TRIZ AND THE FOUR PRONGS OF QUALITY

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"Incrementalism is innovation's worst enemy"
(Nicholas Negroponte, MIT Media Lab)

Abstract

Deming described innovation of product and service and innovation of process as the two most important prongs of quality. Generally speaking, we are not very good at either.

According to the Russian theory of inventive problem solving, TRIZ:-

- all of the world's patents have come from just 40 inventive principles
- all technology evolution trends are predictable.

TRIZ is an extremely potent systematic innovation tool, already in use with companies like Lockheed, Rockwell, Proctor & Gamble, Unilever, Mitsubishi, IBM, BMW, Saab and Ford.

The paper examines how TRIZ is being used to solve seemingly intractable product, process and service problems.

1.0 Introduction

Deming placed a heavy emphasis on the importance of innovation within organisations. The first of the Fourteen Points says:-

"…constancy of purpose means acceptance of obligations like the following:… Innovate… Plans for the future call for consideration of: New service and new product that may help people to live better materially, and that will have a market…"
Out of the Crisis (1)

In other areas of his writings he has also said:-

"One requirement for innovation is faith that there will be a future. Innovation, the foundation of the future, can not thrive unless the top management have declared their unshakable commitment to quality and productivity."
Out of the Crisis

"It is thus not sufficient to improve processes. There must also be constant improvement of design of product and service, along with introduction of new product and service and new technology."
Out of the Crisis

In fact, he even went so far elsewhere in Out of the Crisis to rank the relative importance of each of the types of innovation:-

1) **Innovation in product and service**

2) **Innovation in process**

3) **Improvement of existing product and service**

4) **Improvement of existing process**

He described the four categories of innovation/improvement as 'The Four Prongs Of Quality'.

Beyond these fine words, however, Deming's work contains little of substance in offering help with innovation aspects. Probably the most telling advice comes via the Deming Dimension (2):-

"…the Four Prongs are all essential. They are listed in order of importance; but the order of application has, in practice, generally to be the reverse."
The Deming Dimension

It would be fair to say that much of the remainder of Deming's work – and indeed much of the work of Deming researchers and consultants – concentrates on 'improvement' rather than 'innovation' aspects. This is quite probably because 'improvements' have been seen to be much more amenable to success via plottable, systematic approaches (like SPC). The following quote, also on the subject of innvation, might offer a clue:-

"…it is necessary to innovate, to predict needs of the customer, give him more. He that innovates and is lucky will take the market."
The New Economics (3)

Use of the word 'luck' is interesting here. Interesting because the general perception of innovation – or at least the 'creativity' aspect of innovation – is that it is a highly nebulous, intractable thing. The vast majority of the vast number of texts on creativity (Bibliography) serve only to confirm the view. The quantity of useful – in the context of the world of the engineer 'useable' – output from all of this activity appears to amount to little more than zero.

Russian Naval Officer, Genrich Altshuller did not believe that creativity was about 'luck'. Starting in 1946 he set about an investigation of the global patent database in order to confirm his belief that the inventive problem solving was a predictable, definable process. Since the start of this work, Altshuller and team have accumulated over 1500 man years analysis of something like 3 million of the world's most effective patents.

Altshuller's work on what he called Teorija Rezhenija Inzhenernyh Zadach (TRIZ) – the Theory of Inventive Problem Solving – has now become a potent systematic innovation tool. The creative parts of the innovation process need no longer depend on the rolling of dice or unpredictable flashes of inspiration.

TRIZ has grown into a broad ranging series of tools and techniques (4). These techniques include:-

- **Resolving Contradictions ('Design Without Compromise')**
- **Technology Forecasting**
- **'Ideal Final Result'**
- **Scientific Effects**
- **Function/Process Analysis – 76 Standard Inventive Solutions**

This paper will take a look at each of the tools through real-life examples of how they have been used to generate effective innovations in and across a variety of industries, products processes and services.

In this regard, it is Important to note at this point that, although Altshuller was an engineer and was primarily considered with innovation of products, recent work has demonstrated that many of the principles collected in TRIZ are applicable in other fields – most notably as far as this paper is concerned to the study of management and organisational issues.

"Wealth in the new regime flows directly from innovation, not from optimisation… wealth is not gained by perfecting the known, but by imperfectly seizing the unknown"
(Kevin Kelly, 'New Rules for the New Economy', Wired magazine)

2.0 Resolving Contradictions ('Design Without Compromise')

Western designers have the message 'design is a trade-off' drummed into their heads from day one of their education through everyday on the job. Altshuller's view was that, if we are smart, we should be looking to eliminate the trade-offs rather than work with them (see reference 5 for an example).

One of the most well known parts of TRIZ is the way that Altshuller classified inventive solutions which eliminated trade-offs and discovered that inventors were using only a relatively small number of Inventive Principles in so doing.

A contradiction contains something we wish to improve about our situation and something else which gets worse as we try to improve the first thing. Think for example of a car door. As users, we would like the door to be easy to close and to keep out rain. As designers we see that we have a pair of contradictory requirements because making the door easier to close means using less force; which means less force is available to compress a seal; which means the door won't seal as well; which means it will let more water in. And vice versa.

Traditionally, car door designers have conducted a careful trade-off between the two different requirements. Consequently some doors feel like they require more than two hands to close them, and others still leak.

The beauty of what Altshuller did when looking at problems like this car door problem was to classify the contradictions into a series of generic parameters (Reference 6). In all he found that only 39 such parameters were required to cover all situations (Table 1). He then discovered that for each of the generic contradictions, inventors that had managed to successfully eliminate the contradiction had done so using only a very small number of Inventive Principles. By using the patent database has his foundation, Altshuller effectively achieved a view across all industries. If the car door problem is seen as one of a conflict between 'Convenience of Use' (easier to close) and 'Harmful Side Effects' (more leaks), then by looking across the patent database, we will discover ways of eliminating the conflict from a whole variety of industries. The 'compromise-free' solution to the car door problem is thus as likely to come from the world of computer chips or dentistry as it is from the makers of cars.

In all – after close to 3 million patents – Altshuller has discovered there to be a total of only 40 Inventive Principles (Reference 7, Table 2). For any given individual contradiction, he further determined that only 3 or 4 of the 40 Principles were likely to be relevant.

Let us demonstrate use of the Contradictions part of TRIZ through another example; the bicycle seat (Figure 1).

Figure 1: Typical Bicycle Seat

The bicycle seat is renowned for being uncomfortable. It is uncomfortable because bicycle seat designers have spent the last hundred and fifty years failing to find a balance between sitting comfort and pedalling action which satisfies the various shapes of human being who cycle. TRIZ says that we might have a chance of satisfying everyone if we are able to eliminate the conflicts.

The fundamental conflict is that the saddle must be WIDE to provide comfortable support, AND must be NARROW to permit pedalling action. In terms of the TRIZ Contradiction Matrix, this conflict may be seen as a conflict between a STATIONARY LENGTH (width of saddle) and the SHAPE of the seat. The Matrix suggests:-

- **The Other Way Round** ("make movable parts fixed, and fixed parts movable")
- **Dynamics** ("divide an object into parts capable of moving relative to each other", "if an object is rigid or inflexible make it movable or adaptable")

Which in turn, didn't take long to prompt an idea for a bi-furcated seat as shown in Figure 2:

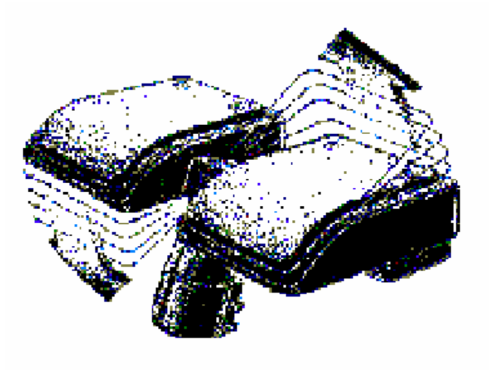

Figure 2: ABS Sports Bifurcated Saddle

(See Reference 8 for a more detailed explanation of this saddle case study.)

As has been said already, the Inventive Principles arose from a study of essentially product-based innovations. The Principles have, however, since been successfully correlated to a number of management situations (Reference 9).
Examples:-

Principle 1 – Segmentation

A) '*Divide an object into independent parts*' – e.g. WBS for large project, divide organisation into different product centres, autonomous profit centres, franchise outlets.

B) '*Make an object easy to disassemble*' – e.g. flexible pensions, flexible manufacturing systems, container shipment, modular furniture/offices.

C) *'Increase the degree of fragmentation or segmentation'* – e.g. quality circles, 'empowerment' (gulp!), distance learning, virtual office/remote working.

Principle 4: Asymmetry

A) '*Change the shape of an object from symmetrical to asymmetrical'* – e.g. more 'P' or more 'S' in the PDSA cycle, skewed normal distributions.

B) '*If an object is asymmetrical, change its degree of asymmetry'* – e.g. 360º appraisals, more equitable 2-way dialogue between management and workers, shift from annual to bi-annual car registration dates (to reduce August sales peak).

Principle 13: 'The Other Way Round'

A) '*Invert the action(s) used to solve the problem'* – e.g. bring the mountain to Mohammed, expansion instead of contraction during recession.

B) '*Make movable parts (or the external environment) fixed, and fixed parts movable'* – e.g. moving pavement with standing people, home-shopping, home banking, park-and-ride.

C) '*Turn the object (or process) upside-down'* – e.g. till assistant is most important part of retail organisation, product- rather than function- based organisation structure.

Principle 24: 'Intermediary'

A) '*Use an intermediary carrier article or intermediary process'* – e.g. ACAS, subcontract transport versus in-house, franchise, travel agent (NB can also mean removal of intermediary – e.g. direct selling).

B) '*Merge one object temporarily with another (which can then be easily removed)'* – e.g. pot holder to carry hot dishes to the table, trouble-shooting or specialist fire-fighting teams.

Whilst not thus far analysed in sufficient depth to be able to define a practical 'management' version of the Contradiction Matrix, the 40 Inventive Principles nevertheless form a series of very effective management psychological inertia removing prompts in their own right (Reference 10).

3.0 Technology Forecasting

Strictly speaking not one of Altshuller's discoveries, but nevertheless consistent with all the trends he did discover is the universal trend towards increasing product 'ideality'. This idea was first discussed by Larry Miles (11). Miles defined 'ideality' or 'value' as:-

Value = Benefits/ (Costs + Penalties)

The 'law' of increasing product (or, indeed, process or service) 'ideality' in the context says that future systems will evolve towards greater benefit, lower cost, and reduced operating penalties. None of these should appear particularly surprising.

Miles' ideas are commonly expressed in terms of the S-curves of product evolution shown in Figure 3. S-curves show trends of increasing ideality through successive generations of product evolution.

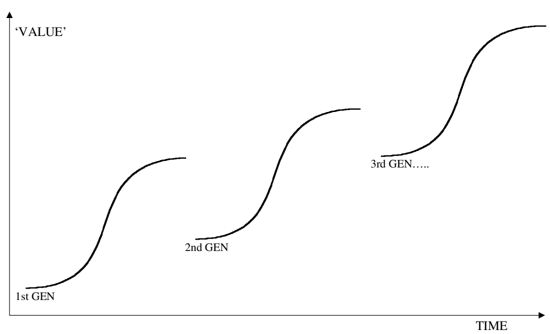

Figure 3: Typical Product Evolution S-Curve

Altshuller's trends of evolution discoveries are based primarily on analysis of the global patent database and have thus concentrated on the physical manifestations distinguishing one product generation from another. Among a host of patterns of evolution spotted by Altshuller (4) is the example of 'trimming'.

The 'Trimming' evolution trend (Figure 4) says simply that products will evolve to contain progressively fewer components. Generally speaking, the reduction will eventually be achieved with no decrease in product functionality. Note two important facts here: 1) there may be an intermediate stage where functionality decreases – although net value will have increased, and, 2) there may also be intermediate stages where part count increases (e.g. car engines). The important point is that they are **intermediate** stages.

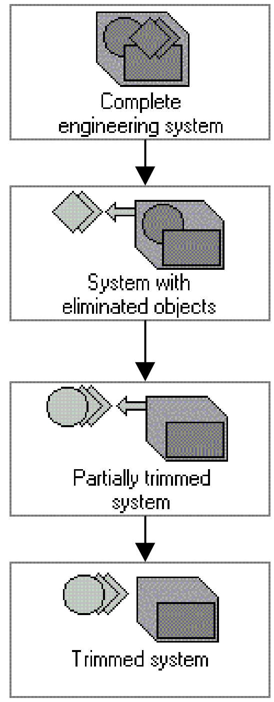

Figure 4: 'Trimming' Evolution Trend

As with the universal trend towards increased ideality, the 'trimming' trend applies equally well to processes and services as it does to products.

Other technology evolution trends identified by Altshuller include:-

- Surface Segmentation
- Space Segmentation
- Substance Segmentation
- Dynamization
- Geometric Evolution of Linear Structures
- Geometric Evolution of Volume Structures
- Controllability
- Action Co-ordination
- Rhythm Co-ordination
- Mono-Bi-Poly Systems
- Introduction of Additives
- Fields, Forces, Interactions

Some of the trends – 'Space Segmentation' (Figure 5) for example are most closely applicable to product evolution:-

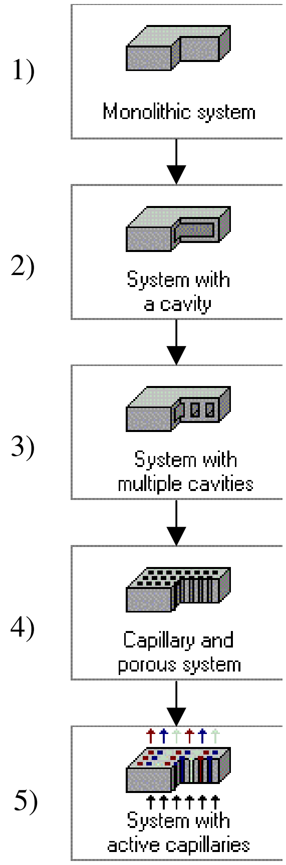

Figure 5: 'Space Segmentation' Evolution Trend

The 'Space Segmentation' trend may be seen to apply to products as diverse as chocolate bars, building bricks, shoe soles and turbine blades.

Different products may be seen to exist at different stages along the evolutionary path. For example, bricks are entering phase 5) – bricks with inbuilt insulation materials – chocolate bars are currently in phase 4), and turbine blade technology is just about ready to enter phase 4). The trend says that each will eventually evolve to phase 5). Beyond phase 5) is either outside the current field of human knowledge or, more commonly, the requirement for the product disappears (e.g. house construction by means other than brick).

Others evolution trends – e.g. 'Action Co-ordination' (Figure 6) – may well be seen to offer useful insight to the development of processes and services:

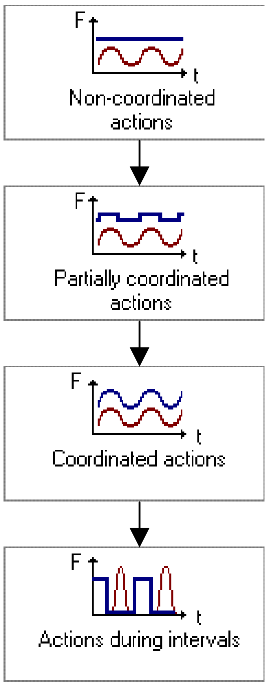

Figure 6: 'Action Co-ordination' Evolution Trend

An example product evolution trend following the 'Action Co-ordination' path is the engine cooling system of a car. Most current cooling systems are at the 'co-ordinated action' stage – i.e. the cooling fan comes on only when a thermostat tells the power supply that the coolant is hot. Recognising the general overall trend towards improved ideality and specifically the desire to improve engine efficiency, the fourth phase of the 'Action Co-ordination' trend suggests the addition of a heater to heat the cold engine such that it gets up to temperature (and hence maximum efficiency) more quickly.

In terms of a process or service following the 'Action Co-ordination' trend, think of the evolution of shift working patterns or information flow between departments within an organisation.

Altshuller's discoveries concerning predictability of technology evolution trends provide organisations with powerful means with which to plan and implement R&D strategy. The trends may also be used with another TRIZ tool; Altshuller's idea of the Ideal Final Result:

4.0 'Ideal Final Result'

Altshuller, conceived the Ideal Final Result (IFR) philosophy as a means of assisting in the systematic derivation of future technology advances. In effect the IFR approach is a way of encouraging organisations to look into the future, to the furthest, ultimate evolution potential of a product.

There are a number of ways in which the IFR can de developed. One such means is to pass through the sequence of questions Altshuller most entertainingly employed to look at ways of feeding rabbits.

The basic sequence of questions is:-

1) What is the final aim?

2) What is the IDEAL FINAL RESULT?

3) What is the obstacle to this?

4) Why does this interfere?

5) Under what conditions would the interference disappear? (What resources are available to create these conditions?)

For the rabbit feeding example, the respective answers were:-

1) rabbits eat fresh grass
2) rabbits feed themselves fresh grass (i.e. no requirement for the owner to feed them)
3) walls of the rabbit cage are immobile
4) since walls don't move, area of available grass doesn't change
5) Enclosure moves to fresh grass when grass inside has been eaten

In theory, passing through the questions successfully should lead to the required IFR solution – at least conceptually. In the case of the above rabbit example, perhaps the answers have suggested the idea of some form of wheeled cage capable of being pushed by the rabbit as it runs out of grass in one space and strives to reach the uneaten grass on the other side of the cage wall?

The IFR is often defined to possess the following 4 characteristics (12):-

1. Eliminates the deficencies of the original system
2. Preserves the advantages of the original system
3. Does not make the system more complicated (uses free or available resources.)
4. Does not introduce new disadvantages

The tests are often useful in a conceptual sense. The fourth question is particularly testing (it is not wholly clear, for example, that the wheeled cage derived in the rabbit example can be configured without adding any disadvantages relative to an unwheeled cage – for a start having wheels costs more than having no wheels).

The IFR approach is nevertheless a very useful problem definition and long term visioning tool applicable to other, more serious applications. Imagine, for example, the hypothetical case of a supermarket chain:

1) What is the final aim?
'one stop shopping'

2) What is the IDEAL FINAL RESULT?
one stop shopping without the shop (or supply depot)

3) What is the obstacle to this?
lack of transport infra-structure (i.e. technology required for 'virtual' shopping already exists – cf: Amazon.com)

4) Why does this interfere?
since there is no infra-structure, it is not possible to transport purchases to the customer

5) Under what conditions would the interference disappear? (What resources are available to create these conditions?)

if there was an infra-structure (what resources are available? – Royal Mail, milkman, bus companies, etc.)

It often turns out to be the case that even though we might be able to envision what the IFR might be conceptually, we find ourselves unable – for example due to technology limitations – to achieve it in practice. A useful technique in such instances is to gradually step back from the IFR to the current state until an achievable solution can be achieved – see Reference 13 for one such example.

Figure 7 illustrates how this type of systematic 'stepping back' approach may be applied to the supermarket problem. For example, if we determine that it is not possible at this point in time to eliminate the need for, say, supply depots we may choose to look at solutions which eliminate the (physical) shops but retain the depots:

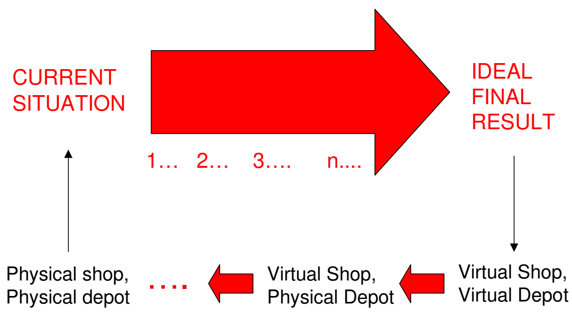

Figure 7: IFR Evolution Paths

Or perhaps picture the also hypothetical case of a washing powder (or, indeed, washing machine) manufacturer:-

1) What is the final aim?
clean clothes

2) What is the IDEAL FINAL RESULT?
clean clothes without the need for an external agent

3) What is the obstacle to this?
without external agent, dirt will not come off

4) Why does this interfere?
since dirt won't come off, clothes aren't cleaned

5) Under what conditions would the interference disappear? (What resources are available to create these conditions?)
if the dirt is removed without an external agent (resources:- dirt, water, clothes… some kind of catalyst? some kind of physical effect?)

Sometimes – as perhaps may be the case with the supermarket example - a solution becomes obvious by the time answers to all five questions have been identified. In other cases, like the above clothes washing case, we may need some additional information if we are to achieve a viable solution. In the case of washing clothes, for example, it would be useful to know whether there are any known chemical, physical or other scientific effects able to provide the capability we are looking for. This desire leads on to another important element of TRIZ; a systematic database of such effects:

5.0 Scientific Effects

Chances are that somewhere in the world of physics, chemistry, mathematics and biology there is an 'effect' that may be relevant to the task under evaluation. Evidence suggests that an individual scientist or engineer will have a working knowledge of somewhere between 20 and 30 of these effects and a passing knowledge of perhaps as many again. Evidence also suggests that if we have a problem, we will attempt to solve it using our current knowledge base if we possibly can (14). That is, we will try to use one of the 20-30 'things' we happen to know about; never mind that they may well not be either the 'best' or even viable solution methods.

TRIZ is not about inventing or discovering these 'effects', but it is very much about classifying them in a way which makes them accessible to problem solvers. The most powerful manifestation of this effects classification method may be found in the Invention Machine 'TechOptimizer' software (15). The software currently contains a massive 1600 physical, chemical and mathematical effects. The total continues to rise. The company's stated aim is to have the whole of human scientific knowledge contained in the software. The great beauty of the software, however, stems from the TRIZ-based idea of classifying effects by the **function** that they perform.

In the preceding clothes washing case for example, we might be interested in looking at ways of 'removing elements of solid substances' or 'breaking down of solid substances'. In which case, the database suggests we might use:-

- Desorption
- Acoustic cavitation
- Acoustic vibration
- Cavitation
- Jet erosion
- Electro-erosion
- Electron impact desorption
- Laser evaporation
- Ion beam
- Redox reactions
- Hydrodynamic cavitation
- Laser gettering
- Longitudinal ultrasonic oscillation
- Ultrasonics
- Friction
- Cryolysis
- Photo-oxidation
- Optohydraulic effect
- Electrical explosion
- Thermo-destruction
- Dissolution
- Electro-rheological effect
- Brushes
- Electrolysis

In other words, a significantly greater number than we might otherwise have identified. Some effects will, of course, turn out to be more relevant to the clothes washing process than others (electrical explosion!), but the point is that we are given access to a broad range of **functional** possibilities for us to evaluate. To help in this process, the software contains useful animations, descriptions, references and limitations for each effect. For example:-

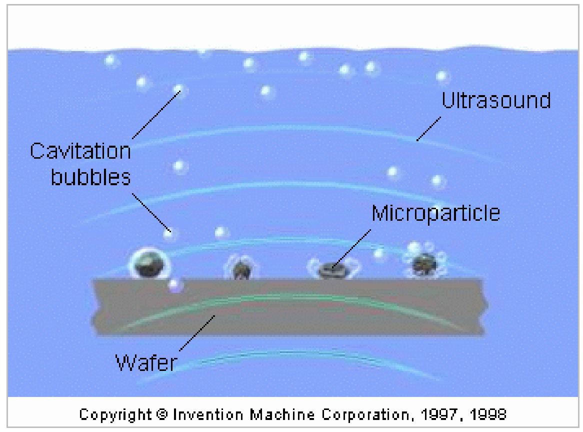

Figure 8: Ultrasound induced cavitation

6.0 Function/Process Analysis – Standard Inventive Solutions

What we have seen so far is the fruit of a quite staggeringly massive piece of work. It is, however, only a relatively brief overview of a relatively small part of Altshuller's overall output. Small because Altshuller also had the idea that it ought to be possible to completely systemise the invention process. The Algorithm for Inventive Problem Solving (ARIZ) is the output of this thinking. The best reference on ARIZ remains Altshuller's seminal work 'Creativity As An Exact Science' (4). What follows here can only hope to be a gross over-simplification of what ARIZ is about.

The first thing to say about ARIZ is that although it was conceived as a reproducible procedure for solving engineering problems, it contains important features and principles which have since been demonstrably proven to work on a wide variety of problems from other disciplines.

ARIZ is again concerned with 'functions'. Altshuller had the idea that a function comprised three essential elements:-

1) a subject
2) an action
3) an object

In all functions, the subject acts on the object as shown in Figure 9.

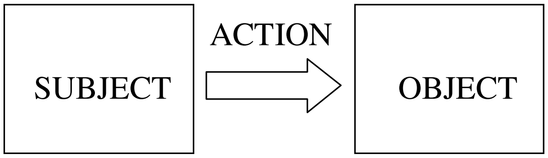

Figure 9: Generic Function Analysis Model

Examples of functions:-

SUBJECT	ACTION	OBJECT
train	moves	people
toothbrush	removes	plaque
pan	heats	water

Sometimes the action is a useful one, and sometimes it isn't. Sometimes it is useful but there may not be enough of it to suit our purposes, sometimes it can have both useful and harmful effects, and so on. Very simply, what Altshuller did was to classify all the different possible types of interaction and then – based on patents and other known solutions – determined a number of ways by which 'better' (i.e. eliminate harmful interactions, increase useful actions which are currently insufficient, etc) solutions might be achieved.

In all, he identified and classified 76 such 'Standard Solutions'. Each Standard Solution is conceptual and generic in nature. They include such things as:-

- 'Introduce a new substance'
- 'Introduce a modified substance'
- 'segment'
- 'co-ordinate rhythm'
- 'make something movable'

As with the Inventive Principles, Altshuller analysed the patent database and other known cases to establish which of the Standard Solutions was most likely to be applicable to a given type of problem.

An important point to note about function analysis is the ability to construct complex models containing multiple subject-action-object relationships. Probably the most effective way to demonstrate some of the ideas contained in ARIZ, however, is to look at a simple example:

Anyone who has parked their car outside on a frosty night will have experienced the frustration of not being able to get their key into an iced lock. A useful subject-action-object scenario to look at here is:-

ICE ➔ OBSTRUCTS ➔ KEY

This is a scenario in which the action 'obstructs' is a harmful one. The solution we require, therefore, should be one which eliminates the action. Candidate Standard Inventive solutions suggested by the method for this problem include:-

a) 'introduction of a new substance' (e.g. us of a non-harmful, ice-melting (WD40) or heat-releasing substance onto the key or introduce an escutcheon-like lock-cover).
b) 'make the ice flexible' – better interpreted in this case as the lock being flexible. A flexible entrance to the lock, for example, would make the (brittle) ice break off.
c) 'make the key flexible' – think perhaps of a smart-card type lock.
d) 'introduce a field' – e.g. induction heater in the lock turned on when key comes into contact with lock.
e) 'pulsating or resonating action' – compare with aircraft electro-impulse de-icing (similar to the flexible lock idea above)
f) 'compound or curved surface' – give the lock a big entrance that the ice will not block, but have the inside of the lock transition down to a small size such that the key need not be any bigger than normal.
g) 'eliminate the key' – why have a key at all? (e.g. some cars have a security alarm triggered by an IR signal from the key; why not use the same signal to also trigger the locking/unlocking of the doors?)

7.0 So Where Does TRIZ Fit Into The Overall Business Picture?

Ellen Domb was probably one of the first investigators to attempt to correlate the applicability of the various TRIZ tools to the different aspects of the business process (16). A modified version of Ellen's correlation matrix is presented here:-

	Contradictions	Technology Forecasting	Ideal Final Result	Scientific Effects	Function/Process Analysis	Use of Resources	Feature Transfer	Other TRIZ Tools
R&D	Y	Y	Y	Y	Y	Y	Y	Y
Design	Y	Y	Y	Y	Y	Y	Y	Y
Leadership	Y	Y	Y	Y	Y	Y	Y	Y
Strategic Planning	Y	Y	Y	Y	Y	Y	Y	Y
Customer Focus	Y	Y	Y	Y	Y	Y	Y	Y
Supplier Focus	Y	Y	Y	Y	Y	Y	Y	Y
Market Focus	Y	Y	Y	Y	Y	Y	Y	Y
Information Flow/Analysis	Y	Y	Y	Y	Y	Y	Y	Y
Human Resource Issues	Y	Y	Y	Y	Y	Y	Y	Y
Process Management	Y	Y	Y	Y	Y	Y	Y	Y
Product Management	Y	Y	Y	Y	Y	Y	Y	Y
Project Management	Y	Y	Y	Y	Y	Y	Y	Y

8.0 Conclusions

1) Deming's Four Prongs Of Quality emphasise the crucial importance of innovation to the achievement of 'quality'. Innovation – and particularly the 'creativity' related aspects of innovation – have traditionally been viewed as nebulous, intractable things. TRIZ offers the basis for systemising the innovation process for the first time. TRIZ equals '**systematic innovation**'.
2) TRIZ was conceived as a series of tools and methodologies to systemise the creative process for engineers. The tools have since been seen to be sufficiently generic to be applicable in some form or other to all product, process and service related issues, across all types of organisation, at all stages in and around the Deming PDSA cycle:-
    - leadership issues
    - strategic planning
    - customer/market focus
    - information flow
    - human resource issues
    - process management
3) TRIZ offers tools for breaking out of traditional 'trade-off' paradigms. Most situations contain Contradictions. The 40 Inventive Principles offer powerful ways of eliminating – as opposed to accommodating – such contradictions.
4) The Ideal Final Result concept is an excellent problem definition tool and a powerful means of guiding long term strategic vision. The approach is equally amenable to product, process and service cases.
5) TRIZ did not 'invent' any scientific effects, but it has seen development of the idea of classification of effects based on the **functions** they perform. Classification by functionality is again a powerful and broadly applicable concept.
6) Altshuller's ARIZ methods offer an even greater level of systemisation capability – albeit in a manner which is largely beyond the scope of the brief introduction possible in this paper.

9.0 References

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"If you can define a problem, it can be solved" (Edwin Land)

1. Weight of moving object	21. Power
2. Weight of stationary object	22. Waste of energy
3. Length of moving object	23. Waste of substance
4. Length of stationary object	24. Loss of information
5. Area of moving object	25. Waste of time
6. Area of stationary object	26. Amount of substance
7. Volume of moving object	27. Reliability
8. Volume of stationary object	28. Accuracy of measurement
9. Speed	29. Accuracy of manufacturing
10. Force	30. Object affected harmful effects
11. Tension, pressure	31. Object generated harmful effects
12. Shape	32. Manufacturability
13. Stability of object	33. Convenience of use
14. Strength	34. Repairability
15. Duration of action - moving object	35. Adaptability
16. Duration of action - stationary object	36. Complexity of device
17. Temperature	37. Complexity of control
18. Brightness	38. Level of automation
19. Use of energy by moving object	39. Productivity
20. Use of energy by stationary object	

Table 1: 39 Elements of the Contradiction Matrix

1. Segmentation	21. Skipping
2. Extraction	22. ‘Blessing in Disguise’
3. Local Quality	23. Feedback
4. Asymmetry	24. Intermediary
5. Combination	25. Self-Service
6. Universality	26. Copying
7. ‘Nested Doll’	27. Cheap/Short Living
8. Counterweight	28. Mechanics Substitution
9. Prior Counter-Action	29. Pneumatics and Hydraulics
10. Prior Action	30. Flexible Shells/Thin Films
11. Prior Cushioning	31. Porous Materials
12. Equi-potentiality	32. Colour Changes
13. ‘The Other Way Round’	33. Homogeneity
14. Spheroidality	34. Discarding and Recovering
15. Dynamics	35. Parameter Changes
16. Partial or Excessive Action	36. Phase Transitions
17. Another Dimension	37. Thermal Expansion
18. Mechanical Vibration	38. Strong Oxidants
19. Periodic Action	39. Inert Atmosphere
20. Continuity of Useful Action	40. Composite Materials

Table 2: 40 Inventive Principles