Systematic Innovation Methods For Architects

Darrell Mann
Systematic Innovation, Bristol, UK

Conall O Cathain
School of Architecture, Queen's University Belfast

ABSTRACT

The paper describes a novel systematic innovation method based on the Russian-initiated Theory of Inventive Problem Solving, TRIZ, exploring a possible new application of the method to the complex design task of designing buildings which combines both technical and aesthetic considerations. The paper explores how TRIZ offers methods for defining and specifying problems in a manner that gives fundamentally more robust solutions. The paper examines the main underlying principles of the method and some of the its problem solving tools - the 40 currently known strategies for overcoming design contradictions, the 'ideal final result tool, and the 8 trends of technological evolution - in the context of their potential role in architecture. The approach is illustrated by means of examples, including the derivation of novel concepts for flexible housing, novel façade treatments and novel transparency design concepts.

INTRODUCTION

Most architects recognise the importance of innovation. Most also equate the idea of innovation to high risk. Whether related to new or improved constructions, construction components, processes or services, the innovation process – if indeed it can be called a process at all – is viewed as a nebulous, unpredictable activity with little or no degree of certainty in terms of either output quality, cost or time.

The paper describes the Russian initiated Theory of Inventive Problem Solving, TRIZ. The method has been built upon over 1500 person years worth of research into the inventive process and the study of nearly 3 million of the world's most successful patented inventions. Since its emergence in the West in the late 1980s, the method has begun to be successfully deployed both as a manual method and as a computer-based tool across a number of engineering companies in the US and, progressively, Western Europe and Japan (1). Although initially conceived as a method for engineers, TRIZ has latterly been successfully applied to a much wider variety of problem types – including non-technical, management type problems.

To date, exposure across the field of architecture has been limited to two speculative papers by the authors dealing with a limited range of problems and tools (2, 3).

The paper presents some of the tools from a TRIZ-based problem definition and problem solving methodology in the light of their observed or expected relevance and applicability to architecture centred problems.

The first section of the paper examines TRIZ from the perspective of the problem solving tools for those previously unfamiliar with the method. Subsequent sections then go on to describe how these tools are beginning to be integrated with other systematic innovation methodologies, and how the combined methods are beginning to be applied successfully across a number of disparate problem types.

TRIZ BASICS

According to its proponents the core findings of TRIZ research on the global patent database are that the world currently contains a very small number - some 40 - of Inventive Principles and that all technology evolution trends are predictable (4,5).

TRIZ provides means for problem solvers to access the good solutions obtained by the world's finest inventive minds. The basic process by which this occurs is illustrated in Figure 1. Essentially, TRIZ researchers have encapsulated the principles of good inventive practice and set them into a generic problem-solving framework. The task of problem definers and problem solvers using the large majority of the TRIZ tools thus becomes one in which they have to map their specific problems and solutions to and from this generic framework.

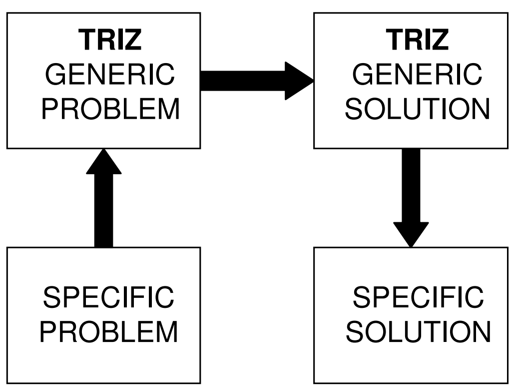


Figure 1: The Basic TRIZ Problem Solving Process

By using the global patent database as the foundation for the method, TRIZ effectively strips away all of the boundaries which exist between different industry sectors. The generic problem solving framework thus allows problem owners working in any one field to access the good practices of everyone working in not just their own, but every other field of science and engineering.

Successful use of the various TRIZ tools requires an approach dis-similar to other creativity methods. Reference 6 discusses the four paradigm shifts – Contradiction, Ideality, Functionality, and Use Of Resources – most commonly observed as important in a TRIZ usage context. We confine our discussion here to the various tools and techniques underlying those paradigm shifts.

Contradictions/Inventive Principles
The Contradictions part of TRIZ is constructed on a comprehensive analysis of patents in which the inventor has successfully 'eliminated' design contradictions. In using the patent database as a foundation, the analysis has inevitably been dominated by engineering solutions, and so there is an inevitable degree of extrapolation involved in applying the tool to other solutions. Nevertheless, previous research has demonstrated that the exact same solution strategies – or 'Inventive Principles' - apply in non-technical (7) and biological (8) situations. Preliminary work relating the Principles to architectural solutions seems to further bear out the relevance and scope of the original TRIZ research and reference 3 reports the results of an investigation to identify examples of the Principles being used in architectural solutions. We list a number of examples for Inventive Principle 4 here:

Principle 4. Asymmetry

A. Change the shape or properties of an object from symmetrical to asymmetrical.

- Introduce a geometric feature which prevents incorrect usage/assembly of a component (e.g. earth pin on electric plug)
- Corner bricks
- Keystone
- Coated glass or paper
- Introduction of angled or scarfed geometry features on component edges
- Non-circular section chimneys reduce drag against prevailing wind direction
- Sloped roofing
- High-flow gutter uses asymmetry to better control entry flow of rainwater from roof into down-pipe (30% more flow for a given entry area)
- "Modern" planning as opposed to classical planning
- Tongued and grooved flooring
- T beam floor construction
- Double doors where one leaf is wider than the other

B. Change the shape of an object to suit external asymmetries (e.g. ergonomic features)

- Human-shaped seating, etc
- Take account of differences between left/right handed, male/female users
- Finger and thumb grip features on objects
- Aerofoil section delivers lift by having diffferent shapes on top and bottom surfaces
- Pull-handles versus push-plates on doors
- Site Planning to respect an individual site

C. If an object is asymmetrical, increase its degree of asymmetry.

- Compound/multi-sloped roofing
- Cable assisted cantilever roofs
- Tilt and turn windows
- Folding doors

The 40 (currently known) Inventive Principles make useful brainstorming aids and, indeed, many TRIZ users simply use the Principles as a way of structuring an idea generation session. In cases where the prospect of brainstorming around 40 solution routes is a little daunting, TRIZ offers users a Contradiction Matrix to help reduce the list of principles to a more manageable three or four. The Matrix has again been constructed largely via analysis of engineering patents. Unlike with the Inventive Principles, subsequent research has shown that the Matrix is less relevant when extrapolated to other areas (9). Initial indications for its relevance to architectural problems suggest the Matrix has merit (2), but much work will be required to validate the tool before it can be used with any degree of confidence this setting.

Meanwhile, we examine a short example here to demonstrate the mechanics of the tool and the useful solution directions it is very quickly able to deliver:

The 'flexible housing' phenomenon is becoming increasingly important in an environment in which housing needs by occupants are changing ever more rapidly as a result of changing lifestyles and demographics. The 'I want the house/room to be big AND small' is a classic TRIZ contradiction problem. Very quickly, the method identifies the following strategies successfully employed by those facing the same problem in other sectors:-

- Principle 17 'Another Dimension' – 'where a design acts within a straight line or plane, make use of the un-used dimensions
- Principle 7 'Nested Doll' – 'place objects inside one another, or allow them to pass dynamically through one another'
- Principle 15 'Dynamics' – 'where a structure is immobile, make it mobile'
- Principle 4 'Asymmetry – as above

Using these as solution triggers either alone or in combination, it becomes possible to identify a variety of possible solution opportunities:-

A traditional Japanese house has no bedrooms: bedding is rolled out at night.
Have multi-use spaces rather than a series of single-use inflexible rooms. This could be achieved by moveable storage walls or room dividers, or, for example a suspended sleeping platform which moves up and down.
Roof spaces capable of being used by adjacent homes in a terrace – such that as, for example, the space requirement in one household shrinks, the loft space can be 'rented' to an adjacent property requiring more space.

Ideality/Ideal Final Result

TRIZ founder, Genrich Altshuller, identified a trend in which systems always evolve towards increasing 'ideality' and that this evolution process takes place through a series of evolutionary S-curve characteristics (4, 10). A key finding of TRIZ is that the steps denoting a shift from one S-curve to the next are predictable. This finding may be expected to play a significant role in helping organisations to predict the evolutionary potential of any given system or sub-system.

The essential paradigm shift between a conventional design approach and the TRIZ approach is that while traditionally, problem solvers start from the knowns of today, the concept of Ideality, employs a strategy in which the problem solver is asked to envisage the 'ideal final result' situation – in TRIZ terms that situation where the function is performed without any resource, cost or harm – and to then use that as the basis from which to work back to a physically realisable solution. This philosophy is illustrated in Figure 2.

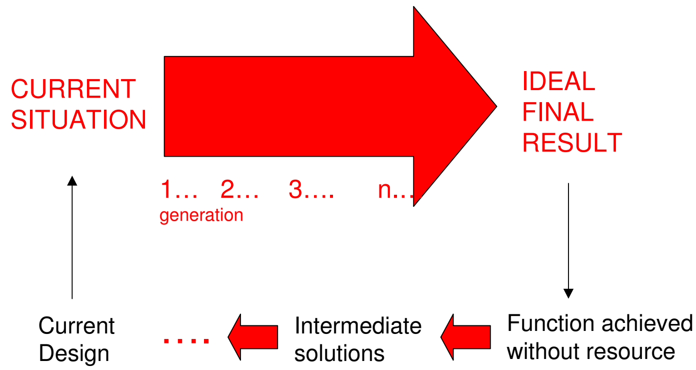
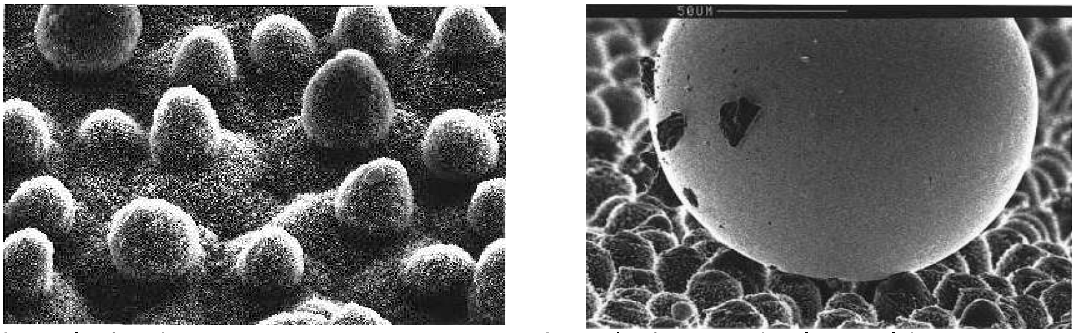


Figure 2: Proposed 'Ideality-Based' Improvement and Evolution Strategy

As well as offering a successful evolution strategy and real problem solutions, it may also be noted that the method also provides a considerable amount of valuable long-term strategy definition data. We look here, however, at a simple application of the tool looking at novel façade design:

Defining Ideal Final Result (IFR) as 'achieve the function without (additional) resources' is intended to suggest the concept of the existing system '*solving the problem by itself*'. The important word here is SELF. Self is a very important word in a TRIZ problem solving context, and the idea of solving problems without complicating the system denotes a powerful step towards increased ideality. Reference 11 discusses the subject in more detail.

We confine ourselves here to discussion of a simple two-step application strategy. Step one involves defining the required function. For example 'clean façade' or 'assemble panel'. Step two introduces the word 'self' – self-cleaning, self-assembling, etc – which is intended to act not just as a useful solution direction, but also as a prompt to examine a functional database in order to establish whether anyone has successfully delivered such a self-X solution in other fields. In the case of 'self-cleaning', for example, we might quickly identify the Lotus Effect as a potential source of a solution. The Lotus Effect comes from the Lotus plant, which has been observed to possess effective self-cleaning properties (Figure 3). Reference 12 describes the first commercial application of an architecturally relevant product based on the Lotus Effect in a façade paint with life properties purportedly well beyond previously known capability. In theory, there is no reason why the concept could not be applied to other architecturally relevant applications – self-cleaning glass (now without an additional coating layer), or roof-tiles, to name but two. Another example of this SELF principle is self-levelling screed.



Lotus leaf - micro-structure

Lotus leaf - water droplet repulsion

Figure 3: Close-up of Lotus Plant Demonstrating 'Self-Cleaning' Properties
(Reference 12)

Trends of Evolution

The self-cleaning example brings us nicely on to an examination of the trends of technology evolution uncovered by TRIZ researchers during analysis of the global patent database. Around a dozen distinct trends of evolution have been identified. We will look at some of them here from the perspective of their practical application in a problem solving context.

We start with a trend known as 'Surface Segmentation' (Figure 4). The trend pattern is illustrated as a left-to-right sequence of design evolutions. In the majority of cases, the left-to-right sequence is related to time (although there are occasional instances where systems are temporarily seen to evolve in the opposite direction), such that systems with features on the left hand end of the pattern occur before those on the right.

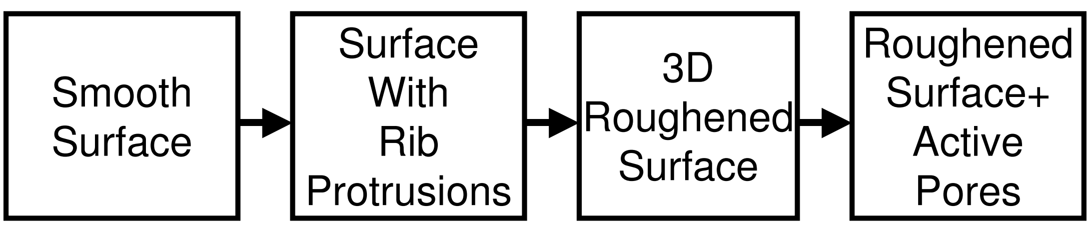


Figure 4: Surface Segmentation Trend

In a problem solving context, the trends offer up suggestions on how to improve the benefits within a given design. In effect, the trend is presenting the problem solver with a message that 'somewhere there is a benefit in moving from left to right along the trend'. In some cases – and the surface segmentation is a good example – this demands a little faith from the user. In aircraft wing design for example, 'conventional logic' suggests that if 'low drag' is a good design aim, then wing surfaces that are smooth are a good way of achieving that aim. The Surface Segmentation trend says, however, that adding protrusions should– offer a potential benefit; and this is in fact what turns out to be the case in that wings featuring 'riblets' tend to possess better drag characteristics than a smooth wing. Similarly a 3D roughened surface (a la shark skin) offers even greater drag benefits.

Our self-cleaning Lotus plant from the previous case study likewise has demonstrated a benefit in evolving to a 3-dimensional surface. The Lotus also incorporates an active secretion; something the Lotus Effect paint has not yet managed to incorporate.

The trick of using the Trends is to make the connections between the specific problem and the generic trends. In practical terms, this means examining a given design from different aspects and levels of focus in order to identify, for example, where 'smooth' things exist – importantly this means zooming out to the macro level and zooming in to the micro or increasingly to the nano-level to find things that are smooth, or have protrusions in one direction, etc.

By way of an example of the deployment of the trends in a problem solving context, we look now at another two trends in the context of their possible applicability to the design of better facades. The first trend is 'Space Segmentation' – Figure 5.

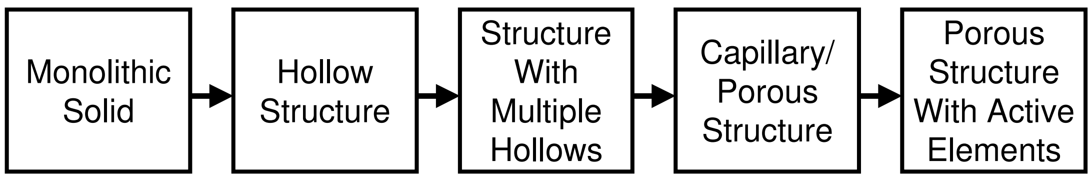


Figure 5: Space Segmentation Trend

This trend may generate immediate connections with the evolution of bricks (where, for example, the 'active' element could be a fire retardent property or some form of insulating material). In order to use the trend to help form better facades, however, we need to pro-actively look for more useful connections. This will again involve us looking at the problem from a variety of different perspectives. By way of an admittedly extreme example of this we might zoom right in to examine an individual fibre of an insulation layer within the façade. If we are able to make this leap, we may see that the fibre is a solid – and hence is at the left hand end of the trend. The trend, therefore, is suggesting that there would be a benefit somewhere in making the fibres hollow. Practical produce-ability issues aside (although several industries have successfully – economically! – made small diameter hollow fibres), an immediate benefit of a hollow fibre is that it acts as a better insulator, while simultaneously using less material, and therefore being less heavy. Animal fur as found on a bear offers a good example of how other areas – in this case nature – have already identified hollowness as a good solution direction.

Now taking the opposite viewing perspective and zooming right out to look at an example of a glazed façade, we may see that there are a good many systems that are at the 'hollow structure' stage of the trend – e.g. double glazing systems. Although the 'multiple hollow' trend might suggest use of triple glazing, the trend is pointing more towards the use of 'foam glass' structures. While these may be some way away from practical reality in an architectural perspective, the final 'active elements' trigger has seen elegant application in a 1999 patent illustrated in Figure 6.

The invention is focused on a critical solar energy in buildings control problem associated with the flow of radiation through the windows and the glass facades. Frequently, the energy and light needs inside the building do not correlate to the solar energy input, leading either to overheating on sunny days or, if employing sun protection glass, to too low exploitation of the solar energy during the heating period. Although mechanical shading systems permit variable solar transmission, they often incur intensive capital investment and maintenance and therefore are expensive. Here is another classic TRIZ contradiction; 'I want the glass to transmit and reflect radiation'. Electro-chromism is a well known (if not widely applied) solution to the contradiction. The reason it is not widely applied is due to its complexity, cost and requirement for an energy input. The Figure 6 patent describes the use of a catalytic and reactive tungsten oxide layer inside a double glazing unit that manages to achieve the required photo-chromic characteristics completely passively. As such it offers an example not only of the Surface Segmentation trend, but also of the

United States Patent [19]
Graf et al.

[11] **Patent Number:** **5,864,994**
[45] **Date of Patent:** **Feb. 2, 1999**

[54] **GLAZING ELEMENT, IN PARTICULAR FOR FACING BUILDING FACADES**

[75] Inventors: **Wolfgang Graf**, Eschbach; **Andreas Georg**; **Volker Wittwer**, both of Freiburg; **Michael Koehl**, Muellheim; **Franz Brucker**; **Andreas Gombert**, both of Freiburg; **Ludwig Thomas**, Berlin, all of Germany

[73] Assignee: **Fraunhofer Gesellschaft zur Foerderung der angewandten Forschung e.V.**, Munich, Germany

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[22] PCT Filed: **Nov. 14, 1995**

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[51] **Int. Cl.**^{6} **E06B 7/00**
[52] **U.S. Cl.** **52/171.3**; 359/360; 359/585; 359/589; 359/581; 359/275
[58] **Field of Search** 52/171.3; 359/360, 359/581, 585, 589, 275

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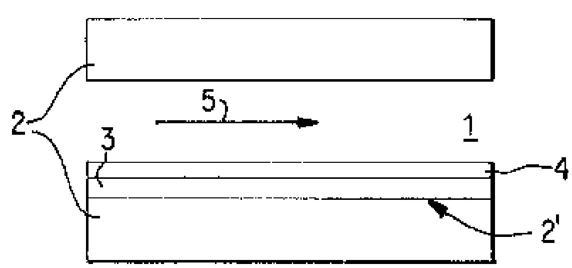
Primary Examiner—Christopher Kent
Assistant Examiner—Yvonne Horton-Richardson
Attorney, Agent, or Firm—Evenson, McKeown, Edwards & Lenahan, P.L.L.C.

[57] **ABSTRACT**

A glazing element, in particular, for facing building facades, having two panes enclosing a gaseous atmospheric intermediate space and having a predetermined layer on at least one pane surface facing the intermediate space. The glazing element is distinguished by the fact that the predetermined layer has a reactive layer applied on one pane and a catalytic layer applied on the reactive layer. The catalytic layer, depending on the composition of the gas atmosphere contained between the panes, activates in the reactive layer. The reaction changes the optical and/or electrical properties of the reactive layer, and varies the composition of the gas atmosphere in the intermediate space, thereby making the electrical and/or optical properties of the reactive layer variable.

27 Claims, 1 Drawing Sheet



evolution towards 'self' activating systems.

Figure 6: US5864994: Glazing element, in particular for facing building facades

A second trend offering potential façade evolution ideas is the Dynamisation trend illustrated in Figure 7. This trend has perhaps less immediate application, and yet the existence of air curtain and light-locks represent 'facades' that have evolved to the right hand end of the dynamization trend. The message from these examples is that with the ideality concept suggesting the evolution of systems towards 'achieving the function, without the resource', if the function of the façade is merely to keep in heat or keep out unwanted intruders, then immobile bricks and mortar solutions are less than 'ideal'. Of course, where the functional requirements of the façade also include things like protection against the elements and structural stability, the structure is progressively likely to be immobile in nature. That isn't to say that mobility isn't a good thing to achieve; merely that it is not a well established solution. Earthquake resistant structures are increasingly employing flexibility to cope with the loads imposed on structures.

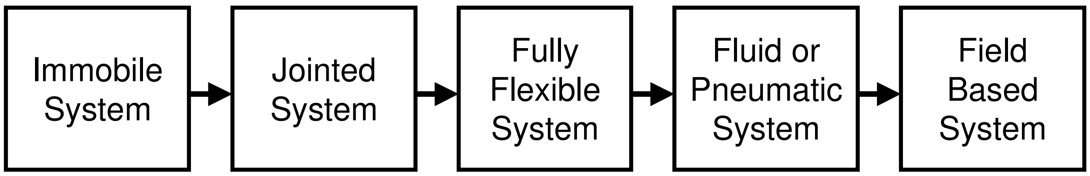


Figure 7: Dynamisation Trend

Geometric evolution (Figure 8) is another commonly observed trend – it has a lot of commonality with the Another Dimension Inventive Principle and is basically saying that there is advantage in turning 2D things into 3D things. By way of example – guttering is usually constructed as a 2D extrusion; the geometric evolution trend is encouraging use of a non-constant section gutter – possible benefits are appearance, control of water flow, self-unblocking, etc.

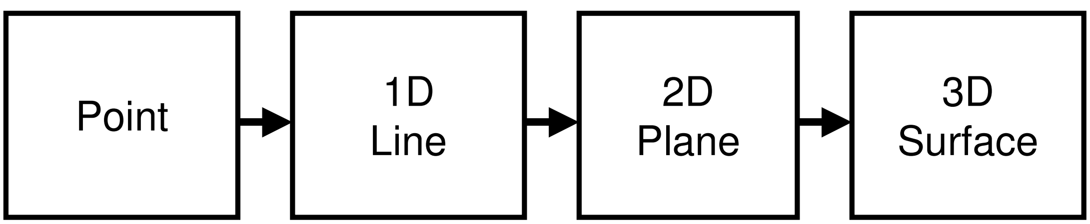


Figure 8: Geometric Evolution Trend

In many senses, the aesthetic aspects of architecture are dominated by the effective use of all three dimensions determining the physical appearance of the structure. It does not appear likely that the geometric evolution trend, or for that matter, the Another Dimension inventive principle have much to offer. Prompts by the method to use asymmetry and curvature (Inventive Principle 14) are perhaps a little more helpful, but it seems clear that TRIZ is currently offering little to help architects when it comes to aesthetic considerations.

Resources

Before leaving the subject of TRIZ trends it is worth noting an important connection with the 'Resources' part of the method. TRIZ encourages unprecedented emphasis on the maximisation of use of everything contained within a system. In TRIZ terms, a resource is *anything in the system which is not being used to its maximum potential*. TRIZ demands an aggressive and seemingly relentless pursuit of things in (and around) a system which are not being used to their maximum potential. Discovery of such resources then reveals opportunities through which the design of a system may be improved. The trends of evolution may thus be seen to offer lots of such opportunities. In essence any system or system component which is a solid or has a smooth surface, or is 2D, or immobile, or has a continuous action, etc is a potential resource. i.e. because it still has untapped evolutionary potential.

SUMMARY

1) The systematic innovation and creativity methodology, TRIZ, is formed around four main pillars, contradictions, ideality, functionality and use of resources.
2) TRIZ contains a broad spectrum of problem definition and problem solving tools, several of which have been shown to be relevant and useful in an architectural context. The concepts of ideality and contradiction elimination are as relevant to architects as they are to designers and problem solvers in any practical application-oriented discipline.
3) The 40 Inventive Principles and Trends of Evolution tools offer a relatively easy route into using TRIZ to help generate novel solutions to architectural challenges.
4) TRIZ is still very ‘engineer’ and ‘function’ focused, and as such it currently has little to offer architects in terms of aesthetic considerations.
5) No systematic innovation methodology can ever claim to be complete. Areas into which the current method may be expanded in future evolution steps to help in the architectural arena, include:-
   - update of TRIZ tools to include new patent, biological and architectural solutions
   - improved knowledge base of architectural problem solving strategies
   - evaluation of other TRIZ tools – S-Fields, Subversion Analysis, etc – for their possible relevance and applicability in an architectural context.

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