Assisting the use of TRIZ laws in partially automating evolution hypothesis construction

D. Cavallucci[1]

[1] INSA Strasbourg/LGéCo, Design Engineering Lab., Strasbourg, France

Summary

Despite laws of engineering systems evolution disclosed by Altshuller are considered as an axiom of TRIZ, their use in projects is very diverse. A first reason is their fuzzy relation (not to say opposition) with traditional marketing orientations which mainly rely on customers. A second is the level of genericity of their expression, making difficult their use within industrial projects. This paper summarizes our work on computer assistance to laws use. Through experiments, both in industry and education, it has been proven that instantiation algorithm and contextualization favors not only the understanding of laws so as their role in an invention process but also the inventiveness of industrial projects.

Keywords: TRIZ|Laws of Engineering Systems Evlution|Inventive Design|IDM-TRIZ|Evolution Hypothesis|Air Intake Manifold

1. Motivation / State of the Art

Since its origins, TRIZ has been exposed by Altshuller as a theory relying on two major postulates[1][2]. The first one stipulates that technical artefacts appear not randomly but according to a limited amount of objective laws [3]. The second brought forward that to switch from one generation to the next, artefacts overpass contradictions in solving them without compromises[4]. While a lot of attention was given to contradictions in education programs, software, methodologies, few researches involved laws of engineering systems evolution[5]. As a result, laws appear in every TRIZ-related definition or book, without very much being deployed in projects.

The first reason lies in the tradition that companies have endorsed for decades in defining themselves as entities aiming at satisfying customers[6]. So customers satisfaction becomes the "reason-to-invent"[7]. From a philosophical viewpoint we can agree on this statement, why should man invent objects (artifacts) if it was not to make their life easier, safer, and happier? Consequently companies, whose role is to manage artefact development and grow their ROI, found logical to listen to customers' needs and base a large part of their strategy of new product development on them [6]. If we add to this the fact that international norms have engraved into official documents this orientation, companies can't escape following customer's needs. Since basing a company's strategy only on placing attention on customer's demand is risky, several researches have revealed that anticipating a tacit demand would be a good compliment [8]. But in fine, customers remain the only target.

Altshuller based his theory on observation of recurrent meta-behavior of inventors when creating new artefacts. He also disclosed that in observing patents throughout the history of artefacts since their infancy, there are some trans-domain regularities. A set of "mega-trends" common to all artefacts, whatever the domain they belong to is.

In TRIZ-related literature, very few contributions concerns operating laws. We can easily find nice interpretation of laws in most TRIZ-related softwares (Goldfire, IWB, I-Win or Creax) with an ergonomic display and series of examples (often illustrated) but no one has attempted yet to axiomatically merge laws interpretation with the rest of a TRIZ process [9][10].

Thinking about new laws (or re-distributing laws hierarchy) is also a well-covered topic. Among them, contributions of Petrov highlighted that law of Ideality was more of a meta laws than a law at the same level as the others[11]. Some others found interesting to create new laws like diminution of man involvement [12]. Such contributions, even if worth to consider, have poorly justified why and how these new laws could be legitimated. As such, deeper explanations would have been appreciated to accept them as real contributions.

STEPS software is the result of a new way of operating TRIZ[13]. It is the result of the cooperation between two worlds: academia and industry. Therefore, the starting point of this project was not to operate TRIZ, but to decompose and rebuild TRIZ based on Ontologies so as to create missing links between TRIZ concepts when necessary before creating any software[14]. A previous publication already presented the way we linked Contradictions and Laws in STEPS through Evolution Hypotheses[15]. After experiencing its use with industrial and education projects, we noted that the use of laws within a process was averagely appreciated by users. The reason was that even if made operational, users were not familiar with manipulating them as it requires interpretation skills and capacities to observe situations in a systemic way. We therefore decided to move a step beyond in facilitating laws interpretation using contextualization algorithms.

This paper will be divided into five sections. After this introduction, a section is dedicated to the methodology we employ to observe and conduct this project. A fourth section is dedicated to illustrate the methodology with a case study. Finally a discussion section is drawn after our experiences and feedback so as to help us to build future research orientations. A conclusion will logically end the paper.

2. Methodology

We postulate that Artificial Intelligence could assist a more intuitive and systematic use of laws in TRIZ projects[16]. To operate our research we use a previous contribution published in ETRIA a few years ago[15]. This research has been transformed into a computer program in java that intends to correlate laws with contradictions by means of a mediator, namely Evolution Hypothesis (EH). These EH have been proven in experiments that it clarifies the deliverable laws can bring to a TRIZ study. In addition, laws have never been correlated with contradictions in previous publications. We consider this situation as abnormal since both axioms of TRIZ lately work independently. This fact is confusing academics or scientists that only rely on an extensively described corpus of knowledge (characterizing also relations between concepts) before accepting a theory as valid.

To better illustrate our approach, here is summarized (due to article length limitations) an example of how exploring laws through semi-automated algorithms can be conducted.

- First step: Using Inventive Design Ontology, key terms qualifying the problem must be disclosed. Each term will then be stored into an UML diagram and tagged in such a way each time within the continuation of the process, this term may appear in a template sentence. This manipulation is called “contextualization” and aims at using accurate generic definitions and replace when appropriate some of its components (mostly nouns) with the one filled in the ontology.
- Second step: Associating to each law (out of the 9 referred as Altshuller’s authorship) an algorithm from which user will navigate by only answering “yes” or “no” (to simplify user interface). Consequently, each law will be interpreted and need to end with either none or several Evolution Hypotheses semi-automatically constructed.
- Third step: locating maturity either intuitively or using Altshuller’s 4 curves’ method.
- Fourth step: Emitting recommendations to concentrate inventive efforts on specific evolution hypotheses according to both evolution strategy and system’s maturity of each law requiring more attention.

3. Case study: MGI Coutier Air Intake manifold

3.1. Case introduction

Air Intake manifold are automotive parts carrying a significant use in the pipeline of engine thermal cycle. They have the role to vehicle air at optimum conditions from the outside to the upper chamber of cylinder zone so as to favor combustion conditions. What is expected here is to maintain optimal the air filling conditions. Nevertheless, we know that cylinder functioning (consequently their demand in air) vary depending on speed (Rpm).

Figure 1: Standard existing Air Intake Manifold

To say it simply, this variation is provoked by a user action on accelerator when manipulating speed. Nevertheless, a large majority of air intake manifolds are of a fixed structure and dimensioned geometrically for the most often used Rpm (for instance 5.400 Rpm in some vehicles). This simply means that at any other speed, manifolds are not in the optimal geometrical conditions that would place air filling in the ideal conditions. As a result, thermal losses can be expected at the end of the cycle.

High-tech vehicle have of course already handle this problematic and created a computer controlled geometrical variations. Some others have made a compromise in adding a new set of pipes having a second geometry so as to switch from a series of pipe to the next depending on the Rpm speed. We therefore have currently in the market either high cost solutions or compromises. This typical situation has been assigned by a European automotive supplier to our research group and we decided to test our newly performed algorithm of law use on it.

3.2. Law use computer assisted

First of all, it is necessary to define all components of Air Intake system. It consists in associating through the system completeness template to define Tool, MUF (Main Useful Function), Object and how tool can be decomposed into a system consisting in Engine, Transmission, Work and Control elements. Then how the MUF "Drive" act on Object "Air" before its realization (state 1) and after its completion (state 2). In our computer program, each element when typed is captured by the system and will be used to contextualize user/computer interface later in the program.

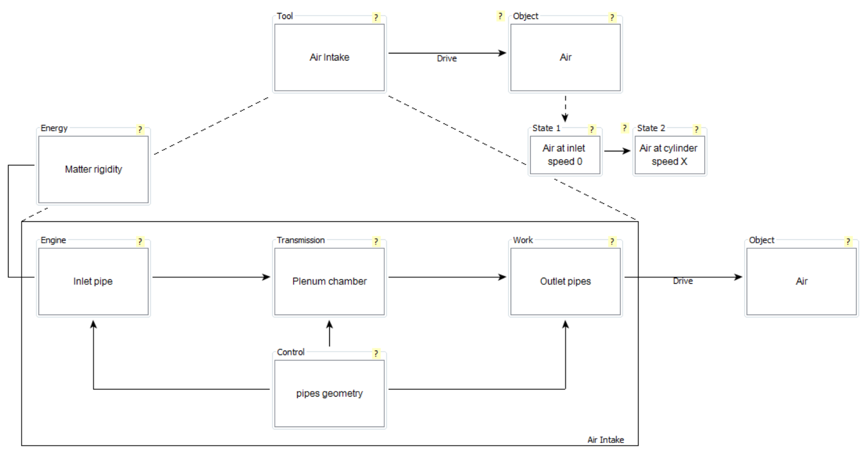

Figure 2: Air Intake case defined through law of system completeness (Law 1).

Secondly, after stating on system's maturity through Altshuller's 4 curves methodology (not explained in this paper) 7 scenario of automatic law ranking [5][15] are applied to our system so as to locate its maturity along a spider-like diagram. The next screen is dedicated to study each law status in deep for either considering that there is nothing to interpret from it or transforming an interpretation into a useful format of an Evolution Hypothesis. When activating the "auto-hypothesis" function, a yes-no like algorithm handle the job to accompany users in the formulation of their Evolution Hypothesis.

Figure 3 shows a screen capture of this exercise and the floating window displays the result of law 1 algorithm (system completeness law).

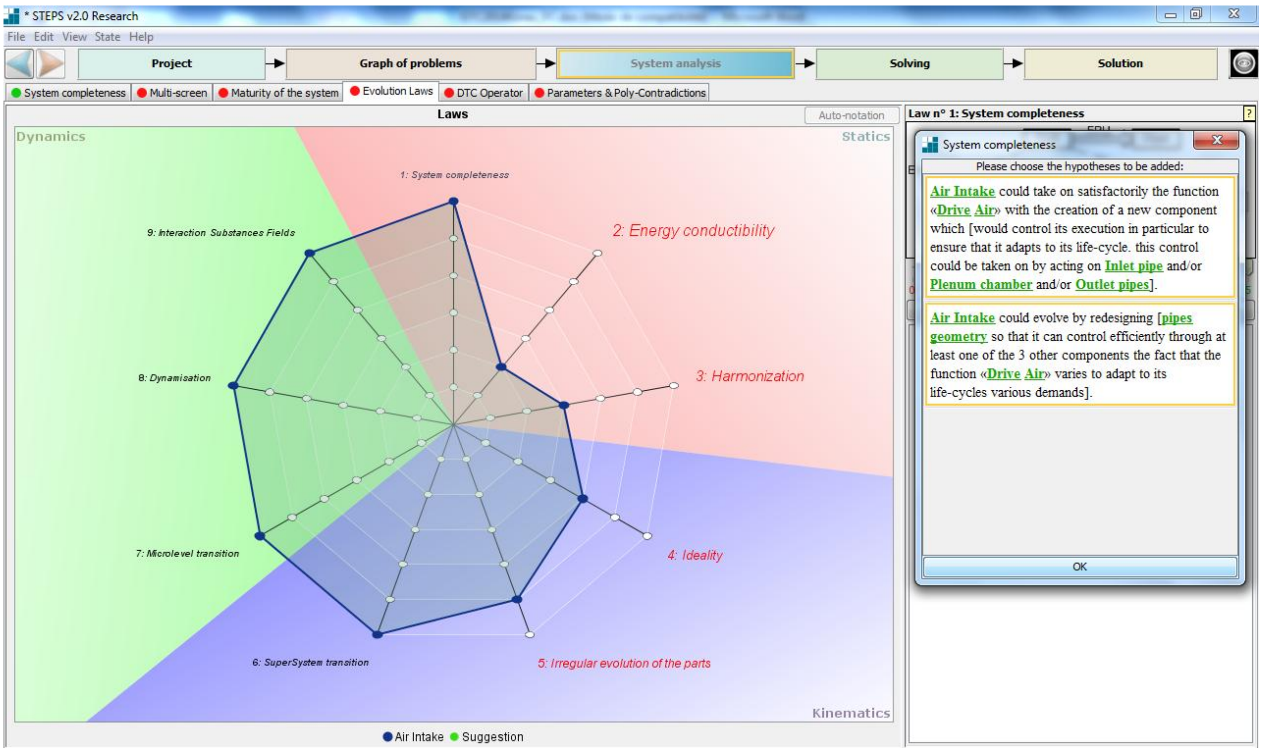

Figure 3: Spider-like diagram for Air Intake Manifold and law 1 automatic EHs

In order to obtain the EHs of each law (laws being weakly marked on the spider diagram should be more carefully considered) users are driven along 9 different algorithm that on the back-end (source code) contains TRIZ's expertise decomposed so as to explore each possibility to interpret a law. In order to be closer to user's understanding of this semi-automatic interpretation, each time a term can be contextualized using a term that has been previously defined, this term is appropriately placed in the sentence being proposed to the user (in green on Figure 4). As it is displayed in figure 4, after a sequence of 12 "YES-NO" options (in our Air Intake case NO-YES-YES-YES-YES-NO-YES-YES-YES-YES-YES-NO) the first "NO" correspond that there are things to say regarding the law, nothing yet defined but it is worthwhile considering it. Second, each time a "NO" is given, the sentence being automatically composed is recorded and brough back at the end of the algorithm as a potential EH regarding this law. In our case, we have:

> *EH1: "Air Intake could take on satisfactorily the function «Drive Air» with the creation of a new component which [would control its execution in particular to ensure that it adapts to its life-cycle. This control could be taken on by acting on Inlet pipe and/or Plenum chamber and/or Outlet pipes]."*
>
> *And*
>
> *EH2:"Air Intake could evolve by redesigning [pipes geometry so that it can control efficiently through at least one of the 3 other components the fact that the function «Drive Air» varies to adapt to its life-cycles various demands]."*

These 2 sentences have been automatically obtained in answering to 12 questions by either YES or NO (see figure 6). We have experienced that users dramatically change their mind when being assisted in the formulation of EH. First when they are newcomers and when they discover TRIZ's laws and try to understand what could be their use in a study. Second when they are skeptical about laws's role into the process and want to restrict their TRIZ use only to the matrix. Laws here can play a role of highlighting which set of parameters involved in contradictions can be considered in priority, since EH plays a role of intermediary elements between Laws and Parameters.

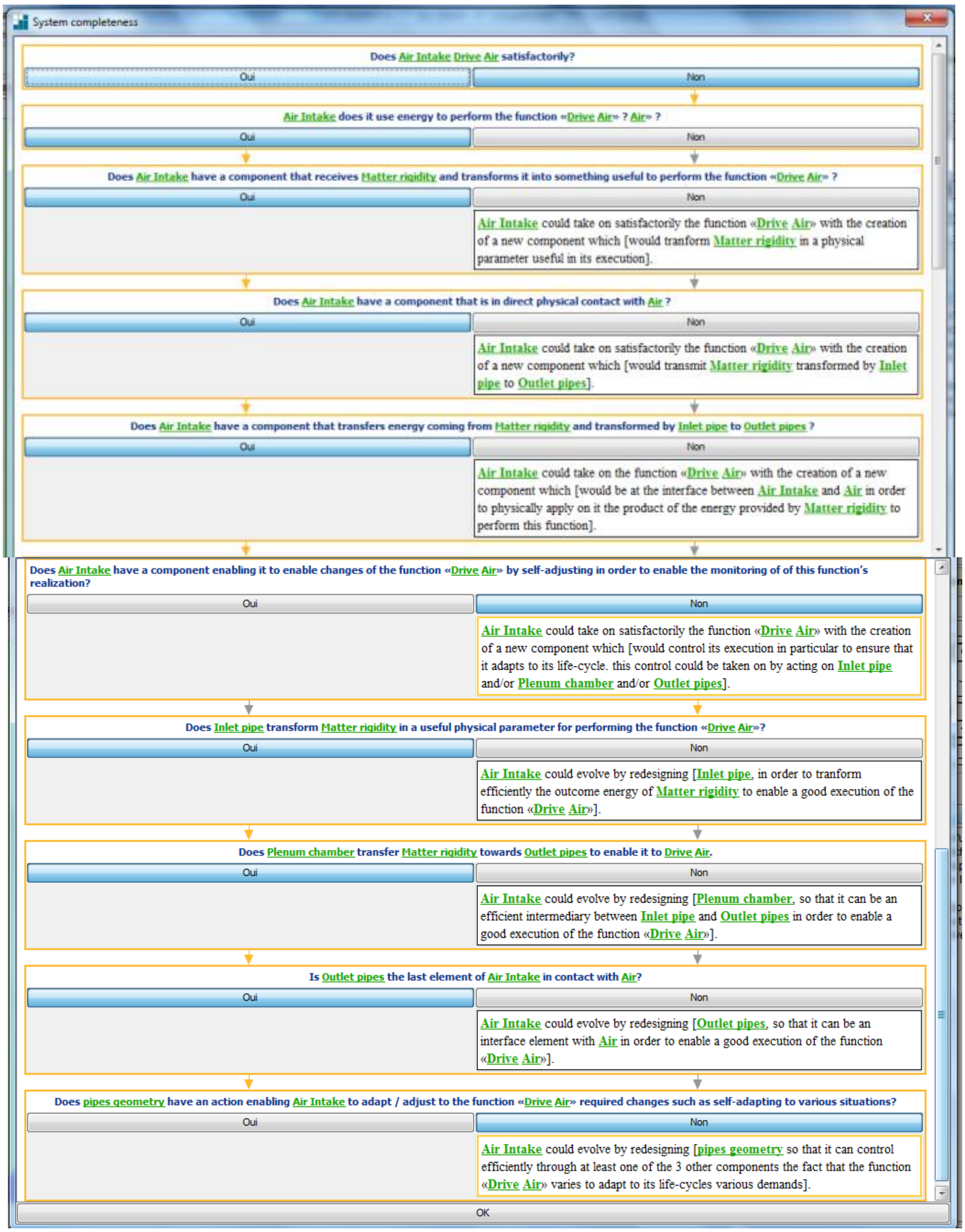

Figure 5: Complete algorithm related to Law 1 for Air Intake Manifold case.

4. Results and Discussion

After 3 series of experiment with INSA Strasbourg engineering student and 4 cases studies in industry, we have analyzed the results and correlated them with a control group (without the use of our methodology – classically conducted like in previous TRIZ literature).

Table 1 shows the obtained results with both our methodology in Industrial circumstances and during education situation. The control group was constituted of a standard student group using TRIZ without any algorithm just after a basic training. Of course this training does include laws as a chapter, but with no specific ways of using it within a process as we have noted in classical TRIZ literature.

Experiments	Percentage of law use (classical approach)	Increase of law use with computer assistance (based on EH produced by groups)	Mean of increase by groups
Control Group for students	20%	-	-
Control Group for Industry	30%	-	-
Mechanical engineering 1	-	69%	58%
Civil Engineering 1	-	85%	
Mechanical engineering 2	-	72%	
Civil Engineering 2	-	78%	
Mechanical engineering 3	-	78%	
Civil Engineering 3	-	85%	
Air Intake Manifolds case	-	80%	32%
Dashboard case	-	65%	
Mascara case	-	45%	
High Speed Train case	-	56%	

Table 1: Summary of Law use within experimental situation

We have observed various consequences of the method use. First of all, law use has been increased by 58% in education while it increases by a factor of only 32% in industry. We interpreted this situation as the sign of a lack of time availability for industrials to concentrate on tasks they cannot feel their real impact. In fact, laws are felt by industrials as highly theoretical while working with contradictions seems more concrete. We therefore observed that naturally laws use was skipped in the process while systematically contradictions were formulated. When laws were used, it was more in studies that were very open to novelties (exploratory ones). While the percentage of law use decreases when in more mature projects. After questioning company experts we understood that project leaders had already in mind where to go, while being only in need of getting inventive ideas.

For educational purposes, the results are much more encouraging as there is a significant increase of law use when passing through our methodology. We interpreted this as offering to student a more structured way of going through something that seemed fuzzy for the control group. When questioning the control group after the exercises, the most encountered answer was that they understood laws as a way to explain TRIZ constitution, not as a tool to be used in projects. Consequently, in control group, only very few teams have chosen to use laws pragmatically. When questioning the rare groups that do use laws, their answer was “we wanted to think out of the box, and we thought laws were a good way to do so”. The other groups answered “we already had in mind where to go; we just needed to find a relevant contradiction to solve to guarantee the inventive output of our project”

This experiment clearly demonstrates that semi-automating laws use with computer assistance has enhanced the relevance of their impact in TRIZ projects. The limitation of our research has also been investigated and we are still looking for improvement of our methodology. We found that during industrial case studies, it was easy for companies to refuse laws interpretations proposals since computer assistance in formulation disturbs human creativity (for most engineers Evolution Hypothesis can’t come from a computer). Psychological inertia was not considered in our study and we discovered that some companies had difficulties to accept what came out of our methodology just because it came from a computer. We are therefore currently investigating new ways of displaying computer results more as an automated database of proposals that of a mandatory step in the process.

5. Conclusion

During the past 6 years, we targeted the robustness of TRIZ processes. We soon arrived to the conclusion that classical TRIZ (the way Altshuller built it and presented it in available literature) was far from being fully computable and was still more of an art than of a science. Nevertheless, truly breakthrough concepts where behind his theory and made his achievement worthwhile to consider for nowadays industrial expectations to systematize innovation. One of the lacking point in which this article focused on was the absence of operational involvement of laws into the flow of TRIZ process. Through the framework of IDM-TRIZ (our reviewed version of TRIZ after several years of academic research) we found logical to operate laws so as to ease their role into the whole inventive process led by TRIZ postulates. It was proven before our experiments that people (both students and industrialists) skipped laws use as no formalized way, like it could exist in Inventive Principle, is proposed within classical TRIZ. A computed version, featuring contextualization functions and Ontologies, has been elaborated to change this situation. This computer program has integrated our STEPS-research software and has been tested with both industrialists during real case studies and several years with INSA students (master level). The results are showing significant progresses in terms of uses, but this situation is of a larger amplitude with student than with people from industry. This was mostly due to the difficulty for people having a financial objective (ROI oriented) to perceive the impact of laws, while student were more just applying the taught methodology eased by the mandatory aspect of going through law use as with any other steps of TRIZ. We therefore realized that deeper research must be conducted to increase user perception of laws impact on a study during the early stage of TRIZ. We conclude that significant progresses have been achieved and that we switched from a marginal use to a more systematic use of laws, bringing both students and professionals towards more TRIZ-oriented findings within inventive projects.

References

[1] G. Altshuller, « Evolution of technical systems ». 1977.
[2] G. S. Altshuller, B. L. Zlotin, A. V. Zusman, et V. I. Philatov, *SEARCH FOR NEW IDEAS: FROM INSIGHT TO TECHNOLOGY (THEORY AND PRACTISE OF INVENTIVE PROBLEM SOLVING)*. Kishinev: Kartya Moldovenyaske Publishing House, 1989.
[3] Y. P. Salamatov, « A system of laws of engineering evolution », *Chance Adventure Petrozavodsk Russ.*, 1991.
[4] G. S. Altshuller, *CREATIVITY AS AN EXACT SCIENCE*. Moscow: Sovietskoe radio Publishing House, 1979.
[5] D. Cavallucci, « Integrating Altshuller's development laws for technical systems into the design process », *CIRP Ann. - Manuf. Technol.*, vol. 50, n° 1, p. 115‑120, 2001.
[6] Y. Akao, *QFD: Quality Function Deployment - Integrating Customer Requirements into Product Design*, 1re éd. Productivity Press, 2004.
[7] J.-W. . Ding, « Research on capturing of customer requirements based on TRIZ », *Jisuanji Jicheng Zhizao XitongComputer Integr. Manuf. Syst. CIMS*, vol. 12, n° 5, p. 648‑653, 2006.
[8] L. Li, G. Li, et S. Huang, « Research on product innovative design method driven by client demands », in *Knowledge Enterprise: Intelligent Strategies in Product Design, Manufacturing, and Management*, 2006, vol. 207, p. 433‑439.
[9] P.-A. Verhaegen, J. D'hondt, J. Vertommen, S. Dewulf, et J. R. Duflou, « Relating properties and functions from patents to TRIZ trends », *CIRP J. Manuf. Sci. Technol.*, vol. 1, n° 3, p. 126‑130, 2009.
[10] P. Zhang et R. Tan, « Using the CAI software (InventionTool 3.0) to solve complexity problem », in *TRENDS IN COMPUTER AIDED INNOVATION*, 2007, vol. 250, p. 115‑123.
[11] V. Petrov, « Laws of development of needs », in *ETRIA TRIZ Futures 2005 Conference, Graz, Austria*, 2005.
[12] D. L. Mann, « Better technology forecasting using systematic innovation methods », *Technol. Forecast. Soc. CHANGE*, vol. 70, n° 8, p. 779‑795, oct. 2003.
[13] D. Cavallucci et N. Khomenko, « From TRIZ to OTSM-TRIZ: Addressing complexity challenges in inventive design », *Int. J. Prod. Dev.*, vol. 4, n° 1‑2, p. 4‑21, 2007.
[14] D. Cavallucci, F. Rousselot, et C. Zanni, « An ontology for TRIZ », *Procedia Eng.*, vol. 9, p. 251‑260, 2011.
[15] D. Cavallucci et F. Rousselot, « Evolution hypothesis as a means for linking system parameters and laws of engineering system evolution », *Procedia Eng.*, vol. 9, p. 484‑499, 2011.
[16] D. Cavallucci et N. Leon, « Computer-supported innovation pipelines: Current research and trends ».