Computer-based TRIZ - Systematic Innovation Methods for Architecture

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Abstract: The Russian Theory of Inventive Problem Solving, TRIZ, is the most comprehensive systematic innovation and creativity methodology available. Essentially the method consists of restating a specific design task in a more general way and then selecting generic solutions from databases of patents and solutions from a wide range of technologies. The development of computer databases greatly facilitates this task. Since the arrival of TRIZ in the West at the end of the Cold War, it has begun to be used with great success across a wide variety of different industries. Application of the method to the field of architecture has so far been very limited. The paper outlines how TRIZ methods may be applied to a number of architectural problems.

1. 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 Russian initiated Theory of Inventive Problem Solving, TRIZ, (1, 2) looks set to do much to change this picture. TRIZ offers architects looking for inventive solutions the prospect of a manageable, predictable, systematic innovation capability. 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. The research has established that:

1. Problems and solutions are repeated across industries and technologies
2. Patterns of technical evolution are repeated across industries and technologies
3. The most powerful innovations use effects and solutions from outside the field where they were developed
4. The most powerful innovations are the ones that eliminate rather than accept compromises

Since its emergence in the West in the late 1980s, the method has begun to be successfully deployed both as a manual method and a computer-based tool by a number of companies in the US and, progressively, Western Europe and Japan. Although initially conceived as a method for engineers, TRIZ has latterly been seen to be successfully applied to a much wider variety of problem types – including non-technical, business type problems. Exposure to TRIZ across the field of architecture has thus far been extremely limited.

This paper discusses how an evolved version of TRIZ, with supporting software tools, is being used to solve previously intractable problems and, using the identified technology evolution patterns, to define the future development potential and paradigm shift potential of a range of building systems and sub-systems. The paper includes examples of TRIZ-derived solutions to a range of architecture-based problems in order to demonstrate how the method may be expected to have as profound an impact on innovation in architecture as it has had in other sectors.

The paper begins with a brief overview of TRIZ and the problem definition and solving tools contained within it.

2. TRIZ – AN INTRODUCTION

The core findings of TRIZ research on the global patent database (Reference 1, 2) are that the world currently contains a very small number (40) of Inventive Principles and that technology evolution trends are predictable.

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 to and select solutions from this generic framework.

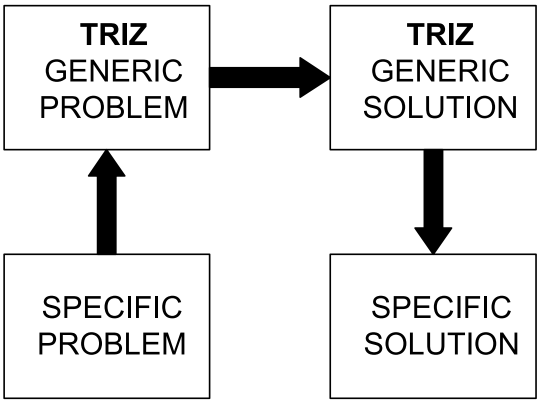

Figure 1 The Basic TRIZ Problem Solving Process

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 engineers and scientists 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.

Readers interested in obtaining a flavour of the breadth of applicability should check out some of the several hundred articles in TRIZ Journal (3).

3. THE FOUR PILLARS OF TRIZ

1500 person years of research have produced a lot of significant innovation tools and methods. TRIZ allows users to deploy each of these tools in either an individual or systematically sequenced manner. Experience using the method in non-Russian work environments has suggested that users often struggle with the various tools and techniques because it is difficult to set TRIZ in the context of 'traditional' problem solving strategies. With this in mind, the description offered here re-casts TRIZ in order to strengthen awareness and understanding of the four main paradigm shifts which distinguish the methodology from others.

The four paradigm shifts – Contradiction, Ideality, Functionality, and Use Of Resources (Figure 2) are discussed below in the context of the central role they each play in creating a deployable and effective problem definition and problem solution methodology.

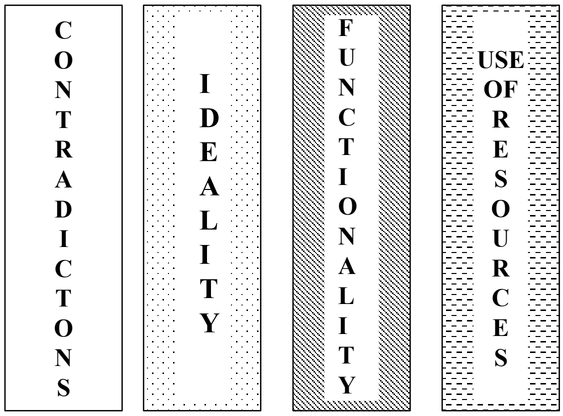

Figure 2. The Four Pillars of TRIZ

3.1 Contradictions

Although often the first of the tools seen by newcomers to TRIZ, Contradictions is probably the tool which is deployed least well. At least part of the reason for this is that the main underlying principle of the Contradictions philosophy – that of seeking to identify and eliminate contradictions – is almost the complete opposite of traditional problem solving strategies, in which the emphasis is very firmly placed on the importance of achieving 'optimum' compromises between conflicting problem parameters. Traditionally, there is a strong tendency to think of the design process as an amorphous bag filled with an incompressible fluid made from the different design parameters, in which, as the designer tries to squash the bag to improve one parameter, it bulges out somewhere else as a different parameter gets worse.

The keen emphasis on 'trade-off' solutions in traditional problem solving practice often means that designers are rarely explicitly aware that conflicts exist. The first major part of the paradigm shift that takes place in the Contradictions part of TRIZ is the need for problem solvers actively to seek out the conflicts and contradictions inherent in all systems. The second part then involves using the TRIZ methodology to try and 'eliminate' (4, 5) those contradictions rather than to accept them. Or, in terms of the incompressible-fluid filled bag analogy, to attach a valve of some kind that allows the amount of fluid in the bag to be altered.

TRIZ contains a number of 'contradiction elimination' tools – primarily the Contradiction Matrix (2) – which encapsulate how others have successfully solved similar problems. TRIZ currently identifies 40 Inventive Principles which might apply in any given contradiction situation. The

Contradiction Matrix allows problem solvers to narrow down that list of 40 to three or four Principles which might apply to an individual contradiction type. The discovery of the 40 Principles does not preclude the existence of a 41st or indeed many more, merely that today inventors have used just 40. Recent research (6) has highlighted the fact that the same principles are also applicable to non-technical problems.

3.2 Ideality

TRIZ founder, Genrikh Altshuller identified an overall trend of evolution for technical systems which states that they will always evolve towards increasing 'ideality.' and that this evolution process takes place through a series of evolutionary S-curve characteristics (1, 7). 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 how and when evolution steps are possible. This is an undoubtedly useful capability when seen relative to the manner in which organisations have traditionally viewed the innovation process.

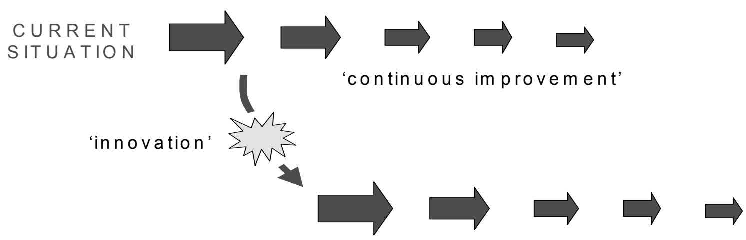

Figure 3. : Traditional System Improvement and Evolution Strategy

Figure 3 illustrates a typical traditional system evolution path. The improvement of systems using this method of operating is very much rooted in the existence of the current situation, and all improvement initiatives use the current design as their foundation. The large-scale innovations then usually appear through what is usually perceived as a highly random process. According to TRIZ and other research, there is a very high likelihood that these major innovations will come from outside the existing industry. In fact, the likelihood is close to 100% (9).

The essential paradigm shift between this approach and the TRIZ approach is that while traditionally, problem solvers start from the knowns of today, the concept of Ideality, demands a strategy in which the problem solver is first asked to eliminate the constraints of today's solution, to then envisage the 'ideal final result' situation – in TRIZ terms where the function is performed without any resource, cost or harm – and to use that as the basis from which a realisable solution is derived. The problem solver may thus be seen to be working back from the 'ideal' to something which is then physically capable of being engineered. This strategy is illustrated in Figure 4. Several examples of this strategy in operation can be found in (9,10).

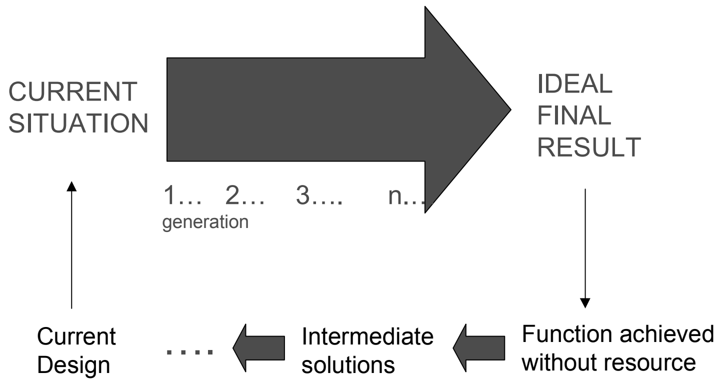

Figure 4. Proposed 'Ideality-Based' Improvement and Evolution Strategy

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.

3.3 Functionality

Although the functionality aspects of TRIZ owe a significant debt to the pioneering work on Value Engineering by Miles (11), the method of defining and using functionality data is markedly different. It is sufficient at the very least to merit discussion as a distinct paradigm shift in thinking relative to traditional occidental thought processes. Three aspects are worthy of particular note:-

1. The idea that a system possesses a Main Useful Function (MUF) and that *any system component which does not contribute towards the achievement of this function is ultimately harmful.* In a heat exchanger, for example, the MUF is to transfer heat to the working medium; everything else in the system is there solely because we don't yet know how to achieve the MUF without the support of the ancillary components. (Systems may of course perform several additional useful functions according to the requirements of the customer.)
2. In traditional function mapping, the emphasis is very much on the establishment of positive functional relationships between components.

TRIZ places considerable emphasis on plotting both the positive *and the negative relationships* contained in a system, and, more importantly, on using the *function analysis as a means of identifying the contradictions* in a system.

3. Functionality is the common thread by which it becomes possible to share knowledge between widely differing industries. A motor car is a specific solution to the generic function 'move people', just as a washing powder is a specific solution to the generic function 'remove solid object'. By classifying and arranging knowledge by function, it becomes possible for manufacturers of washing powder to examine how other industries have achieved the same basic 'remove solid object' function. '*Solutions change, functions stay the same*' is a message which forms a central thread in the TRIZ methodology~~:~~

The emphasis TRIZ places on functionality demands that problem solvers adopt a much more flexible approach to the way in which they look for solutions to their problems. The age of the specialist is coming to an end; it is no longer sufficient for mechanical engineers to only look for mechanical solutions to their problems when someone from, say, the chemical sector may already have discovered a better way of achieving the function being sought – Figure 5.

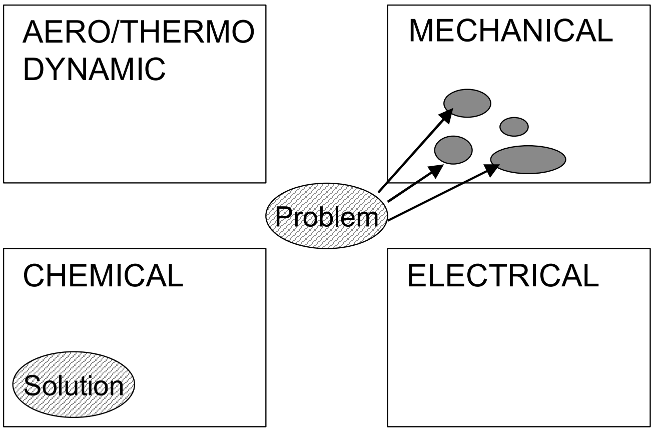

Figure 5. Solution Spaces

Functionally classified knowledge databases are now becoming commercially available. Probably the most comprehensive – currently containing around 6000 effects and examples – comes from Invention Machine (12). One of the following examples will provide a demonstration of the use of this kind of knowledge base in helping to solve architecture problems.

3.4 Use Of Resources

The last of the four main paradigm shifts contained within TRIZ is the simplest, and relates to the unprecedented emphasis placed 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*. 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.

In addition to this relentless pursuit of resources, TRIZ demands that the search for resources also take due account of negative as well as the traditionally positive resources in a system. This is done because experience has demonstrated that the discovery of a negative resource coupled with application of the 'Blessing In Disguise' Inventive Principle can often lead to significant design improvements.

For example, Russian engineers often think of resonance as a resource. This is in direct contradiction to most Western practice, where resonance is commonly viewed as something to be avoided at all costs. TRIZ says that somewhere, somehow, resonance in a system can be used to beneficial effect. In effect, resonance is a potent force lever capable of amplifying small inputs into large outputs. Resonance is currently being used to generate beneficial effects in a number of new product developments from vacuum cleaners (resonating brush fibres to enhance extraction of dust particles), paint stripping systems on ships (firing a pulsed jet of water – existing resource! – at the local resonant frequency of the hull), and in helping to empty trucks carrying powder-based substances more quickly.

The following case study examples serve to demonstrate how the different TRIZ tools and techniques can be brought together to give problem solvers new perspectives on the way they think about the systems they create:

4. EXAMPLE 1 – 'WINDOWS'

Access to enable window cleaning to take place is a functional requirement seemingly forgotten about in too many building designs. Window cleaning is traditionally done by a manual soap-and-water operation. TRIZ encourages problem solvers to think about the functionality to be delivered – in this case –'clean a surface' and to then use that as a means of identifying if there may be other means of achieving the same function. A functionally arranged knowledge base allows us to tap into the good and potentially relevant solutions to the same functions we require to deliver. In the case of ‘clean a surface’, the current knowledge bases do not map directly onto our requirement, but providing we can make the jump between our problem and the generic knowledge framework contained in the database, we have a means of accessing the solutions of others – Figure 6.

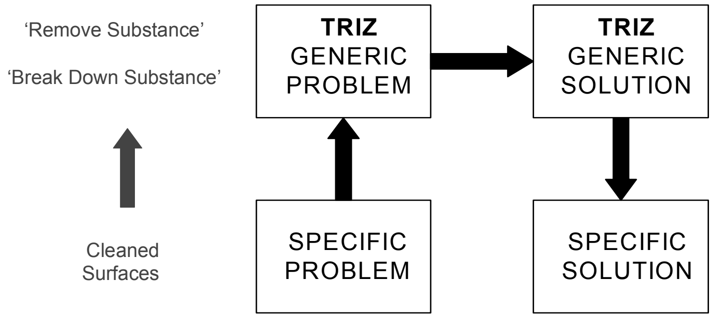

Figure 6. Abstraction of ‘Clean Surface’ onto Knowledge Base.

In this case, the knowledge base will then show us that many other problem solvers have already successfully achieved solutions to the functional requirement – Figure 7.

While several of these solutions may offer an improved method over current strategies, we will choose instead to extend the overall approach to think about the ideal final result cleaned surface situation – a surface that cleans itself. The word ‘self’ is very important in a TRIZ context and ‘things that achieve functions for themselves’ offer great benefits to customers. The functional database of solutions to the ‘self-cleaning’ requirement is somewhat smaller than the above, but nevertheless contains reference to the Lotus Effect. The Lotus Effect – named after the plant – points us towards the very effective manner in which the leaves of the plant clean themselves.

Having found a potential solution to the functional requirement, the problem solver is then required to translate the generic solution into a specific solution. In the case of ‘self-cleaning glass’ using the Lotus Effect, that process is currently the subject of an ongoing patent application. In the meantime, a similar desire for ‘self-cleaning facades has already led to the development and launch of a ‘self-cleaning’ façade paint (13).

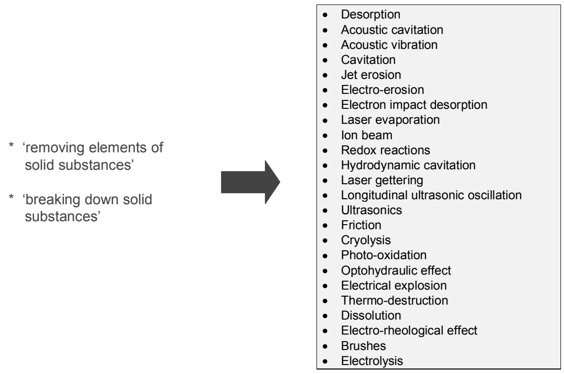

Figure 7. Many Ways of Achieving the Function 'Clean Surface'

5. EXAMPLE 2 – 'RAMPS'

Access ramps are a blight on many a public building, being both aesthetically unpleasing, and a source of inconvenience for the vast majority of users including those for whom they are provided. Ramps represent the lowest common denominator design compromise. In TRIZ terms, every time an architect sees compromises, the method is trying to suggest better alternative solutions.

The TRIZ Contradiction Matrix offers systematic means of tapping into the good solutions of inventors who have successfully fought rather than accepted the compromises. In the case of 'ramps', the design contradiction centres on a desire to get up and down steps of a variety of heights with the minimum level of inconvenience. The 'compromise-free' solution then is one that allows us to deliver the function (get up and down steps) **and** not have any inconvenience to any user. In the generic terms of the Matrix, this contradiction corresponds to one of length versus ease of operation. The Matrix then suggests that the best inventive solutions to this generic conflict have involved either transferring the delivery of the function to something else, or getting the thing that wants the function to achieve it 'by itself'.

These generic solution triggers are often very useful ways of changing our perspective on a problem. In this case, they are helping the problem owner to stop thinking about a 'ramp', and to start thinking about how the wheelchair user (the person that wants the function delivered) can deliver the function. This shift in thinking might then point us towards use of a knowledge base to help us to see if someone else has successfully made the same sort of shift in thinking. In this case, we might examine the global patent database in search of inventions which have delivered the function 'raise (or lower) human (in a wheelchair, up or down a step or series of steps)'. From a list of over 70 potentially relevant inventions, we find one – US patent US5701965: 'Human Transporter' (Figure 8) – which has recently entered the market in the United States.

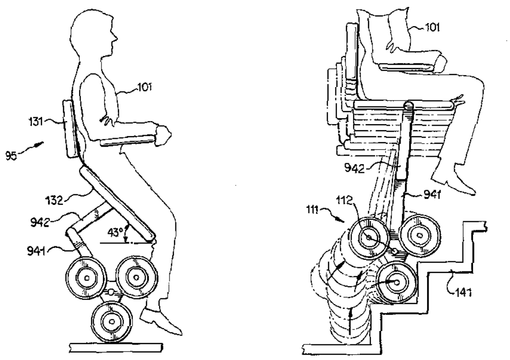

Figure 8. US Patent 5701965, Human Transporter

Of course, this solution is but one of a wide range of possibilities which also include 'wheelchairs' that successfully break out of the psychological inertia associated with the use of 'wheels' by employing 'legs'. And, although it performs many functions in addition to the 'raise human' one relevant to the ramp issue – for example its (low cost) gyroscopic control system allows the occupant to stably rise up on two wheels to achieve eye-to-eye contact with a standing person – it comes with compromises of its own. In the fullness of time, TRIZ techniques will facilitate the elimination of these compromises. In the meantime, if it serves only to help architects and regulation authorities to break out of the 'ramp' paradigm and into one that encourages solution closer to source at the wheelchair level, it has served a useful purpose.

6. EXAMPLE 3 – 'LIFETIME HOMES'

Staying with the theme of raising and lowering humans, but now extending the function to a desire to move between storeys by means other than the specific solution of a flight of stairs, we comment on current suggestions that the designs of new domestic dwellings should include special provision in the construction of the first floor to facilitate the future installation of a lift in order to accommodate aging occupants that become unable to use a staircase.

Again, here we see a case of design guidance specifying a design solution rather than focusing on the delivery of the desired function. A ‘lift’ is but one of a number of ways of moving between levels within a building; just as ‘a staircase’ is another. The point of switching from a solution-based to a function-based way of looking at the world is that while solutions can and often do change, functions stay the same. In other words, humans will always want to go up and down between different levels, but likely as not also, they may well wish to achieve that function by means other than those which blinker our thinking today.

Even worse in this case is the potential requirement that buildings will have to have redundant structure permitting the future **possibility** of having a lift installed. If we also allow ourselves to be bound by the psychological inertia that tells us that lifts travel vertically up and down, we have imposed some massively limiting design constraints on architects and on our society. Most ‘lifts’ do travel vertically up and down; but that doesn’t mean all have to. Nor does it mean that the means of delivering the function has to either.

Again, the use of a TRIZ-based functional knowledge search of the US patent database, for example, reveals over 70 patents related to powered means of transition between floors in buildings.

The Stannah-style stairlift is a relatively crude alternative solution for delivering the function. Crude as it is (lots of contradictions for TRIZ to help eliminate!), the design concept has at least made use of an existing resource. A multi-storey building with a staircase has a ready made means of accessing one floor from another – so why force builders to include another? One of the problems with the Stannah design concept is that it demands attachment to a structural wall. While this may not be too major a constraint, in TRIZ terms, it is one that ‘ideally’ we would not impose on ourselves. Thus US patent 5105914 (Figure 9) delivers the same functionality as the Stannah, but does not require attachment to anything other than an existing resource called the staircase, nor does it require installation on a footprint bigger than the staircase.

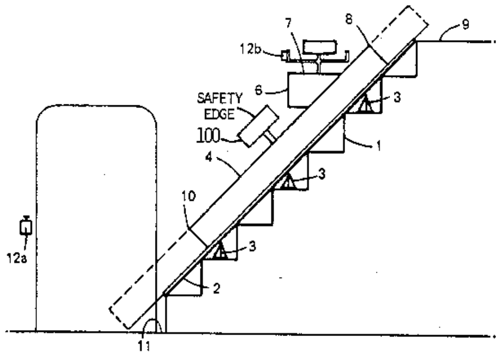

Figure 9. US Patent 5105914, Stairlift

7. EXAMPLE 4 – 'STAYING WARM'

We end with another short case study aimed at reinforcing the importance of recording the functions and attributes required from a given structure, and then using software knowledge bases to identify possible solutions to each functional requirement. The example here examines the functional requirement of a building façade to provide insulation. Again, 'insulation' is not a problem unique to the field of architecture; it is a functional requirement found in most if not all other scientific and engineering disciplines.

For the first time, TRIZ-based software gives problem solvers ready access to the 'good' functional solutions discovered and exploited in these other disciplines. Potentially, several of those solutions offer significant benefits over the ones 'traditionally' used within any given individual field.

In the case of 'insulation' – or, in terms of the generic functional classification used in the knowledge-bases, 'stabilise thermal parameters' – there are close to 200 scientific effects capable of delivering the function (Figure 10). Many of the list appear to offer significant opportunities for architectural innovation. To access them, however, will demand that architects adopt new ways of looking at the world outside their discipline.

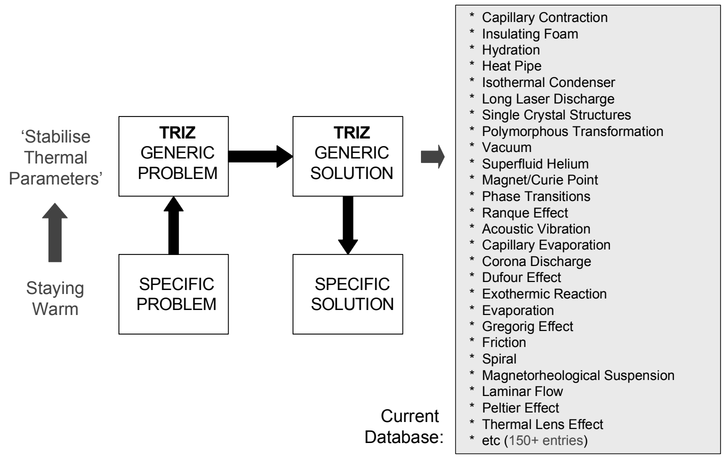

Figure 10. How Other Fields Achieve the Function 'Stay Warm

8. SUMMARY

1. The systematic innovation and creativity methodology, TRIZ, is formed around four main pillars, contradictions, ideality, functionality and use of resources.
2. TRIZ is a comprehensive systematic innovation and creativity method with a massive pedigree of published output. It offers a generic problem-solving framework into which other tools have already begun to be successfully integrated.
3. TRIZ has not previously been applied in the field of architecture, to the authors' knowledge. Preliminary evidence from the case studies presented here suggests that the method offers much potential for systemising the innovation process in architecture.
4. TRIZ-based knowledge bases enable architects to readily identify and explore the good solutions of others in other fields.
5. Such knowledge bases would benefit from expansion to incorporate the 'good solutions' known about by architects that have not been discovered in other disciplines.

9. REFERENCES

Altshuller, G., 1984, *Creativity As An Exact Science*, Gordon & Breach.
Salamatov, Y., 1999, *TRIZ: The Right Solution At The Right Time*, Insytec BV, The Netherlands
Mann, D.L., 2000, "Contradiction Chains", *TRIZ Journal*, January 2000.

Mann, D.L., 1999, "*Design Without Compromise: A New Perspective on Fluid Power System Component Design*", *PTMC International Workshop*, PTMC99, Bath, September 1999.
Mann, D.L., E. Domb, 1999, "40 Inventive Management Principles With Examples", *TRIZ Journal*, August 1999.
Mann, D.L., 1999, "Using S-Curves and Trends of Evolution in R&D Strategy Planning", *TRIZ Journal*, July 1999.
Utterback, J, 1996, *Mastering The Dynamics Of Innovation*, Harvard Press.
Mann, D.L., 2000, "Strength versus Weight Contradictions in Bridge Design", *TRIZ Journal*, March 2000.
Mann, D.L., 2000, "Design Without Compromise, Design For Life", *International Fluid Power Exposition*, IFPE 2000, Chicago.
Miles, L. D., 1961, *Techniques of Value Analysis and Engineering*, McGraw-Hill Book Company, New York NY.
www.invention-machine.com
www.botanik.uni-bonn.de/system/bionics.htm
www.triz-journal.com