



## VALIDITY OF TECHNICAL SYSTEM EVOLUTION TRENDS – A PATENT STUDY

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### Abstract

It is widely accepted among TRIZ specialists that technical systems evolution occur along certain lines, patterns, paths, trends and, according to TRIZ founder [1], laws. In this paper, we refer to all these as technical system evolution trends (TSETs). If it is assumed that the future will be, at least to some extent, a continuation of the past, it follows that TSETs could be used to (qualitatively) predict the future of technical systems. TRIZ forecasting is based on these assumptions. But are TSETs valid? In this paper, we analyze TSETs, assess their validity and propose some directions for further investigation.

*Keywords: TRIZ, Technical System Evolution Trends, Technology Forecasting.*

### 1. Introduction

Altshuller [1] hypothesized that the development of technical systems follows certain laws. A law might be defined as a generalization that describes recurring facts or events in nature and society. We consider that Altshuller's laws of technical systems evolution are not really laws, but heuristics. An heuristic can be defined as a rule of thumb, based on past experience, that indicates a general and probable direction where solutions might be found, but provides no guarantees. In TRIZ, the inventive principles and the standard solutions are examples of heuristics.

Similarly to other TRIZ heuristics, Altshuller's laws of technical systems evolution were obtained through abstraction from patents. Altshuller defended that, given a technical system, it would be possible to predict its future developments using the laws of evolution.

The word law, originally used by Altshuller, is barely found in contemporary TRIZ literature. In most books and papers, it has been replaced by lines, patterns, paths, and trends, which we refer to through the umbrella term technical system evolution trends (TSETs) in this paper.

The purpose of this paper is to investigate available TSETs and assess their validity for technological forecasting purposes. First, the methodology is described. Then, a review of available TSETs and an assessment of their validity is presented. Finally, conclusions and suggestions for further research are drawn.

### 2. Methodology

As a result of the unusual way of its creation, TRIZ lacks formality, making it subject to strong criticism (the reader can find lots of it on the Anti TRIZ-Journal [2]). There have been



few attempts to answer the question “Can you prove that TRIZ is valid?” A common answer is the roundabout “TRIZ works! I have successfully used it in such, such and such cases.” TSETs, as a part of TRIZ, are no exception to this problem. Undoubted proof of TSETs validity might be impossible, but could something be done to assess it?

We think that the validation methodology for TSETs should involve search for examples (and counter-examples) in a statistically significant number of high level patents. According to Altshuller [3], level 3, 4 and 5 total 23% of patents. This validation process would be very time consuming, because:

- USPTO database alone includes about 4,000,000 patents issued since 1976;
- The estimated effort for defining the level of a patent is around 0.25 man-hour;
- The estimated effort for studying a patent – understanding the patented solution, the problem that was solved and identifying TSETs which could be associated to the patent – is around 0.5 man-hour;

Considering that a group of specialists would agree 1% is a statistically significant number of patents to be analyzed (probably a small figure for statistical validation), and above premises, the level definition effort would be  $4,000,000 \times 0.01 \times 0.25 = 10,000$  man-hour. The analysis effort would be  $4,000,000 \times 0.23 \times 0.01 \times 0.5 = 4,600$  man-hour. The whole effort, 14,600 man-hour, would take more than 8 years of a person involved full time in this task. This task is, to the best of our knowledge, currently not prone to automation.

Thankfully we have freedom of choice, plenty of more attractive tasks to choose and will not spend 8 man-years or more validating TESTs. This is the reason why we did not even start trying to statistically validate them, but rather decided to look for indications of their validity or invalidity. Our methodology involved:

1. Finding TSETs in TRIZ literature;
2. Analyzing TSETs from different authors, and developing a list of independent TSETs;
3. Searching examples and counter-examples of the independent TSETs in high generality patents. According to Hall et al. [4], generality is a statistical measure indicative of the impact of a patent. High generality occurs when a patent is cited by subsequent patents that belong to a wide range of IPC (WIPO International Patent Classification) classes.

These three steps are detailed below.

### 3. Compilation of TSETs

Our literature research resulted in the TSETs listed below.

The 8 laws of technical systems development were proposed by Altshuller [1]: Completeness of a system’s parts; Energy conductivity; Harmonizing rhythms; Increasing ideality; Uneven development of a system’s parts; Transition to a super-system; Transition from macro to micro-level; and Increasing use of su-fields. In comparison to more recently proposed TSETs, as described below, Altshuller’s laws are stated at a relatively high level of abstraction. These



TSETs also admitted direct and reverse transformations, although separated (Transition to a super-system and Transition from macro to micro-level).

Polovinkin [5] described 8 “transformations in accordance with the evolution trends” as a class of his “heuristics for systems transformations”: Change from homogeneous or disordered (in space and time) substances or fields to inhomogeneous and ordered; Co-ordination or discoordination of action; Use of pauses; Dynamization; Field transition from direct action to changing action to impulses; Transition from macro to micro-level; Transition from mechanical field to acoustic, electrical, chemical and magnetic; and Combination of elements for similar functions, different functions, and opposite functions. According to our research, Polovinkin’s system was the first to include bidirectional TSETs (Co-ordination or discoordination of action).

It is not completely clear if Altshuller gave up on the term law but, in 1989, Altshuller et al. [6] published 8 evolution “patterns”: S-curve; Increasing ideality; Uneven development of a system’s parts; Increasing dynamism and controllability; Increasing complexity followed by simplification; Matching and mismatching of a system’s elements; Transition to micro-level and increased use of fields; and Decreasing human involvement. Some similarity to Altshuller’s first proposal [1] remained and this is the only system found where reference to the evolution along the S-curve is made as a TSET.

Petrov [7] suggested a detailed hierarchical system of technical system evolution laws, that proceeds from general to specific TSETs. Not considering the hierarchy, these are: Completeness and abundance of a system; Energy conductivity; Rhythm coordination; Increasing ideality; Uneven development of a system’s parts; Dynamization; Transition to micro-level; Increasing degree of fragmentation; Transition to capillary and porous materials; Increasing use of voids; Increasing saturation of a system’s specific energy; Transition to more controllable fields; Increasing participation of su-fields; Increasing saturation of information; Transition to super-system; and Mono-bi-poli. Petrov’s system also admits bidirectional TSETs (Mono-bi-poli and convolution) and is the first one to sketch a scheme for a technical system’s evolution along the TSETs.

Very similar to Altshuller’s first proposal [1], Salamatov’s [8] TSETs are: Completeness of a system’s parts; Energy conductivity; Harmonizing rhythms, Dynamization; Increasing use of su-fields; Uneven development of a system’s parts; Transition from macro to micro-level; Transition to a super-system; and Increasing ideality.

Also very much in alignment with the first TSETs formulated by Altshuller [1], Linde & Hill’s [9] TSETs are: Completeness of a system’s parts; Energy conductivity; Rhythm coordination; Infiniteness of technological evolution; Increasing ideality; Uneven development of a system’s parts; Transition to a super-system; Simplification; Transition from macro to micro-level; Transition from instrumentation to automation; and Increasing use of su-fields.

The 1995 version of Invention Machine software [10] included these TSETs: Segmentation; Introduction of voids; Dynamization; Increasing intensity of fields, forces and actions; Mono-bi-poly; Introduction and elimination of intermediaries; Rhythm coordination; Evolution from



action in a point to action along a line, plane and 3 dimensions; Increasing use of su-fields; Smart substances. This system is similar to that of Petrov [7] but less complete.

Apparently seeking to formulate only TSETs at a relatively high level of abstraction, Savransky [11] described 9 paths of evolution: Physical state changes; Transition from continuous to vibrant and resonant interactions; Evolution from action in a point to action along a line, plane and 3 dimensions; Increasing adaptability; Increasing use of voids; Decreasing human involvement; Expansion and convolution; Transition to super-system and micro-level; and Rhythm coordination and discoordination.

Mann [12] suggests 31 trends of evolution: Smart Materials; Space Segmentation; Surface Segmentation; Object Segmentation; Evolution Macro to Nano Scale; Webs and Fibres; Decreasing Density; Increasing Asymmetry; Boundary Breakdown; Geometric Evolution (Linear); Geometric Evolution (Volumetric); Dynamization; Action Co-ordination; Rhythm Co-ordination; (Matching to External) Non-Linearities; Mono-bi-poly (Similar); Mono-bi-poly (Various); Mono-bi-poly (Increasing Differences); Reduced Damping; Increasing Use of Senses; Increasing Use of Colour; Increasing Transparency; Customer Purchase Focus; Market Evolution; Design Point; Degrees of Freedom; Trimming; Controllability; Reducing Human Involvement; Design Methodology; and Reducing Number of Energy Conversions (Tending to Zero).

Mann's system is the one with the greatest number of TSETs. Each of these is segmented into steps, in an attempt to provide guidance to the user and also to make evaluations of "evolutionary potential" possible. For instance, "Smart materials" suggests that there is a tendency for systems to proceed from passive materials (step 1) to materials adaptable in one way (step 2) to materials adaptable in two ways (step 3) to fully adaptable materials (step 4). For each trend, the author provides reasons that could trigger evolution to the next step. The evolutionary potential is an evaluation of how far a system could evolve along the particular trend.

#### 4. Analysis of TSETs

The next step should have been to create a compilation of independent TSETs. However, from the literature search, we concluded that such compilation was not necessary – we could use the most detailed set, proposed by Mann [12]. These could be directly used for the main purpose of our research: to assess validity of TSETs by searching for examples and counter-examples. More specifically, we did not use the full set of Mann's trends. We excluded three of them, which we considered not related to the evolution of artifacts: Customer Purchase Focus and Market Evolution (both marketing trends) and Design Methodology (a trend related to the design process).

Thus, from the original 31 proposed by Mann, the TSETs used for the assessment were 28: Smart Materials; Space Segmentation; Surface Segmentation; Object Segmentation; Evolution Macro to Nano Scale; Webs and Fibres; Decreasing Density; Increasing Asymmetry; Boundary Breakdown; Geometric Evolution (Linear); Geometric Evolution (Volumetric); Dynamization; Action Co-ordination; Rhythm Co-ordination; (Matching to



External) Non-Linearities; Mono-bi-poly (Similar); Mono-bi-poly (Various); Mono-bi-poly (Increasing Differences); Reduced Damping; Increasing Use of Senses; Increasing Use of Colour; Increasing Transparency; Design Point; Degrees of Freedom; Trimming; Controllability; Reducing Human Involvement; and Reducing Number of Energy Conversions (Tending to Zero).

## 5. Search for examples and counter-examples

Our search was focused on the highest generality US patents, according to the study by Hall et al. [4] (the 68 patents listed in Table 1).

Each patent was read and understood. Then, the state of the art section was read and, in many cases, also patents cited in this section, so as to thoroughly understand the transition from the situation described in the state of the art section to the solution described in the particular patent. Finally, for each of the chosen TSETs, we checked:

1. If it could have been used to prompt the inventor towards the patented solution;
2. If it contradicted the transition proposed in the patent.

Table 1 – The 68 highest generality US patents studied

4,271,566	4,051,159	3,981,100	4,047,965	4,215,682	3,957,741	4,290,052
4,138,306	4,295,987	4,248,924	4,089,804	4,107,784	4,172,066	4,289,513
4,168,531	4,218,294	3,972,759	4,264,641	4,005,388	4,070,348	4,143,417
4,156,066	4,223,984	4,257,810	4,304,244	4,315,998	4,328,533	4,330,654
4,334,246	4,337,211	4,358,545	4,369,284	4,497,930	4,378,411	4,412,018
4,433,082	4,451,619	4,454,055	4,519,909	4,521,564	4,539,655	4,544,446
4,548,375	4,568,632	4,579,473	4,613,517	4,630,355	4,645,943	4,647,413
4,705,762	4,159,222	4,063,993	4,729,809	4,772,452	4,835,372	4,920,432
4,973,493	4,985,296	5,003,204	5,285,494	4,343,853	4,096,227	4,124,528
4,344,146	4,523,297	4,528,311	4,720,512	4,721,601		

Amongst the 68 chosen patents, we found counter-examples of 9 TSETs and examples of 16 TSETs, as shown in Tables 2 and 3.

Table 2 – The 9 TSETs with counter-examples in the 68 highest generality US patents studied

Surface segmentation	Object Segmentation	Boundary Breakdown
Increasing Use of Senses	Decreasing Density	Geometric Evolution (Linear)
Dynamization	Mono-bi-poly (Similar)	Degrees of Freedom

Table 3 – The 16 TSETs with examples in the 68 highest generality US patents studied

Smart Materials	Space Segmentation	Reduced Damping
Webs and Fibres	Action Co-ordination	Increasing Use of Colour
Increasing Transparency	Controllability	Design Point
Dynamization	Rhythm Co-ordination	Mono-bi-poly (Various)
Mono-bi-poly (Increasing Differences)	Reducing Human Involvement	Evolution Macro to Nano Scale
Trimming		

At this point, we wondered what results Altshuller’s original and smaller set of TSETs [1] would lead to. Further analysis shown that three of these had counter-examples in the 68 highest generality US patents, and that all of them had examples. The TSETs with counter-examples were: Energy conductivity; Uneven development of a system’s parts; and Increasing use of su-fields.

## 5. Conclusions

The main conclusion is that, more often than not, both Altshuller’s (9 of 9) and Mann’s (16 of 28) TSETs would have provided useful directions for a system’s development, if they had been used to arrive at the 68 high generality US patents analysed. From these results, we can also confirm that TSETs indeed are heuristics, not laws – they provide a general direction for further development of a technical system, but give no guarantees.

Altshuller, Polovinkin, Petrov, Salamatov and Savransky admit bidirectional TSETs. Our results corroborate their approach. Authors could accept the bidirectional character of many TSETs and include means of evaluating if and when direct or reverse use of a particular TSET would be preferred.

We perceived a tendency towards more and more TSETs in the literature, which are increasingly specific and stated at a lower level of abstraction. We initially suspected that a smaller set of TSETs (like those of Altshuller [1]) tends to be more universally valid. Our results did not support this assumption, because we found 3 counter-examples from 8 Altshuller’s TSETs and 9 counter examples from 28 Mann’s TSETs – very similar proportions.

From our experience using TSETs, we feel that smaller sets of TSETs tend to provide more freedom of thought (and less guidance) to the user. Bigger sets tend to make idea generation more direct (and perhaps easier) for the user, but can become tiresome and more frustrating.

Considering the usability problems stated above, Petrov [7] has a good solution, because his hierarchical structure allows the user both to generate ideas with more freedom (from the few basic TSETs) and with more guidance (from the numerous specific TSETs).

Further research is necessary concerning the effectiveness of TSETs for qualitative forecasting, idea generation and idea evaluation. How to devise new TSETs? How long is a



particular TSET valid? As discussed above, when should one use a TSET as formulated and when should one use the opposite? If a hierarchy such as Petrov's is used, what are the criteria for defining the most promising path along which a technical system might evolve? Is it possible to connect TSETs and social or market trends? How? Is it possible to establish a universal scheme of evolution [13]? Is it accurate and useful to use evolutionary potential [12]?

Researchers interested in these and other questions regarding TSETs are kindly invited to contact the corresponding author.

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