CHAPTER 4

MODEL DEVELOPMENT

4.1 INTRODUCTION

Analysis of a diverse suite of creative thinking techniques, invention heuristics and a number of scientific discoveries has suggested that they can be described collectively by ten, conceptually distinct, thinking strategies or *mechanisms*, i.e. ways in which the attributes of a problem can be manipulated in order to produce novel ideas. In inventive problem solving, these mechanisms are used in various combinations and applied to different types of problems.

The purpose of this chapter is to develop a suitable framework that incorporates these mechanisms and also highlights their use and relationships. In order to tailor this model to situations that characterise many typical engineering problems, this generic model will then be integrated with a simple physico-mechanical systems model.

4.2 GENERIC MODEL FOR INVENTIVE IDEATION

The ten mechanisms identified in Chapter 3 have been integrated into a generic model of inventive ideation (**Figure 4.1**). The circular format has been chosen as basis in order to reflect three key aspects of the mechanisms and the themes to which they belong, *viz*

(a) the frequency with which they occur in invention heuristics and the creativity literature,
(b) the types of problem to which they are applied predominantly, and, in conjunction,

(c) the metaphorical distance that they take the thinking from the problem.

4.2.1 Frequency

The clockwise arrangement of the mechanisms represents a decreased frequency with which they appear in the TRIZ Inventive Principles (IPs) and have been applied in the broad range of problems analysed for this thesis. Therefore, as a general rule of thumb, the model could be applied in a systematic manner by starting off the thinking with application of the Adjust mechanism and continuing in a clockwise direction.

4.2.2 Types of problem

Spatially, the model can be divided into an upper and a lower half. The three themes in the upper half, *viz* Change, Analogy and Convert, are used mostly to explore the temporal, physical and sensory-related attributes of objects, such as colour, action, function and size. The two themes in the lower half are used predominantly for spatially-based problems that involve objects and/or their parts, groups of objects or their environment.

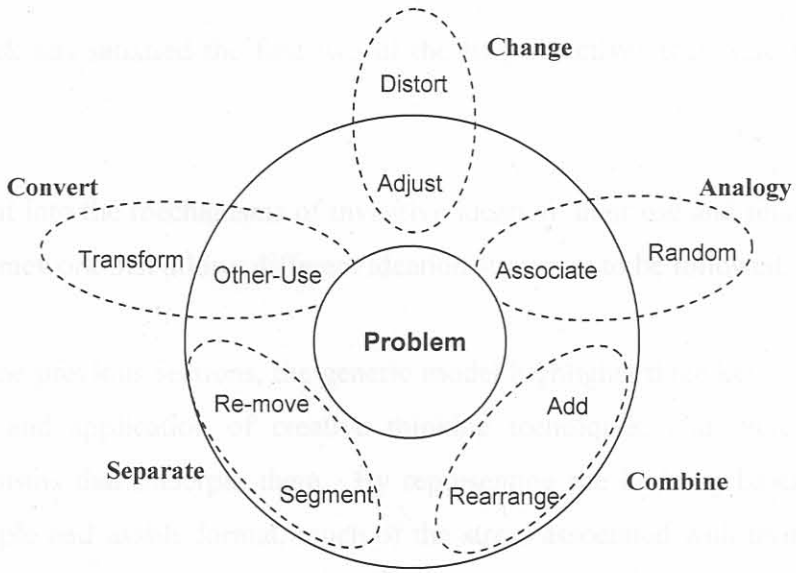

Figure 4.1 Generic model for inventive ideation.

4.2.3 Metaphorical distance

The distance from the centre of the model is representative of the metaphorical distance that the particular mechanism removes the thinking from the problem. For instance, the mechanisms positioned on the inside of the (outer) circle represent those that are associated more strongly with the so-called 'left brain' or 'engineering' approach to problem solving. These are typically mechanisms that require relatively minor amounts of flexibility and in which the value of the inventive manipulation can mostly be evaluated directly.

The three mechanisms outside the border are associated more strongly with the 'right brain' or potentially more novel type of problem solving. Contrary to the mechanisms on the inside, their purpose is not to lead directly to solutions that can be judged for value, but rather to create stepping stones and fresh perspectives that can guide the thinking in new directions. Once these new directions have been established, a substantial degree of mental flexibility and intuition is required to mould the thinking into new shapes and ideas.

4.2.4 Objectives

Thus far, the work has satisfied the first two of the five objectives that were spelled out in Chapter 2, *viz* to:

(1) provide insight into the mechanisms of inventive ideation, their use and relationships, and
(2) establish a framework that allows different ideation strategies to be followed.

As described in the previous sections, the generic model highlights three key aspects relating to the selection and application of creative thinking techniques, and therefore also the inventive mechanisms that underpin them. By representing the building blocks of creative thinking in a simple and usable format, much of the stress associated with trying to produce large quantities of new ideas is eliminated. As detailed in the following Section, positioning a graphic representation of the problem in the centre of the model would provide a detailed map,

and powerful tool, to systematically explore how the various mechanisms could be applied to the problem.

Furthermore, in establishing an explicit framework for inventive ideation, the model also enables the problem solver or group to select a suitable mechanism, or range of mechanisms, that best suit their skills, needs and the particular type of problem. For example, if the problem was centred on physical attributes, the thinking might focus first on the mechanisms in the top half of the model. By the same token, if the problem could be approached linearly (for instance, trying out options sequentially), the mechanisms inside the border might be favoured. This could be interspersed with provocations and other 'intuitive' mechanisms where relevant.

The following Section is aimed at addressing Objective 3 of the research, namely to expand the generic model into one that is tailored specifically to physico-mechanical problems. This would provide the inventor with Ideation Domains, a structured approach to target specific system attributes and explore the various ways in which they could be manipulated.

4.3 SYSTEMS MODEL

In order to tailor the generic model for application to typical physico-mechanical problems, i.e. those dealing predominantly with inanimate objects, their properties and functions, a simple systems model was developed. As such, the ideation model would be applicable not only to relevant engineering problems (typically those with a mechanical or physical basis) but also to a wider range of disciplines and industries. Since it incorporates the inventive principles of TRIZ, that have already found application also in non-engineering fields, it is reasonable to assume that the ideation model should be applicable to these fields as well.

The systems model has a number of components, definitions of which are presented in **Table 4.1**. These should be interpreted in conjunction with **Figure 4.2**. The term 'object' is used here in a wide sense to include tangible things (e.g. bicycle, bank, boat) as well as for instance substances.

Table 4.1 Key descriptors of systems model.

System	Object or group of objects within an Environment
Environment	The physical, temporal, spatial and other context(s) with which an Object is associated or in which it operates, including medium, actions and resources. The Environment may vary in extent depending on the problem.
Object	A technique, its subsystem or a single element. Normally a tangible entity providing functionality derived by integration of parts or elements.
Resource	Other objects or influences, e.g. fields, energy, waste, forces
Action	Activity, motion or operation with a certain order, speed, frequency, duration, associated with the 1) preparation, 2) operation and 3) maintenance and/or repair of the Object.

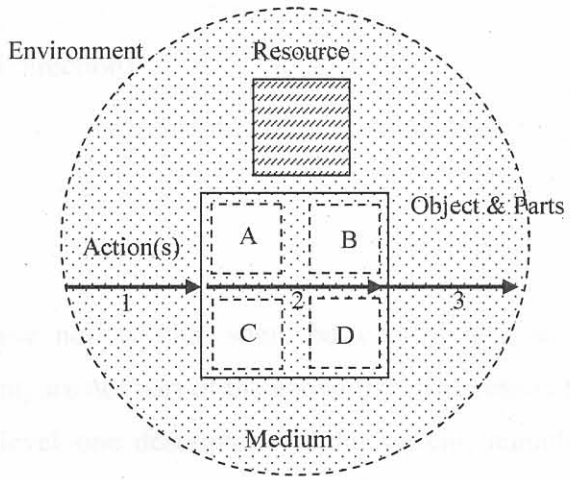

Figure 4.2 Systems model, showing object(s) and the elements of its environment.

4.3.1 Attributes

As mentioned in Section 3.4, analysis of the various creative thinking techniques and invention heuristics was accompanied by a study of the attributes to which the mechanisms were mostly being applied to. This was done in order to establish the descriptors that would adequately represent the systems model, as per the following list:

1. Object(s) (including their grouping and parts)
2. Environment (including resources and medium)
3. Function / use / usefulness
4. Quantity / magnitude
5. Material (substance)
6. Properties (physical and ambient)
7. Sensory attributes
8. Concentration
9. Curvilinearity
10. Orientation
11. Dimension
12. Symmetry
13. Actions (types and direction)
14. Order
15. Frequency
16. Duration / interval

The reader would have noticed that some basic attributes, such as shape, size (and its dimensions) and weight, are not part of the above list. The reason for this is that the attributes in the list represent level one descriptors of the system, namely, parameters that are not influenced, nor can be changed, by others at a lower level. These first-level attributes describe a range of 'meta-attributes' that include shape (which for instance could be a function of symmetry or the orientation of an object), size (which is influenced by things such as the constituent substance and its properties), and weight (which is a function of size and interaction with the environment, amongst others). By the same token, these meta-attributes describe a next level of 'meta-subjects', or broad topics, such as education, technology, transport, politics, and management.

4.4 IDEATION DOMAINS

The ideation model applicable to physico-mechanical problems, shown in **Figure 4.3**, was derived by integrating the systems model (Figure 4.2) with the generic model of inventive ideation (Figure 4.1). This was used to develop a detailed version of the ideation model, that highlights the variations that are possible within each mechanism-attribute pair. These mechanism-attribute pairs, forthwith referred to as ***Ideation Domains (IDs)***, are conceptually distinct entities that group inventive principles on the basis of the dominant inventive mechanisms and attributes that are involved. The development was done first in the form of 'first principles', i.e. each mechanism was mapped against the various attributes of the system model shown in Figure 4.2.

By way of illustration, the following two examples show how the Segment and Add mechanisms were mapped in order to establish the various ways in which they may be applied.

Segment

1. Divide an object into individual modules or parts (labeled A to D in Figure 4.2).
2. Segment an Object or process together with its Environment (e.g. so that each part can function in different, most suitable or optimised conditions).
3. Segment an Action, i.e. break a continuous action up into intermittent or periodic actions.
4. Segment Duration, e.g. instead of making something durable (and therefore, often expensive) to last for a long time, use a number of short-lived, cheap ones.

Add

1. Add together a number of (similar) objects.
2. Make a (moving) object interact with its medium (e.g. aeroplane wing).
3. Let the object interact with a resource, e.g. use a field in conjunction with field-activatable components.
4. Combine the object with others in its environment (e.g. that provide certain functions and can easily be integrated), or that are introduced from outside the environment.
5. Add an Object temporarily (e.g. to hold, carry or support something).

6. Introduce a new or different Action (e.g. to fill idle time, or to counter harmful actions).
7. Introduce an Action prior to the working environment (e.g. prepare an object for stresses or conditions it will encounter during operation.)
8. Add a Function (make something perform multiple functions, as well as any auxiliary functions).
9. Add a sensory attribute to complement or replace an existing one (e.g. sound, taste, visual).
10. Add backup (e.g. a parachute).
11. Add Action information (provide feedback or feedforward).

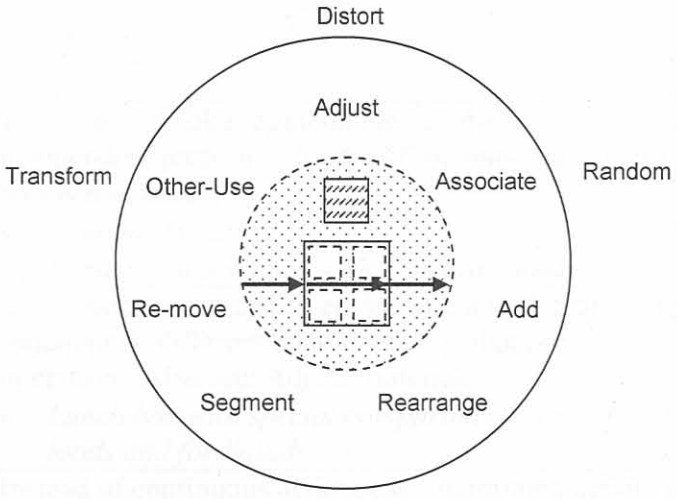

Figure 4.3 Model for inventive ideation, tailored to a physico-mechanical context.

Once the basic analysis has been done, the IPs were analysed at sub-principle level (e.g. sub-principles 10A and 10B were analysed individually rather than principle 10 being analysed as a whole) and used to populate the model.

The detailed ideation model, illustrated with examples from the creative thinking and TRIZ literature (De Bono 1993; Tate & Domb 1997) is shown in **Table 4.2**. In order to retain the conceptual identity of IDs as far as possible, several IPs have been decoupled or broken up, for example, IP17 (Another Dimension) was split between Adjust Orientation (Tilt or re-orientate

object) and Adjust Dimension (Instead of a line or plane, use a plane or 3-D space). In a number of cases, a IP could be categorised into more than one ID (the same was noted with the way in which the 40 IPs are configured). However, in this first version of the model it was decided against duplication and a principle was thus represented only in the ID with which it was deemed to have the biggest commonality. For purposes of cross-reference, **Appendix 2** provides a summary of the mechanisms involved in each IP.

Table 4.2 Detailed version of the ideation model in a physico-mechanical context, grouped according to IDs.

SEGMENT		**IP** [1)]
Object (& Environment)	1. Divide, or make segmentable, an object or system into independent parts or individual functions, e.g. for easy or quick removal or assembly. • *Modular furniture.* • *Replace solid shades with Venetian blinds.*	01ABC
	2. Segment object and/or environment such that each part functions in different conditions, e.g. that are most suitable for its operation. Also see: Adjust Material. • *Lunch box with special compartments for hot and cold solid foods and for liquids.*	03AB
Action	Instead of continuous action, use intermittent action, e.g. periodic or pulsating. • *Replace a continuous siren with a pulsed sound.*	19A
Duration	Replace something durable (long-lasting / expensive) with a number of short-lived (replaceable / inexpensive) ones. • *Plastic cups, disposable diapers, many kinds of medical supplies.*	27A

[1)] IP(s) that matches the particular ID most closely. In the interest of brevity, no separators are used, e.g. 03AB represents principles 03A and 03B.

REMOVE / MOVEMENT		IP
Object	1. Allow relative *movement* between objects or parts, e.g. to find the best operational position or condition. • *Adjustable steering wheel, seat, or side mirror.*	15AB
	2. Limit (need for) *movement* (distance or position changes), e.g. pre-arrange required objects close to action. • *Kanban arrangements in a Just-in-Time factory.*	12A 10B
	3. *Remove* object partly, or completely, from environment: Make aspects of the object visible or known before (or after) its application, i.e. preview or review. Isolate an object from the medium. • *Protect parts with thin films to prevent corrosion.*	None
	4. *Remove* in space: Separate or extract a useful / functional or interfering / undesired part(s) or property from the object or its environment. • *Locate a noisy compressor outside the building where compressed air is used.* • *Use fibre optics to separate the hot light source from the location where light is needed.*	02A
	5. *Remove* in time: Discard, disperse or dissolve things that have fulfilled their functions. • *Use a dissolving capsule for medicine.*	34A
Action	Remove an action from an object or its environment: Perform, before (or after) necessary or normal, a required change of the object. • *Pre-pasted wall paper.*	10A

ADJUST		IP
Action	1. Change the type and direction of motion, e.g. linear to rotary or swirl motion. • *Produce linear motion of the cursor on the computer screen using a mouse or a trackball.* • *Instead of wringing clothes to remove water, spin them.*	14C
	2. Invert the action or use opposite action, make traditionally fixed (especially large or heavy) parts, static fields or processes movable or adaptive, and vice versa. • *To loosen stuck parts, cool the inner part instead of heating the outer part.* • *Mobile banks (banking vans).*	13AB 15C 28C
Sensory attributes	1. If one sensory attribute is used for a function, change to, or complement by, another. Also see: Use Other • *Use smell instead of a warning light or sound to alert people to faulty equipment.*	None
	2. Change the colour / transparency of an object, parts or its environment. • *Use safe lights in a photographic darkroom.*	32AB
Material	1. Make objects interacting with a given object (environment) of the same material, or with identical properties (e.g. polarity). • *Make a container out of the same material as its contents, e.g. to reduce chemical reactions.*	33A
	2. Use composite or smart materials instead of uniform ones. • *Composite epoxy resin/carbon fibre golf club shafts are lighter, stronger, and more flexible than metal.*	40A
Properties & state	1. Use a gas, aerosol, liquid or gel instead of a solid, change the physical aggregate state. • *Comfortable shoe sole inserts filled with gel.* • *Transport oxygen or nitrogen or petroleum gas as a liquid, instead of a gas, to reduce volume.*	29A 35A
	2. Porosity: Make a solid object porous or use porous elements, use spume or foam as a combination of liquid and gas properties. • *Drill holes in a structure to reduce the weight.*	31A 29D
	3. Change the degree of flexibility. • *Use adjustable dampers to reduce the noise of parts falling into a container by restricting the motion of the walls of the container.*	35C
	4. Ambient: Change the temperature, pressure, humidity etc. • *Lower the temperature of medical specimens to preserve them for later analysis.*	35D, 29C

Curvilinearity	Change from rectilinear to curvilinear parts, surfaces and forms, use rollers, balls, cones, spirals and domes. • *Ball point and roller point pens for smooth ink distribution.* • *Use arches and domes for strength in architecture.*	14AB
Symmetry	Change the shape or properties of an object, grouping or process from symmetrical to asymmetrical ('break symmetry'). If already asymmetrical, increase the degree of asymmetry. • *Asymmetrical mixing vessels or asymmetrical vanes in symmetrical vessels improve mixing.* • *Put a flat spot on a cylindrical shaft to attach a knob securely.*	04AB
Orientation	Tilt, rotate or re-orientate object, part or process, turn it upside down. • *Empty grain from containers (ship or railroad) by inverting them.* • *Measure the height of something by turning it on its side.*	17C, 13C
Dimension	Instead of a line or plane, use a plane or space. Use a multi-storey / layer assembly instead of single, use another side of a given area. • *Two-dimensional barcodes.* • *Use thin films or flexible shells instead of 3-dimensional structures.*	17ABD 30AB
Concentration	1. Change the concentration, composition or consistency, e.g. increase the degree of inertness, enrichment or purity. • *Treat wounds in a high pressure oxygen environment to kill anaerobic bacteria and aid healing.* • *Prevent degradation of a hot metal filament by using an argon atmosphere.*	35B, 38AB 39AB
	2. Merge or group identical or similar objects, essential resources, elements or actions in a key place and / or time. Conversely, if concentrated things cause undesirable effects, disseminate or disperse them, reduce their concentration. • *Vanes in a ventilation system.* • *Computers in a network.*	05A
	3. Place objects within each other, make one pass through a cavity in the other. Store a substance in the pores or capillaries of another. • *Measuring cups or spoons, Russian ('matroishka') dolls.* • *Store hydrogen in the pores of a palladium sponge.*	07AB 31B
Quantity / magnitude	1. Space or substance: Use slightly less or more of the same method, space or substance, if 100% is hard to achieve. • *Allow slightly more room to guide an object into a tight space, e.g. key into keyhole.*	16A
	2. Load: Make all parts perform at full load all the time. • *Flywheel (or hydraulic system) stores energy when a vehicle stops, so the motor can keep running at optimum power.*	20A

	3. Harmful effect: Amplify a harmful factor to such an extent that it is no longer harmful. • *Use a backfire to eliminate the fuel from a forest fire.*	22C
	4. Feedback: Change the magnitude, speed or influence of feedback. • *Change sensitivity of an autopilot when within 5 miles of an airport.*	23B
Frequency	1. Oscillate or vibrate object; if oscillation already exists, change the frequency. Use piezoelectric vibrators instead of mechanical ones. • *Electric carving knife with vibrating blades.* • *Distribute powder by vibration.*	18ABD
	2. If an action is already periodic, change its amplitude or frequency. • *Replace a continuous siren with sound that changes amplitude and frequency.*	19B
Order	Make objects or operations parallel, bring them together in time, perform things in a different sequence. • *Mulching lawnmower.*	05B
Duration	Conduct a process (e.g. hazardous or harmful) or stages at high speed. • *Cut plastic faster than heat can propagate in the material, to avoid deforming the shape.*	21A

DISTORT [2]		IP
Object (Parts)	Remove key objects or parts from the system. • *What if restaurants didn't serve food ? Or bookshops didn't stock books ?*	None
Orientation	Change the orientation of the object or key parts. • *Suppose planes landed upside down.*	None
Symmetry	Break the symmetry. • *The provocation 'Wheels are square' leads to the idea of having wheels that can adapt automatically to the topography of the terrain.*	None
Action	Remove, reverse or exaggerate key actions in normal system. • *You brush your teeth before you eat.*	None
Frequency	Increase or decrease the frequency or amplitude of actions. • *Students are examined every minute.*	None
Duration	Decrease or increase the normal duration of actions. • *A phone call always lasts only 2 seconds.*	None

[2] Whilst the Distort mechanism is, predominantly, a more 'extreme' version of Adjust, it is also related to Remove and, less often, Segment. Unlike Adjust, it is intended to provoke the thinking rather than to produce possible solutions directly. Whilst many of the IDs using Adjust may be useful for provocation, the attributes listed here normally yield particularly strong provocations.

ASSOCIATE		IP
Relevant system attributes	For example, Action: Utilise relationships between Action and other system attributes in things in the same or other environments. • *Cameras and guns are both aimed at targets - what features of the other can each use?*	None

RANDOM STIMULATION		IP
Relevant system attributes	Generate a remote analogy and force analogies and new ideas. • *What features of an aeroplane can be used to design a better stapling machine ?*	None

REARRANGE		**IP**
Object (Parts)	Re-arrange / re-position parts or concepts (physical or virtual) and their features to achieve new ideas or added functionality. • *Re-arranging 'fragments' of a TV screen gives the idea of multiple channels that can be watched simultaneously.* • *Re-arranging parts of the tail fin on an aeroplane gives the idea of drag reducers (small fins) on the tips of the wings.* • *Repositioning the eye at the tip rather than the top led Elias Howe to invent the sewing machine needle.*	None

ADD		**IP**
Function	1. Make an object or parts perform multiple functions, e.g.: Within same environment: • *Combine plate glass with burglar proofing to form safety glass.* Things that share features or attributes: • *Combining a stamp and a billboard gives the idea of putting ads on stamps or envelopes.*	03C 06A
	2. Make an object serve or organize itself by performing auxiliary helpful functions, supplementary and repair operations. • *A soda fountain pump that runs on the pressure of the carbon dioxide that is used to "fizz" the drinks. This assures that drinks will not be flat, and eliminates the need for sensors.* • *Halogen lamps regenerate the filament during use - evaporated material is redeposited.*	25AB
Object	1. Add together, use sequentially, or simultaneously, a group of uniform objects or principles instead of a single one. • *Multicylinder combustion engine.* • *Magnify the principle of a ski, thus allowing it to lift out of the water.* • *Combine a number of TV screens to form a giant screen.*	None
	2. Restore or repair (consumable) parts while in operation, or use easily replaceable parts. • *Self-sharpening lawn mower blades.*	34B

	3. Use an intermediary (temporary) carrier article or process, merge one object temporarily with another which can easily be removed, e.g. temporary insert parts or cushioning components. • *Carpenter's nailset, used between the hammer and the nail.* • *Pot holder to carry hot dishes to the table.*	24AB D
	4. When needing to merge incompatible materials or things (wrt properties, shape etc), introduce something compatible with both in between. • *Welding copper and aluminium.*	None
Action	1. External to environment: Subject something to the same action or conditions it will be experiencing during operation. Provide emergency means (backup) to compensate for the low reliability of an object. • *Pre-stress rebar before pouring concrete.* • *Back-up parachute.*	09B 11A
	2. Internal to environment: Eliminate idle time or intermittent actions, use pauses between actions to perform similar or different actions. • *Print during the return of a printer carriage, e.g. dot matrix, daisy wheel, inkjet printers.*	20B
	3. If physical actions take place close to another (either in space or time), introduce a different one inbetween. • *Computer mouse with roller wheel and clicking next to it.* • *Use different fingers to play the same key on a piano quickly after another.*	None
	4. If an action has both harmful and useful effects, add anti-actions to control harmful effects. Eliminate a harmful action by adding another harmful action. • *Buffer a solution to prevent harm from extremes of pH.* • *Add a buffering material to a corrosive solution.*	09A 22B
	5. Introduce feedback / feed forward to improve a process or action. • *Signal from gyrocompass is used to control simple aircraft autopilots.*	23A
Environment	1. Medium: Make object interact with its environment. • *Use buoyancy or Archimedes forces.* • *Hydrofoil, aeroplane wing.*	29B
	2. Resources: Merge object with others in its environment, e.g. to reduce weight. • *Use a helium balloon to support advertising signs.* • *A lift using counterweights.*	08AB

	3. Resources: Use fields (electric, magnetic, etc.) to interact with object, in conjunction with field-activated, e.g. ferromagnetic, particles. • *Heat a substance containing ferromagnetic material by using a varying magnetic field.*	28BD
Sensory attributes	Add coloured or luminescent tracers for things that are difficult to see. • *In murky liquids, add luminescent tracers.*	32C

OTHER USE / USE / USE OTHER		**IP**
Properties	**Use.** Exploit available or natural phenomena to good effect. E.g. exploit resonant frequency, those that occur during phase transitions, thermal expansion or contraction, heat capacity, thermal conductivity, sources of energy, etc. • *Heat pumps use the heat of vaporisation and heat of condensation of a closed thermodynamic cycle to do useful work.* • *Destroy kidney stones using ultrasonic resonance.*	36A 37AB 18C
Environment	**Other Use.** Resources: Use waste, useless or readily available resources to achieve a positive or desired effect or function. • *Dump old tyres in the ocean to form artificial reefs.* • *Use hot milk rather than steam to melt out-of-spec butter patties.* • *Use a screwdriver to open a tin of paint.*	22A 25C
Object	**Use Other.** Use an Other format or version of something. E.g. replace mechanical or physical means by sensory (optical, acoustic, taste or olfactory) means, replace an (unavailable, expensive or fragile) object or process with copies (optical, UV or IR). • *Use a bad smelling compound in natural gas to alert users to leakage, instead of a mechanical or electrical sensor.* • *Listen to an audio tape instead of attending a seminar.*	28A 26ABC

TRANSFORM		IP
Spatial - Temporal	For a spatial arrangement, find something with a similar structure in the temporal domain, or vice versa. • *The bricks in a wall are similar to the ticking of a clock, both occurring with regular frequency.*	None
Object	Convert something into a sensory attribute. • *What colour is the company ? What does it taste like ?*	None
Sensory	Allocate the properties of one sensory attribute to another. • *What does the colour smell like ?*	None

4.4.1 Objectives

With the definition of Ideation Domains, the third objective of the research is met. The inventor or problem solver is now provided with a structured way of targeting specific system attributes and to explore the various ways in which they could be manipulated by means of relevant mechanisms. As will be described in more detail in Chapter 5, this platform was also used to develop a simplified version of the TRIZ Contradiction Matrix (CM) (Ross 2006a,d). Further work (Ross 2006b) included the development of a unique graphic icon for each ID, which would enhance the teaching and application of the method.

4.4.2 Advantages

Four key advantages offered by Ideation Domains are the following:

Complementary functions

The cells without an IP (i.e. marked 'None') indicate IDs where the CM can potentially be complemented by the relevant mechanisms or the creative thinking techniques that use them. As pointed out in Chapter 2, this was one of the key motivators for integrating the two approaches. Whilst it should be noted that not all the mechanisms are applicable to all the system attributes, it is evident that application of the Distort, Association and Random

stimulation, Rearrangement and Transform mechanisms in particular could be useful to complement the 'linear' nature of the heuristics.

Access similar IPs

Since an ID describes the variations that are possible within any specific mechanism-attribute pair, it provides access to a range of IPs that could effect the same, or similar, inventive outcomes. This would alert the problem solver / inventor using a particular inventive principle to others that could be used in the same context.

For example, considering the ID of Removing Object: In addition to using IP10B (Pre-arrange objects in the most convenient place so they don't lose time for delivery) the inventor may consider other related principles, *viz* IPs 12A (Limit the need for movement), 15AB (Allow relative movement between objects or parts), 02A (Remove in space) and 34A (Remove in time), or Remove an object partly or completely from its environment (which is not an explicit IP, but embedded in both 02A and 34A).

Target specific attributes

A third advantage is the fact that the IDs highlight the different ways in which an attribute could be manipulated by means of the relevant mechanisms. This enables an inventor to focus on a particular aspect of the problem and gain direct access to all the options around it.

For example, if inventive options were sought to change or use the Environment of the object in some way, the following IDs may be investigated:

- Segment Object and/or Environment such that each part functions in different conditions, e.g. most suitable for its operation,
- Add Environment (Make object interact with the medium, merge object with others in its environment, use fields to interact with object, in conjunction with field-activated, e.g. ferromagnetic, particles),
- Other Use for Environment (Use waste, useless or readily available resources, energy or substance to achieve a positive or desired effect or function).

Target specific mechanisms

Fourthly, the model also points out the ways in which a mechanism can be applied to different attributes. This provides potentially useful analogies to an inventor using a specific IP.

For example, if IP19A (Segment Action) was used to improve the visibility of an object (such as for instance by means of a flashing light), the inventor might also consider IP01 (Segment Object) as a possible analogous source of ideas. In this case, the object could for instance be broken up into smaller modules that could be spread in such a way as to provide advance visibility (e.g. the warning lights leading up to an obstacle in the road).

4.5 VERIFICATION

4.5.1 Other models

Since it has been derived from an analysis of creative thinking techniques and invention heuristics, as well as some historical events, it is problematic to verify the ideation model. None of these could be used as benchmark as that would mean that the model is essentially verified against itself. However, some measure of its ability to describe inventive ideation in a context where objects and their properties are the focus is to compare it with other models of similar complexity and application. One such model that comes to mind is ASIT (Horowitz & Maimon 1997), described in Section 1.4.5, consisting of the following five tools:

1. Unification. Assign a new use to an existing component.
2. Multiplication. Introduce a slightly modified copy of an existing object or part into the system.
3. Division. Divide an object and re-organise its parts.
4. Break Symmetry. Turn a symmetrical situation into an asymmetrical one.
5. Object Removal. (i) Remove a component from the system. (ii) Assign its function to another object existing in the close environment.

Using the 10 generic mechanisms as basis, the ASIT tools can be represented as follows:

Table 4.3 Analysis of ASIT tools in terms of generic mechanisms.

ASIT tool	Description per IDs
Unification	Other Use / Add Function
Multiplication	Adjust (parameter as per modification) and Add
Division	(Segment) and Re-arrange Object
Break Symmetry	Adjust Symmetry
Object Removal	(i) Remove Object (ii) Use Other

Even if the level of detail that is supplied in Table 4.2 was ignored, it is apparent that the ASIT tools are by comparison limited and insufficient to capture the extent and nature of the ideation model. Being a simplified (and reduced) version of the IPs, it also contains none of the intuitive mechanisms. In addition, it fails to recognise the scope of mechanisms described by the ideation model; for instance it does not describe Use Properties or Add Object.

4.5.2 Other examples

The model was also verified empirically by establishing its ability to produce ideas that were created by other creative thinking techniques, most notably Random stimulation. In this regard, the reader is referred to the examples presented in Chapter 5.

4.6 RANDOM STIMULATION

One of the objectives of this thesis is to provide more insight into the situations in which Random stimulation would offer the type of ideas that are claimed in the literature as not possible by 'any sort of logical design'. Despite some interesting examples in the literature to illustrate the application and benefit of the technique, the perception remains that, in general, they may not be representative of its usefulness (the reader is referred to Section 2.2.5 for further detail in this regard). The question arises whether there are situations in which a structured, systematic approach could lead to the same ideas more directly, and under which circumstances random stimulation would offer opportunities that other techniques could not.

In order to better understand the types of problem and conditions under which this would apply, a basic analysis of the technique was conducted.

4.6.1 Analogies

Random stimulation is one of several creative thinking techniques that use analogies as sources of new ideas. These analogies are generated in two basic ways, *viz* directly or randomly (Ross 2006e).

Direct analogy. In direct association, one or more attributes (features) of the problem serve as fixed points, or *beacons*, to identify other things that share the particular feature. This process normally starts by identifying concepts that have a strong and direct commonality with the problem, and progressively the search is moved on to concepts that are more generic or in which the relationship with the problem may be less distinct. As shown in **Figure 4.4**, direct association can thus be represented as a concept 'fan' in which, the further away from the problem, the wider the fan and the less direct the associations become. The symbols within the problem represent the conceptual structure of different parts of the problem, e.g. key features or functional relationships.

For instance, a problem that involves opposite actions such as 'starting and stopping' (such as for example in a timer switch) might have closely associated concepts such as 'on and off' or 'begin and end'. Moving further away there may be more generic concepts such as 'birth and death', 'ebb and flow', 'low and high' or 'day and night'. Each of these in turn is associated with a variety of others. The resultant concepts are then inspected for distinguishing features or relationships that could be useful to solve the problem or provide fresh perspectives.

Random analogy. A random concept is one which has no obvious or logical relation to any part of the problem. Rather than a step-wise progression in a known direction, the random concept is generated with the purpose of putting a gap, which at first would (and needs to) seem unbridgeable, between it and the problem. Exactly how big this gap needs to be and how it is determined are however not always clear.

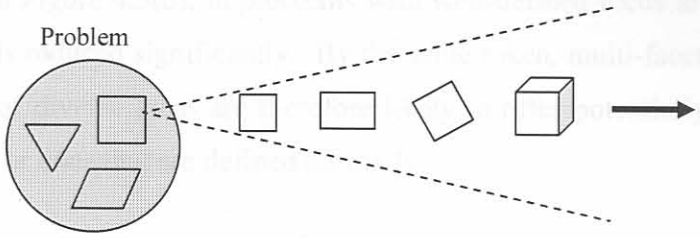

Figure 4.4. The 'fan' of direct association.

Connections are subsequently sought between the new concept and the problem. In some cases, there would be a strong and clear overlap with the problem, and the chosen feature would thus have an obvious or direct use. In others, there would be only a weak or even no real connection, in which event the thinker needs to force one through, for instance, further exploration and/or manipulation of the random concept.

4.6.2 Success of technique

The success of random stimulation can be expressed in terms of the extent to which the random concept maps, or can be forced to map, onto the problem. As shown schematically in **Figure 4.5**, this is influenced by three main elements, namely (a) the type and scope of the problem, (b) the extent (size) of the random concept and (c) the remoteness of the random concept. Again, the symbols inside the problem (circle) and the random concept (ellips) represent the conceptual structures of each.

Type and scope of problem

Open-ended problems present a comparatively large number of potential mappings as in such a case the emphasis is on the quantity and diversity of ideas that are generated. Any connection of the random concept with the problem, no matter what type of idea results, is sought. As suggested in Figure 4.5(a), the random concept can be manipulated in different ways to effect such mapping – for instance, by 'rotating' it the diamond can be made to map onto the square, or the top part of the pentagon could be forced to map onto the triangle.

However, as shown in Figure 4.5(b), in problems with well-defined focus areas the scope for successful mappings is reduced significantly. By the same token, multi-faceted problems that cover a broad range of diverse areas are therefore likely to offer potentially more mappings than simple problems or ones that are defined narrowly.

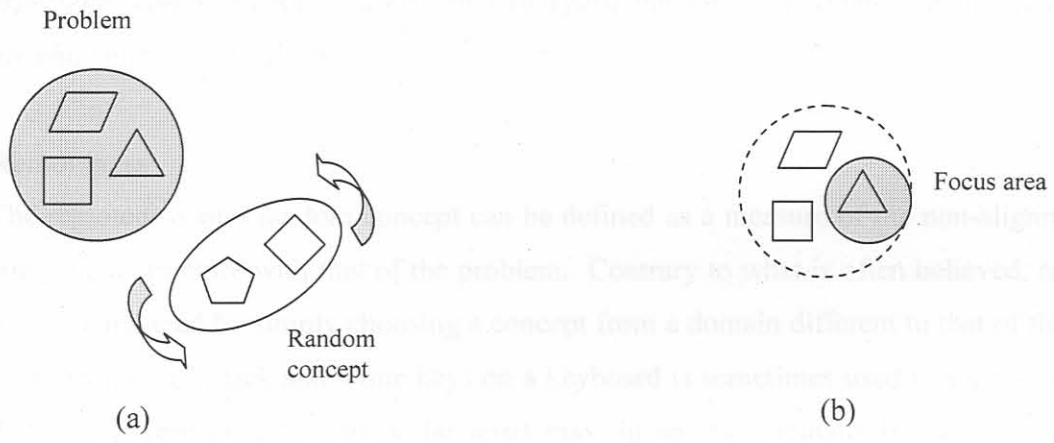

Figure 4.5. Schematic representation of a problem and a random concept. (a) Open-ended problem, (b) defined problem with specific focus area.

Extent of random concept

The greater the extent or conceptual 'reach' of the random concept, the bigger the probability that some part of it would map, or could be made to map, onto the problem. Whilst concepts normally have only a limited number of key elements that are central to the main theme, each of these are linked to a host of secondary ones. It is therefore unlikely that no connection whatsoever can be made between a problem and any given concept, however remote it may be, if the search for instance also included secondary elements. De Bono (1993 : 177) for example states that '*it has never happened to me that the random word is too remote...what happens quite often is that the random word is so closely connected to the focus* (i.e. the problem) *that there is little provocative effect.*'

However, systematically exploring the resultant 'cloud' of random concepts becomes laborious and difficult to manage and thus may prove detrimental to a focused thinking process rather

than aiding it. Importantly, it can also affect the motivation of the thinker adversely if useful ideas are not forthcoming, and it is widely accepted that under such circumstances it is better to rather start with a new random concept. Also, these far-flung searches are unlikely to provide deep insights or illuminate new directions of thought - as Hofstadter (1982) observes: '*The most reliable kinds of genuine insight comes from strong analogies in which one experience can be mapped onto another in a pleasing way. The tighter the fit, the deeper the insight, generally speaking.*'

Remoteness

The remoteness of a random concept can be defined as a measure of the non-alignment of its conceptual structure with that of the problem. Contrary to what is often believed, remoteness is not guaranteed by simply choosing a concept from a domain different to that of the problem – the analogy of black and white keys on a keyboard is sometimes used to suggest that things that in one respect appear to be far apart may, in another, actually be very close. In the technique of word association (Nolan 1987) for instance, three successive steps are normally considered sufficient to generate a concept which structure and features are not traceable to that of the problem.

Finding a strong connection between the random concept and the problem becomes increasingly difficult the less their conceptual templates have in common. Even though the mental flexibility and creative experience of the thinker can effectively reduce remoteness by forcing more mappings and perhaps better identify areas of potential benefit, the ideas resulting from this would tend to be weak or not specific to the problem.

4.6.3 Application

To summarise, the above observations suggest that, in situations where key attributes or features of the problem are readily apparent, e.g. such as in simple, well-defined problems, direct association should be more efficient and easier to use than random stimulation. The advantage of the 'fan' in such a situation is the fact that a range of concepts that already share a specific feature(s) with the problem are generated directly, thus increasing the probability of

useful relationships being identified. The level of skill and the effort to do this are also low in comparison to that of random stimulation, where various features of the random concept often need to be considered from a number of different angles.

In situations where harmful factors or undesired effects need to be overcome, the creative thinking mechanism of reversal could be applied first to create a (positive) beacon(s) for subsequent association. Other mechanisms could also be used in conjunction with association. A simple invention heuristic often used in physical problems is for instance to introduce a sensory attribute (e.g. smell, sound and taste) in situations in which it was not prevalent.

Random stimulation is potentially more useful for fuzzy problems or ones that are broadly defined and involve a wide and diverse array of interrelated issues, e.g. reducing unemployment, increasing levels of education, or reducing crime. Under these circumstances, direct association may be ineffective since it may be difficult to identify the beacons (key concepts and their attributes, as well as the links between them) distinctly. However, it should be noted that each random stimulation will typically address only a particular aspect of a problem, and as such a large number of these may be necessary in more complex situations to address the full scope of a problem. The technique may also be applied in cases where the strategy is to deliberately produce far-out solutions that can later on be trimmed down or made more practical (Souder & Ziegler 1977).

4.7 FLOW TECHNIQUES

Once a new concept has been created by the application of one or more inventive mechanisms, different routes are followed to bring it to a new idea. In the case of linear techniques such as Attribute Listing, where the thinking is done within the problem space, this is normally a simple case of evaluating the alternative option for its direct value. If no such benefit is obvious, the thinking moves on to produce another alternative. For example, if a triangular picture frame does not appear to offer direct value, the next step would be to assess whether a hexagonal one would, and so on.

In contrast to the linear techniques, the non-linear ('intuitive') techniques rely largely on the principle that stepping stones (also called springboards, intermediate impossibles or random juxtapositions) are created which allows the thinking to follow new directions. For instance, as was shown in Section 3.1.1 for Group C techniques, the techniques of Movement (De Bono 1993) are advocated to be used in conjunction with deliberate provocations.

In the course of this work, a number of additional techniques have been identified which are useful to build on initial concepts and thus create new ideas. Reflecting the role of 'freewheeling' in brainstorming, a flexible and fluid way of building on basic concepts, they have been named Flow techniques. They are loosely based on the premise that if one mechanism was used to create a stepping stone, applying the same mechanism again is likely to lead to an idea. By way of brief illustration, the Flow techniques as follows:

4.7.1 Adjust other

The Adjust mechanism is often useful to generate ideas after Distortion was used to create a provocation, by tweaking other attributes of the problem to normalise the situation as far as possible.

For example, the provocation '*Wheels are square*' may point the thinker to other attributes of a wheel that can be adjusted to minimise the bumpy ride. One idea would be to make very soft tyres, or for instance tyres that can adjust to the topography of the terrain.

4.7.2 Add

Similar to Adjust, the Add mechanism is often useful in conjunction with Distortion. A new thing or function is introduced to a situation that was deliberately distorted, in order to restore the original function as far as possible. For example, if wheels were square, adding something (in this example, a self-adjusting suspension) would smooth the bumpy ride.

4.7.3 Associate

As a Flow mechanism, Association is useful in conjunction with itself, or either the Adjust or Add mechanisms.

An advertising company needs new ideas. One medium to consider would be sound, e.g. Associate television. One person talks while others listen and watch; this is interrupted by adverts, which subsidises the subscription.

Considering a different situation where one person talks and others listen, direct Association leads to concepts such as a telephone conversation, a public speech, a church sermon and so on. Selecting the first option leads to the idea of having adverts on the telephone line, subsidising the call.

4.7.4 Transform

If the Transform mechanism was used to develop new insights through changing the domain or level of the problem, applying the same principle again returns the thinking to the original domain or level of the problem.

New ideas are needed for improved bricklaying. The bricks in a wall are similar to the homing of a pigeon, both occurring with regular frequency. The homing of the pigeon suggests something that always knows its correct place, no matter from which direction it approaches. Transforming this concept back to the problem gives the idea of putting some kind of pattern or protrusions on the bricks which would always allow them to be aligned easily and in the same manner.