradiction models and thus at using computers, this limit no longer exists, and the model can evolve. Moreover, some formal limits of contradictions have also been elicited by the authors and lead to the proposal of a generalized model to formulate the problems.

2.1 TRIZ models of contradictions

The first model of contradiction, called "technical contradiction", is the understanding that two requirements on the system cannot be both satisfied, and thus are in conflict. Satisfying one of the two requirements, or one of the two parameters, can be recognized as representing two states of the system, satisfying two specs of this system. Khomenko, in (Khomenko et al., 2009), proposed a more precise definition of this level of definition of the problem, describing these parameters as Evaluation

Parameters. Evaluation Parameters are used to check if the problem is solved or not, but they are not used as design parameters of the system, but rather as specs of the system.
A second model of contradiction proposed in TRIZ for problem representation is called the "physical contradiction". This model focuses the problem on a single element of the system, which is recognized as the core of the problem. One assumption of TRIZ-based methods is that a problem can always be formulated as a physical contradiction. A physical contradiction represents the requirement for one element to be in two different states. In (Khomenko et al., 2007), a relationship between the models of contradiction has been clarified, and a system of contradictions has been presented, as illustrated in Figure 1. This system of contradictions clarifies the role of each contradiction, as the physical contradiction indicates a way to act on the system. It is formulated based on a parameter, which is classified as an action parameter (Dubois et al., 2009); and the technical contradiction highlights two contradictory parameters that must be satisfied, in other words, two parameters of the specs, called evaluation parameters. The value of the action parameter must be Value 1 (thus defining a first state of the system) to satisfy the first evaluation parameter, but the value of this action parameter must be Value 2 (defining a second state of the system) to satisfy the second evaluation parameter. The desired result is, of course, to satisfy the objective with the two evaluation parameters.

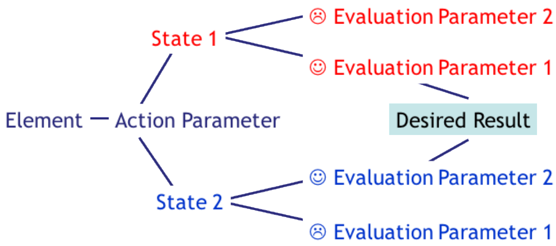

Figure 1. System of contradictions

2.2 Generalized System of Contradictions

In (Dubois et al., 2015), the formulation of contradictions, and more specifically, the formulation of technical contradictions has been compared with a Pareto-frontier in two dimensions. Indeed, the classical TRIZ technical contradiction model is built by considering only two evaluation parameters, and it represents the fact that increasing one parameter means decreasing the second one. The consideration of only two parameters has been recognized as a limit of the TRIZ model, as real problems are generally multidimensional problems. In the work of (Cavallucci et al., 2010), a model of the technical contradiction for multidimensional problems, called polycontradictions, is proposed by grouping together evaluation parameters that are positively correlated. A polycontradiction is a system of contradictions with two sets of contradictory evaluation parameters. In (Dubois et al., 2009), the authors proposed a generalization of the model of the system of contradictions, to be able to represent multi-dimensional problems regardless of the correlations between the parameters. In this Generalized System of Contradictions (GSC), it is not only one action parameter but a set of action parameters that is taken into account, linked to two sets of evaluation parameters, as illustrated in Figure 2.

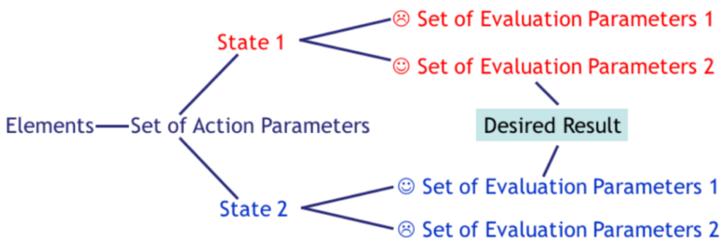

Figure 2. Generalized System of Contradictions (GSC)

Applying the dialectical approach to a solutionless problem is equivalent to presenting it as an opposition. The first detected opposition is between the required values of the set of evaluation parameters and the possible values of the set of action parameters.

2.3 Automatic extraction of Generalized System of Contradictions

To extract contradictions, information about the technical system of interest is required. Our method uses the outputs of a design of experiments (DoE), which is a statistical optimization method that can be used to describe relations between the input and output parameters of a system and/or optimize the output of a system for a given set of input parameters (Montgomery, 2001). A theoretical bridge between the DoE and generalized technical contradictions is presented in (Dubois et al., 2009a). In (Lin et al., 2013), an exact algorithm for identifying the entire set of generalized technical contradictions that occur in the design of experiments (DoE) is proposed. GTCs can be characterized by the set of definitions that allows the extraction of GTCs from a DoE. Let us suppose that there is no experiment satisfying all of the evaluation parameters at the same time. As illustrated in figure 3, identifying a GTC in such a DoE involves searching for the following:

1. Three sets of evaluation parameters (Y1,Y2,Y0) whose union is the entire set of evaluation parameters and whose intersection is an empty set.
2. Three sets of experiments (E1,E2,E0) whose union is the entire set of experiments and whose intersection is an empty set.
3. The satisfaction of the first set of evaluation parameters Y1 for the first set of experiments E1 and the satisfaction of the second set of evaluation parameters Y2 for the second set of experiments E2.
4. At least one evaluation parameter from the second set of parameters Y2 that is not satisfied in each experiment of the first and third sets of experiments E1 and E3.
5. At least one evaluation parameter from the first set of parameters Y1 that is not satisfied in each experiment of the second and third sets of experiments E2 and E3.

Y1= {y1,y3}   Y2= {y2,y5,y6}

E1= {e1,e3,e4,e5,e7}

E2= {e2,e6,e9}

E0= {e8}

							Y1		Y2			Y0
		x1	x2	x3	x4	x5	y1	y3	y2	y5	y6	y4
E1	e1	1	1	0	0	1	1	1	0	1	1	1
	e3	1	0	1	0	0	1	1	0	0	0	0
	e4	1	1	0	0	0	1	1	1	0	0	1
	e5	1	0	1	0	1	1	1	0	1	1	0
	e7	1	0	1	1	0	1	1	0	0	0	0
E2	e2	0	1	1	1	1	0	0	1	1	1	0
	e6	0	1	0	1	2	0	0	1	1	1	1
	e9	0	1	0	0	2	0	0	1	1	1	1
E0	e8	1	0	0	0	1	1	0	0	1	1	1

Figure 3. Generalized System of Contradictions in an experiments table

This problem has been solved by transforming the generalized technical contradiction research problem into a Binary Integer Program problem.

Then, the following step, for one chosen GTC, is to extract the related GPC. In (Lin et al., 2014), the authors proposed making this extraction by a second Binary Integer Programming. One can summarize the GPC extraction principle in 3 steps:

1. Set the BIP;
2. Solve the BIP and define the items generating the concepts of the GPCs;
3. Build the GPCs by coupling the items of Concept1 and Concept2.

In (Lei, 2016), a process is proposed to extract the GSC out of an experiments table. This process is represented in Figure 4.

The first four steps of the proposed process are in regard to the selection of the action parameters and their value by SVM weights. The output is a reduced set of action parameters and values, which facilitate GPC extraction. This set leads towards performing a new group of experiments, as shown in Step 5. Thus, the GTCs are extracted for the new experiments, and then the GPCs are used to form a generalized system of contradiction.

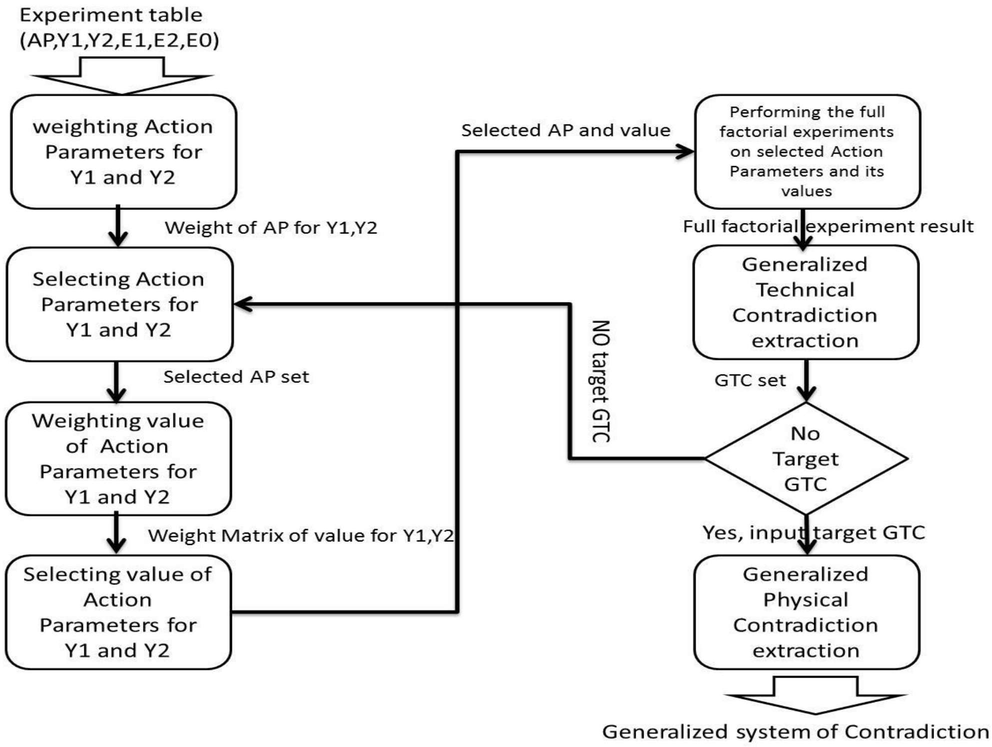

Figure 4. Process of GTC-based extraction

3 PROBLEMATIC

Based on the previously presented models of contradictions, several questions arise. Is the model of the Generalized System of Contradictions really necessary? Can it enable problem resolution? When several contradictions are formulated, how should the prior contradictions to be solved be chosen?
To address this question, the authors propose to follow the methodology presented in Figure 5. The aim of this method is to both propose a method that enables solving "unsolvable problems" using the contradictions model and to highlight the usability of the different models and thus the relevancy of a generalized model of contradictions.

1. The first step is to understand the limits of the considered system and thus to build a model of this system, identifying the evaluation parameters and the set of action parameters.
2. It is then possible to use a simulator to search fit the optimums for the considered system. Then, either an optimum fits the specs, or it is necessary to go to step 3.
3. First, the classical TRIZ technical contradictions are searched, to test whether each exists or not and thus to validate the need for the GTC, if no classical TRIZ technical contradiction is found.
4. If no classical TRIZ technical contradiction is found, then the Generalized Technical Contradictions will be extracted.
5. The next step is to choose, among the extracted technical contradictions (generalized or classical ones), the one that will be considered a priority to solve. For GTC, the contradictions built out of experiments on the Pareto Frontier will be chosen.
6. For the chosen technical contradiction, the classical TRIZ physical contradictions will be searched, to test whether each exists or not, and thus to validate the need for the GPC if no classical TRIZ physical contradiction is found.
7. If no classical TRIZ physical contradiction is found, then the Generalized Physical Contradictions will be extracted
8. The chosen Physical Contradiction can then be considered for resolution. If GPCs are to be considered, then contextual Physical Contradictions (physical contradictions based on only one action parameter, but only true within some context) will be chosen for resolution.

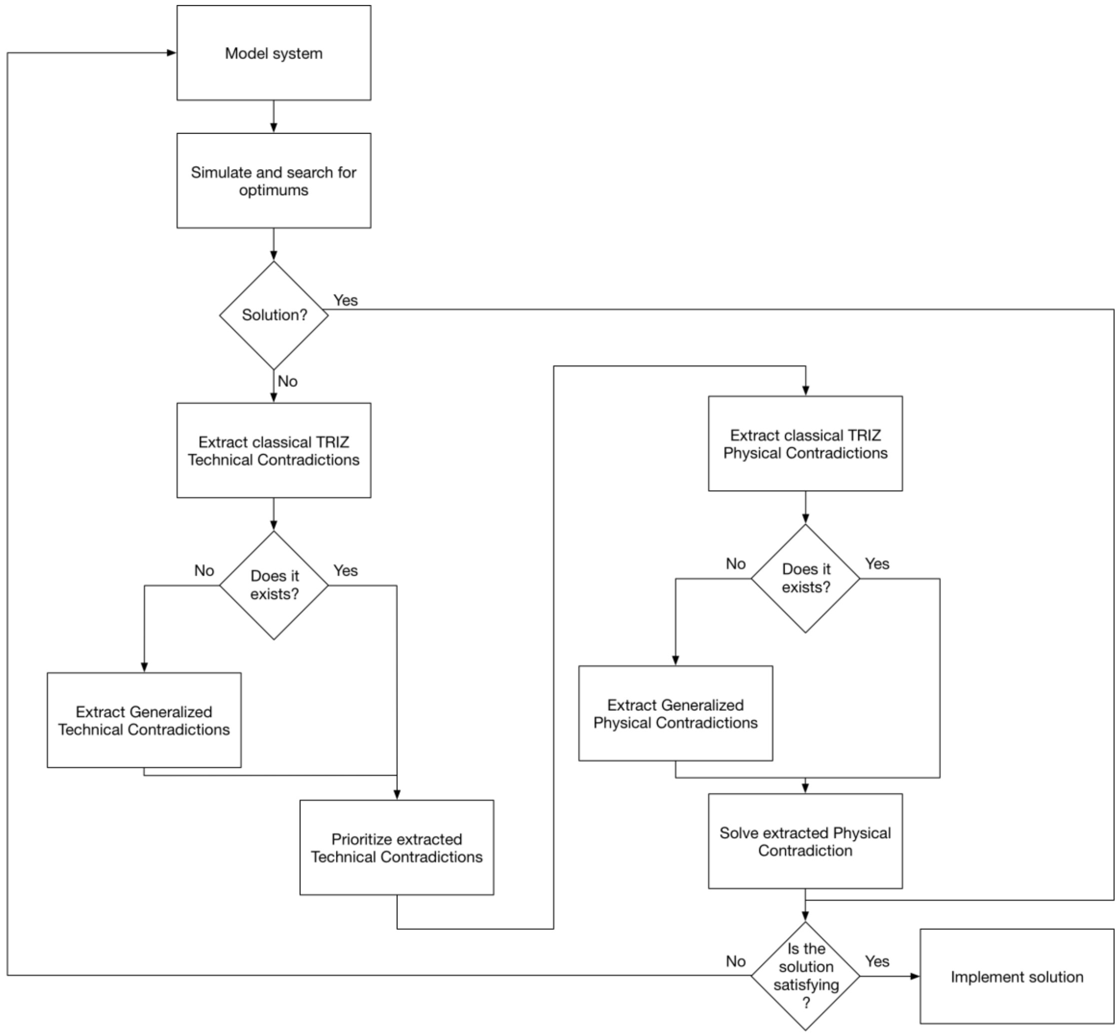

Figure 5. Process flow for problem resolution

4 CASE STUDY

The process presented in Figure 5 will now be applied to a case study, to present its feasibility and also describe the implementation of each step in greater detail.

4.1 Initial problematic situation description

An automotive supplier producing electronic devices (interface modules and battery chargers) aims to reduce the cost of its picking process. They are working with three teams on 8 hour shifts, to enable continuous service. To deliver the products, 5 operators must prepare raw material and feeding trolleys. The company uses 19 trolleys, which must be prepared to be delivered to production lines. The trolleys are localized in a specific zone (the trolley zone), and the raw material is stocked in several racks in the general raw material stock. The 5 operators require 7 hours to fulfill the 19 trolleys. Thus, they do not have enough time to fill the trolleys, deliver them to the production lines and perform other tasks. The company then requires external operators to assume the tasks and avoid a break in production. Of course, the service breakdown must be null after the logistics cost reduction.

4.2 System modelling

Based on the previous description, a list of specs, i.e., of Evaluation Parameters, has been identified:

- Evaluation Parameter 1 (EP1): delay to fill the 19 trolleys (in hours), which must be less than or equal to 8 hours, 8 hours being the shift time.
- Evaluation Parameter 2 (EP2): total load for operators (in hours), which must be less than 26 hours.
- Evaluation Parameter 3 (EP3): total waiting time (in hours), which must be less than 10 minutes.

- Evaluation Parameter 4 (EP4): medium capacity reserve (in hours), which must be between 3 and 6 hours.

A set of 3 action parameters, recognized as variables of the systems, have also been elicited:

- Action Parameter 1 (AP1): mode of assigning trolleys to operators, which can be either the initial state of the company (1), or balanced (2), or each operator is assigned to a trolley (3). In the initial situation, there was a significant difference among the workloads attributed to each operator. Thus, for each different number of operators, the workloads of the operators were balanced. In the case where the number of operators is equal to the number of trolleys, each operator is assigned a trolley (3).
- Action Parameter 2 (AP2): number of available operators, which can vary between 2 and 19.
- Action Parameter 3 (AP3): picking strategy, which can either be the operator going back and forth from the trolley to the stock for each item (1), or a course through the warehouse pushing the trolley (2).

The evaluation and action parameters were identified by applying a solving approach based on the methods and tools of lean warehousing. First, the main sub-problems composing the initial problem were detected, in particular, the set of wastes related to the operators' tasks. The root cause analysis of each problem enables the identification of the evaluation parameters of each problem and the action parameters that influence them.

The model for this warehouse problem has been implemented in Witness, as illustrated in Figure 6.

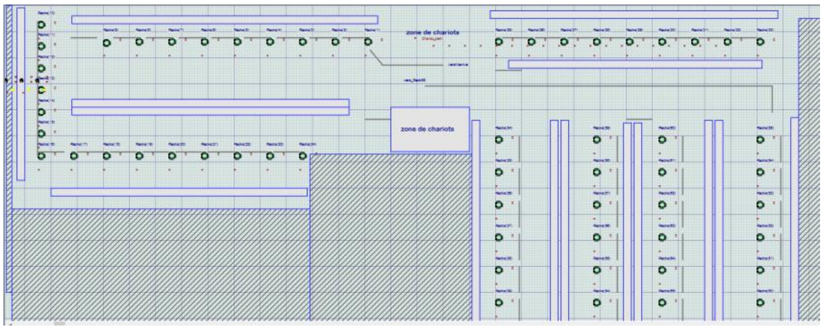

Figure 6. Witness model of the warehouse problem

Then, the experiments presented in Table 1 were conducted.

It can be considered that no satisfying solution has been found by the simulations. Accordingly, the next step will be to extract the contradictions.

4.3 Technical Contradictions extraction

No classical TRIZ Technical Contradiction can be found. In fact, human experts would consider, for example, a technical contradiction between EP2 and EP3; in most cases, if EP2 is satisfied, then EP3 is not, and vice-versa. However, the first experiment shows that it is possible to satisfy both of them, and the same is true for any pair of Evaluation Parameters. Thus, even if no solution is recognized in Table 1, no classical TRIZ Technical Contradiction can be extracted.

The use of the algorithm presented in (Lin et al., 2013) makes it possible to extract all the GTCs from Table 1 automatically. From this table of experiments, 11 GTCs have been extracted. Thus, the question arises of how to prioritize the GTCs for the next steps.

4.4 Prioritize extracted technical contradictions

One of the proposed strategies is to hierarchize the contradictions with regard to two points:

- The number of Evaluation Parameters considered in the GTC, as the aim of solving a contradiction is to fit the requirements of the EPs implied in the contradiction. The more are considered, the better.
- The number of experiments implied in the formulation of the GTC, as the authors consider in this way the formulation of the system of contradictions will be more representative of the problem.

Based on these two proposals, one GTC is recognized as higher priority than the others, as it considers 4 EPs and is based on considering 19 experiments. This GTC opposes the satisfaction of EP2 and the satisfaction of (EP1, EP3, EP4).

Table 1. Warehouse problem experiments

Experiment	Assignment of trolleys to operators (AP1)	Number of available operators (AP2)	Picking strategy (AP3)	Delay to fill the trolleys (in hours) (EP1)	Total load for operators (in hours) (EP2)	Total waiting time (in hours) (EP3)	Medium capacity reserve (in hours) (EP4)
e1	2	1	2	18.78	19	0.00	0.00
e2	2	2	2	9.53	19	0.16	0.00
e3	2	3	2	6.56	19	0.42	1.60
e4	2	4	2	4.98	19	0.64	3.14
e5	2	5	2	4.23	20	1.27	3.98
e6	2	6	2	3.61	20	1.70	4.57
e7	2	7	2	3.22	21	1.95	5.04
e8	2	8	2	2.88	21	2.37	5.36
e9	2	9	2	2.66	22	2.94	5.58
e10	2	10	2	2.48	22	3.07	5.82
e11	2	11	2	2.35	22	3.12	6.01
e12	2	12	2	2.20	22	3.32	6.15
e13	2	13	2	2.04	22	3.63	6.26
e14	2	14	2	1.91	23	4.27	6.35
e15	2	15	2	1.83	24	5.24	6.39
e16	2	16	2	1.82	25	6.14	6.44
e17	2	17	2	1.81	25	6.63	6.51
e18	2	18	2	1.81	26	7.18	6.56
e19	3	19	2	1.81	26	7.61	6.61
e20	1	5	1	7.31	28.70	0.00	2.26
e21	2	2	1	15.30	29.10	0.00	0.00
e22	2	3	1	9.49	27.40	0.00	0.00
e23	2	4	1	7.27	28.20	0.00	0.96
e24	2	5	1	6.60	28.80	0.00	2.25
e25	2	6	1	5.17	29.42	0.00	3.10
e26	2	7	1	4.52	30.00	0.00	3.70
e27	2	10	1	3.17	28.90	0.00	5.11
e28	3	19	1	2.61	29.40	0.00	6.45

4.5 Physical Contradictions extraction

Regarding the technical contradiction, no classical TRIZ physical contradiction can be recognized in the overall table. If considering only part of the table, a classical TRIZ System of Contradictions can be formulated, for example, considering only experiments e19 and e20, a system of contradictions seems to apply, as illustrated in Figure 7.

This type of partial consideration of the overall system is the one performed by human experts when formulating TRIZ contradictions. The problem is that the limits of validity of this formulation are not necessarily apprehended.

Thus, to build a more robust System of Contradictions, the GSC makes it possible to develop a more explicit formulation of the problem. For the previously chosen GTC, 126 GPCs could be formulated.

Experiment	Assignment of trolleys to operators (AP1)	Number of available operators (AP2)	Picking strategy (AP3)	Delay to fill the trolleys (in hours) (EP1)	Total load for operators (in hours) (EP2)	Total waiting time (in hours) (EP3)	Medium capacity reserve (in hours) (EP4)
e19	3	19	2	1,81	26	7,61	6,61
e20	1	5	1	7,31	28,70	0,00	2,26

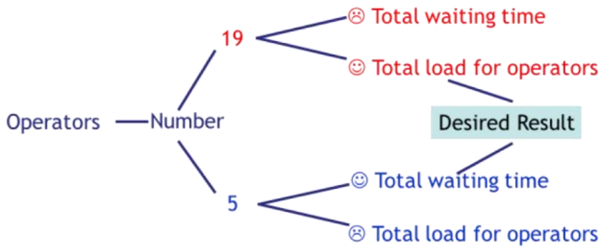

Figure 7. Classical TRIZ System of Contradictions, based on partial table

Among these formulations, some are specific, as they can be recognized as classical TRIZ physical contradictions, but with an explicit limit of validity, called the context of the contradiction. For example, one member of the contextual TRIZ System of Contradictions extracted from the table is illustrated in Figure 8.

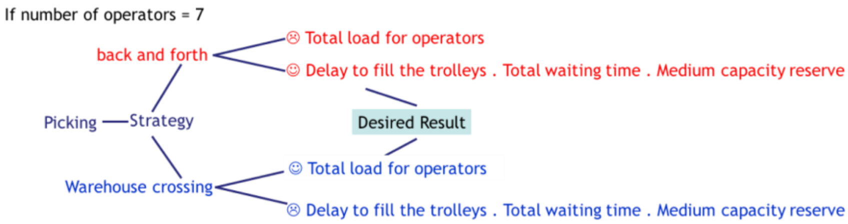

Figure 8. Contextual GSC

In this formulation of the problem, it is understood that the problem to solve is to fit the strategy of picking, which must fit the properties of going back and forth, to satisfy the delay to fill the trolleys, the waiting time and the capacity reserve; but at the same time to fit the properties of the strategy of crossing the warehouse, which satisfies the total load for the operators. The benefit of this formulation is that it enables the application of TRIZ separation principles for physical contradictions by defining the domain of validity of the contradiction, thus eliciting the constraints the concept of solution must fit.

4.6 Proposal of concept of solution

Analysing the presented contradiction through ARIZ, an idealization of the desired solution (called in Analyzing the presented contradiction through ARIZ (Algorithm for Inventive Problem Resolution, the more complete method of TRIZ), an idealization of the desired solution (called in TRIZ the Ideal Final Result) was presented as follows: "operators must move from trolleys to stock inside the warehouse when a new article is required, to decrease the time to fill the trolleys, to limit the waiting time and to have a good reserve capacity; however, the operators must move all throughout the warehouse during their journey, to decrease the load for operators". Analyzing this formulation highlighted the fact that time is a particular resource for this problem and that separation in time (one of the separation principles of TRIZ) could be applied. Thus, a new strategy has been proposed based on planning the operators' start. Initially, all the operators started simultaneously, and waiting time occurred. If they all perform the same journey, crossing the warehouse, but begin with a delay, it will positively affect the total load. With this type of configuration, a solution has been proposed, with the following results: delay to fill the trolleys = 7 hours; total load for operators = 18,7 hours; total waiting time = 6 minutes and reserve capacity = 5,3 hours.

5 DISCUSSION

In this article, the authors sought to illustrate the benefits of the GSC model based on the non-systematic existence of classical TRIZ contradictions for unsolvable problems. A second purpose was to introduce the first hypotheses for prioritization of generalized contradictions. The following hypotheses have been built on the exhaustiveness and robustness of the formulations:

- The robustness is considered in terms of experiments with the Pareto frontier of the binary model of EP, as when solving problems that are not on the Pareto frontier, the proposed solutions could be less efficient than the ones that already exist among all realized experiments.

- The exhaustiveness relies on considering the contradictions implying more experiments in the set of experiments E1 and E2.

These two assumptions must now be validated by comparing the resolution of these robust and exhaustive contradictions with contradictions that do not satisfy these conditions.

Another remaining question is whether the proposed solution, which satisfies all the requirements, has been improved by optimization with the new strategy. A better solution has been found with 4 operators. Thus, is the constraint implied by the context really important in the formulation of the GSC? This question must be considered by solving more problems to generalize an answer to this question.

Our final remark is about the example used in this article, which is quite minimal in terms of the number of considered parameters. The subject of how to tackle more complex problems has also been considered in (Lei, 2016), where the use of Support Vector Machines has been proposed as a robust means to analyze and perform regression on large data.

REFERENCES

Belski, I. and Belski, I. (2008), Cognitive Foundations of TRIZ Problem-Solving Tools. *In:* Vaneker, T. (ed.) *TRIZ Future Conference.* Twente, The Netherlands.

Cavallucci, D., Rousselot, F. and Zanni, C. (2010), Initial situation analysis through problem graph. *CIRP Journal of Manufacturing Science and Technology,* 2**,** 310-317.

Cavallucci, D., Rousselot, F. and Zanni, C. (2011), An ontology for TRIZ. *Procedia Engineering,* 9**,** 251-260.

Chang, Y.-S., Chien, Y.-H., Yu, K.-C., Chu, Y.-H. and Chen, M. Y.-c. (2016), Effect of TRIZ on the creativity of engineering students. *Thinking Skills and Creativity,* 19**,** 112-122.

Chechurin, L. and Borgianni, Y. (2016), Understanding TRIZ through the review of top cited publications. *Computers in Industry,* 82**,** 119-134.

Dubois, S., Eltzer, T. and De Guio, R. (2009), A dialectical based model coherent with inventive and optimization problems. *Computers in Industry,* 60**,** 575-583.

Dubois, S., Lin, L., De Guio, R. and Rasovska, I. (2015), From Simulation to Invention, Beyond the Pareto-Frontier. *In:* Christian Weber, S. H., Marco CantaMESsa, Gaetano Cascini, Dorian Marjanovic, Serena Graziosi (ed.) *20th International Conference on Engineering Design (ICED).* Milano, Italy: Design Society.

Jafari, M., Akhavan, P., Zarghami, H. R. and Asgari, N.(2013). Exploring the effectiveness of inventive principles of TRIZ on developing researchers' innovative capabilities: a case study in an innovative research center. *Journal of Manufacturing Technology Management,* 24**,** 747-767.

Khomenko, N., De Guio, R., Lelait, L. and Kaikov, I. (2007), A framework for OTSM-TRIZ-based computer support to be used in complex problem management. *International Journal of Computer Applications in Technology,* 30**,** 88-104.

Khomenko, N., Guio, R. D. and Cavallucci, D. (2009), Enhancing ECN's abilities to address inventive strategies using OTSM-TRIZ. *International Journal of Collaborative Engineering,* 1**,** 98.

Lei, L. (2016), *Optimization methods for inventive design (Méthodes d'optimisation pour la conception inventive).* Docteur, Université de Strasbourg.

Li, Z., Atherton, M. and Harrison, D. (2014), Identifying patent conflicts: TRIZ-Led Patent Mapping. *World Patent Information,* 39**,** 11-23.

Lin, L., Dubois, S., De Guio, R. and Rasovska, I. (2014), An exact algorithm to extract the generalized physical contradiction. *International Journal on Interactive Design and Manufacturing (IJIDeM),* 9**,** 185-191.

Lin, L., Rasovska, I., De Guio, R. and Dubois, S. (2013), Algorithm for identifying generalized technical contradictions in experiments. *Journal Européen des Systèmes Automatisés (JESA),* 47**,** 563-588.

Miller, G. A. (1956), The Magical Number Seven, Plus or Minus Two Some Limits on Our Capacity for Processing Information. *Psychological Review,* 63**,** 81-97.

Souili, A., Cavallucci, D. and Rousselot, F.(2015), A lexico-syntactic Pattern Matching Method to Extract Idm-Triz Knowledge from On-line Patent Databases. *Procedia Engineering,* 131**,** 418-425.