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Application of evolution's laws

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Abstract

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Technical systems evolution follow trends, some laws describe the different steps of evolution of those systems. These laws are known as "laws of technical systems evolution" from the TRIZ theory. The aim of this paper is to propose an approach facilitating the use of the evolution laws, as part of a framework for innovation.

To achieve our goal we start by an analysis of each definition of the three first evolution laws. It's analysis we'll permit to extract with precision part of the definition we'll use to construct a model helping the use of the laws. The model we propose is composed of a short quiz that users must answer. The purpose of these questions is to guide the user as far as possible in the identification of functional elements of the system and possible developments of innovative products, as recommended by the three first laws. After that, we'll conduct an experimentation to taste this model on two kinds of participants, some of them are software developers working in differents companies, they do not know the TRIZ theory. The other participants are students in training who learned some tools to innovate, they are not completely novices on TRIZ.

To conclude, we'll present the relevance of our approach to use systematically the first 3 evolution laws of TRIZ.

*Keywords***:** TRIZ, Evolution's laws, Technical System, Systematic Innovation.

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1. Introduction

Sometimes, invention does not provide the expected success. Such a failure may be related to either its incompatibility with the current expectations of customers, or that this invention is overtaken. Or more simply cause of companies who do not use the new method of systematic innovation [9].

Technical systems obey laws that describe the trends of systems evolution. These laws are known as "laws of technical systems evolution" from TRIZ. Among these laws, we will discuss the first, which states that a system should be composed of four elements in order to be operational and viable. According to [7], this evolution laws may also address the problem stated in the previous paragraph because they allows systematizing innovation. It begins to be leveraged by researchers and experts in the theory TRIZ innovation strategy and problem solving. The aim of this paper is to propose an approach facilitating their use as part of a framework for innovation.

As part of our research on TRIZ, we identified the lack of scientific papers dealing of evolution laws [10].

The literature don't explain how to use laws, she classifies only laws in 3 categories:

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- The first category, including the first 3 laws, indicate the static laws. The laws describing the global organization of the system;
- The second category, including the following 3 laws, indicate the kinematic laws. They are laws to improve the system;
- Finally, the third category, including the last laws, indicate the dynamic laws. She presents other ways of evolution.

This article addresses the problem of: how to use systematically the static evolution laws of TRIZ in the prediction of future generation of systems?

2. Methodology

The followed protocol used to find an approach to apply the evolution law as a framework of innovation is explained bellow:

- We start by analyzing semantically several versions of the definition of each evolution law to extract information about the characteristics that must being respected to satisfy the evolution of a technical system according to these law,
- Then we represents this information in a structured schema to construct a kind of an algorithm which explain step by step how to apply the three first evolution laws.

2.1 Analyzing the first law

We start by analyzing the first evolution law for determining the characteristics of functional elements of a technical system. Here are some versions of the definition of the first law:

a. To operate, a technological system must include at least four sub-units: an energy source (the engine), the transmission, and a body of work (an actuator) and a control part or control organ. At least one of the entities must be controllable and each of the four entities must be present in the system and achieve the function in a minimum configuration [6]. In its definition, Pascal CRUBLEAU assigns key words to define functional elements of technical system: energy source for the engine and actuator for the operator, these key words enrich the definition of law 1 because they can help in identifying elements of the system.

b. For a system to ensure its main function, it must have 4 fundamental parts ideally fulfilling their role in the functioning of the system. These 4 main parts are [2]:
   - The engine: whose function is to generate the energy required to ensure the main function.
   - The element of transmission: that will stream this energy towards the working element.
   - The working element: that will ensure the contact between the system and the physical element on which it acts.
   - The control element: its main function is to react to the variations in the system behavior by adapting automatically to its form, structure and output.

The consequences for this law are as follows:

- Each element must participate fully in the good working of the system
- At least one of the parts must be controllable.

Again this definition provides more details on the characteristics of the functional elements of the technical system, by 1) giving the engine the ability to generate energy, 2) considering the transmission element as channel of this energy, 3) stating that the work item is in direct contact with the object on which the system works and that the main function of the controller is to adapt to changes in the system.

c. In his thesis Guillermo Cortes Robles [5] gives the following definition: To be operational a technical system requires four essential elements:

- A source of energy: a motor.
- An element to transmit energy produced or processed by the engine, body work.
- A body of work that physically performs a function.
- A monitoring body.

The presence of a supervisory body, implies that at least one component of the system must be controllable; prerequisite for the correct behavior of the system. A further indication provided by this version is that the engine is responsible for the production or the processing of power.

e. In his thesis SCARAVETTI defines the law 1 as follows: To perform a function, energy must be used, processed and transmitted, each of the 4 preceding entities must be present and help to achieve this function in the technical system [8]. Control of the operator near the completion of the action is a guarantee of successful operation. The criterion for this act is the number of entities involved in control.

Other relevant information in that definition relates to the proximity of the control entity to the operator, the more control is close to the operator the more efficient is high.

f. In a document written by Denis CHOULIER during a workday in TRIZ France, CHOULIER proposed these following definitions of the functional elements of the system [4]:

- The unit of work represents the "active ingredient" of the system.
- The power unit is a system interface. It transforms the energy it gets in some form outside the technical system in a form suitable for transmission to the work unit.
- The transmission is the part of a system that links energy between the work unit and the engine. It is geographically located between them.
- The control unit acts to modulate the level of action of the working unit according to changes in external conditions, and also those of the source of energy.

This latter definition provides benefit details on the functional elements of the system. It presents the engine as an interface system, which converts the energy outside the system in a form usable by the work unit. This definition geographically places the unit of transmission between the engine and the work unit.

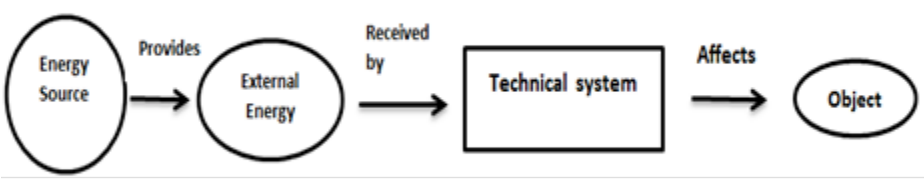
By analyzing the different versions of the definition of the first law, we showed that:

a. These definitions have one thing in common about the need to have a controlling entity of the four elements of the system;
b. The four elements of the system must participate in the production, exploitation, processing and transmission of energy;
c. The characteristics of the functional elements of a system that caught our attention through these definitions are:

Functional elements	Important Features
The work unit	- The work unit is composed of the element of the technical system which is in direct contact with the object changed by the system. - It allows the realization of system function (considered as an actuator).
The engine	- The engine is composed of the element that generates or transforms the energy needed to operate the system. - It transforms the energy from the external system in an energy usable by the work unit
The transmission unit	- The transmission unit is composed of elements that transmit energy; it channels the energy of the engine to the work unit. - It is situated between the power unit and the work unit
The control unit	- The control element is one that allows the system to adapt to different variations of operation. - The best operating system is the one that places control at the work unit

Table 1: Characteristics of technical systems elements

In the table above, we noticed a link between internal entities of the system and the external energy received by the system and the object on which the system operates. Indeed, the engine receives external energy and transforms it to make it usable by other system components. The operator element of the system acts directly on the external object that is changed by the system. All this leads us to determine the scope of the system, before starting to study the system. As shown in the following picture:



Picture 1: Delimitation of the technical system

2.2 Analysis the second law

Here are some versions of the definition of the second law that we will analyze:

a) For a system technique works, it is necessary that the energy flows easily through its parts. It is particularly necessary that the energy generated by the engine is transmitted to the work unit [1].
b) A necessary element in the viability of a system is the free flow of energy through all its parts. Therefore, it is essential to transmit energy from the engine to the work unit via the transmission unit [5].
c) In its report [4] proposes to seek the reason for the loss of energy to improve the functioning of the system, he also evokes the notion of performance of each component to be satisfactory for a system to function properly.

Results of analyzing this law are:

- A free flow of energy between system components to minimize the loss of energy,
- An effective performance of each unit of the system.

2.3 Analysis the third law

Here are some versions of the definition of the third law that we will analyze:

a) For a technical system working properly, rhythms (frequency, timing, ...) of its parts must be coordinated. This law has two aspects: The actions of the different parties tend to be fully coordinated, or even to complement each other (some work during the rest of another) and rhythms (frequency, periodicity, ...) harmonize [1].

b) There are few systems that operate continuously. Temporalities of action of various system components and technical components of the environment (energy source and object) must be studying [4].

The optimal operating condition according to the law 3 is:

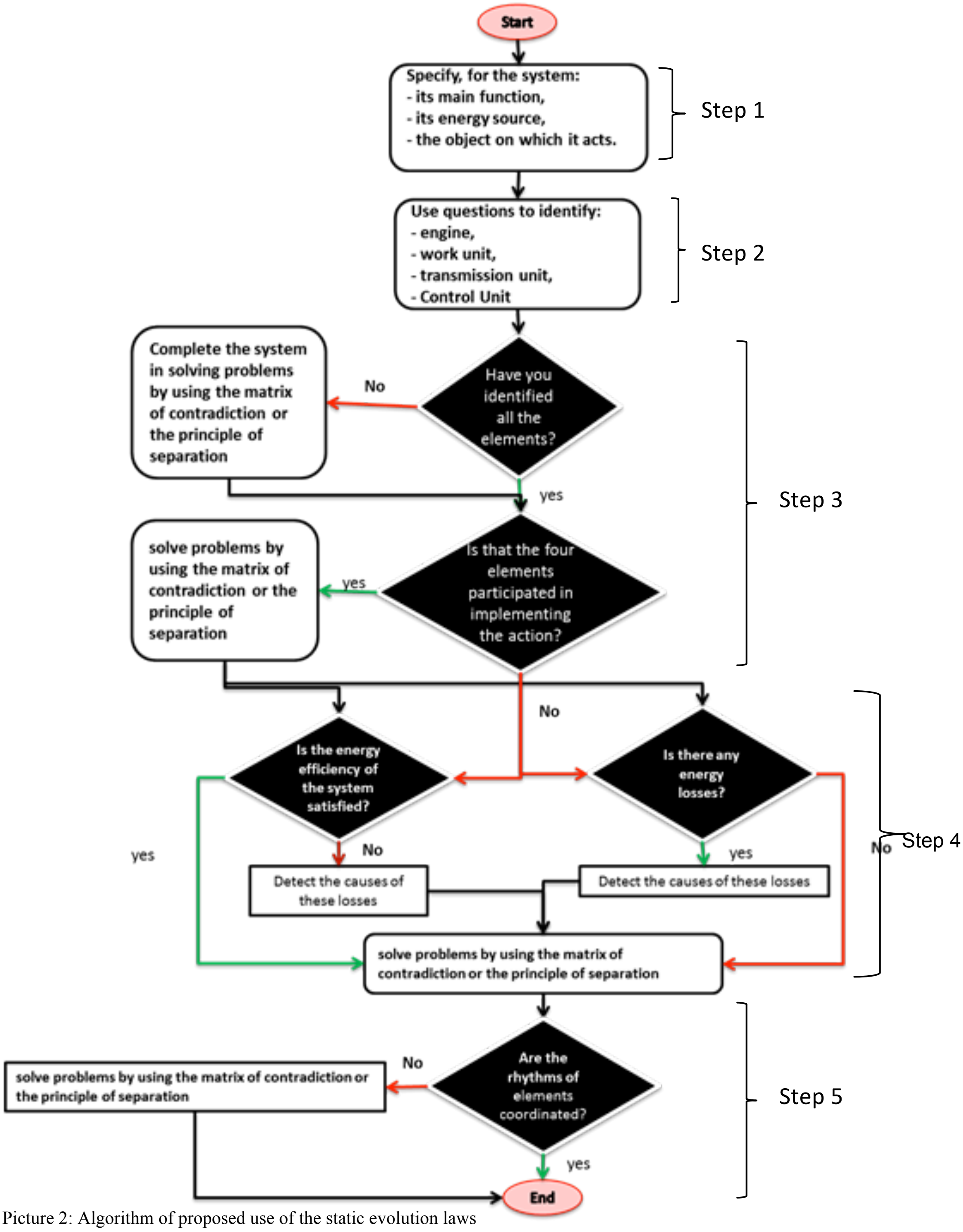
- The rhythms of operating system components must be coordinated.

3. Model proposed to use the evolution's laws

Our solution is to propose a model to effectively make the system evolve according to the directions of development of the first 3 evolution laws.

The model we propose is composed of a short quiz that users must answer. The purpose of these questions is to guide the user as far as possible in the identification of functional elements of the system and possible developments of innovative products, as recommended by the three first laws. To do this, we used the characteristics identified in the analysis of the definitions of these laws made in the previous section.

To generate these questions we based ourselves on CHOULIER document [4] exposed during a working session to TRIZ France, and we also used some of the question of this document because we found them very effective.



Picture 2: Algorithm of proposed use of the static evolution laws

The model of picture 3 applies as follows:

Step1: System delimitation

At first, this step determines the boundaries of the technical system (product study) with its external environment, by specifying:

- The main function of the system,
- The external power, allowing it to perform this function,
- The source of external energy,
- The object on which the system operates (the object that will be changed by the system).

The following questions were used at this step to define the system delimitation:

- To determine the system's primary function is simply asking the question "What is the main function of the system to study?"
- To determine the energy and its source, we ask the following questions "What is the nature of the external energy received by the system that allows it to perform its primary function?" and "What is the source of this energy?"
- The question "What is the object on which the system works?" identifies the external object. This question can also be formulated differently: "What is being changed by the system?"

Step 2: Identification of functional elements

For the second step, the user is asked to identify the functional elements of the system by answering questions. The elements and questions used for identification are:

Identification of the work unit

The work unit is composed of the element that is in contact with the object on which the system operates. It is the system interface with the element on which he acts. It allows the realization of the main function of the system. For an easy identification, we propose the following question:

- "Which part of the technical system is in direct contact with the object on which the system works?"

Identification of the engine

The engine is composed of one or more elements that transform the intensity or the nature of the energy used to feed the system in a given use context. It recovers energy, in some form, from outside the technical system and transforms it into a usable form for other system components. Here are the questions that we propose to identify it:

-"Remember the source of energy?" this question aims to remind the user that the engine is the border of the system with the energy. And the detection of this energy source will facilitate the identification of the engine that is in contact with it.

-"What is the system element directly in contact with this source of energy?" By answering this question the engine, will be identified.

-"Verify that this element of the system captures the energy and transforms it into another form of energy used by another element of the system?" This last question is for testing the correctness of the previous answer, because the engine is not just an element in contact with the source of energy, it serves to transform this energy.

Identification of the transmission unit

The transmission unit consists of one or more elements that allow the transmission of energy. It is the bridge that links energy between the work unit and the engine. It is geographically situated between them. To identify it we ask the following questions:

- "What is the path of the energy?" Transmission draws the energy path, and this question will help identify the elements belonging to this path.
- "What are the elements that carry energy?" The answer to this question allows the identification of the transmitting unit.

Identification of the control unit

The control unit is composed of elements that determine the level of action of the work unit. It acts to modulate the level of action of the working unit according to changes in external conditions. To identify it we ask the question

- "What is the element that determines the level of action of the work unit?"

Step 3: satisfaction of conditions of development according to law 1

If one or more functional elements of the system are missing or do not participate in the realization of the main function then the user will be asked to complete the system by creating that element or improving it. This first step consists in an improvement of the operating conditions of the system by making the defective element active. An incomplete system will not survive for a long time in front of another complete competitive system. To improve the system our model advices to define the weakness related to system components, and then translate it into contradiction, and finally solve it using either the matrix of contradiction or the principles of separation.

Previous work [3] has already demonstrated that the contradictions are related to the laws of evolution. Hence, we will use the results of this work to link the laws of evolution with the resolution of contradictions.

Here are the questions for step 3:

- "Are that the four functional elements of the system that have been identified? and Do they all contribute to the achievement of the main function?" The answer to this question shows whether the system is composed of four elements, or if there are elements missing. It also verifies that all elements contribute to the achievement of the main function of the system, and there is no inactive element.
- If items are missing or inactive then complete the system, "What are the weaknesses of these elements? Translate and resolve conflicts."
- "Is the control unit identified? "This question is for testing whether there is a system entity that is controlled. If there is no control unit, then we recommend completing system control unit close to the work unit.

Step 4: satisfaction of conditions of development according to law 2

In this step, it is required the user to check for energy losses, to detect the cause of these losses and solve them using the tools of TRIZ for resolution of contradiction. Then verify the effectiveness of the overall system performance to improve if it is fairly satisfactory.

- "Is there any energy losses during operation of the system? "What are they due?" The first question is for testing whether there are energy losses that reduce the effectiveness of the system. The second is used to detect the reasons for these losses.

"Expressing the weakness of the system relative to the loss of energy?" This question is intended to express the relative weakness of these energy losses, than translate ii to a contradiction for resolving it using the TRIZ solving tools.
- "Is the energy efficiency of the system satisfied? If not express weakness related to this problem?" The purpose of these questions is to express the contradiction related to the weak performance of the system to solve it and evolve the system in accordance with the criteria of law 2.

Step 5: satisfaction of conditions of development according to law 3

This step focuses on the evolution of the system to a coordinated operation rhythm between its internal and external elements (internal: functional components and external: power source and object on which the system acts). The questions that guide the user to change the system according to these criteria are:

"The rhythms of operation of the functional elements of the system, of the energy source and of the object are coordinated? If not express weakness related to this problem" The purpose of these questions is to solve the deficiency of the system related to a rate of uncoordinated operation between internal and external elements of the system. And then resolve this contradiction.

At this stage of progress of our works, we have not computerized our algorithm yet. This shod the object of later developments.

4. Experimentation l

The purpose of this experimental study is to test the efficiency of our model. So, we conducted two experiments to verify that our solution allows users to easily apply the evolution statics laws.

4.1 First experimentation

This first experiment aims to test the application of the law 1. Specifically, test our algorithm on the identification of functional elements of a technical system by users, namely the engine, transmission unit, work unit and control unit.

We have chosen 2 different publics to realize our tests. Indeed, we wanted to observe if the initial knowledge of TRIZ had an incidence on the contribution of our algorithm. We'll present our results in the conclusion of our article.

Participants in this first experiment are software developers with at least two years of experience with functional analysis, and students in their last Ph.D. year dealing with the problems of computer science and management. The 15 participants in this experiment do not know TRIZ, they have an average age of 28 years (min = 26, Max = 29).

We perform this first experiment on two steps:

a) In the first step we just present a definition of the first evolution law to participant and then we ask them to identify the four functional elements of the technical system studied
b) In the second step we present to the participants the first steps of our algorithm that we perform on one technical system to better explain to them how to apply it and after we ask participants to

use the steps of the algorithm related to the first evolution law for identifying the 4 elements of the studied systems.

To carry out this experiments we used technical systems selected from 2 different use scenarios: hair dryer and roller skates.

During this experiments, each participant answer the questionnaire individually, using Skype-meetings over Internet.

During the first step the participants were unable to identify the functional elements of the systems. The only items they were able to identify (to some extend) were the engine and the transmission unit for the air dryer. The average of the results is presented in table 2:

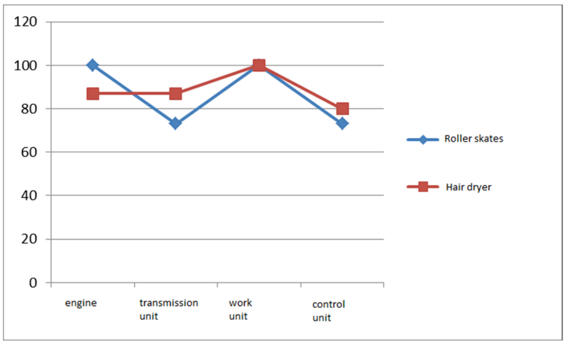
Unit/System	Hair dryer	Roller skates
Work unit	20 %	20 %
Engine	100 %	20 %
Transmission unit	53.33 %	13.33 %
Control unit	26.66 %	20 %

Table 2: Result for identifying the element of system without using the proposed algorithm

But during the second stage, where the user used the algorithm that we proposed to apply for law 1, they were more likely to find functional elements of the systems. The average of the results is:

Unit/System	Hair dryer	Roller skates
Work unit	86.66 %	100 %
Engine	100 %	100 %
Transmission unit	86.66 %	73 %
Control unit	80 %	73 %

Table 3: Result for identifying the element of system by using the proposed algorithm



Picture 3: Result of testing the algorithm in applying the first evolution law

Picture 3 shows that the curves of the results of correct responses to the application of this law, when using the algorithm on both systems studied are evolving almost identically. The correlation obtained on these two series is 0.69, meaning that they are correlated.

Since the study focused on two completely different systems in operation and in their energy supply and that the results showed a good correlation between them, then we can argue that part of the algorithm on the application of law 1 is reliable.

4.2 Second experimentation

The second experiment was designed to test the proposed algorithm on its ability to identify system deficiencies and to resolve to evolve the system following the recommendations of the static evolution laws n° 2 and n° 3.

Participants in the second experimental study are students in training on the innovation of the Engineering Institute of Sciences and Techniques in Angers (ISTIA). They have an average age of 23 years (min = 21 Max = 30). These 35 students are not completely novices on TRIZ, they attended 24 hours of training on the evolution of technical systems based on TRIZ. They also have a little experience in the field of creativity and functional analysis, knowing that they have completed 18 hours of courses on creativity and 24 hours of instruction on the analysis of the value (of which a portion was dedicated to functional analysis). They therefore have a profile allowing them to carry out design activities based on sound foundations they acquired during their training.

We perform this second experiment on two steps:

a) In the first step we just present a definition of the second and third evolution law to participant and then we ask them to check whether the system studied fulfills the terms set by the laws 2 and 3? If not then what are the possible improvements for the system (its components and their functions) to fulfill those conditions?
b) In the second step we present to the participants the steps of our algorithm related to the laws 2 and 3 that we perform on one technical system to better explain to them how to apply it and after we ask participants to follow this steps of the algorithm for identifying possible improvements for the system studied to satisfy the condition of the laws 2 and 3.

To carry out the experiments we used technical systems selected from 4 different use scenarios; dishwasher, vacuum, hair dryer, and pen.

During this experiments the participants were grouped in a single classroom at the Institute of ISTIA, they had half a day to answer the questionnaire. They had to answer questions individually; this is the reason why no pause was allowed.

a) Results obtained for the law n° 2

During the first step, participants were very little to find the right answer on the weakness of the system and improvements possible to satisfy law 2. But during the second stage, the results obtained after applying the algorithm shows a better rate of correct answers. Participants were mostly able to identify deficiencies related to poor system efficiency as developing. The results for the application of law 2 are shown in the table below:

System	First step (without algorithm)	Second Step (using algorithm)
Vacuum	28.57 %	85.71 %
Dishwasher	11.42 %	80 %
Hair dryer	37.14 %	97.17 %
Pen	34.28 %	100 %

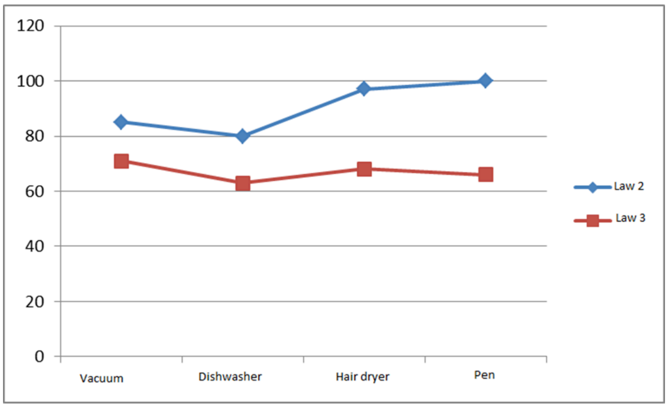
Table 4: Result obtained when applying the law 2

b) Results obtained for the law n° 3

During the first step, participants were very little to find the right path of development to satisfy law 3. But during the second stage, the results obtained after applying the algorithm shows that the participants were mostly able to identify the shortcomings of the systems related to poor coordination of the rhythms of operation. The results for the application of law 3 are shown in the table below:

System	First step (without algorithm)	Second Step (using algorithm)
Vacuum	31.42 %	71.42 %
Dishwasher	20 %	62.86 %
Hair dryer	22.85 %	68.57 %
Pen	17.14 %	65.71 %

Table 5: Result obtained when applying the law 3



Picture 4: Comparison of curves obtained when applying the algorithm to the laws 2 & 3

Picture 4 shows that the curves of the results of correct responses when using the algorithm on both the law 2 and the law 3 are evolving almost identically, then we can argue that part of the algorithm on the application of those law is reliable. This allows us to assert the validity of our algorithm.

5. Discussion

Our model is designed for the application of laws can lead for developing the study predictive of future generations of technical systems. As with TRIZ, this model is applicable in the field of technical engineering. It is making improvements on existing systems by multiplying them, which can lead to important innovations leading to the appearance of a new system.

For the realization of experiments we used criteria consistent with tests of the models. We have abstained from any intervention from the participants in order to don't affect the results. Technical systems were chosen so that they are different in their constitution as their destination, for example some with electric motor (electric power) and other non-electric operated by manual power.

Participants involved in the experiment are few initiated or not in TRIZ, it was difficult to combine several TRIZ specialists in one day. Also the use of beginners in innovation was the only healthy solution. The positive results obtained during the experiments showed that this was not negative, it proved more compelling for our model, since novices were able to use it easily.

6. Conclusion

Results of our research was realized by modeling the evolution laws in a innovation's framework. we propose an algorithm offering questions that guide thinking of every user to development's right path to follow. Our model allows:

- Definition of system from its external environment marked by its energy source, and the object on which it acts, and identification of its functional elements. Its purpose consist to detect any lack or failure among these elements. This is the first step in this evolution according to Law n° 1.
- An evolution of system according to Law n° 2, in solving problems related to lose of energy or energy efficiency unsatisfactory.

Through this article, we showed that it is possible to apply the static evolution laws in a simple way through a process of innovation. Till now we have found very few tools or scientific contributions that can inform on use of evolution's laws. The results obtained by ours experiences pushing us to consider this method as an approach integrating other laws of evolution. It's a first step to a systematic utilisation of all the other laws of evolution.

References

[1] Ameglio, F. 2005. "Les lois d'évolution de TRIZ pour une nouvelle methode de veille prospective". Université Paul Cézanne Aix-Marseille III (UPCAM).

[2] Cavallucci, D. and Weil, R. D. 2001, "Integrating Altshuller's Development Laws for Technical Systems into the Design Process." CIRP Annals – ManufacturingTechnology.

[3] Cavallucci, D., Rousselot, F. et al. 2009. "Linking Contradictions and Laws of Engineering System Evolution within the TRIZ Framework."Blackwell Publishing.

[4] Choulier, D. 2010. "Réflexions sur les lois d'évolution de TRIZ". Université de technologie de Belfort-Montbéliard.

[5] Cortes Robles, G. 2006. "Management de l'innovation technologique et des connaissances : synergie entre la théorie TRIZ et le Raisonnement à Partir de Cas". France. Institut National Polytechnique de Toulouse.

[6] Crubleau, P., 2002. "L'identification des futures generations de produits industriels. Proposition d'une demarche utilisant les lois d'evolution de TRIZ". France, université d'Angers.

[7] Fey,V., Rivin, J. 2007. "Innovation on Demand- New Product Development Using TRIZ". journal of product innovation management. 24 (6) : 635–636.

[8] Scaravetti, D., 2004. "Fomalisation préalable d'un problème de conception, pour l'aide à la décision en conception préliminaire". France. Ecole nationale supérieure d'arts et métiers.

[9] Kawakami,T., Durmusoglu,S; and Barczak,G. 2011. "Factors Influencing Information Technology Usage for New Product Development- The Case of Japanese Companies† journal of product innovation management". 28 (6): 833–847.

[10] Zouaoua, D., Crubleau, P., Choulier, D., Richir,S. 2011. "First avolutionary step towards innovation using laws of system completeness". ETRIA. 355-367