MPHIL

Improving innovation using TRIZ

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IMPROVING INNOVATION USING TRIZ

VOLUME 1 OF 1

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Abstract

This Thesis describes the result of the need for an automotive engineering company to evaluate the effect of the implementation of the TRIZ method within the engineering related departments of the business. The purpose of the research was to gain an understanding of the hypothesis that TRIZ is a more effective innovation tool than traditionally applied innovation methodologies within the automotive industry.

The objective was to derive, plan and deliver a TRIZ training programme, and to understand the effect of this intervention on the business through the action research methodology. The nature and process of innovation at the company was expected to be defined and measured in support of this objective.

A review of literature failed to reveal an acceptable definition of innovation as a process. This led the author to investigate the nature of innovation by using the IDEF0 modelling tool. This helped to develop deeper understanding of innovation, and a measurement system to evaluate the innovativeness of the patent history of the company. Implementation of TRIZ enabled the researcher to develop best practice in teaching and using TRIZ in an industrial setting. Feedback from 17 workshop participants was that TRIZ tools were on balance easier to learn and understand than the commonly used methodology FMEA, and useful in their daily work. This view is supported through the ability of several workshop participants to solve a seemingly intractable problem that had thwarted several attempts at solution using the companies incumbent tools and approaches to problem solving and creativity.

Insights gained into the nature and definition of innovation within this Thesis were surprising, and merit further study. TRIZ, in combination with other creativity enhancing methods is recommended as a powerful tool to increase the innovation power of automotive companies, and potentially more widely.

Acknowledgements

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Also, the author would like to thank the management of Avon Automotive / DTR VMS and colleagues who participated in the workshops with effort and professionalism. .

Finally, thanks to my wife Elizabeth, and daughters Lucy and Amy for giving me space, time and understanding.

1 *Introduction to the company setting*

At the time of the research on which this thesis is based, Avon Vibration Management Systems (VMS) with a turnover of £32M was part of the automotive division of Avon Rubber PLC with total turnover of £750M. It has subsequently been acquired by DTR, a privately owned automotive component manufacturer based in Korea. Throughout this thesis, the company is referred to as Avon VMS, as this was the case at the time of the main activity of the research. The company designs, develops and manufacturers a wide range of engine and chassis mounting systems which are supplied to many major global automotive Original Equipment Manufactures (OEM's). Avon VMS is widely recognised within the industry as being a leading innovator in the field. It was amongst the first to manufacture hydraulically damped engine mounts, and in the 1980's developed a technology called the "air spring diaphragm". This patented technology allowed the company to offer the first electronically switched, twin state engine and gearbox mounts (see Figure 1).

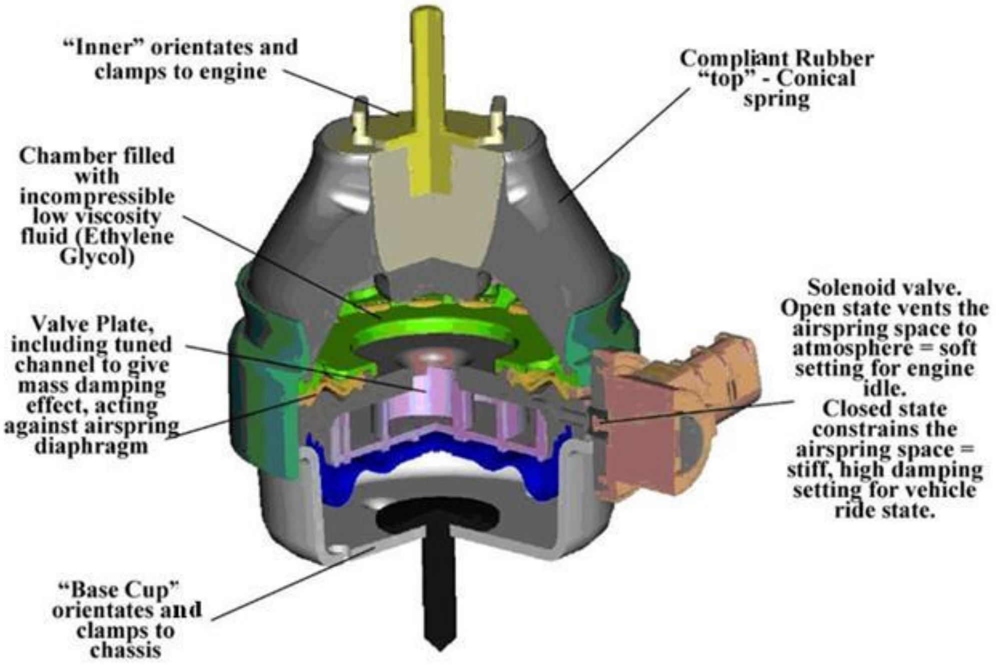


Figure 1. Quarter section view of a typical Avon 2 state switching engine mount.

This enabled an engine mount to be very soft and compliant for engines with unrefined idling characteristics, but immediately to switch to a stiff setting when driving. Prior to this, the necessary compromise between these opposite states meant unsatisfactory vibration within the cabin at idle and insufficient damping of engine movement during driving.

The most recent major development success (2003) has been the worlds first production application of a closed loop active engine mount, launched on the diesel version of the Jaguar XJ saloon. Vibrations from the engine up to 300 Hz are effectively cancelled, resulting in an exceptionally smooth idle, combined with well controlled damping for ride and handling characteristics.

2 Project

This section describes the reasons for the research and explains the key research questions. It also outlines the overall plan of action and approach taken.

2.1 Statement of need

2.1.1 Market conditions and trends

Pricing pressures in the automotive component supply industry are intense. OEM's have encouraged the development of supply capacity in low cost economies particularly in the Far East. This continues to cause difficulties for many Western European component suppliers who find it extremely difficult to compete on price.

In the mid to late 1990's automotive OEM's put in place strict purchasing procedures that grouped component families into commodity groups. Within these groups, several suppliers were encouraged to become technically capable of high quality supply according to strict guidelines. This created an open market between suppliers where the only differentiator would be price. Previously, suppliers were often able to protect their pricing by differentiating on performance or manufacturing quality. This new approach tended to reduce these opportunities. For the successful companies, the reward was a closer relationship with the OEM's, and higher volumes of business. These larger revenues allowed Tier One (T1) suppliers to set up technology R+D centres with which to develop advanced technologies, and participate in vehicle development programmes at the earliest stages – typically 3 years before vehicle launch. This enabled the OEM's to delegate development work at the component level to the T1's and concentrate on improvements to vehicle and system level technologies.

This strategy enabled the OEM's to demand ever cheaper prices for low technology and long running existing components whilst also receiving high levels of technical support for improvements at the component level. During this time of rationalisation, many smaller independent component manufacturers were either bought out by the T1's, or went out of business.

The reason for the survival of Avon as a small player was its ability to develop patent protected solutions to technically challenging problems. The company also had the capability to create advanced, highly automated manufacturing processes that offset some of the disadvantages of operating in a relatively high cost economic environment. For instance, the traditional method for filling hydraulic engine mounts with hydraulic fluid was to submerge the product during assembly. Avon developed the "dry-fill" method which enabled the process to be largely automated, and become significantly more cost effective.

The majority of the business with the Audi / VW group was won because of the inherent ability of the Avon engine mounts to deliver the dynamic characteristics required for the "North / South", front wheel drive layout of most Audi vehicles and engine derivatives. Competitor solutions tended to be inferior to Avon technology in this regard, allowing the Audi Engineering community to justify a small price premium in return for a more refined and therefore more competitive product in the marketplace.

In the suspension mounting bush sector, Avon developed the "Durabush" – a hydraulically damped suspension bush that outlasted competitor products in durability testing by over three times, whilst also delivering superior damping performance. This allowed Avon to win significant business, with the Ford Mondeo being the first high volume application of this technology.

However, over time, competitor products would be expected to improve technically. And with already substantially higher manufacturing volumes, these competitors would also be able to offer lower price points – threatening the long term viability of Avon as an independent player in the market. Further to this, these large T1 suppliers were also developing manufacturing capacity and strategic partnerships in the Far East, putting further downward pressure on pricing.

It was these threats that required Avon VMS to continue developing compelling product innovations, to reduce costs in existing products, and achieve both of these objectives with minimum investment in time, tooling and resources. It is against this background that the research project was conducted.

2.1.2 Research aims and objectives

The following is a broad statement describing the overall aim of the research :

"To gain greater understanding of the usefulness and effectiveness of TRIZ (Altshuller, 1984) at Avon VMS"

The research objectives of the project were to :

1. *Propose and plan an acceptable way to introduce TRIZ at Avon.*
2. *Measure the effect of TRIZ implementation upon the company's innovation and problem solving capability.*
3. *Record the lessons learned to form a useful case study, and add to the body of knowledge of the industrial use of TRIZ.*

2.1.3 Research questions

1. *What is the best way to introduce TRIZ in an automotive engineering supplier?*
2. *How does the TRIZ method impact upon innovation?*
3. *How does TRIZ compare to existing tools widely used within the automotive industry?*

2.1.4 Limitations

This research was conducted within a single company, within the automotive industry. Conclusions drawn within this thesis must therefore take this narrow focus into account, especially when extrapolating conclusions into other industrial or commercial settings.

A rigorous analysis of innovation methodologies was not conducted prior to the commencement of the research programme. TRIZ had been selected as the preferred methodology to be implemented prior to commencement of the research programme.

2.2 Project Approach

The methodology for conducting this research needed to satisfy the requirements of both the improvement objectives of the host organisation (Avon VMS) and the academic standpoint of the research organisation (University of Bath). Following a review of literature concerning relevant research methodologies, and after considering experimental, surveys and case study approaches, the action research methodology was chosen. The following section (2.3) is a summary of the literature review of action research.

2.3 Action Research

The action research methodology was initially developed within the social sciences. When studying groups, or individuals, the act of introducing a researcher into the environment, inevitably changes the system being studied. The validity of pure observational research can therefore be undermined by the research activity.

Several approaches are available within the action research methodology dependant upon the context of research. Organisational Development (OD), which is credited as being founded by Kurt Lewin (Scott A, 2008) is defined as “organisation improvement through action research” (Bell, 1995). Lewin developed a methodology of changing organisations by unfreezing, freezing and refreezing. This was further developed by Johnson (Johnson R, 1976)into a formalised methodology summarised in (Figure 2).

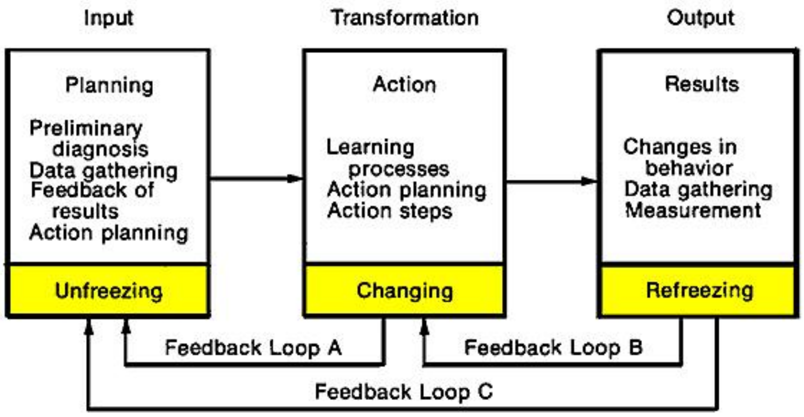


Figure 2. Summary of the Action Research Methodology (Johnson, 1976).

The Input stage is a data gathering, diagnostic and planning activity. The objective is to reach a point where the system under study can be "unfrozen". This is a state of readiness for an intervention and is similar to the "current state map" in lean and six sigma methodology of value stream mapping (Barker, 2005b) Care must be taken that the input stage activities do not affect the current system. Simply measuring a current system can have the effect of modifying its behaviour even without a specific intervention step. During this step, feedback from subsequent cycles (feedback loops A and C) are considered ensuring that the cycle of action takes into account all previous lessons.

The transformation stage is where an intervention in the system is made, and changes implemented. Lessons can be learned during this step, which should be recorded and fed back into the input stage 1 (loop A). Likewise, lessons from previous "output" cycles can be applied to this stage in order to improve the effectiveness of the intervention (feedback loop B).

Finally, the output stage is where the change, or transformation having being brought to a conclusion, is monitored in order to gather data. The "refreezing" element is essential, to allow the system to be accurately measured and comparisons made to the original system. It is also important to record lessons to be applied back to the previous stages, feedback loops B and C.

The needs of the researcher conducting the research and those of the client organisation can sometimes be in conflict due to differing priorities and perspectives of the two parties (Kock, 1996). The initial phase of defining the project can therefore be considered to be a negotiation. Fig 3 shows how the fundamental objective of the organisation is for improvement, and the researchers' objective is for knowledge. It is therefore necessary that the research services and basic theories used during the research are aligned with the perceptions and behaviours of the culture of the organisation being studied.

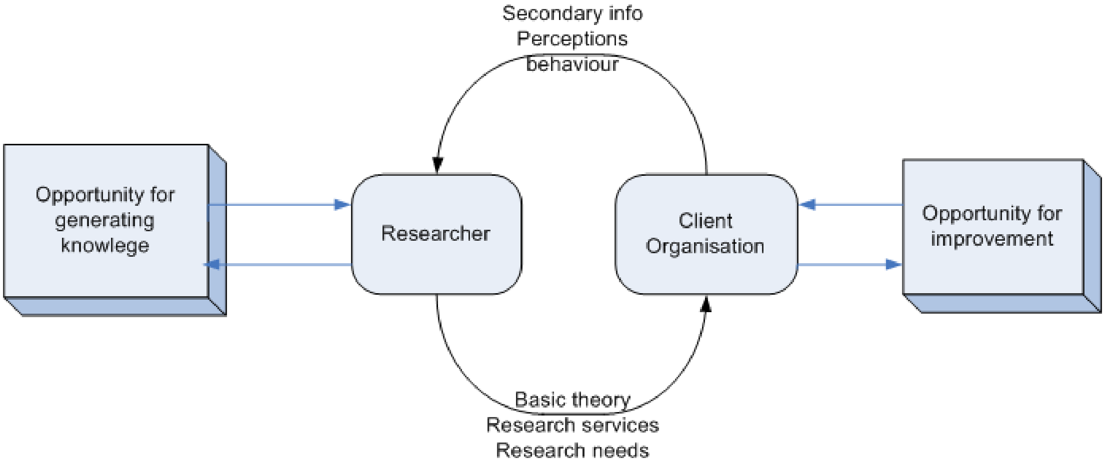
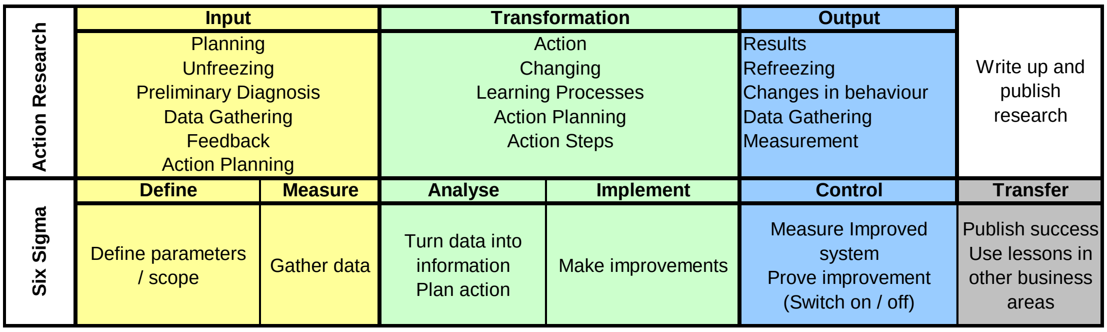


Figure 3. Negotiation in Information Systems Action Research (Kock, 1996).

In the late 1990's Avon PLC adopted Six Sigma as its formal improvement methodology. Improvement activities according to the Six Sigma method follow the steps according to the acronym DMAICT - Define Measure Analyse Implement Control Transfer. (Pande P S, 2000). Figure 4 shows a comparison between the activities of Organisation Development (OD) action research and six sigma DMAICT.



	Input		Transformation		Output	
Action Research	Planning Unfreezing Preliminary Diagnosis Data Gathering Feedback Action Planning		Action Changing Learning Processes Action Planning Action Steps		Results Refreezing Changes in behaviour Data Gathering Measurement	Write up and publish research
	Define	Measure	Analyse	Implement	Control	Transfer
Six Sigma	Define parameters / scope	Gather data	Turn data into information Plan action	Make improvements	Measure Improved system Prove improvement (Switch on / off)	Publish success Use lessons in other business areas

Figure 4. Comparison between Action Research and DMAICT Six Sigma project steps.

Although the DMAICT method is normally used in engineering and business improvement projects, familiarity helped the organisation in understanding and supporting the research project. Hence, the research objectives and the research method are well aligned for both the client company and research organisation. Using the DMAICT structure therefore was valid from both perspectives, and was used for structuring the project plan.

Using this approach, it was possible to formulate a research plan that maintained academic validity in a format acceptable and useful to the company.

2.4 Project plan

The step by step approach to the research programme is shown in (Figure 5) The phases are mapped against the DMAICT steps.

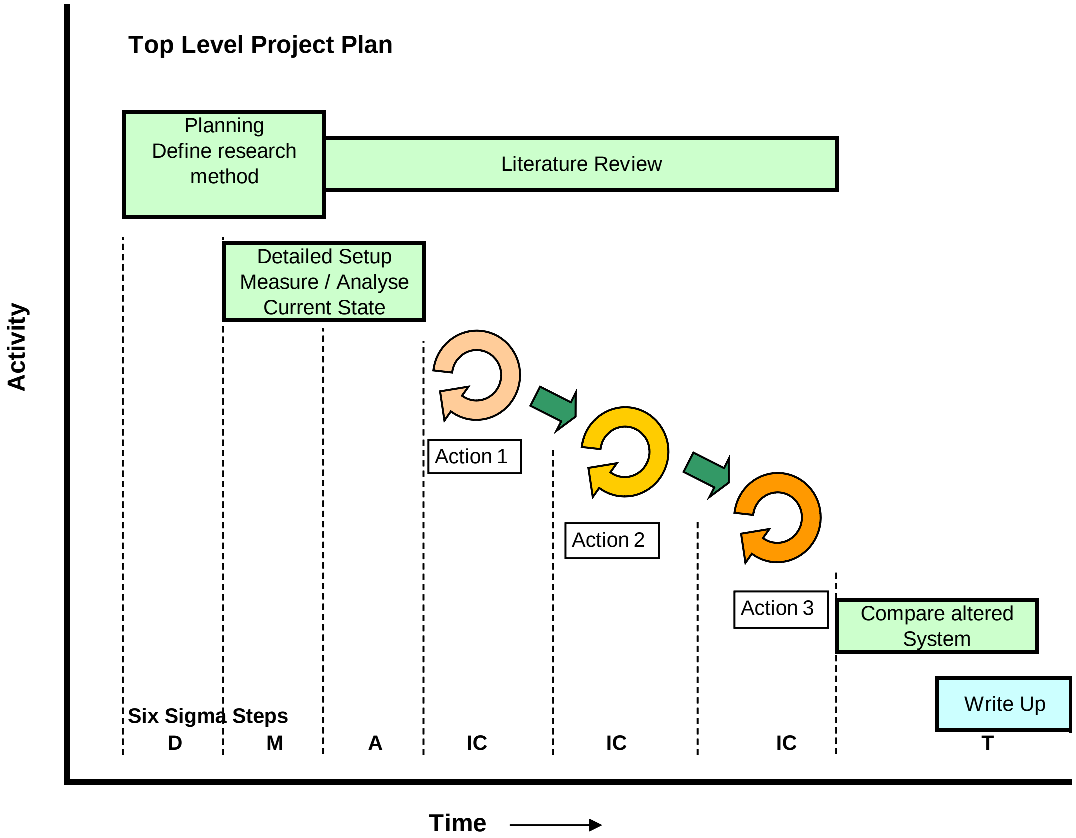


Figure 5. Overall research project plan.

The activities to be undertaken in each of the six sigma DMAICT steps were :

Define

To agree the appropriate research method and project approach. To understand how innovation at Avon was currently undertaken, and investigate if this could be formalised into a process definition. To uncover relevant useful case studies in the literature and select the best approach for TRIZ training and implementation.

Measure

Determine a set of measures that could be used to compare the original system, with the modified system (post TRIZ implementation).

Analyse

To look for trends in the measured data, and establish a metric with which to compare TRIZ generated ideas with traditionally generated ideas.

Implement

Implement TRIZ workshops whereby small groups would be trained, using real company problems as live case studies and feedback from the trainees requested.

Control

Review the data and feedback from each action event (workshop), and feed into next implementation action event. This and the prior step to be repeated three or four times to maximise learning and benefit to the company.

Transfer

Formulate objective conclusions about the TRIZ method, and suggest ways to integrate TRIZ into the standard operating procedures of the business.

This approach satisfied both the needs of research, and the needs of the company.

3 World view of innovation and literature review

This section looks at the way in which innovation is seen and described by the world, and the philosophies, tools and methodologies available to conduct innovation. The first part of the section (3.1) introduces the reader to TRIZ, in order to set the context of the method. A broad view of innovation and creativity in literature is then investigated in order to give context.

3.1 TRIZ

TRIZ is the Russian acronym for *Teoriya Resheniya Izobreatatelskikh Zadatch,* "the theory of inventive problem solving".

TRIZ was originated in the USSR by Henrich Altshuller (1926-1998). (Savransky, 2000) In his early career he was a naturally gifted engineer, and was put in charge of a small team in a Russian Naval research group. At this time he was interested in the subject of creativity and problem solving, and was surprised that no standard procedure or methodology existed to help technicians generate good solutions quickly. He therefore started to research this topic, and to study patents. Having systematically studied many patents across a broad spectrum of disciplines and industries, Altshuller found that there were a finite number of inventive principles used to create inventive steps – eventually totalling 40. Also, he found that technology tends to develop along several predictable evolutionary trends – eventually totalling over 30. This was the basis for a number of tools and methods to help problem solvers to align their specific problem with a standard problem, and then to consider the standard trends and principles that others have successfully used to solve these problems.

A fundamental principle of TRIZ is that "someone somewhere has solved a problem like yours". It is this approach that leads to the following diagram (Figure 6).

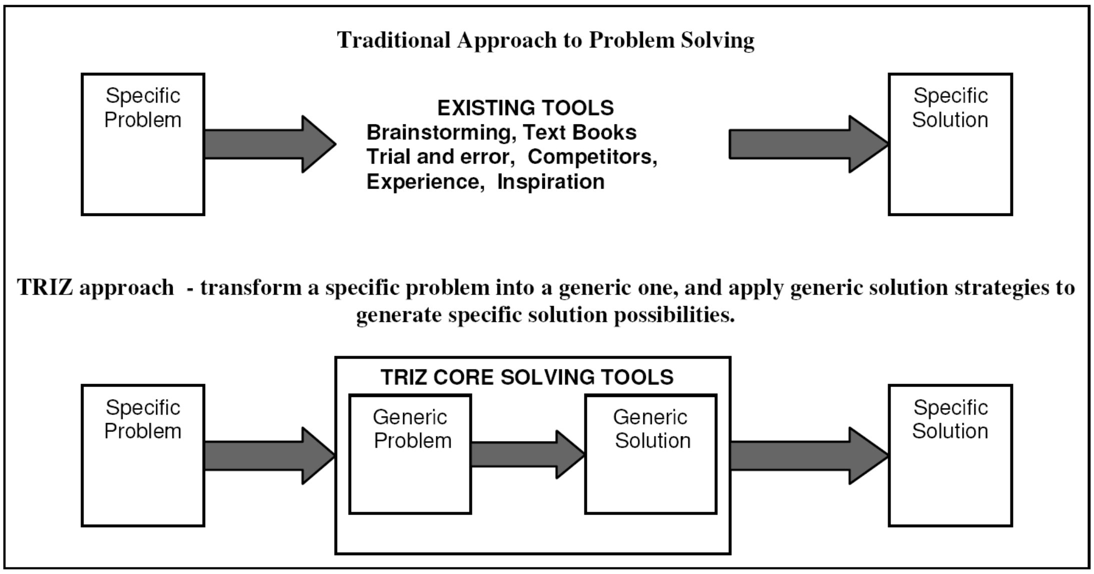


Figure 6. Comparison between traditional and TRIZ approach to innovation.

There are many problem definition tools in TRIZ that help to standardise the specific problem in hand, and reformulate it into a generic problem. From the significant body of research that had been undertaken by Altshuller's team, the problem solver is introduced to generic solutions. Hence, a connection can more easily be made between a problem situation and an inventive, powerful solution.

Altshuller spent several years in a Siberian Labour camp because of Stalinist objection to his theories, but later was able to continue his work until his death in 1998 (Lerner, 1991). With the fall of the iron curtain in 1989, TRIZ was exposed to Western Academics and researchers, and several books translated into Western languages. Several of Altshullers followers moved to the West to continue research and set up consultancy practices.

Over Altshullers lifetime, the method was developed such that TRIZ could also be considered to have an over-arching philosophical element, similar to the Total Quality, Lean and JIT culture in Japan in the 1980's and 90's. In the West, and particularly the automotive industry, much of this philosophy element is encapsulated within the Six Sigma movement. TRIZ cannot be seen in any companies as a stated fundamental philosophy upon which the business operates. Rather, individual tools are used in isolation, incorporated with existing tools and methodologies (Mann, 2002a).

It is generally recognised that Six Sigma has very few elements that aid users in ideation and creative problem solving (Filmore, 2008). Some of the TRIZ tools have been welcomed by the Six Sigma community, as additional tools within their toolkits. However, in common with western manufacturing businesses, very few, if any mainstream innovation / engineering / management consultancies have adopted TRIZ in the broader philosophical context.

Chapter 4.4 gives an overview of several of the key TRIZ tools, with a brief summary of each.

Several of the TRIZ tools, used in isolation can be used as part of the brainstorming method, to create large numbers of ideas. However, the philosophy of TRIZ is to focus problem solving effort into areas most likely to be successful, rather than generating large quantities of ideas. In fact Altshuller specifically singles out Thomas Edison for criticism for his "unscientific" approach to developing solutions using large numbers of experiments to see which works best (Altshuller, 1999). The focused, directed approach of TRIZ is in contrast to the trial and error methods of Edison.

3.2 Innovation definitions and approaches to innovation

The concise Oxford English Dictionary defines to Innovate as to "make changes in something already existing, as by introducing new methods, ideas, or products." (

A literature search uncovered the following, from researchers and consultancies operating in the innovation field who had defined innovation as :

- A way of satisfying unmet customer needs - (Ulwick, 2002)
- Doing things better or action x knowledge x creativity (Mann, 2004)
- The first implementation of an invention – (Sajal, 1982)
- The act of introducing something new (Wolfe, 2008)
- Innovation = creativity x risk taking (Byrd, 2003)
- Innovation = creativity + commercialisation (Stamm, 2008)

It can be concluded therefore that innovation is made up of elements of invention, creativity and application. Furthermore, a full understanding of innovation requires an understanding of these key constituents.

3.2.1 Inventiveness

The dictionary definition of the verb ***invent*** is to "think up or create (something new)". The adjective ***inventive*** means "resourceful or creative" In practice the precise meaning of invention is not well defined, as evidenced by (Mandel, 2008). In this paper there is a quote from the Graham v John Deere court proceedings :

"This Court has observed, [that] '(t)he truth is, the word ('invention') cannot be defined in such a manner as to afford any substantial aid in determining whether a particular device involves an exercise of the inventive faculty or not' Its use as a label brought about a large variety of opinions as to its meaning both in the Patent Office, in the courts, and at the bar".

Despite the difficulties of defining inventiveness in the legal world, there are formalised standards for assessing the inventiveness of an idea in the TRIZ world. The analysis method of Altshullers research team categorised patents into five levels (Savransky, 2000, Altshuller, 1999). This is summarised in Table 1.

Level	Attributes
1 – Regular	Minor improvements, enhancements – often improving an existing trade-off.
2 – Improvement	Development of a system by reducing a contradiction or adding new functions – using knowledge within a single field of knowledge / discipline.
3 – Invention inside Paradigm	Radical change from earlier system utilizing knowledge from outside the existing industry or discipline. Removal of tradeoffs, expansion of the field of application.
4 – Break-though outside Paradigm	Radical departure from existing system. Creating a new generation of methods for delivery of a function. Using a different scientific principle from the existing system.
5 – Discovery	Uses principles outside of existing scientific knowledge.

Table 1 Categories of inventive levels of patents (Savransky, 2000).

In essence therefore, inventiveness is about the size of the step between an existing system and a new system and how obvious that step is to the observer of the idea who is technically qualified and competent, or “skilled in the art”.

3.2.2 Creativity

Creativity is a frequently used term within many areas of human endeavour, from the arts, to science, sport, technology, psychology and even accounting! In the literature, the foremost discipline concerning the study and understanding of creativity is cognitive psychology. In this field there are two camps (Boden, 1990) the inspirational / romantics, and the non romantics. The romantics concentrate on the subconscious, mystical abilities associated with the right hemisphere of the brain. Creativity is about freedom of expression, miraculous flashes of inspiration and short circuits of reasoning. They look at great creative individuals such as Mozart, and suggest that they possess some extreme super human talent that seems to come from outside – divine inspiration. As such creativity can be seen as something bestowed upon a person, rather than something from within (Gilbert, 2009). The encouragement of creativity has emphasis on breaking down barriers to freedom of expression, freeing people from inhibitions, celebrating randomness and unthinking experimentation in a childlike playful state of mind. The brainstorming technique was born from this stable. (Osborn, 1963). The inspirational/romanic view is that creativity runs counter to logical and rational thought. Hence, this camp is vehemently opposed to the proposition that creativity could in the future be generated by Artificial Intelligence (AI).

The non-romantics view creativity as something that has process, logic and reason associated with the left hemisphere. (Figure 7) It is to do with making unobvious connections or associations between thoughts and ideas, but done so in a logical manner (Buzan, 1984).

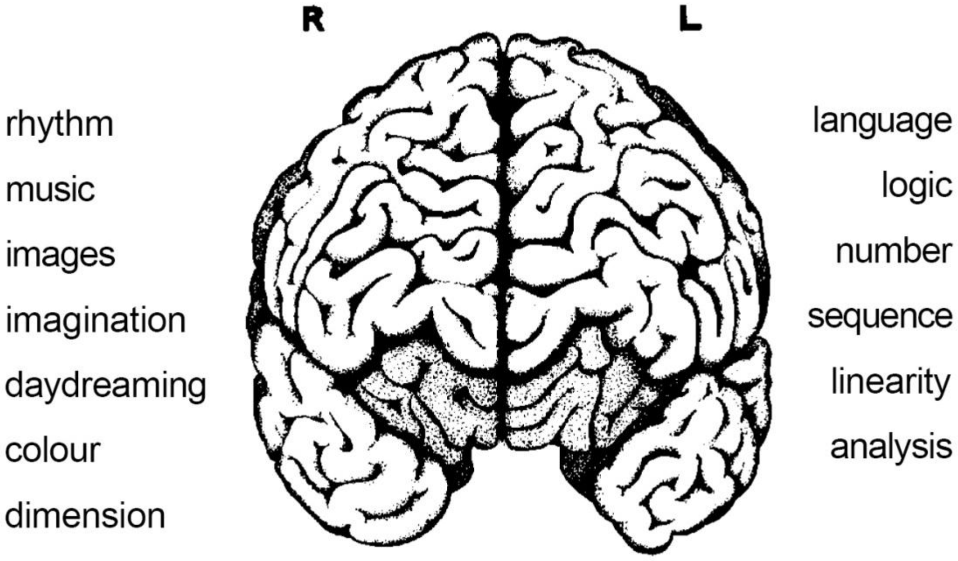


Figure 7. Left and Right brain functions (Buzan, 1984) .

De Bono (de-Bono, 1998) emphasises the significant difference between creative thinking and scientific rational, logical, critical, analytical thinking styles, routed in the teaching of the "big three" Greek philosophers Socrates, Plato and Aristotle (de-Bono, 1998). Also according to de Bono (de-Bono, 1992) creativity is about non obviousness, or "unexpectedness". He also discusses the difficulty of defining creativity in business due to its association with the arts and "creative industries" such as advertising and music. As such, de Bono teaches that there are aspects of romantic and non-romantic standpoints within creativity, and coined the phrase "lateral thinking", which spans both camps.

Creativity is defined in the Oxford English Dictionary as – "to create something new". As such, it has many similarities with the word invention. Creativity is therefore very similar to inventiveness. However, inventiveness has more emphasis on producing a technology, or solution to a problem compared with creativity that has a much wider context. Perhaps the most complete definition in the literature, is by Amabile (Amabile, 1996).

"A product or response will be judged as creative to the extent that (a) it is both a novel and appropriate, useful, correct or valuable response to the task at hand, and (b) the task is heuristic rather than algorithmic" (p. 35), i.e. it does not have a clear and readily identifiable path to solution

Inventiveness can therefore be seen as being a part of creativity.

3.2.3 Application

In contrast to the uncertain definitions for inventiveness and creativity, *application* is well defined as a business process. There are procedures and business process models for design, assessing business cases, making risk assessments and market launch. A widely adopted approach is the stage gate process, originally developed by Cooper et al (Figure 8).

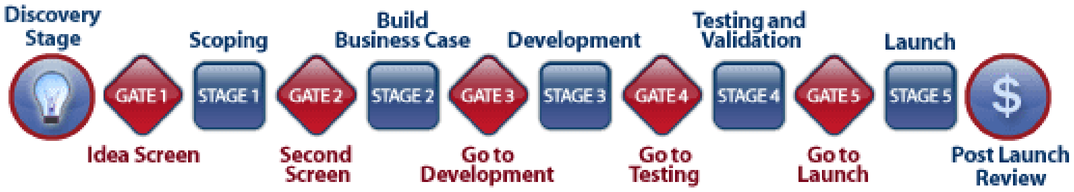


Figure 8. Stage Gate Process of Product Development (cooper 2008_

There are many other methodologies for the application aspects of innovation, and they will be described and considered in section 3.3.3. In the automotive industry there are strictly applied standards for product development and launch, these can be found in the standard (2007)

3.2.4   Innovation as a Whole

After considering the three basic elements of innovation, consideration can be given to innovation as a whole. In the literature, Christensen identifies two types of innovation – incremental, and disruptive (Christensen, 1997) Each will be considered in turn.

3.2.4.1 Incremental Innovation

Avon Automotive, in common with the western automotive industry in general have adopted the “lean” approach to manufacturing developed in Japan since the 1950’s. One of the seminal works widely read within the industry is “The Machine that Changed the World” (Womack, 1990). The authors investigate the differences between western traditional automotive industry and Japanese lean companies, looking at the differences in manufacturing strategy, but also in the approach to research and development. They draw the conclusion that lean companies have been successful because they have concentrated on perfecting small step changes, in contrast with the traditional western approach of larger more risky steps in development. Within the lean and design for six sigma literature, the emphasis is in reducing waste in the product development cycle, such that products can be developed rapidly with fewer resources, for example (Hosnedl, 2008, Shavinina, 2003, Stamm, 2008, Basem, 2009). By clearly understanding specific customer requirements and optimising products to address those requirements, successful, profitable products can be produced more quickly and with less waste. This philosophy is deeply embedded within the Kaizen method of improvement, where many small changes are implemented, adding up to large scale improvements in performance. This has been extremely successful in making production processes more efficient, and this approach has also been carried forward into R+D activities. In the book, The Elegant Solution, (May, 2007) the Toyota approach to innovation is explained in depth. One paragraph summarises the emphasis:

"*It you want big leaps, take small steps. If you want quantum impact, sweat the details. If you want to boil the ocean, do it one cup at a time. If you want excitement, get boring: Think method. Think metrics. Think micro*".

From the standpoint of creativity, this type of innovation is clearly associated with logic, reason and control. It has very little to do with free thinking irrational flare and inspiration. The inspirational romantic creativity camp would not approve !

3.2.4.2 Disruptive Innovation

In the book, Built to Last, (Porras J, 2000), several highly successful, long lasting companies termed "visionary" and "class leading" are studied in depth. These are compared with organisations that are similar and profitable, but have not performed as highly as the visionary group. They investigate two approaches to innovation (although they use the word progress instead). One they call "purposeful evolution", which is equivalent to incremental innovation as described above. The other they term "BHAG" – Big Hairy Audacious Goal. BHAG's are typified by Boeings bold decision to develop the 747 aircraft – a highly risky decision that could have bankrupted the company. Purposeful evolution is typified by 3M and their approach to making many changes and innovations that are tried out on a small scale. Failures quickly fall by the wayside, and successes are developed. In "Idealised Design" (Ackoff, 2006) the emphasis is on the need for radical step changes, other authors and research groups support this need for revolutionary change - such as Christensen

(Christensen, 1997). These two conflicting views of innovation are explained in figure 9.

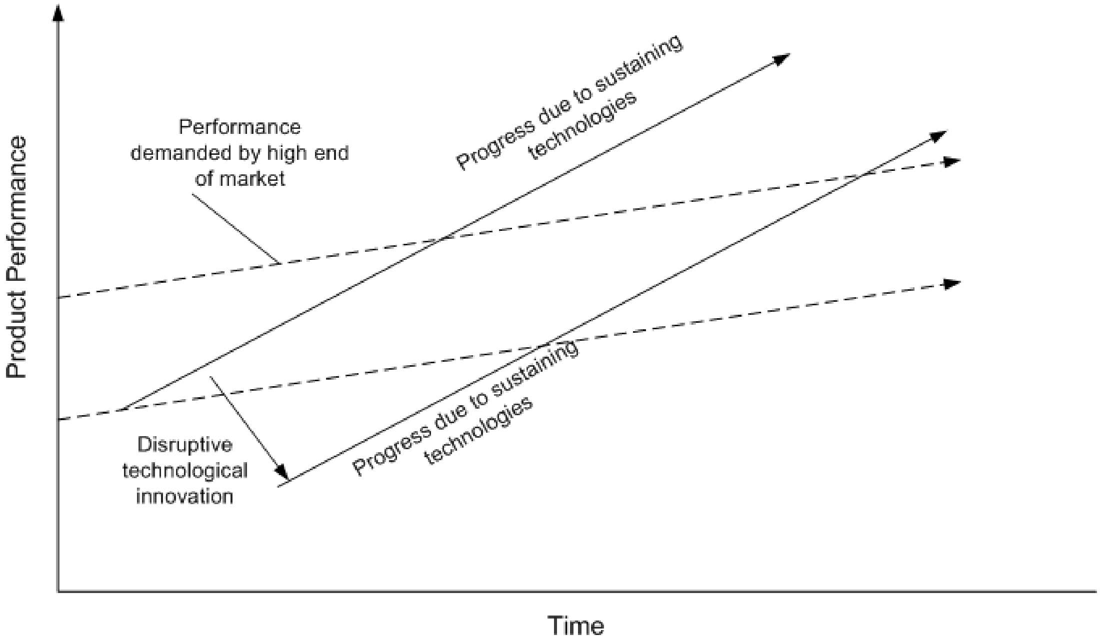


Figure 9. Incremental and Disruptive Innovation (Christensen, 1997).

This model therefore harmonises the debate between incremental and disruptive innovation. Both co-exist within the innovation paradigm. Organisations must recognise both forms of innovation and manage their businesses in a way that encourages both type effectively.

A further point which should be noted is in the work of (Gladwell, 2000). In his book Tipping Point – it is pointed out that small, seemingly insignificant factors or ideas can unexpectedly “tip” and become unexpectedly powerful. It therefore holds that ideas and proposals categorised as incremental or sustaining technologies can become unexpectedly disruptive. This gives rise to a significant challenge for management to encourage the right type of innovation at the right times.

3.3 Innovation best practice – philosophies and tools review

It has been shown that innovation is made up of creativity, invention and application. Innovation best practice therefore requires best practice in each area, as well as the subject in itself. In this section, best practice in the areas is reviewed.

3.3.1 Best creative practice

The inspiration/romantic standpoint is that the main barrier to creativity is rigid thinking, and preconceptions that need to be broken. Logical, rational critical assessment need to be separated from the creative process in order to allow free, unfettered thinking. There is theory concerning the creative personality, the nature, form and temporal dynamics that affect creative thought in the workplace. This includes the affect of sleep, moods and emotions (Amabile M, 2005, Frese M, 2008).

In a significant study of creativity in the workplace (Amabile, 1996), it was found that several factors affected the ability of workers to be creative, (Figure 10).

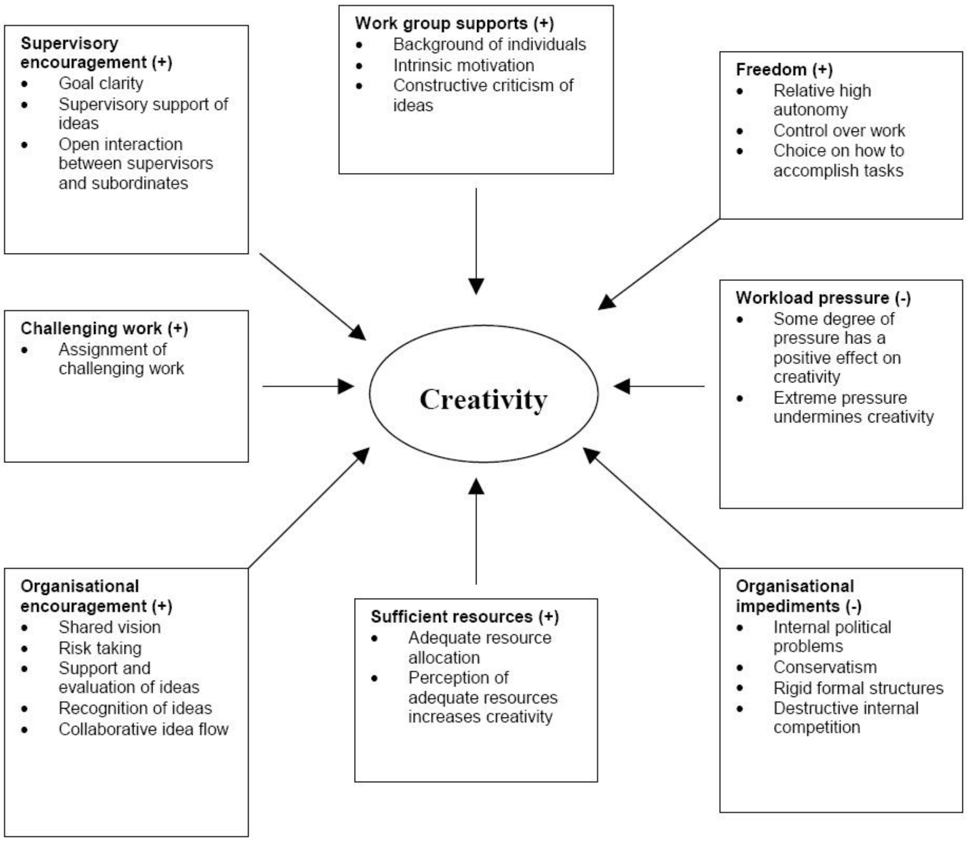


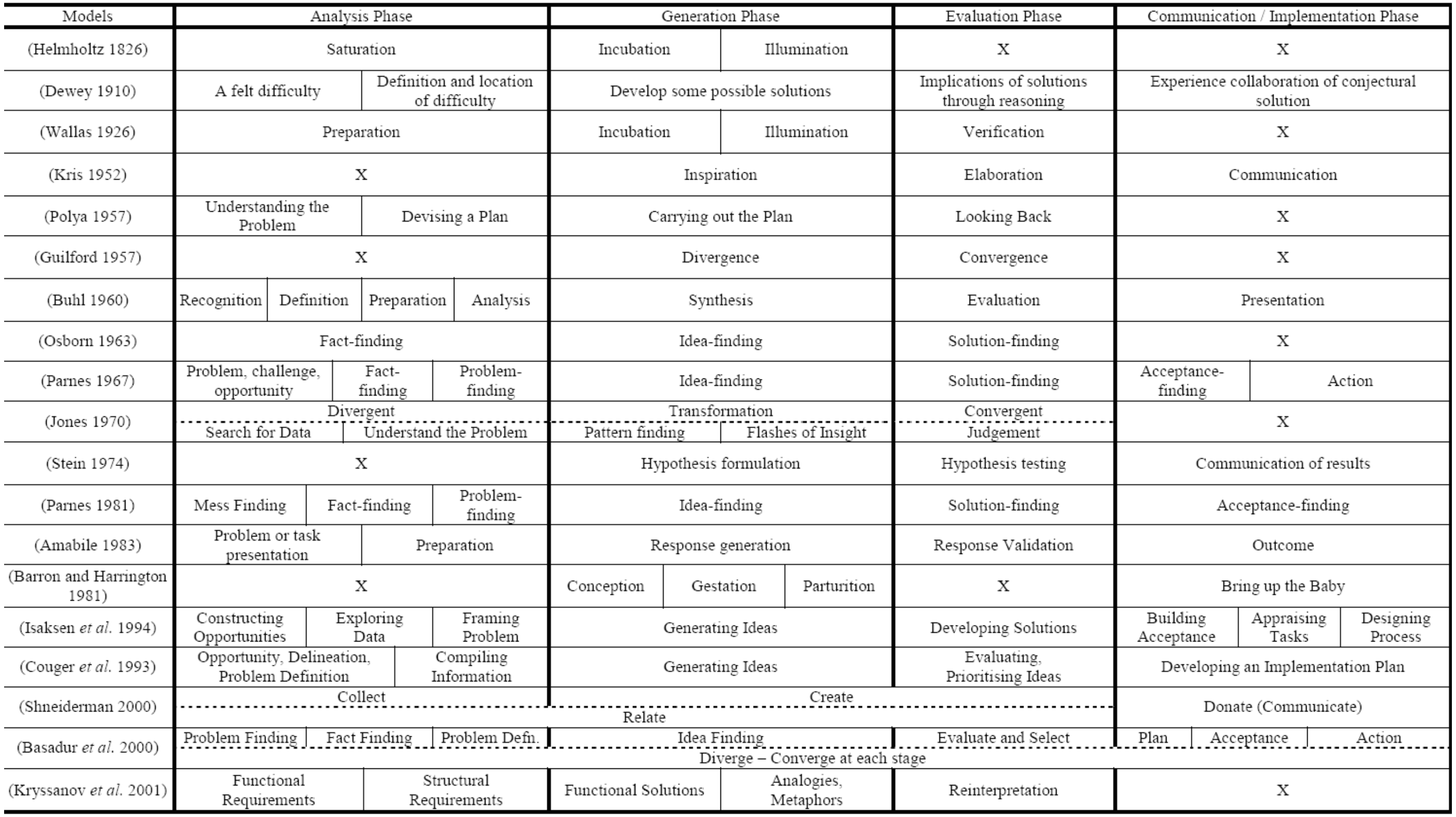
Figure 10. Model for assessing the climate for creativity (Amabile 1996).

The challenge to business leaders is to organise and lead the workforce such that barriers to creativity are reduced, and positive affects encouraged.

This approach to creativity has also created the idea of physical space set aside for creative activities. The author was able to visit the iLab (innovation lab) operated by the Post Office at Coton house in Rugby UK, (Figure). This was also visited by Dr E de Bono in 2007, and he is quoted “The most innovative and creative environment I have seen globally” (de-Bono, 2007). It includes play areas, “chill out zones”, musical instruments, games areas, computer and multi-media resources.

Figure 11. iLab at Coton House - Post Office Innovation Centre

On the non-romantic side of the creativity community, the emphasis is on method. The concept is that process and methods can be designed to utilise logical and rational thinking styles to enhance creativity. There are many of these techniques in fact there are 97 listed by (Zusman, 1999). The primary creative methods have been summarised (Howard, 2008a), and can be shown in table form for comparison, (see table 1a).



Models	Analysis Phase	Generation Phase	Evaluation Phase	Communication / Implementation Phase
(Helmholtz 1826)	Saturation	Incubation Illumination	X	X
(Dewey 1910)	A felt difficulty Definition and location of difficulty	Develop some possible solutions	Implications of solutions through reasoning	Experience collaboration of conjectural solution
(Wallas 1926)	Preparation	Incubation Illumination	Verification	X
(Kris 1952)	X	Inspiration	Elaboration	Communication
(Polya 1957)	Understanding the Problem Devising a Plan	Carrying out the Plan	Looking Back	X
(Guilford 1957)	X	Divergence	Convergence	X
(Buhl 1960)	Recognition Definition Preparation Analysis	Synthesis	Evaluation	Presentation
(Osborn 1963)	Fact-finding	Idea-finding	Solution-finding	X
(Parnes 1967)	Problem, challenge, opportunity Fact-finding Problem-finding	Idea-finding	Solution-finding	Acceptance-finding Action
(Jones 1970)	Divergent Search for Data Understand the Problem	Transformation Pattern finding Flashes of Insight	Convergent Judgement	X
(Stein 1974)	X	Hypothesis formulation	Hypothesis testing	Communication of results
(Parnes 1981)	Mess Finding Fact-finding Problem-finding	Idea-finding	Solution-finding	Acceptance-finding
(Amabile 1983)	Problem or task presentation Preparation	Response generation	Response Validation	Outcome
(Barron and Harrington 1981)	X	Conception Gestation Parturition	X	Bring up the Baby
(Isaksen *et al.* 1994)	Constructing Opportunities Exploring Data Framing Problem	Generating Ideas	Developing Solutions	Building Acceptance Appraising Tasks Designing Process
(Couger *et al.* 1993)	Opportunity, Delineation, Problem Definition Compiling Information	Generating Ideas	Evaluating, Prioritising Ideas	Developing an Implementation Plan
(Shneiderman 2000)	Collect	Create Relate		Donate (Communicate)
(Basadur *et al.* 2000)	Problem Finding Fact Finding Problem Defn.	Idea Finding Diverge – Converge at each stage	Evaluate and Select	Plan Acceptance Action
(Kryssanov *et al.* 2001)	Functional Requirements Structural Requirements	Functional Solutions Analogies, Metaphors	Reinterpretation	X

Table 1a. Comparison of creative process models (Howard 2008a)

There is a healthy and wide-ranging debate amongst the innovation community as to the effectiveness or otherwise of these tools, and their relative merits. Traditional brainstorming is the most widespread tool and has been studied extensively. Researchers have found that although widely used, the results are not as positive as is often presented by practitioners (Isakensen, 1998).

It is interesting to note that as a company perceived as highly innovative in its field, Avon only included basic brainstorming techniques within its formal operational procedures. It had not formally adopted techniques such as de Bono six thinking hats, although several technical mangers were aware of the technique. The "Facts, Problems, Ideas, Solutions, Acceptance" FPISA method (Basadur 2000) had also been taught in management training workshops, and was used by some managers to augment brainstorming sessions. Other than these, if any techniques were used, they were at the discretion of the individual designer / problem solver in line with their personal experience and education.

3.3.2 Best Inventive Practice

In section 3.1, it was found that the act of invention is part of creativity. Therefore, to be good at creativity, invention needs to be encouraged, and vice versa. Management of Intellectual Property (Hipple) is an important aspect of innovation as it significantly affects the commercial potential of creative and inventive ideas. Companies must create strong patents, and networks of patents. They must also encourage good practice in the development of strong brands, trademarks registered designs and copyright (Jolly A, 2004). This includes ensuring awareness across the organisation of IP issues, and in particular the need for confidentiality.

There also needs to be vigilance on the part of the company in terms of looking for infringements to their IP. (Jolly A, 2004)This is the traditional model of innovation that has served industry for many years. It is termed "Closed Innovation" as shown in fig 12.

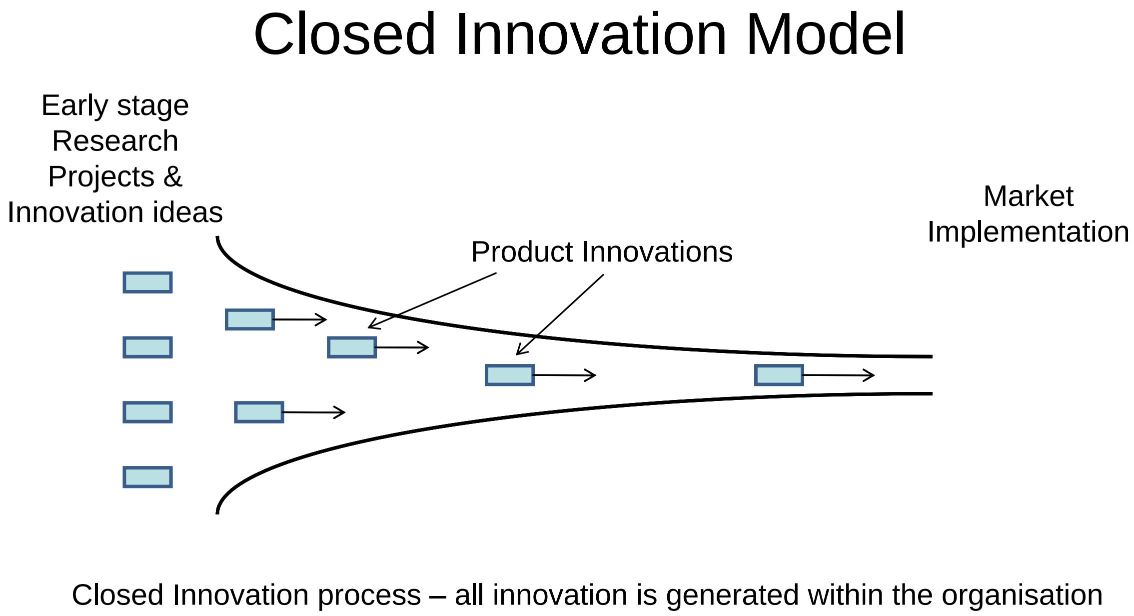


Figure 12. Closed innovation model (Chesbrough, 2006)

However, this is now being challenged by a new approach termed Open Innovation (Chesbrough, 2006) Open Innovation runs counter to the closed innovation model, as instead of planning to keep all IP rights within the control of a single entity, companies are encouraged to seek partners outside of the company see (fig 13).

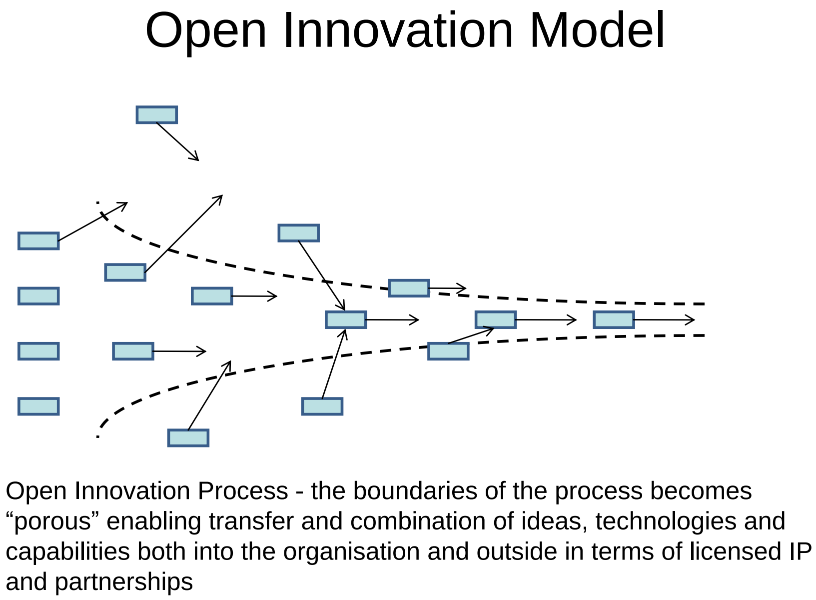


Figure 10 Open innovation model (Chesbrough, 2006)

There are many ways to approach open innovation, for example through the use of “crowd-sourcing”, innovation consultancies and benchmarking activities with non-competitive businesses.

Currently, the automotive industry is not at the forefront of open innovation. Collaboration between the OEMs’ and supply base has been open for many years, but so far, component developer / manufactures such as Avon use a closed innovation model.

3.3.3 Best Application Practice

There are internationally recognised standard methods of programme management such as PRINCE 2 (Bentley, 2003), which cover taking projects from concept to market, see (fig 14). Within the automotive industry there are defined procedures for taking new products to market - advanced product quality planning (APQP). These procedures are formalised within industry standards such as ISO TS16949.

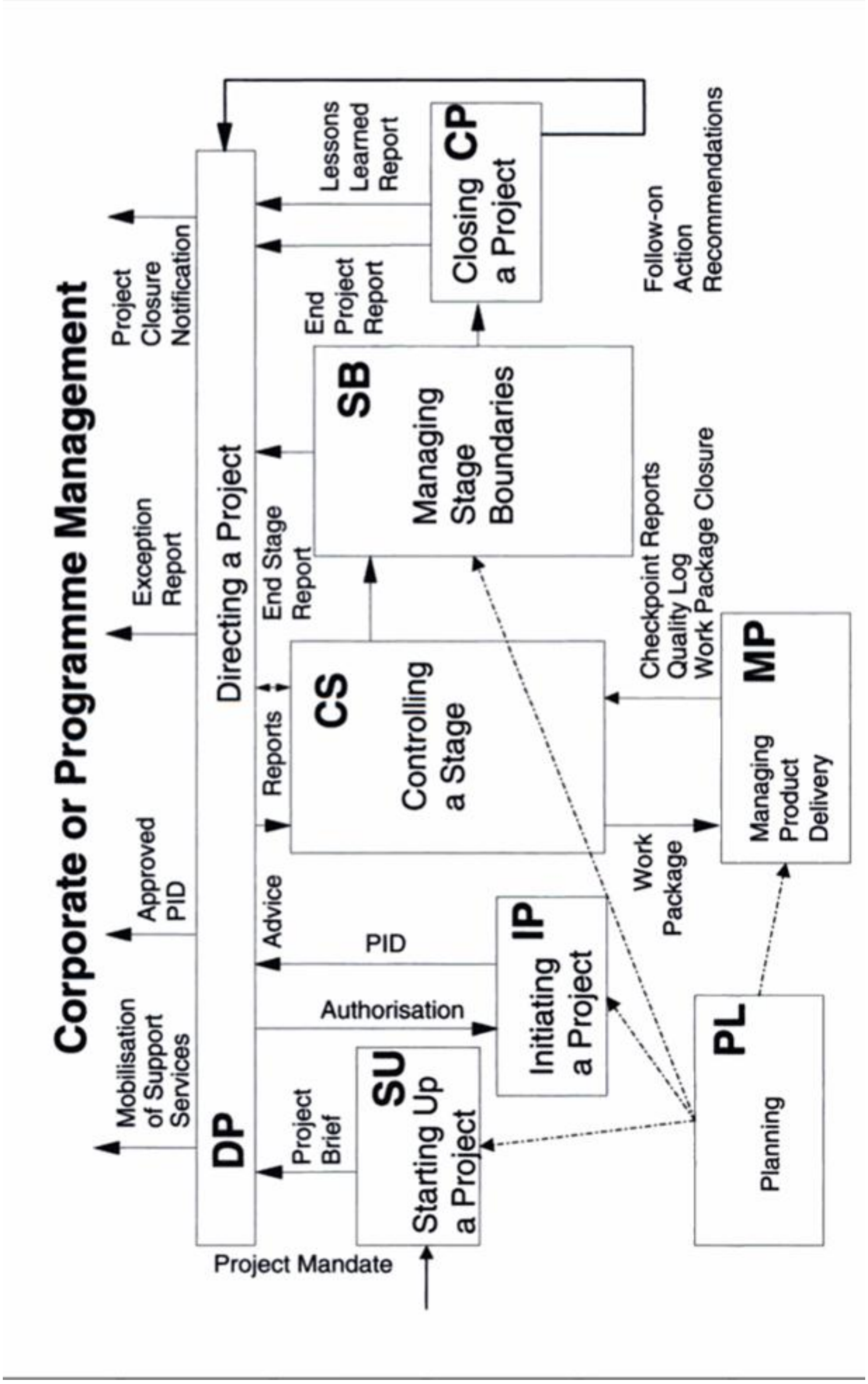


Figure 14. Overview of Prince 2 model of programme management (Bentley, 2003).

3.4 Six Sigma / Lean

Six sigma is a comprehensive methodology for business and manufacturing process improvement. It brings together statistical and other improvement tools into a cohesive, structured approach to business improvement (Brue, 2002). The core principle is that improvement stems from reduction in variation, with the quality target being 3.4 defects per million opportunities (DMPO) – the mathematical statistical term for Six Sigma levels of quality. The rationale is that if variation in manufacturing and business processes is improved to Six Sigma capability, then the total system becomes optimised, more efficient, and profitable. Companies such as Motorola and GE have attributed business success to the adoption of Six Sigma, in particular in reducing costs (Brue, 2002, Pande P, 2000). There is a large and vibrant community of Six Sigma practitioners, academics and researchers. The DMAICT methodology for managing improvement projects within Six Sigma has already been described in section 2.2.

Sigma level	DPMO	Percent defective	Percentage yield	Short-term Cpk
1	691,462	69%	31.00%	0.33
2	308,538	31%	69.00%	0.67
3	66,807	6.70%	93.30%	1
4	6,210	0.62%	99.38%	1.33
5	233	0.02%	99.977%	1.67
6	**3.4**	**0.00%**	**99.99966%**	**2**
7	0.019	0.00%	99.9999981%	2.33

Table 2 - showing defect rates vs sigma level (Avon Six Sigma Training material 2005).

Investigation of the literature reveals that Six Sigma is effectively an extension of Total Quality Management (TQM). Six Sigma has often been described as "TQM on Steroids" (Chang, 2006). TQM was developed in the later part of the 20th Century, bringing together the work of Quality "Guru's" such as W. Edwards Deming, Philip B Crosby, J.M. Juran, Armand V. Feigenbaum and Kaaru Ishikawa. This combined approach was known as the Quality Revolution. Through this "revolution", business leaders came to the realisation that Quality, when built into the culture and fundamental ways of doing business was a source of competitiveness, and the responsibility of everyone involved in the business from the very top of the organisation, to its shop floor employees, suppliers and partners (Stamatis, 1997). The standpoint of Avon PLC was that the Six Sigma initiative would replace all previous TQM initiatives and structures, and would include all improvement projects within the company. It is recognised that many companies may not see Six Sigma in this way, instead considering the Six Sigma statistical tools to be applied within other overriding improvement initiatives such as Lean Manufacturing (which is described later in this section). This is understandable, as many of the Six Sigma tools were are also cited as being within TQM and Lean philosophies – especially the works of Deming, Taguchi and Ishikowa (Chang, 2006, Stamatis, 1997, Pande P, 2000).

Responsibility for Six Sigma within Avon PLC lay at board level with the quality director. He personally ran comprehensive training courses across the global business to roll out the strategy. This top down approach followed the martial arts classifications of "belts", to designate the various levels of six sigma capability of individuals within the business. Yellow belts have a small amount of awareness training, and black belts have the full training package and experience of running real improvement projects – green and orange belts sit in between. The author was trained to Black Belt level. Six Sigma was a natural extension of the quality management, and standard operating procedures of Avon PLC. This included the New Product Introduction (NPI) procedures, which as pointed out in section 3.2.4, were considered to be within the scope of the innovation definition and highly relevant to this research project. It also included the business approach to technical problem solving. This is a set of tools and procedures to solve diagnostic problems, when something has deviated away from a known correct state. The tools and procedures within the Avon Six Sigma procedures covering creative / inventive solutions to problems were brainstorming, and the recently adopted FPISA process. (Basadur, 2000).

During the final two decades of the 20th Century, the increasing competitiveness of the major Japanese manufacturing industries, and particularly the automotive sector was driven by the Lean Manufacturing philosophy. Much of this was created through the development of the Toyota Production System. Lean thinking is based upon the premise that manufacturing should only do what the customer is paying for. Anything else is considered waste. It is said that within the Japanese manufacturing culture that poor quality and waste should be thought of as being “worse than a thief” (Pisano G, 1991, Barker, 2002b). Although stealing is bad, typically the item stolen still exists in society, and can be recovered, or even still serve a useful purpose. However, when something is wasted it is lost to society forever. According to most lean manufacturing references there are “seven deadly wastes”. Avon decided to add an eighth waste – “not utilising human resources” (Barker, 2002b) – see Table 4. Avon PLC integrated the lean manufacturing philosophy within the Six Sigma initiative. However it is also noted that many companies integrate Six Sigma within Lean Manufacturing philosophy.

Waste	**Description / example**
Transportation	Multiple handling, delay in material handling, unnecessary handling.
Inventory	Holding or purchasing more that the absolute requirements for raw material supplies, work-in-progress, finished goods.
Motion	Any motion, of people or machinery that does not add value.
Waiting	Time delays, idle time (not value add time).
Over Processing	Any non-value adding work or procedure
Over Production	Making more product than is required by the customer (ie. over making).
Correction	Producing an output (part or service item) that is not right first time and is rejected or reworked.
Not utilising Human Resources	Wasting the skills and abilities of the operators / workers in the business. Not asking for or not acting on upon suggestions for improvement.

Table 3 The Eight Deadly Wastes as defined by Avon PLC

To aid memorisation within Avon, the acronym TIMWOOCN (Pronounced Tim Woocken) was developed. (Table 3)

Within the lean manufacturing philosophy many methodologies have been developed to eliminate waste. (Womack, 1990, Ohno, 1988, May, 2007) The most famous is JIT – “Just In Time” manufacturing flow. This is a way of organising production such that products are only produced when needed, with the minimum amount of inventory and short transportation routes.

During the 1990’s the Lean / Six Sigma movement focused upon manufacturing / operations, but have more recently, in the 00’s applied the principles more widely across business functions (Creveling C, 2003, Pande P, 2000, May, 2007, Hosnedl, 2008, Basem, 2009). Within Product Development, this is termed Design for Six Sigma (DFSS). Unlike standard Six Sigma, a single stepwise implementation strategy (DMAICT) is not defined, and several have emerged from literature, academia and practitioners. The principle structure is DMADV – Define, Measure, Analyse, Design, Verify. Another is the I^{2}DOV – Invent/Innovate, Develop, Optimise, Verify (Creveling C, 2003).

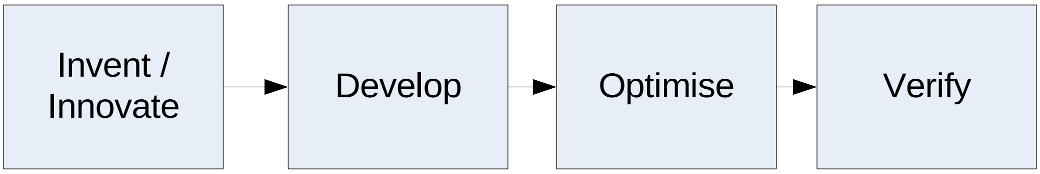


Figure 15. I^{2}DOV – Design For Six Sigma Methodology (C.M. Creveling, 2003)

It is interesting to note the use of the word “innovate” within Creveling’s first step. Considering that the definition of innovation includes an element of introduction of ideas / application, the author considers this is a clear example of the general lack of clarity of the definition of innovation. It is assumed that in this case, the word is used in the context of creativity and ideation.

At the time of the workshops conducted for this research, Avon had started to look into design for Six Sigma as some aspects of ISOTS16949 were beginning to increase the need to include statistical analysis and validation of designs prior to production introduction.

3.5 Problem Solving

Although the only formal creative tool within the Avon procedures was brainstorming, the company did have a formalised procedure and set of tools for problem solving. In common with typical automotive industry standard practice, the formalised method was the sequential methodology 8D sometimes also referred to as TOPS (Team Oriented Problem Solving) 8D (Joy, 2002).

The step by step '8D' structured problem solving tool (Table 4), was widely accepted and used within Avon and was a standardised industry wide approach to problem solving within the automotive industry. A similar approach was required for the TRIZ tools, which would also maintain the flexibility that inventive problem solving requires. It was decided that the order in which the tools were introduced in the workshop would be the recommended order for using the TRIZ tools in the Avon environment.

Step	*Description*	**Key tools and actions**
D0	Decision to use 8D Process	Emergency response action, trends, symptoms & customer response.
D1	Team Info	Select team members with appropriate skills – team goals and roles.
D2	Describe Problem	Data driven systematic way, time lines, process flow, stair stepping, is/is not cause and affect, problem definition.
D3	Containment Actions	Action plans, painter charts, risk analysis sheets validation plan.
D4	Find and verify root cause	Is / is not, brainstorm, FMEA, cause and effect diagrams.
D5	Define Permanent Corrective Actions and Verify	Define decision criteria, brainstorm solutions, select best option, validation plan, controlled experiments.
D6	Implement Corrective Action & Validate	Problem prevention worksheets, switch fix on and off, cause and effect, FMEA, control charts, performance data metrics.
D7	Prevent Systemic Problem	Review D0-D6 brainstorm options.
D8	Congratulate Team	Document contributions, team leader reviews.

Table 4 Avon Automotive 8D problem solving procedure (Barker, 2002a)

4 Detailed Setup

In this section the way in which the first action was planned and executed according to the plan in section 2.3 is detailed.

4.1 Defining Innovation using the IDEF0 method

The first “Input” stage of the action research method is to Define and Measure the current system. The typical ways of defining innovation as a process, are summarised by (Howard, 2008a) See section 3.1.1. However, these models of innovation were considered to be merely descriptions of a product development or ideation process rather than giving a clear understanding of the process of innovation itself. A suitable definition and measurement system was therefore required to be developed specifically for the research project.

The IDEF0 business process mapping system (IDEF0, 2005) developed in the 1980’s/90’s is a hierarchical definition tool that uses strict guidelines for analysing processes and presenting them to others. At the heart of this method is the idea that a process or function is a verb, and any verb can therefore be mapped as a process. Innovate is a verb and therefore suitable for modelling using the IDEF0 method. The hierarchical nature of this technique allows the appropriate level of detail to be uncovered, and indeed to rise above the Avon new product development system, to a more generic definition.

According to the IDEF0 method (IDEF0, 2005), any process must have inputs, controls, mechanisms and outputs (see Figure6).

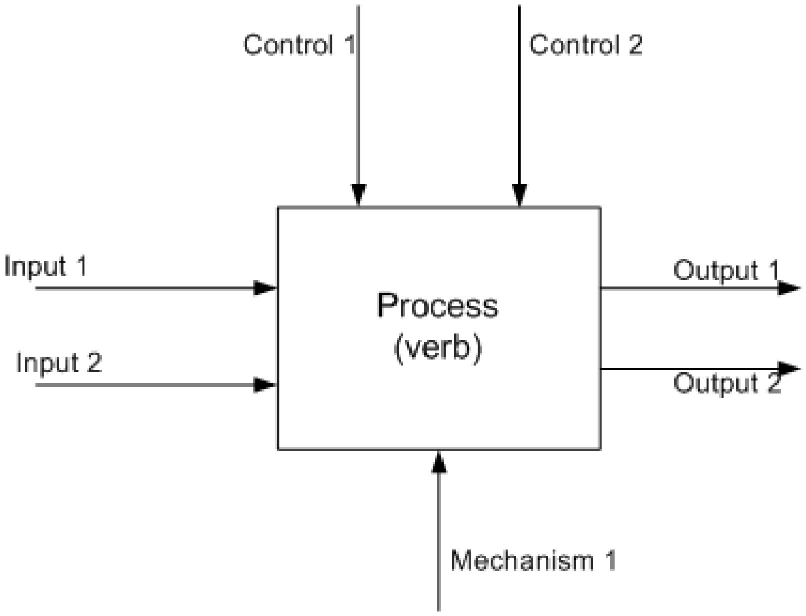


Figure 16. Generic IDEF0 Function box and data / object arrows (IDEF0, 2005)

Inputs are transformed or consumed by the process - (the raw material or ingredients).

Controls specify the conditions for the function to produce the correct output.

Outputs are the data or objects resulting from the function.

Mechanisms are the means and resources which support the process.

Models of complex processes are built up by decomposing the function boxes and data arrows such that a hierarchical structure is built (Fig 17).

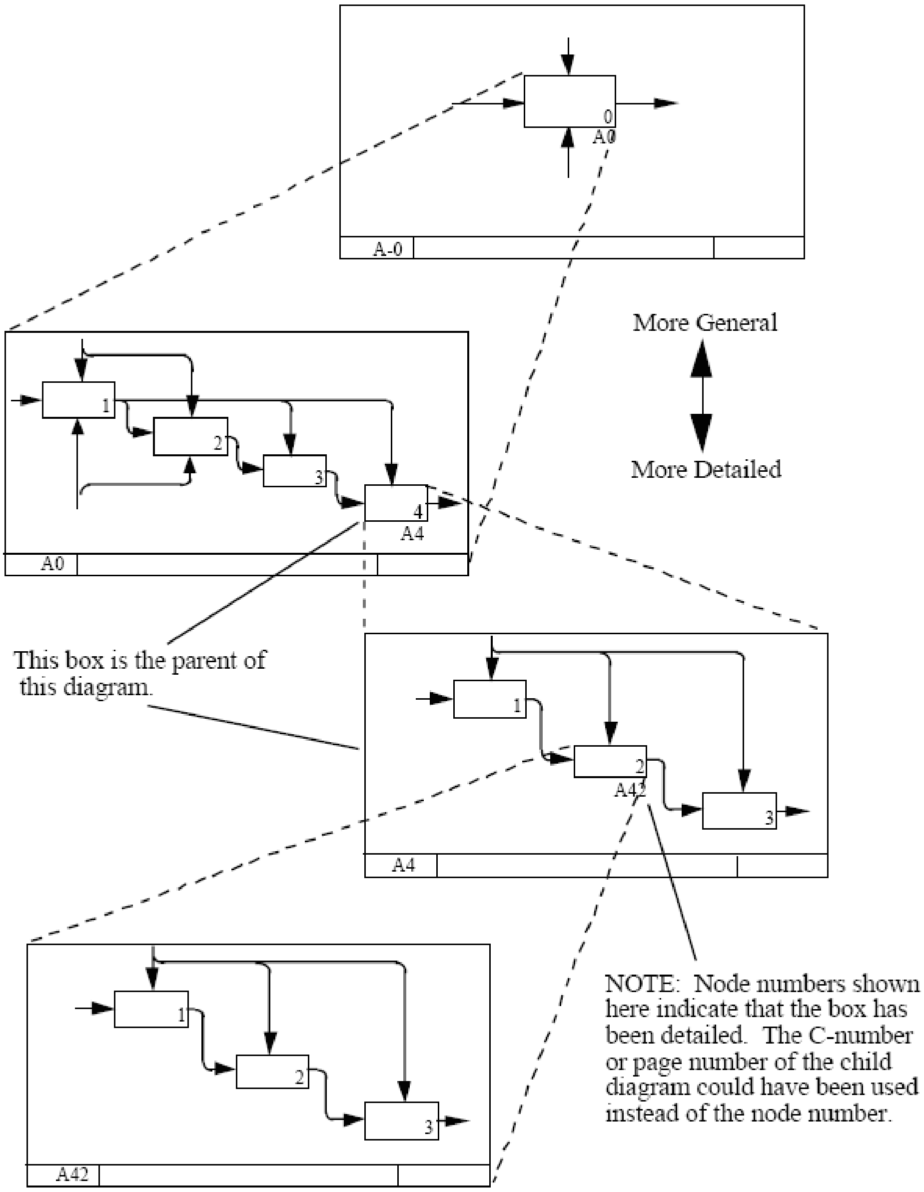


Figure 17. IDEF0 decomposition model structure (IDEF0 2005).

The Input to Innovation

Many authors describe innovation as been driven by customer requirements, for instance (Ulwick, 2002). As with many tools that pre-date Six Sigma, the Quality Function Deployment (QFD) method is part of the six sigma toolkit and would also suggest that companies looking to innovate should start by analysing customer requirements, (Mizuno S, 1994, Barker, 2002b) and creating products and services that satisfy those needs. The natural assumption is that this start point is an input.

However, the IDEF0 method is very specific in its description of an input as something that is “modified, or consumed by the process”. Clearly, although customer needs do change over time, the basic functions they want to achieve, or the jobs they want done remain constant. Although each new vehicle programme tends to increase the requirement of certain design parameters, the fundamental requirements of engine mounting systems have been constant over many years, and hence cannot be an innovation input according to IDEF0. Inventive or creative steps, add to, and therefore modify the body of knowledge within an organisation, an individual or more broadly within society. Therefore, **the input to innovation is knowledge**. But because some knowledge will always be hidden to the problem solver, the definition derived in this research is **available knowledge** – that knowledge which is available to the innovator.

Innovation Outputs

Economic theory credits innovation as being the underlying mechanism of macro economic growth, which can be measured in monetary terms (Sahal, 1981). In an industrial context, monetary value comes from either increased revenue, decreased costs or a combination of the two. Two outputs therefore result from Innovation. The first, and most important from a business perspective can be expressed in terms of profitability or **added value.** The second output of innovation is **increased knowledge / IP.**

Innovation Controls

Customer requirements are an arbiter of the benefits of innovation output, and therefore clearly categorised as a control. A second control is the requirement of the new idea to satisfy the laws of science and technology. The final generic control is the requirement of the innovation to satisfy the needs of the business – in terms of strategic objective, profitability and legislation. One can observe that there are conflicting requirements between these three controls. For instance the customer will require very low costs, whereas the supplier will prefer high costs. In order for the terminology for defining these controls to be more easily understood, they were termed constraints, ie constraints set by customer requirements and specifications, constraints within the limits of technology and science and constraints according to the needs, limitations and objectives of the business.

Innovation Mechanisms

Mechanisms were determined to be the resources required to be supplied by the business to generate innovation. The key resources are people, to create, invent and introduce the innovation. The people need to be supported by infrastructure with which to work, for instance, a place to work, to design, to manufacture, to test, to validate, to sell and to supply. There are also the tools and methodologies that are used to organise and manage the process. This allowed the top-level IDEF0 diagram of innovation to be drawn (see fig 18).

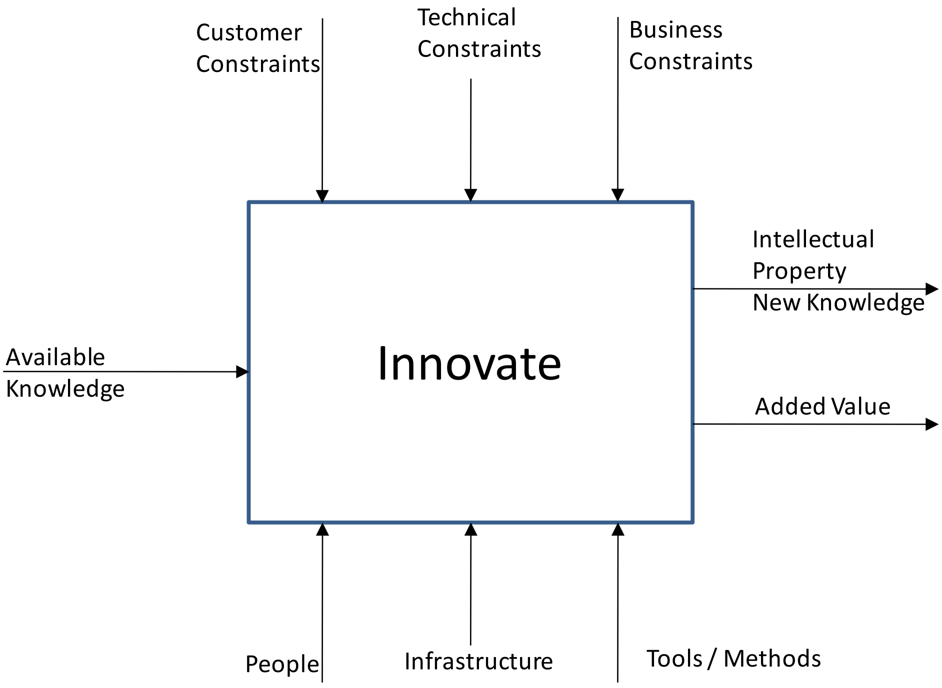


Figure 18. IDEF0 Top level A-0 diagram of the innovation process

The second layer of detail within the IDEF0 structure needed to include up to seven discrete sub processes. Observation of the stage gate process (Cooper, 2008), and the internal Avon procedures shows a clear breakdown into three separate sub process that in keeping with IDEF0 thinking are not necessarily sequential:

Technology Development - Ideation / concept screening, ending in a concept proposal.
Business Development – finding the market.
Business Realisation – exploiting the market.

The second level A0 diagram was derived (Figure 19).

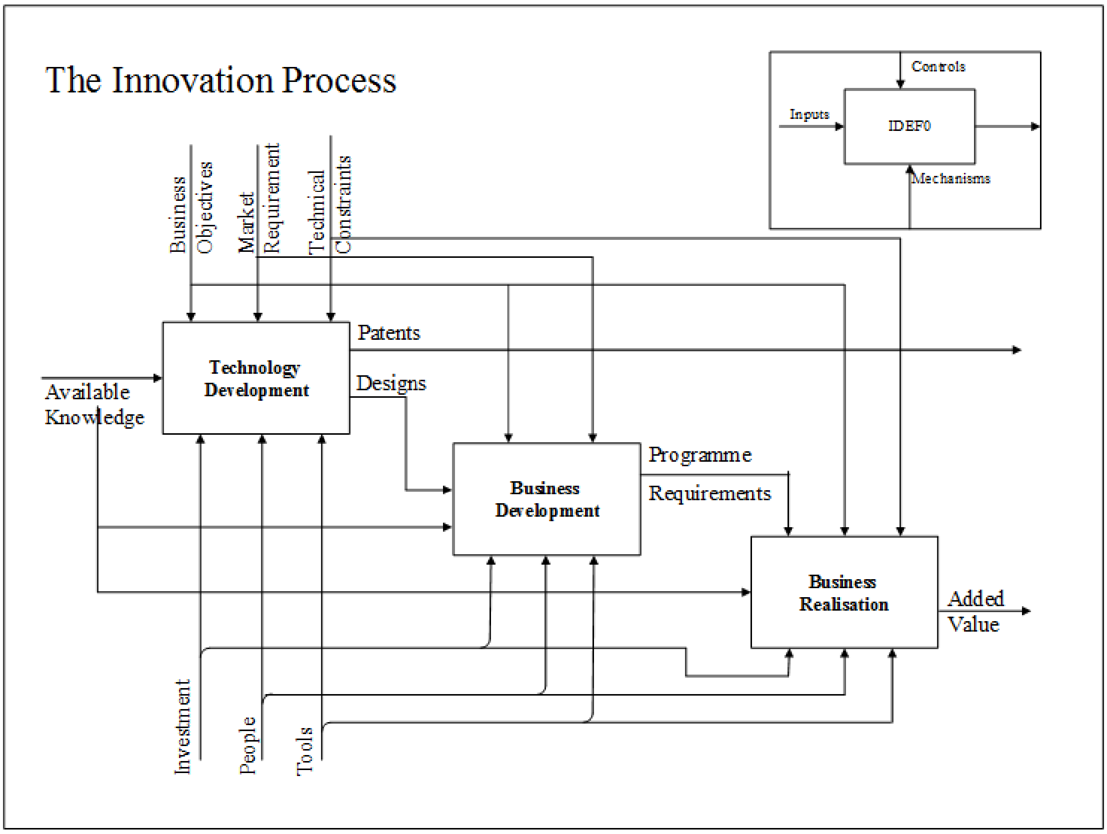


Figure 19. IDEF0 Level 0 decomposition - Innovation Process

These two diagrams were found to be sufficient to be used to derive a simple but effective method for understanding and measuring innovation as a process.

4.2 Measurement System

A relevant metric needed to be derived specifically for the research program. It needed to be simple to use, applicable to all types of innovation, consistent and repeatable over time and be able to be applied retrospectively. Using the IDEF0 model as a guide, five sub categories were identified that could be measured in the style similar to the World Class Benchmarking system (Barker, 2005a). These are :

- Commercial Potential
- Inventiveness
- Value Added
- Implementation Cost
- Risk

Each of the scoring categories is now explained in detail. In keeping with Altshullers five levels of inventiveness (Altshuller, 1999) each category is given five levels - with a higher score always being better.

Commercial Potential

The more closely a product meets or exceeds the requirements of a customer specification, requirement or need, the more likely it will be that the customer will place the order with Avon. The likelihood of achieving a higher price is also increased, especially if competitors are unable to match the performance. It can be concluded that there is a relationship between the customer constraints arrow and the output arrow of added value on the IDEF0 innovation model. Avon's primary marketing targets are large automotive customers which have many departments often with conflicting requirements. Each of these requirements can become the highest priority in the decision making process, dependant upon characteristics of the vehicle development project. Therefore, an "innovation" will be more likely to succeed if it meets the requirements of more departments, i.e. widely appealing. It will also be more likely to be successful if it is deeply compelling to the customer. This thinking leads to a 2x2 matrix (see Fig 20)

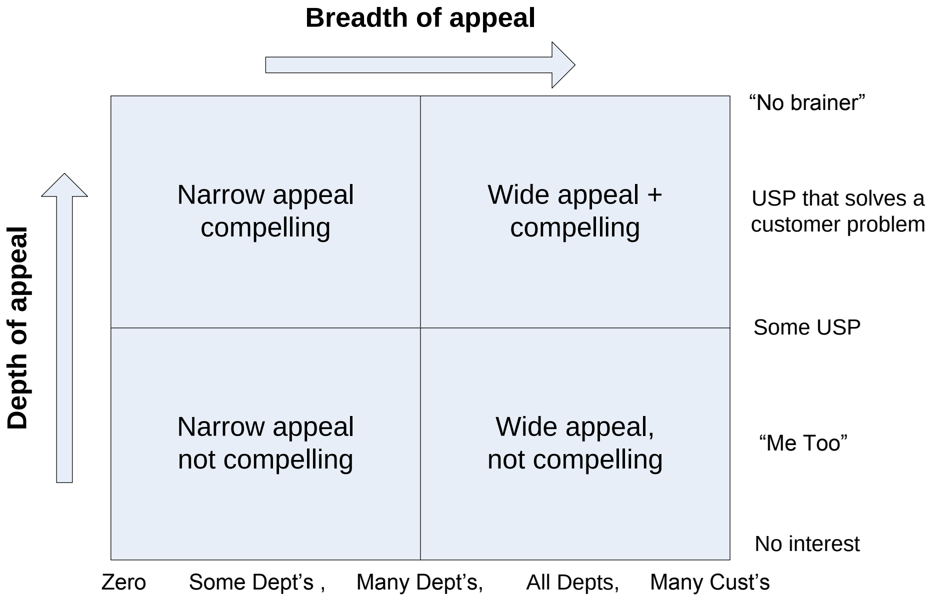


Figure 20. Guide for assessing commercial potential.

By way of example, a proposed idea may improve the durability of a component for a specific customer, whilst reducing piece part cost. If this would result in reducing returns from the field due to premature failures, it would be very compelling to the engineering department, but of little interest to the refinement team. Purchasing would clearly support the idea, and thus would score somewhere in the low scoring end of the top right hand box. If the idea involved a price increase, then the idea would fall into the "narrow appeal – compelling" box and the success would depend upon the ability of the customers engineering department to justify the improvement to its senior management on a cost / benefit analysis basis.

The highest scores should be given to ideas that have broad and deep appeal. The ideal innovation therefore must be deeply compelling to all departments within all potential customers.

Questions that help in this assessment are:

- How well does the idea match the needs of the customer?

- Does it help to resolve a difficult trade-off currently accepted by the industry?
- Does the idea differentiate Avon from competitors?
- Does it benefit the customer in a unique way ?

Cost is a factor in assessing this question, because price is certainly a customer constraint and some innovations are driven by cost saving. However, cost is assessed later on, and should not be the primary concern in this category.

Inventiveness

This category is heavily based around Altshullers' levels of inventiveness (Altshuller, 1999). This factor concerns the size of step made from existing technology. From the findings in chapter 3 the patentability of the idea is an indicator of the creativity or inventiveness of an idea. If the proposal consists of a family, rather than a single possible patent, the idea should be scored as highly inventive.

Value Added (Margin)

Value added = Sales Volume x Gross Margin

Note : Gross margin can also be termed 'Contribution' or 'Direct profit'.

Gross margin is simply the difference between the unit sales price and the unit variable cost. The sales volume impact has already been taken into account within the commercial potential category. The main factor evaluated here is the ability for Avon to increase its profitability - the difference between the cost, and the price.

Some ideas are highly inventive, and satisfy customer technical requirements, but are costly to produce. The customer may be willing to pay an increased price for a performance benefit, but will almost always be reluctant to do so. Even with highly protected, patented technology, there will always be strong pressure to drive down cost. The ideal is to achieve a win/win situation, where prices can be lowered whilst increasing margin. This is most likely to lead to increased sales volume, by increasing the depth of appeal to a wide range of customers (commercial potential measure) and therefore cash.

Cost (Development)

$$\text{Ideality} \; = \sum \text{benefits} \;\; / \;\; \sum \text{Costs} + \sum \text{Harm})$$

Equation 1 - Ideality (Altshuller 1984)

To this point, all of the elements discussed have largely considered the benefits of the innovation - i.e. the top line of the ideality equation (Eq 1). The bottom line of the equation concerns the costs of the mechanisms and resources to deliver the new products or services to the marketplace. Highly complex technology often requires long lead-times, and significant resource to develop. As development resource is finite, selection of the right programmes to go through the selection phase gate is critical to the future profitability of the business.

Lead-time is a good indicator of development cost. If a technology is likely to take more than three years to develop, then it cannot be achieved within a single vehicle development programme. If a new idea is developed for a particular vehicle programme, it is usual for the customer to contribute to the development cost. If this funding is not available, then the long term costs can be a significant impediment to development.

Some ideas however actually reduce development costs, by solving problems with the incumbent technology, or simplifying the product. This is especially true if the idea reduces the parts count, or solves a durability issue. If this is the case, the score in this section will be high.

Risk

Consideration is given to the risks associated with the assumed benefits not occurring, any harmful affects being generated, or weather any costs are likely to over-run.

Considering each side of the IDEF0 innovation model in turn :

Risk to the **input** - has the scope of development been wide enough? If not, there could be other, superior technologies, unknown during the development that reduce the lifespan of the technology.

There is a risk that **customers** are not interested. Some ideas do not achieve their anticipated benefit due to changing **customer** perception over time. For instance, an idea that focuses on vehicle refinement may be discarded because the customer puts more emphasis on sporty handling. There may be general market trends, or legislation that could work against the technology from the customer perspective.

Risk with **Avon** internal **constraints**. Will the idea become outdated due to changing Avon requirements. Perhaps the idea relates to a product or process that is about to cease production, or maybe legal, environmental or strategic issues will affect it negatively in the future.

Consider the risk to achievement of performance, or the risk of hidden costs. These are mostly likely to be hidden in **technical constraints**. Many ideas do not succeed because of unanticipated technical problems. On the other hand, some ideas are strong because they reduce the risk of using the existing technology, in which case they should score very highly here.

Finally, consider the risk of the development resources. Do the resources exist to support the development to production, and is there a risk that resources may be insufficient? Unless a very strong business case is made, additional resources are not easily obtained.

Assessment Approach

Research objective two was to measure changes in the innovation process as a result of TRIZ implementation. Therefore, a current state benchmark needed to be established in order to make a valid comparison, using the measurement system derived earlier in this chapter. There was no formal wide-ranging database of ideas on which to conduct the study, such as a suggestion scheme. Looking into the past to select ideas would be time consuming and subject to bias. However Avon VMS policy towards patent generation has remained largely consistent over time. The patent history was therefore selected as the reference database of innovation ideas. The initial assessment was made by discussing each patent with individuals involved at the time. Scores were recorded as though the session was conducted at the time of filing the patent.

The results are shown as follows in Figure 21 :

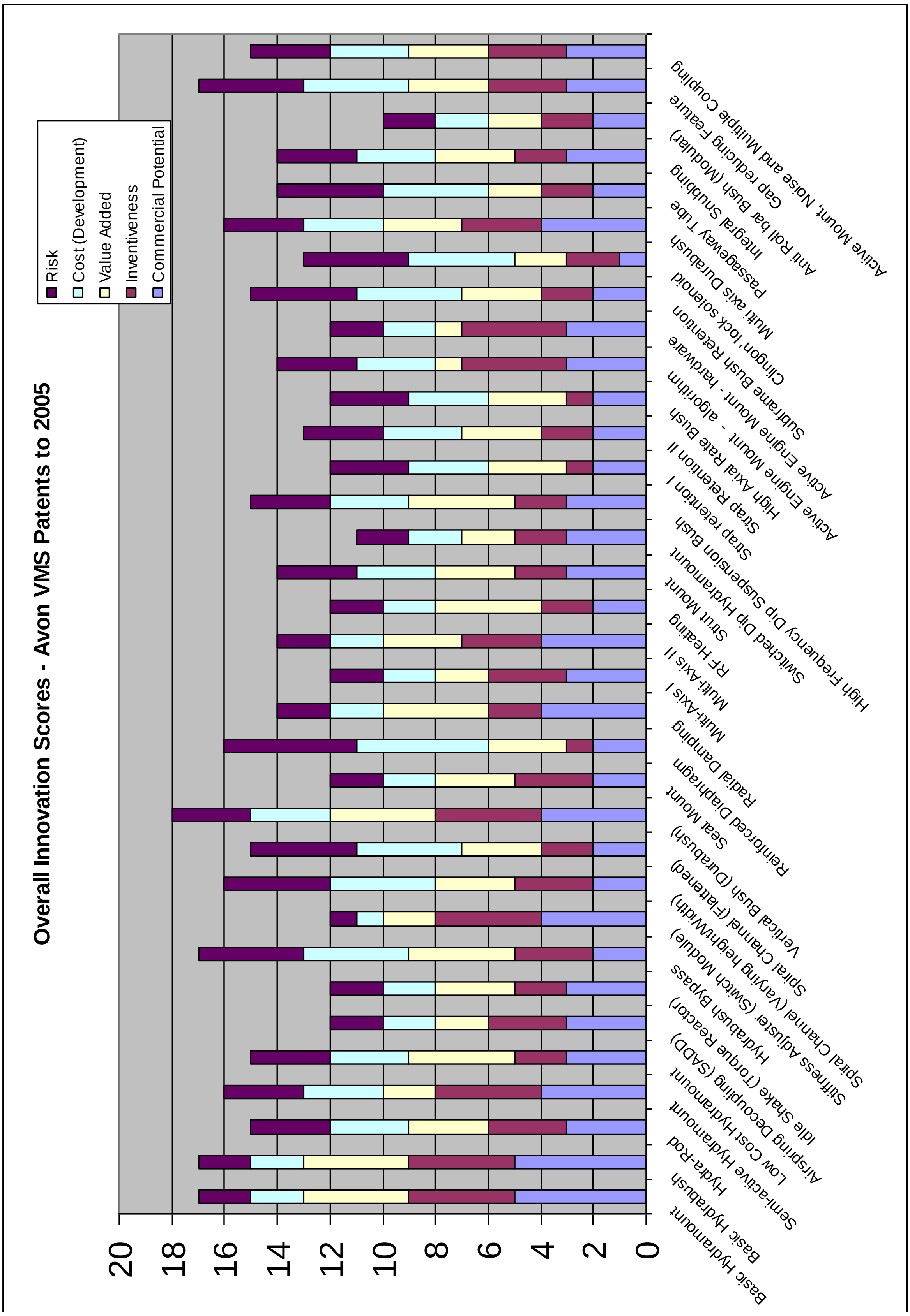


Figure 21. Innovation Metric Score of Avon VMS Patent (Ranging from early 1980's until 2004

4.3 Overall Approach

One of the most successful case studies in TRIZ implementation is Samsung (Kim, 2003). The first recorded use of TRIZ within Samsung was 1998 when a Russian TRIZ master was invited to solve a problem on a hard disk drive. The results were disappointing and were not accepted. However, it was realised that the reason for the poor outcome was that the TRIZ specialist lacked sufficient domain knowledge. Samsung decided to train Engineers in basic TRIZ, and to work together with the TRIZ specialists. They estimated that proficiency in TRIZ, would take between one and two months full time training. As this was unrealistic, they would use TRIZ specialists for "difficult problems" but also widely train their engineers in the theory, with two days of basic training followed by 120 hours of on-line and distance learning. (Platt, 2004). The published results of this are for the improvement in an 8 mm camcorder, which resulted in 3 patents, an improved productivity of 50% and reduced rejects in a process from 14% to 5%. The target for the project was to save £100k, and the achieved saving was £200k (Cheong S, 2008, Kim, 2003). Since this time, Samsung have trained over 15,000 engineers in TRIZ and transformed from being an industry follower to become one of most prolific generator of patents globally. In 2008 Samsung was granted 7,404 US patents, with IBM 6,576 and Microsoft 2,931 in third place (Reuters, 2009).

Two recommendations from the Samsung case study were considered to be applicable to Avon. The first was to start by training departmental managers. This would give managers the opportunity to give reasoned and helpful feedback, enabling the workshop content and delivery to be tailored to their staff and departmental requirements. As the managers workshop could be seen as an experimental session, various training approaches could be trialled to see which worked best, without loosing credibility within the wider business. However the experimental nature would mean it would have the highest potential risk of failure, leading to the managers seeing TRIZ in a bad light. This could have stopped the project prematurely.

The second recommendation from the Samsung case study was to develop a benchmark TRIZ project. Samsung recommended that the subject of this project should be high profile, and address a significant business need. It was considered that the managers workshop would be an effective environment for soliciting suggestions for potential benchmark projects. It was also decided that when inviting participants, each person would be asked to propose a problem on which to work, providing a collection of potential projects from which to select an appropriate benchmark project. The selected benchmark project could then be used and worked on by a team selected from people who had conducted the initial TRIZ training.

4.4 Workshop content and Timing

In this section the rationale for tool selection is presented. Several of the tools were combined and adapted from literature to create specific Avon TRIZ versions. The general TRIZ tools are introduced whilst explaining each tool specifically created for the Avon workshop.

4.4.1 Selection of Tools, Teaching Sequence and timing

Studies of TRIZ training (Mann, 2002b) have shown that after TRIZ workshops, trainees can be considered to fall into four categories as seen in table 5:

Response to TRIZ training	**%**
TRIZ is not for me	10
Preference for one tool	50
Preference for one tool, but will learn new tools as the need arises	35
TRIZ "virus" – becomes self learning	5

Table 5 Typical outcomes following TRIZ training (Mann, 2002b).

Assuming that TRIZ education within Avon would follow a similar pattern, then for the 10% for whom TRIZ is 'not for me', it would be ineffective use of time to have a long, involved course. Therefore to make the best use of the participants time, it was decided that the workshop should cover the content typical of a two day training event, but be the equivalent of one full working day. This would be achieved by splitting the course into two highly focused half days.

It was decided that the training should include the following TRIZ tools :

1. Brief history of TRIZ.
2. The underlying philosophy and scope of TRIZ.
3. Problem Definition Tools :
   a. 'Ideality', and its application to real problems.
   b. 'Functionality', and the Main Useful Function (MUF).
   c. Finding 'resources' within systems.
   d. formulation of physical and technical contradictions.
4. Solution Tools.
   a. the contradiction Matrix and 40 Principles.
   b. Trends of evolution.
5. "putting it all together" - a flow chart approach to using TRIZ.

This list was selected by considering the fundamental key TRIZ concepts (Mann, 2002c, Kim, 2003, Altshuller, 1999, Savransky, 2000, Rantanen, 2002, Mann, 2002a) and the experience of the author attending a 2-day TRIZ workshop at CREAX nv, Belgium.

By conducting the training on-site, the workshop was able to use time more effectively than typical off-site third party events. The introductory presentation was able to be made separately to each department covering basic TRIZ principles and history, effectively removing an item from the course content. There would also be no requirement for icebreaking or introductory sessions as with public courses. In the two weeks in between the sessions, attendees were asked to read the book 'Simplified TRIZ'(Rantanen, 2002) which would allow participants time to reflect on the first part of the course, and learn additional topics at their own pace. Any questions could be dealt with outside of the course itself. For candidates in the "TRIZ virus" category as described in Table 5, several copies of Hands on

Systematic Innovation (Mann, 2002a) were purchased, as this was felt to be the most appropriate, detailed reference TRIZ text.

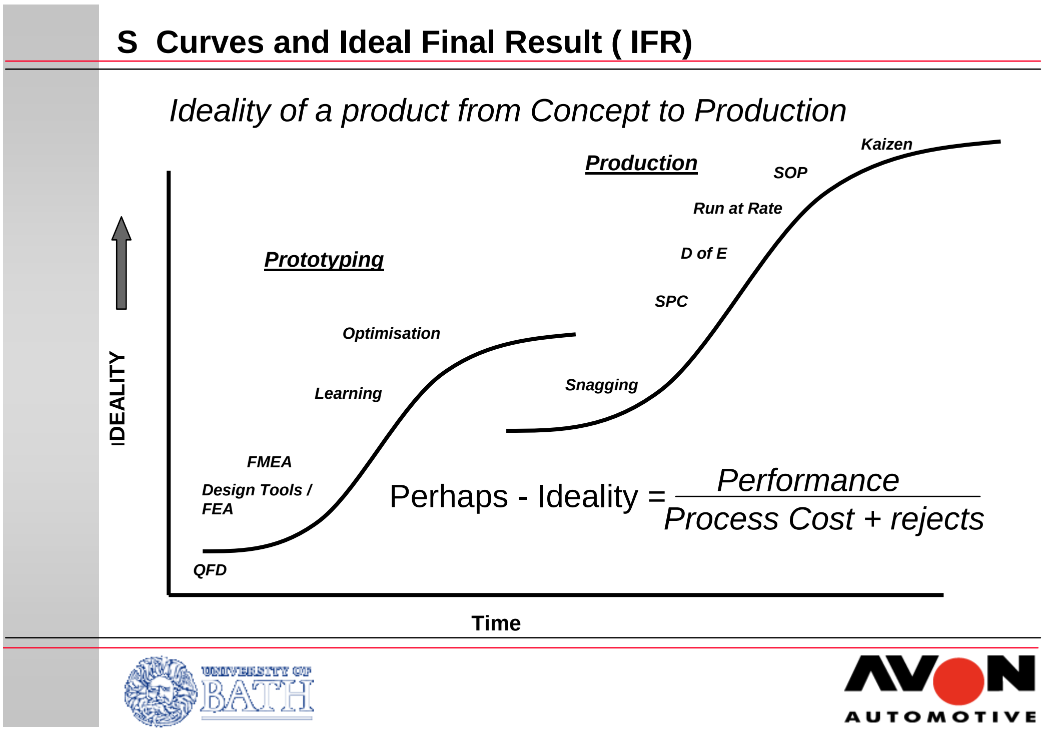
TRIZ practitioners have found that trainees struggle with the lack of a clear procedure for using the TRIZ tools. They find it difficult to know which tool to use, for which type of problem, and in what order. A common question is “which is the best TRIZ tool?” (Hipple, 2003, Mann, 2002c, Kraev, 2007) To help with this concern, the tools were to be taught in the order most likely to be used in typical mechanical problem solving situation likely to be encountered by Avon engineers. This would re-enforce step 5 in the list above.

Tools included in the training workshop are detailed in the following sections. Also forms have been designed to assist the problem solver to use the tools both in the workshop environment and during real problem solving situations.

4.4.2 Ideality / S-Curves

In studying the patent database, Altshuller recognised that technology does not develop in a linear fashion, but follows the S-Curve principle (Altshuller, 1999). A system for delivering a function develops slowly in its infancy at first, followed by rapid improvement, as early stage problems are rectified. As the most effective improvements are adopted, the “law of diminishing returns” takes over, slowing the rate of improvement until the system hits a fundamental limit and becomes fully mature. (Fig 22) At this point a new system may be invented that is fundamentally more capable of higher performance, but in its infancy is often inferior to the performance of the system it is replacing.

To demonstrate this phenomenon, a typical Avon VMS product was mapped by considering its ideality (eq 1) of time during the development process. During the early development phase the prototype manufacturing system ideality is increased to a point where it hits an optimised level, the systems fundamental limit. When the production manufacturing system is introduced, it has the potential to have significantly better ideality than the prototype manufacturing method, but is usually inferior in the early stage due to "snags" in the process. The production tooling and process develops through the S curve until the fundamental technical limit is reached (figure 22). During the transition from one system to the next the product performance requirements remain constant, but the means of delivery is changed.



S Curves and Ideal Final Result (IFR)

Ideality of a product from Concept to Production

$$\text{Perhaps - Ideality} = \frac{\text{Performance}}{\text{Process Cost + rejects}}$$

Figure 22. S Curve of development into production as presented in the workshops

TRIZ theory applies this concept to any function, regardless of complexity or type (Altshuller, 1984, Mann, 2002b). It is applicable to non technical functions, such as business services as well as technical functions (Mann, 2004, Rantanen, 2002). It is a fundamental principle of TRIZ that for a given function, ideality improves towards a state where all of the function is delivered, without any cost or harm ie, the equation tends to infinity. This is known as the Ideal Final Result (IFR). A good example of this is the activity "find information". Less than one generation ago, researching information required a trip to the library, telephone calls and physical paperwork, all of which generated costs and harm such as wasted time and material. On-line search engines such as Google have increased the functionality of search, improved search relevance, and dramatically reduced search time to almost zero. In other words this is close to the IFR, see fig 23.

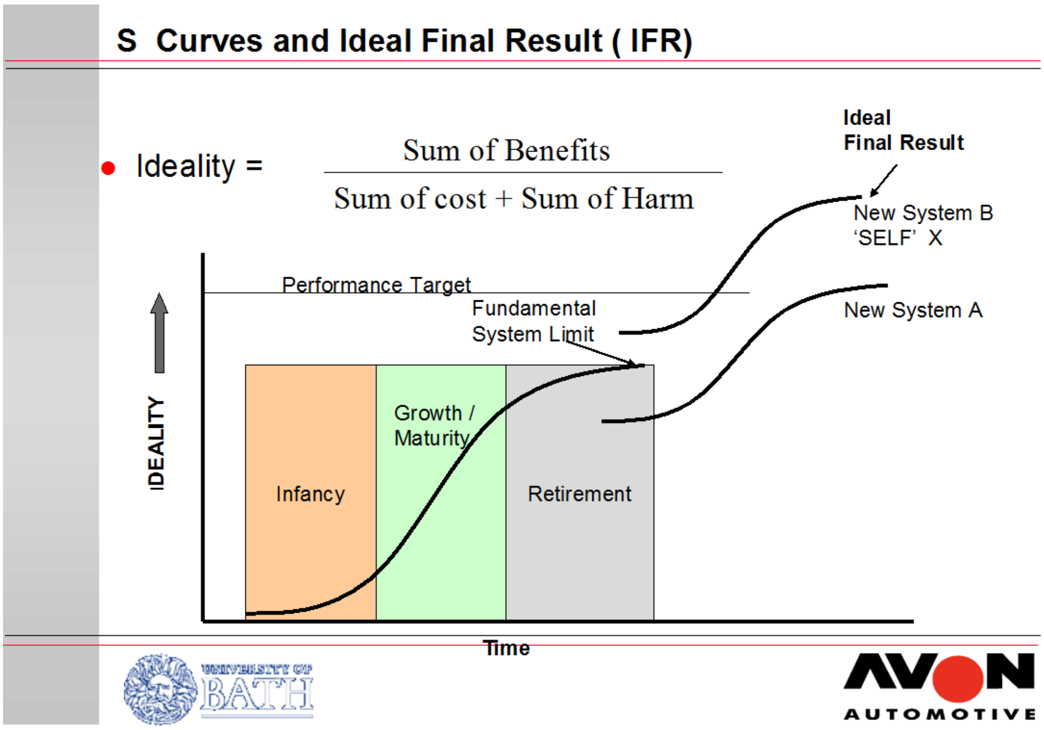
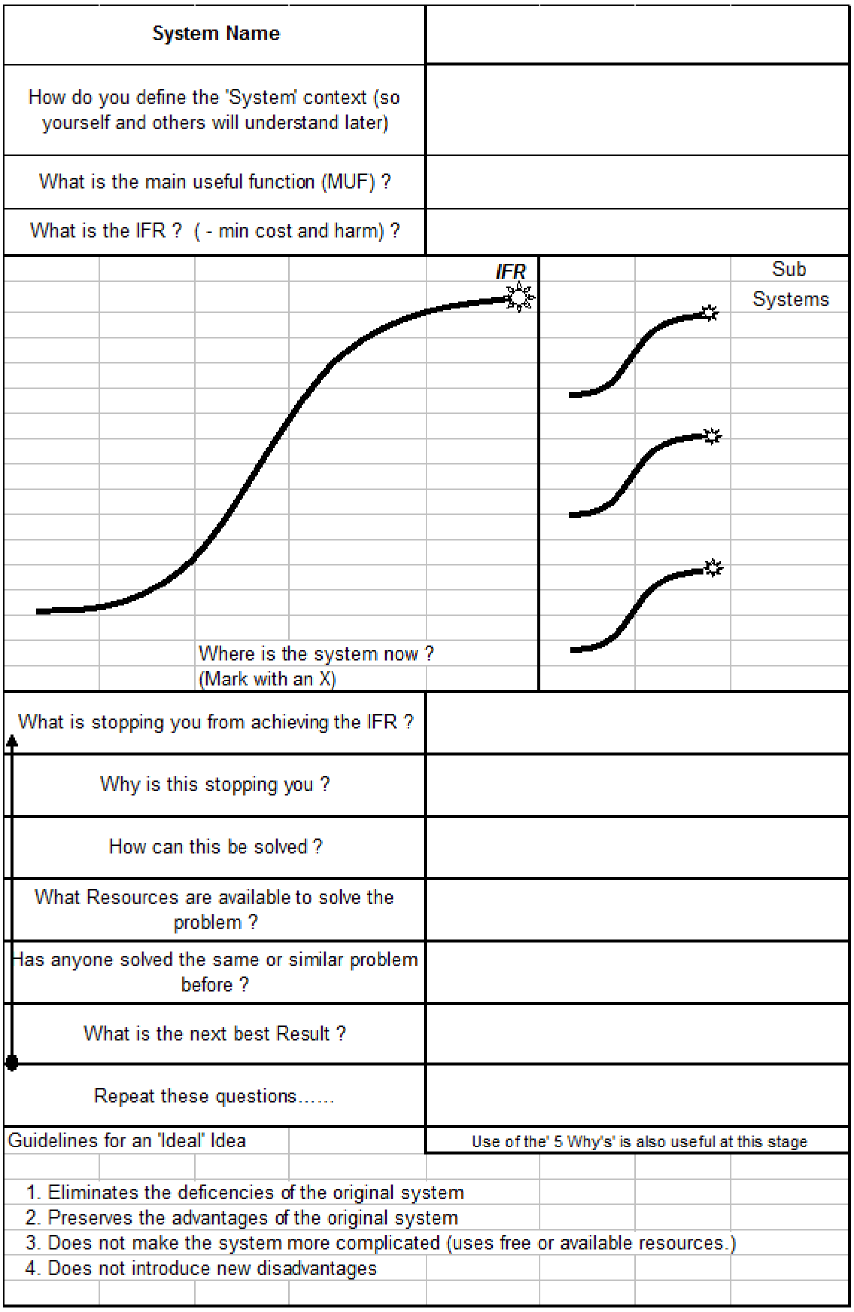


Figure 23 Ideality of a system towards the Ideal Final Result (Mann 2003).

A worksheet was devised to take the problem solver through several steps, it incorporated not just Ideality, but also the S-Curves and problem definition statements. A reminder was also added about what constitutes a good solution (Mann, 2002a, Rantanen, 2002) - (see Figure 24). In the literature, a guide to systems that are nearing the IFR is the prefix "self" (Altshuller, 1984, Mann, 2002b, Savransky, 2000, Rantanen, 2002). For example, systems that are self aligning, self cleaning, self activating, are likely to be mature methods of delivering those functions.



System Name	
How do you define the 'System' context (so yourself and others will understand later)	
What is the main useful function (MUF) ?	
What is the IFR ? (- min cost and harm) ?	

IFR

Sub Systems

Where is the system now ?
(Mark with an X)

What is stopping you from achieving the IFR ?	
Why is this stopping you ?	
How can this be solved ?	
What Resources are available to solve the problem ?	
Has anyone solved the same or similar problem before ?	
What is the next best Result ?	
Repeat these questions……	
Guidelines for an 'Ideal' Idea	Use of the' 5 Why's' is also useful at this stage

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

Figure 24. Avon VMS IFR worksheet problem definition tool.

The purpose of this tool is to first concentrate the mind on the most important function to be delivered, and to imagine the most ideal way to deliver that function. i.e. to maximise the function, and minimise the cost and harm – tending to zero. The first section includes a statement to invite the problem solver to clearly state the definition of the system being considered. This helps to avoid confusion, or a lack of clarity over exactly what is being studied when communicating to others, or future reviews of the problem.

The S-Curve analysis encourages the problem solver to consider the maturity of the system in relation to the IFR. If the system is not close to the IFR, this promotes a mind-set that there is still potential for the system to develop. If it is close to the IFR, then a new system probably needs to be developed, which requires a fundamentally different approach to finding a solution. This part of the tool also encourages consideration of the development history of the system, and where it is heading – i.e. the concept of time. Through encouraging evaluation of the sub system S-Curves, the mind is also being prepared to look at the hierarchy of the system – concept of space. Thinking in time and space is the fundamental principle behind the 9-windows tool (see section 4.4.4).

The middle section of the tool is a step by step questioning technique adapted from (Mann, 2002a, Rantanen, 2002), which starts the process of working back from the ideal, perfect scenario through next best, steps. It also introduces the concept of identifying resources that could be used to solve the problem – again these are considered in more detail in the 9-windows tool as in section 4.4.4. The concept of looking for similarities between the specific problem identified, and other situations is introduced before the user is asked to repeat the process, and ask "why questions" frequently.

Finally, there is a list of the four guidelines (Rantanen, 2002) that describe the ideal solution. That the solution eliminates the deficiencies of the original system, preserves the advantages of the original system, does not make the system more complicated (uses free or available resources) and does not introduce any new disadvantages. This provides a small amount of idea evaluation, and discourages the problem solver from settling for ideas that do not significantly increase ideality.

By using this single page tool, the problem solver gets to define what is being studied, and is then guided in thinking about, and recording the initial elements of further tools, including the formulation of statements that help to identify contradictions – a key TRIZ concept.

4.4.3 Contradictions

An Excel spreadsheet was developed to create a template for identifying and recording contradictions (figure 25). The problem solver is invited to describe what in the system is being considered, and then to identify and record “trade-off” contradictions. When a parameter such as ***weight*** needs to “get better”, other parameters, for example ***strength*** are often compromised. This pair of conflicting parameters is known in TRIZ as a trade-off contradiction (Altshuller, 1984). This follows logically from the IFR/S-Curve tool in the previous section 4.4.2, which has already invited the problem solver to consider factors that are preventing the achievement of the IFR.

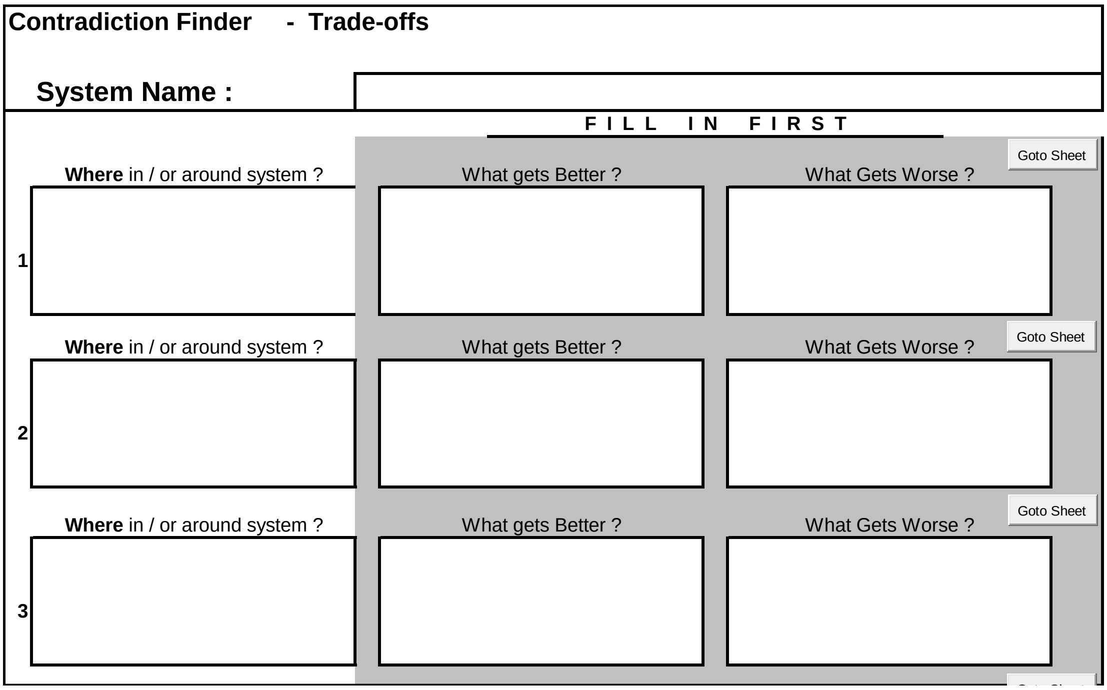
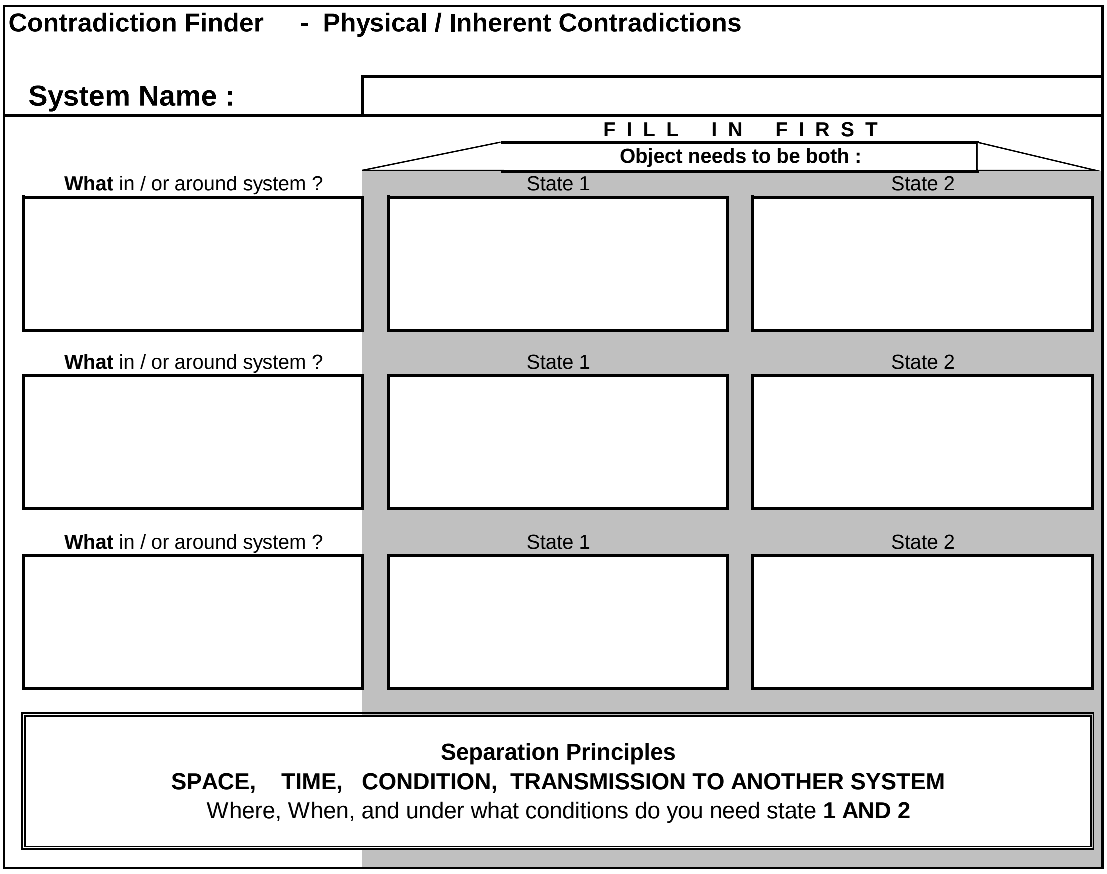


Figure 25. Avon VMS contradiction finder - tradeoffs.

The template shown in Figure 25 provides space for the problem solver to give the system under consideration a name, and then to identify the contradicting tradeoff parameters. The left most box "where in / or around system" was included to help the problem solver to record where the tradeoff exists, which helps in understanding the contradiction when referring back to the work, or sharing with others.

The second type of contradiction occurs when a feature or parameter of a system needs to be in two contradictory states simultaneously. For instance, it may need to be both large and small, fast and slow, strong and weak, hot and cold, present and absent. This is known as an inherent, or physical contradiction. A worksheet was included in the Excel spreadsheet to provide a template for physical/inherent contradictions. This included a reminder about the four ways to eliminate this type of contradiction, ie the separation principles, see figure 26



Contradiction Finder - Physical / Inherent Contradictions

System Name :

FILL IN FIRST

Object needs to be both :

What in / or around system ?	State 1	State 2
What in / or around system ?	State 1	State 2
What in / or around system ?	State 1	State 2

Separation Principles
SPACE, TIME, CONDITION, TRANSMISSION TO ANOTHER SYSTEM
Where, When, and under what conditions do you need state **1 AND 2**

Figure 26. Avon VMS contradiction finder - physical / inherent contradictions

4.4.4 Nine Windows and Resources

The purpose of this tool is to develop understanding of the problem in time and space. Within this framework the problem solver is guided in the identification of resources which could be used to address contradictions, and increase ideality. Resources are defined in TRIZ as "anything in or around the system that is not being used to its full potential". This includes harmful things (Mann, 2002b).

Figure 27 is the standard TRIZ concept known as the System Operator, or nine windows tool :

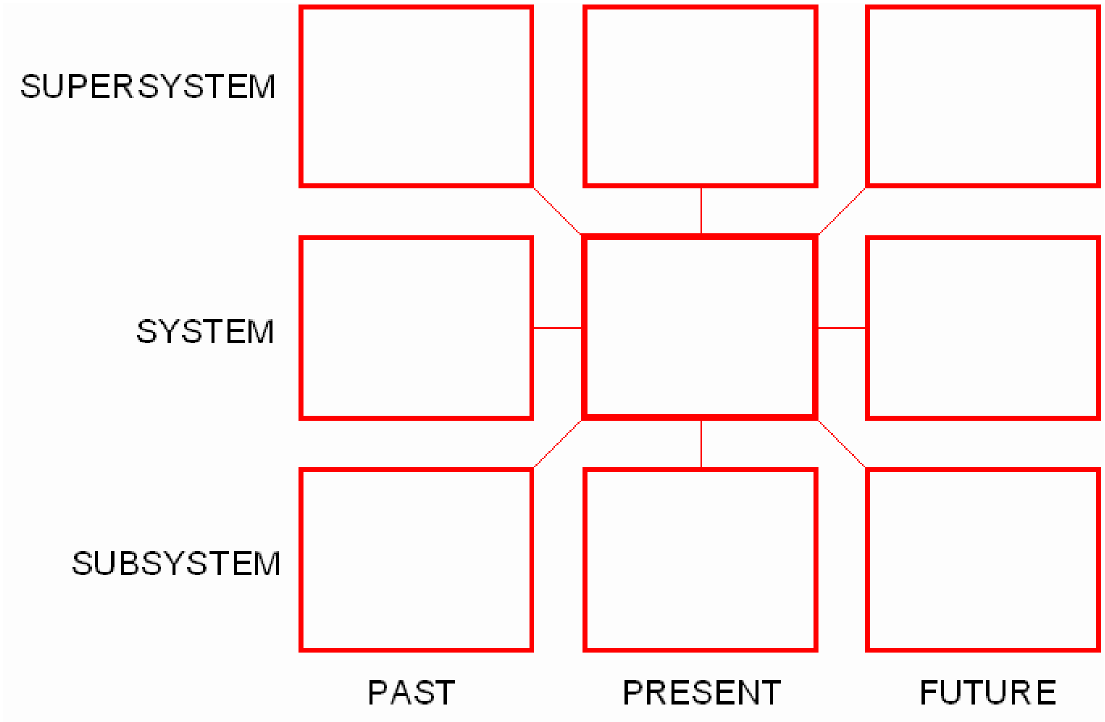
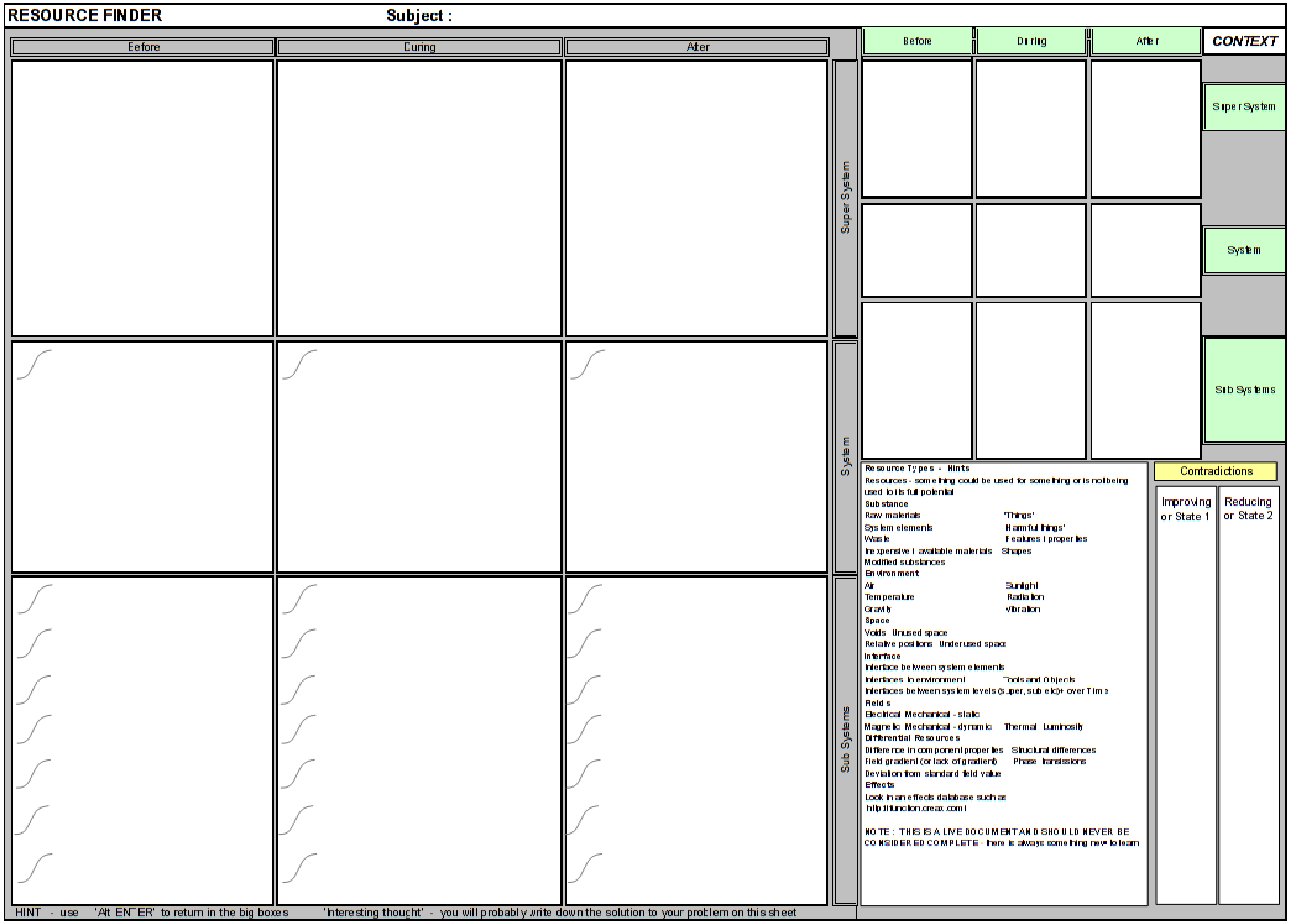


Figure 27. The nine windows (Mann 2002).

The panes in the left hand column are defined as being in the past, the central panes being the present and the right hand being the future. The middle row of panes is the system, the lower row is the sub systems and the top row the super-system to which the system belongs. The definition of what the future means, i.e. whether it is generally the future, or a specific point in time, and what the system levels are, are decisions made by the problem solver. The central pane of the nine windows therefore becomes the time and space that the problem solver decides is the focal point of the problem / system under consideration. This is typically the time and space that the problem solver naturally tends to focus on. The inability of the human brain to break out of this "box" is a contributing factor to the phenomenon called "psychological inertia" (Pisano G), whereby the problem solver tends to jump to conclusions, rush to solutions and fail to see the problem from different standpoints (Altshuller, 1999, Mann, 2002a, Rantanen, 2002, Savransky, 2000). One of the purposes of the nine Windows tool is to hold the problem solver in problem definition mode, postponing the natural rush to generating solutions.

The resources available within each pane are identified and recorded. Whilst attending a TRIZ training workshop (Creax nv Belgium), the author observed that some participants experienced difficulty in relating their problem situations to the nine window panes. It was therefore decided to separate the definition of the nine windows from the recording of resources. An A3 spreadsheet was developed to achieve this (fig 28).



RESOURCE FINDER **Subject :**

Before During After

Super System

System

Sub Systems

Before During After **CONTEXT**

Super System

System

Sub Systems

Resource Types - Hints
Resources - something could be used for something or is not being used to its full potential
Substance
Raw materials 'Things'
System elements Harmful things'
Waste Features / properties
Inexpensive / available materials Shapes
Modified substances
Environment
Air Sunlight
Temperature Radiation
Gravity Vibration
Space
Voids Unused space
Relative positions Underused space
Interface
Interface between system elements
Interfaces to environment Tools and Objects
Interfaces between system levels (super, sub etc)+ over Time
Fields
Electrical Mechanical - static
Magnetic Mechanical - dynamic Thermal Luminosity
Differential Resources
Difference in component properties Structural differences
Field gradient (or lack of gradient) Phase transitions
Deviation from standard field value
Effects
Look in an effects database such as
http://function.creax.com/

NOTE : THIS IS A LIVE DOCUMENT AND SHOULD NEVER BE CONSIDERED COMPLETE - there is always something new to learn

Contradictions

Improving or State 1

Reducing or State 2

HINT - use 'Alt ENTER' to return in the big boxes 'Interesting thought' - you will probably write down the solution to your problem on this sheet

Figure 28. Avon VMS resource finder and nine windows tool pro forma

The top right hand corner of the A3 sheet, and the main body, are divided into the nine windows. The top right area is to focus the attention of the problem solver on drawing / sketching the context of each pane. The act of sketching is a useful way of exploring a problem (Goldschmidt, 1991, Verstijnen, 2004). Sketching helps to develop analogy, which is particularly important to TRIZ, and is a skill that some people find difficult This is re-enforced by the need in the workshop to offer balance between learning thinking styles (Felder, 1988). Sketching, especially with paper and pencil adds a tactile and visual element to the learning experience. Once the context is derived in the top right hand corner, the problem solver can then populate each of the panes in the main central area with identified resources. Small S curves were added to serve as a reminder of the maturity of the system, and a check list of potential resources included in the right side. This list was derived from literature, in particular (Mann, 2002b, Savransky, 2000, Rantanen, 2002).

A link was also included within the tool to a database of functions and effects (Creax). This is a helpful, and free on-line database containing look-up tables for scientific principles that deliver specific functions.

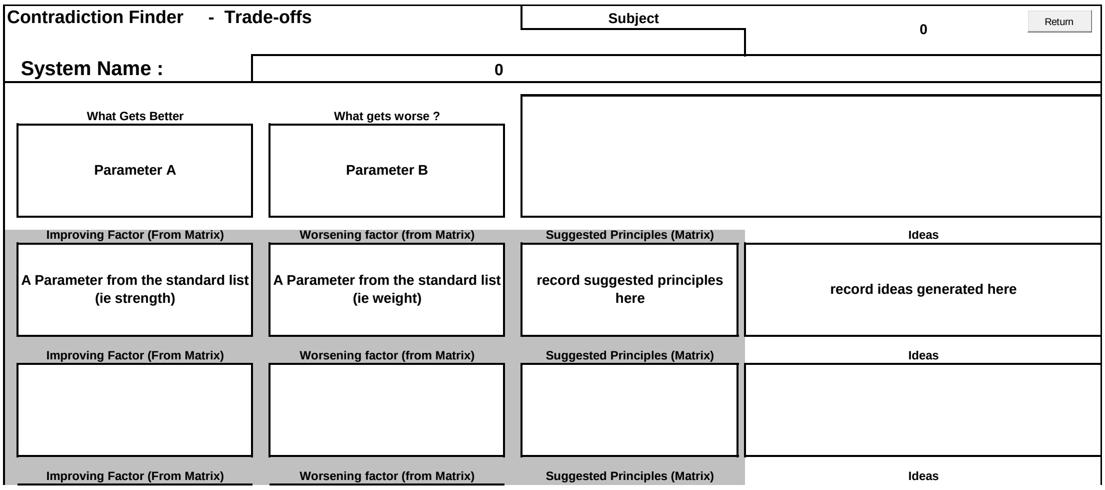
4.4.5 The matrix and 40 Inventive Principles

The matrix is often considered the heart of TRIZ, although there is some debate between practitioners over its use. Mainly because other tools are thought to be less complex, and more powerful (Mann, 2003)

Through researching millions of patents, Altshullers research team identified 40 inventive principles that inventors had used to solve contradictions. Examples of inventive principles are to "*segment*", or "*use thin films*", or "*use asymmetry*". These inventive principles can act as brainstorming aides, guiding problem solvers in good directions. However, to consider all 40 inventive principles for a single problem was thought to be time consuming, and therefore Altshuller derived the Matrix (Lerner, 1991). A contradiction is described through using a standardised list of parameters, such as *strength, weight, ease of use, loss of energy* etc, with each parameter describing one half of the trade off contradiction. Altshullers' team investigated over

2 million patents, and populated the matrix with the inventive principles most commonly used to solve each contradiction pair. The matrix is therefore a lookup table which guides the problem solver to a short list of inventive principles that have been found to successfully resolve a contradiction according to the patent database.

When relating the language of the specific problem to the matrix parameters, there can very often be multiple interpretations of meaning. For instance, improving the efficiency of a technical sub system may lead the problem solver to look to improve "*loss of substance*", but also "*loss of energy*" may also seem relevant or even "*energy used by moving object*". By clicking the "Go to Sheet" button on the contradiction finder Excel worksheet shown in figure 25, the problem solver is taken to a supplementary worksheet, shown in figure 30. This allows each contradiction pair, as described in the language of the specific problem, to be interpreted in different ways according to the matrix parameters. The ideas generated by the suggested inventive principles can therefore be included at this point.



Contradiction Finder - Trade-offs

Subject: 0

System Name : 0

What Gets Better: Parameter A

What gets worse ?: Parameter B

Improving Factor (From Matrix): A Parameter from the standard list (ie strength)

Worsening factor (from Matrix): A Parameter from the standard list (ie weight)

Suggested Principles (Matrix): record suggested principles here

Ideas: record ideas generated here

Improving Factor (From Matrix)

Worsening factor (from Matrix)

Suggested Principles (Matrix)

Ideas

Improving Factor (From Matrix)

Worsening factor (from Matrix)

Suggested Principles (Matrix)

Ideas

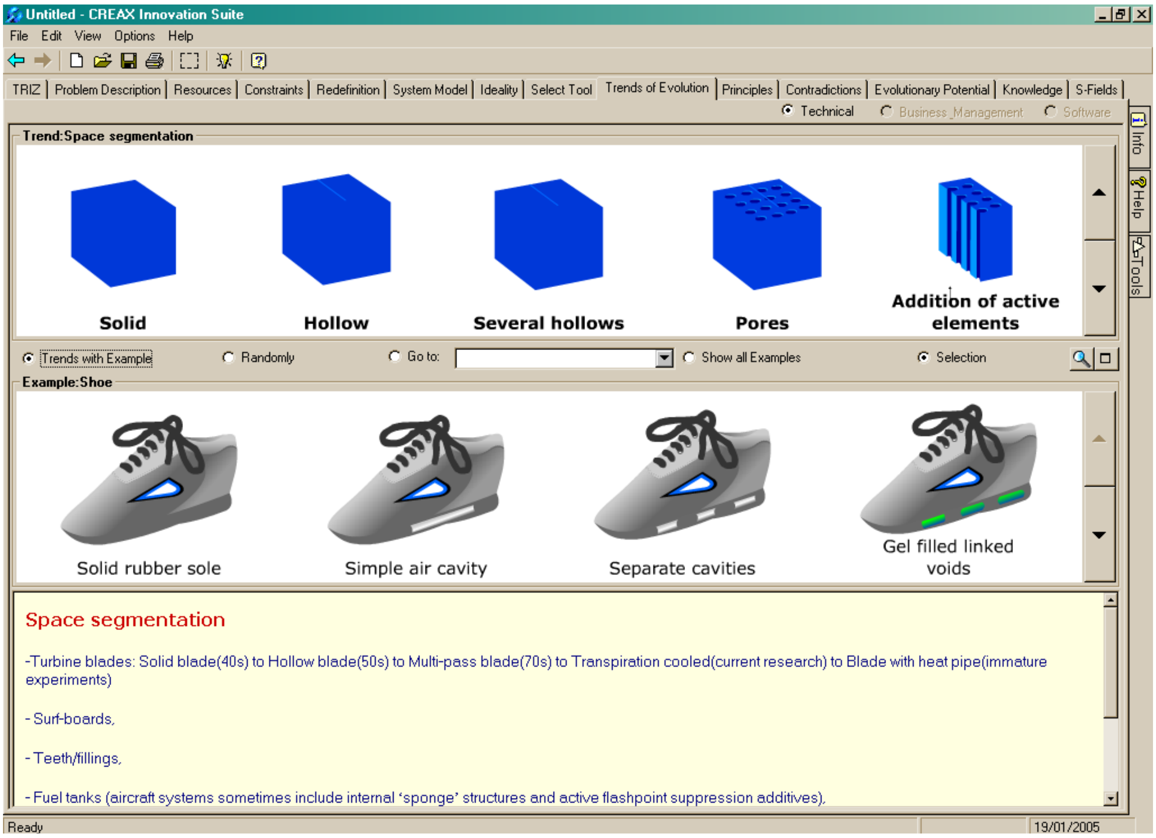
Figure 29. Avon VMS Contradiction finder worksheet for capturing contractions and ideas.

The use of the matrix is said to help the problem solver overcome psychological barriers, as the mind is put into a mode of expectancy that someone has already solved a similar problem before – making the specific problem in hand seem less intractable (Mann, 2002b).

More detail on the use of this tool is described in the case study in 5.3.5

4.4.6 Trends of Evolution

The trends of evolution are essentially patterns of technological jumps. Each jump solves a contradiction and advances the system along the S-Curve towards the IFR. These jumps also relate to the inventive steps that are a fundamental attribute of patentable ideas, see Section 3.2.1.



Space segmentation

-Turbine blades: Solid blade(40s) to Hollow blade(50s) to Multi-pass blade(70s) to Transpiration cooled(current research) to Blade with heat pipe(immature experiments)

- Surf-boards,

- Teeth/fillings,

- Fuel tanks (aircraft systems sometimes include internal ‘sponge’ structures and active flashpoint suppression additives),

Figure 30. Example of Trends of Evolution – Space Segmentation – screen shot from Creax innovation suite software tool.

Figure 30 shows one of the trends – space segmentation. This illustrates how technology has evolved from left to right, from entities that are solid, through several steps and into elements that are porous with active elements. The example shown is for the evolution of the training shoe. It was noted that this trend was also evident within the products of Avon VMS, see fig 31.

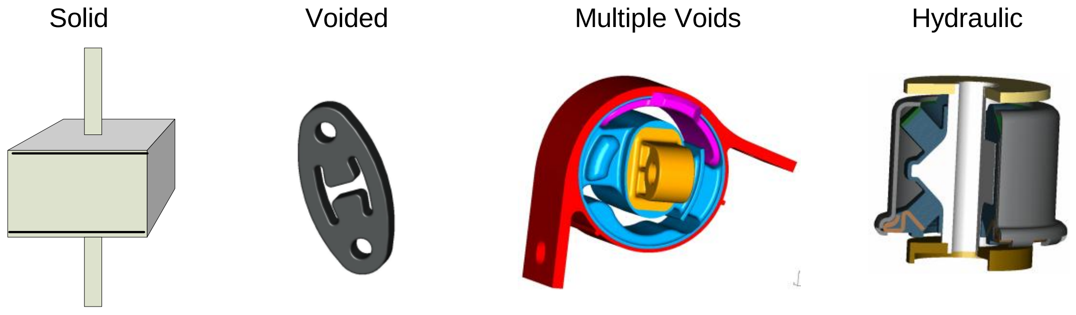


Figure 31. Illustration of the development of rubber components over time (left to right) – in accordance with the TRIZ trend "Space Segmentation".

It can be noted that according to the space segmentation trend, the automotive vibration management industry has evolved through a similar path to the sports footwear industry. There are over 30 of these trends and unlike the 40 principles are being added to by researchers into TRIZ globally (Mann, 2002b).

The job of the problem solver is to make a connection between the system being studied, and the trend. The trend then effectively challenges the problem solver to think of ways to move the technology along the trend. This is explained in more detail in 5.3.6

The following tools were considered, but not included, and would be added to any future 'advanced TRIZ' training :

- Smart Little People
- Function / Attribute Analysis (FAA)
- Trimming
- Algorithm of Inventive Problem Solving (ARIZ)
- Substance-Field Modelling
- 76 Inventive Standards

These tools were considered too complex to include within the scope of a short introductory workshop. More details can be found in literature (Savransky, 2000, Mann, 2002a, Rantanen, 2002, Altshuller, 1999).

4.5 Teaching Methods

It is known that people have different learning styles and a well documented model is the cycle of learning (Figure 32).

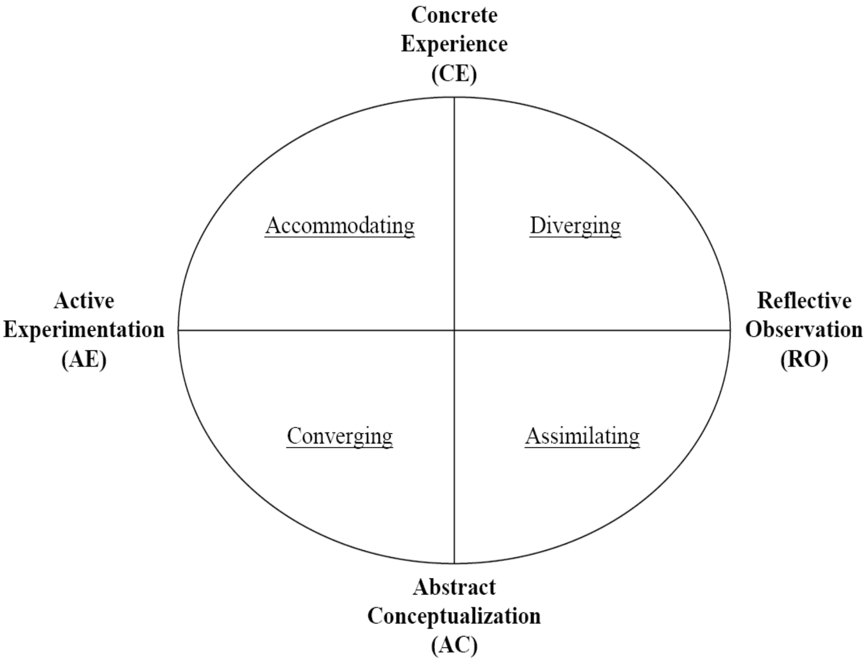
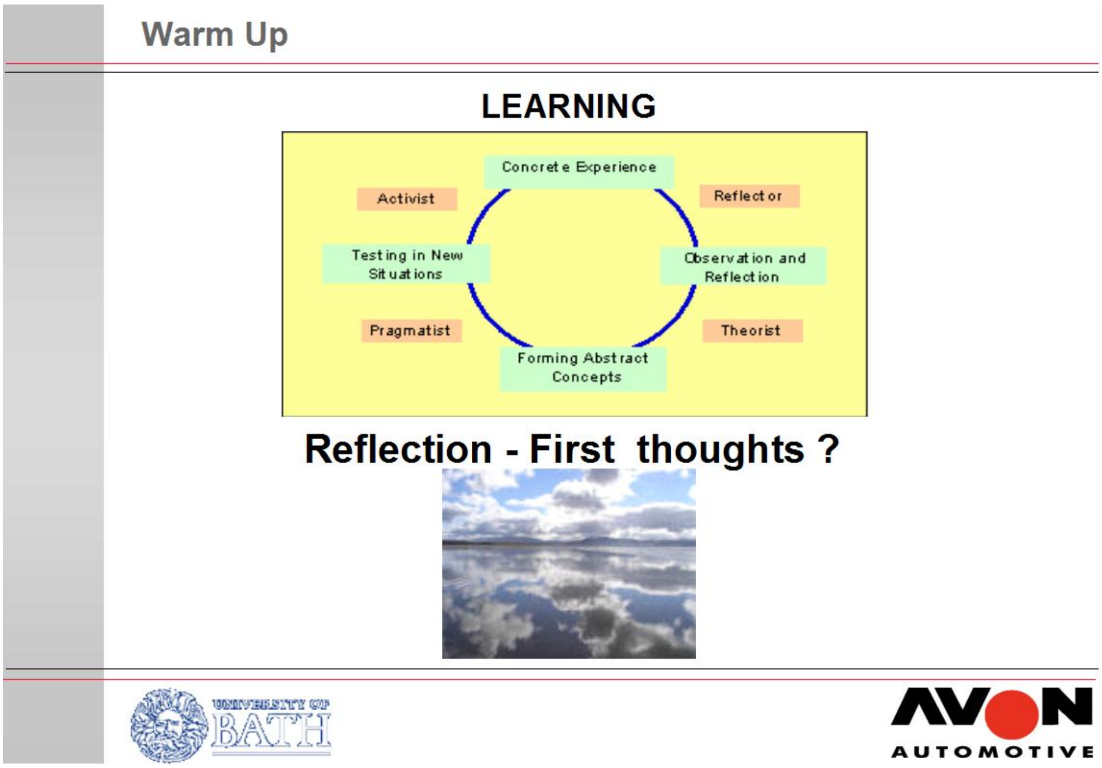


Figure 32. The Experiential Learning Cycle and Basic Learning Styles (Kolb, 1984).

When delivering course content, learning is aided by clearly presenting which thinking mode the delegate is supposed to be in and why. (Hill, 1990, Rosewell, 2004). If the delegate knows when they are supposed to be in specific thinking mode and why, then learning is likely to be more complete. This was re-enforced within the training using the following graphic within the power-point presentation (Figure 33)



Warm Up

LEARNING

Concrete Experience

Activist

Reflector

Testing in New Situations

Observation and Reflection

Pragmatist

Theorist

Forming Abstract Concepts

Reflection - First thoughts ?

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Figure 33. Learning cycle as presented in the course introduction.

It was presented to the delegates that concrete experience could not be taught in the workshop, but would be gained by use in the real world. Within the workshop delegates were not simply there to be taught in a theorist / lecture style, but through trying to use the tools on sample and real problems themselves, and to reflect on the learning experience. This was also supported by research into effective teaching of engineering (Felder, 1988, Reid, 1987) which emphasises the use of a range of activities to stimulate kinaesthetic, auditory, and visual learning by allowing group discussion, working as individuals, and through lecture style presentation of theory and content.

4.6 Preparation for the Workshop

In addition to preparing the presentation slides, case study material was needed in order to be able to refer to a constant set of examples when explaining the tools. Two sample problems were formulated, based upon real industrial situations and half of the group looked at each tool. One example is shown in Appendix 8 – the “Avon Power generation problem”, which challenges the workshop participants to solve a problem with excessive coal dust. These problems would then be used as worked examples with which to introduce various TRIZ tools, with the desired outcome that participants would experience the usefulness of the tools in generating good solutions in a problem that felt real to them.

A clear risk was that someone may solve one of the problems immediately without TRIZ – hence it was thought that two case studies would be useful in case of this eventuality.

5 Implementation Phase

This section presents the way in which the action cycles were applied. The lessons learned and feedback loops.

5.1 Action Cycle 1 - Managers Workshop

All of the Managers invited attended the session, which was a good sign of support for the project.

The first task was to get the participants feeling engaged with one of the example problems. Initially, no TRIZ tools were available to the team, and they were tasked with trying to solve these example problems in the way they would normally tackle such a situation. Sufficient information was available in the problem explanations to allow several highly inventive, but non obvious solutions to be offered, needing only basic general technical knowledge. The teams were asked to suggest solutions, and discuss how Avon would approach solving these problems.

The workshop then moved through the planned agenda as detailed in Appendix 11.1 and then two weeks later, having read the book Simplified TRIZ (Rantanen, 2002), the second session shown in Appendix 11.2 was conducted and all the new forms/tools used “in anger” for the first time.

5.2 Reflection and Learning

According to the Action Research methodology described in section 2.3, reflection was undertaken on the first action cycle.

The pace of the course seemed too quick for most participants in session one. Two theoretical case studies were felt to be unnecessary and required two sets of explanation. Some content presented to the managers about the research programme background and the innovation process would also not be necessary for further workshops.

Key elements that were recorded in the reflection sessions were :

- The example problems felt real enough to the participants and helped to “break the ice” at the beginning. But two case studies were felt unnecessary
- When considering the case studies, there was a perception that the team were trying to find the one right answer. It needed to be stressed repeatedly that there could be several solutions offered, and there was no specific single one correct answer.
- Contradictions were a powerful tool, but the matrix seemed more complex than necessary.
- Simplified TRIZ (Rantanen, 2002) did not explain the matrix very well, but was very useful for everything else (there were some typographical errors found in the book which let it down also).
- The IFR tool (see section4.4.2) was well received – especially for non-technical problems. One manager felt that it had helped with a budget setting problem
- There was a need to generate a specific Avon case study.
- After working through several of the example problems brought by the attendees, the author realised that the use of the FAA tool for mapping the problem would have been helpful. It was considered that this tool would fit very well into the organisation due to its similarity to the functional chunking part of the Design FMEA method. It was recommended that this tool be added to the workshop content.

The delivery and professionalism of the course was acceptable, and the managers unanimously agreed that the training would benefit their employees. They were keen to see what ideas may come from it. It was proposed to use a standardised form with questions to stimulate debate during the reflection sessions. Some of the data was collected during reflection sessions after use of each tool – to get the initial opinions of the participants. The main feedback form see appendix 11.9 was to be completed within 2-3 days of the course and returned to the trainer (the author).

5.3 Action Cycle 2 – Workshop 1

The feedback from the managers workshop was implemented. Only one theoretical case study was used, FAA was added to the first day in place of the content explaining background to the research programme.

One person was unable to attend, meaning the first workshop was five rather than six people.

A delegate who was a Quality Engineer brought the “MSB Engine Mount” as a case study (Frobisher, 2006). An engine mount that had been in production for around 12 months and suffered from recurring customer concerns which despite significant effort had not been resolved. 100% of the mounts had to be checked against a measuring fixture, and adjusted if found to be out of alignment. Occasionally, this was not sufficient, resulting in further customer concerns, and inspection / sorting activities at the customer assembly line.

The mount had been developed by an experienced simultaneous development team using Advance Product Quality Planning (APQP) techniques, including: phase gate sign-off, design review, process review, Design-FMEA and Process-FMEA. The usual design solution for easy orientation of the products during assembly is to develop right-hand and left-hand components, with interlocking features. This is known as Poke-Yoke (Japanese term for mistake proofing). In this case however, tooling cost considerations led to the development of a common left / right design. The engine mount passed all validation tests at prototype and pre-production development phases. It was jointly signed off by Avon and the customer as acceptable. The orientation problem only became apparent at the customer assembly plant several months after the start of production. The development team, including the customer engineers had agreed that because the orientation could be adjusted manually, if any misalignment did occur the line assembly operator would be able to easily adjust to engage with the twin fixing bolts. This risk was deemed acceptable in comparison with the tens of thousands of pounds worth of tooling investment that would have been involved in producing left and right hand variants.

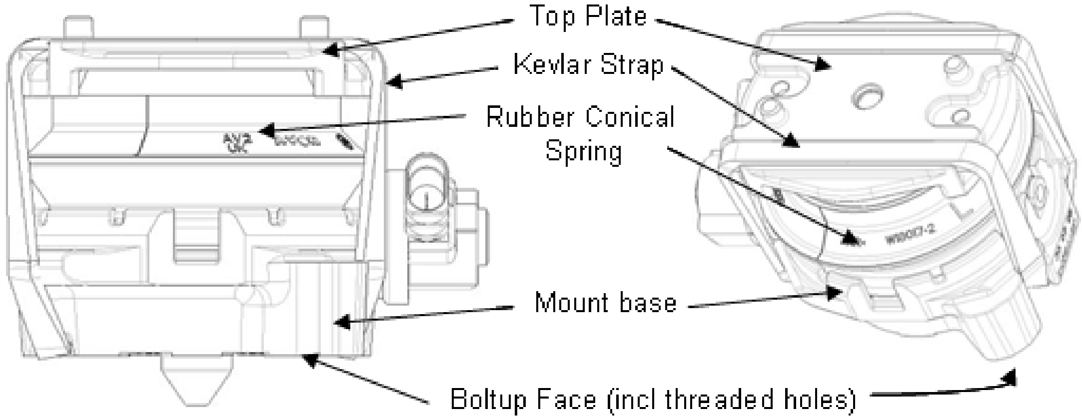


Figure 34. Drawing showing the key components of the "MSB" engine mount.

During final assembly of the engine mount at Avon, a pre-load is applied to the engine mount by a special purpose machine which compresses the rubber conical spring (see fig 34) to enable the straps to be positioned. When the pre-load is removed, the conical spring tries to return to its free state and the straps go into tension, holding the 'top plate' in place. Three separate attempts were made by the cross functional team to resolve the problem. The 8D process was used in a disciplined manner (see section 3.5, Table 5), and multiple meetings were held, including data capture, brainstorming and route cause analysis. CAD design work was conducted, involving three of Avon's most experienced designers. The only valid permanent corrective action proposed was the introduction of left and right hand versions of the top strap guide plate – which would take six months to develop and require significant capital investment. The only practical solution offered was to add orientation features to the strap assembly jig to accurately line up the top plate to the engine mount during strap assembly. It was expected that the preload of the straps would hold the top plate in its angular position. But although this reduced the number of rejects, the problem was not solved – the number of mounts needing rework was between 20% and 30% from batch to batch. Neither the company nor the customer had been able to offer a better solution. The problem was brought to the TRIZ workshop as an impossibly difficult test, and unsolvable without resorting to unbudgeted spend on new or significantly modified tooling.

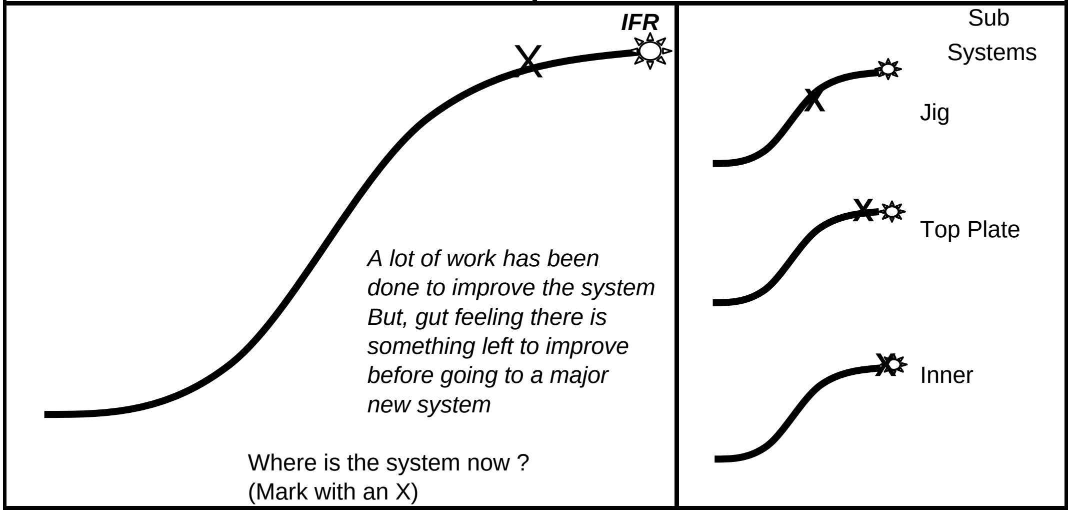
The challenge was accepted. The author of this thesis had been the programme manager responsible for introducing the product into production, had chaired the majority of the 8D meetings, and been in contact with the customer. Hence there was a shared resolve to find a solution if there was one, but also the concern that one could not be found. However, the use of the problem would at least form a good case study for use of the tools, and no-one would blame the method if a solution was not found – it was after all, impossible.

How each tool was used, in sequence within the workshop using the MSB problem as a worked example is now described.

5.3.1 IFR S Curve Tool

The IFR S-Curve tool completed during the workshop is shown in fig 35.

System Name	**MSB Top Plate**
How do you define the 'System' context (so yourself and others will understand later)	MSB Engine Mount top plate - orientation problem at Customer and Avon final QA check
What is the main useful function (MUF) ?	Orientation of top pips to base holes
What is the IFR ? (- min cost and harm) ?	Orientation always maintained - at - zero cost



A lot of work has been done to improve the system But, gut feeling there is something left to improve before going to a major new system

Where is the system now ?
(Mark with an X)

What is stopping you from achieving the IFR ?	Cannot be Poke-Yoke with 1 top plate - jig not capable (yet)
Why is this stopping you ?	Can't think of a better way of solving problem
How can this be solved ?	Make process Poke Yoke and stop top plate from rotating
What Resources are available to solve the problem ?	Kovolis, P+D, AJM, Team, Operators, QA, experience, minor design changes
Has anyone solved the same or similar problem before ?	Must have, but don't know where / who !!!
What is the next best Result ?	6 Siqma capability
Repeat these questions……	
Guidelines for an 'Ideal' Idea	Use of the' 5 Why's' is also useful at this stage

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

Figure 35. IFR S-Curve Worksheet for the MSB Engine Mount Top plate orientation problem as completed in Workshop 1.

The IFR S-Curve tool helped the team to :

- Think in terms of function. In the top right hand section, orientation of the top pips to the base holes was identified as the main useful function (MUF) of the system.
- Focus on maintaining the function at zero cost, and not accept that a solution should incur any expenditure. The IFR was defined as always maintaining orientation with zero cost.
- Realise that there was likely to be some potential for development in the system as a whole, and that the assembly jig had most unexplored development potential. This was achieved by identifying the most important sub systems, and "X" on the S-Curves according to the teams opinion of each systems maturity.
- Realise that the solution could be solvable, being simply a matter of stopping something rotating. This can be seen in the questions being answered systematically in the lower right section of the form. The process needed to be Poke Yoke, which is the Japanese manufacturing term for "mistake proofing" (Ohno, 1988), and the top plate prevented from spinning.
- Identify sources of possible resource to solve the problem, which included the suppliers and production operators, or minor very low cost design changes.
- Understand that the next best result after zero rejects would be six sigma capability. However the team rejected the approach of settling for this as a target, rather that it should be absolutely impossible to create a misaligned product.

The mindset of the team after using this tool, had noticeably changed from one of scepticism about a solution being found, to a more positive outlook. It also helped to draw up the ideality equation :

$$\text{Ideality} = \frac{\text{Top plate orientation}}{\sum \text{Piece cost, Tooling cost, development cost } + \text{rework costs}}$$

Equation 2 Ideality equation describing the MSB Engine mount problem

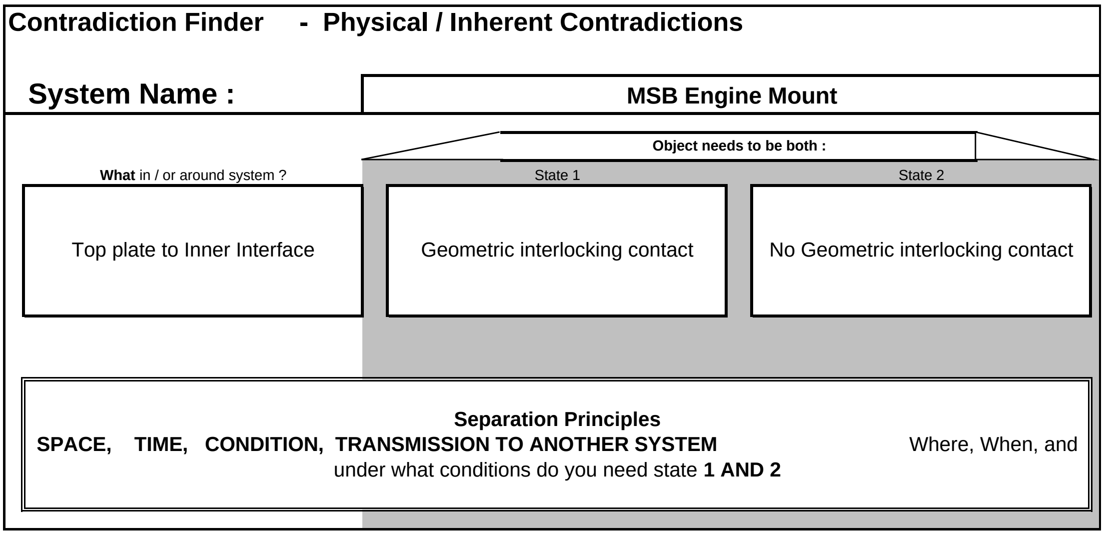
The idea of a self aligning feature, where the mount aligns itself during assembly by the customer was discussed. The team could not think of a way to achieve this without modifications to the design of the interface with the vehicle, which would not be feasible. But maybe something to note for future designs. No further ideas as to a solution were offered at this time.

5.3.2 Contradictions

Using the contradiction finder tools described in section 4.4.3, the team were required to work in small groups to identify contradictions, of both the inherent and trade-off types.

Inherent / Physical Contradictions identified :

New tooling required for orientation and *new tooling* ***not*** *required* for cost
‘*Interlocking*’ is required for orientation and ‘***not** interlocking*’ is required for cost
Strap tension to be ‘*tighter*’ (to react torque) and Tension to be ‘***not** tighter*’ (due to the requirement of the mount performance customer specification).



Contradiction Finder - Physical / Inherent Contradictions

System Name : **MSB Engine Mount**

Object needs to be both :

What in / or around system ?	State 1	State 2
Top plate to Inner Interface	Geometric interlocking contact	No Geometric interlocking contact

Separation Principles
SPACE, TIME, CONDITION, TRANSMISSION TO ANOTHER SYSTEM Where, When, and under what conditions do you need state **1 AND 2**

Figure 36. Showing the physical / inherent contradiction of the MSB top plate orientation problem according – as filled in during workshop 1.

To complete the contradiction finder tool, the separation principles needed to be identified.

Separation in Space - where does the contradiction exist? - The contradiction occurs only at the top portion of the mount.

Separation in Time - when does the contradiction exist? - The contradiction exists after the engine mount is completed, and up to the time at the time of engine assembly. But it can also be thought to exist only at the moment of bolt insertion on the customer assembly track, but also at any time after the mount is completed.

Separation on Condition – Under what conditions does the contradiction exist? – When a twisting force acts upon the mount (from an external source, or possibly relaxation of the strap).

Use of this tool led the team to consider ways to self align the mount using the packaging during assembly at the customer.

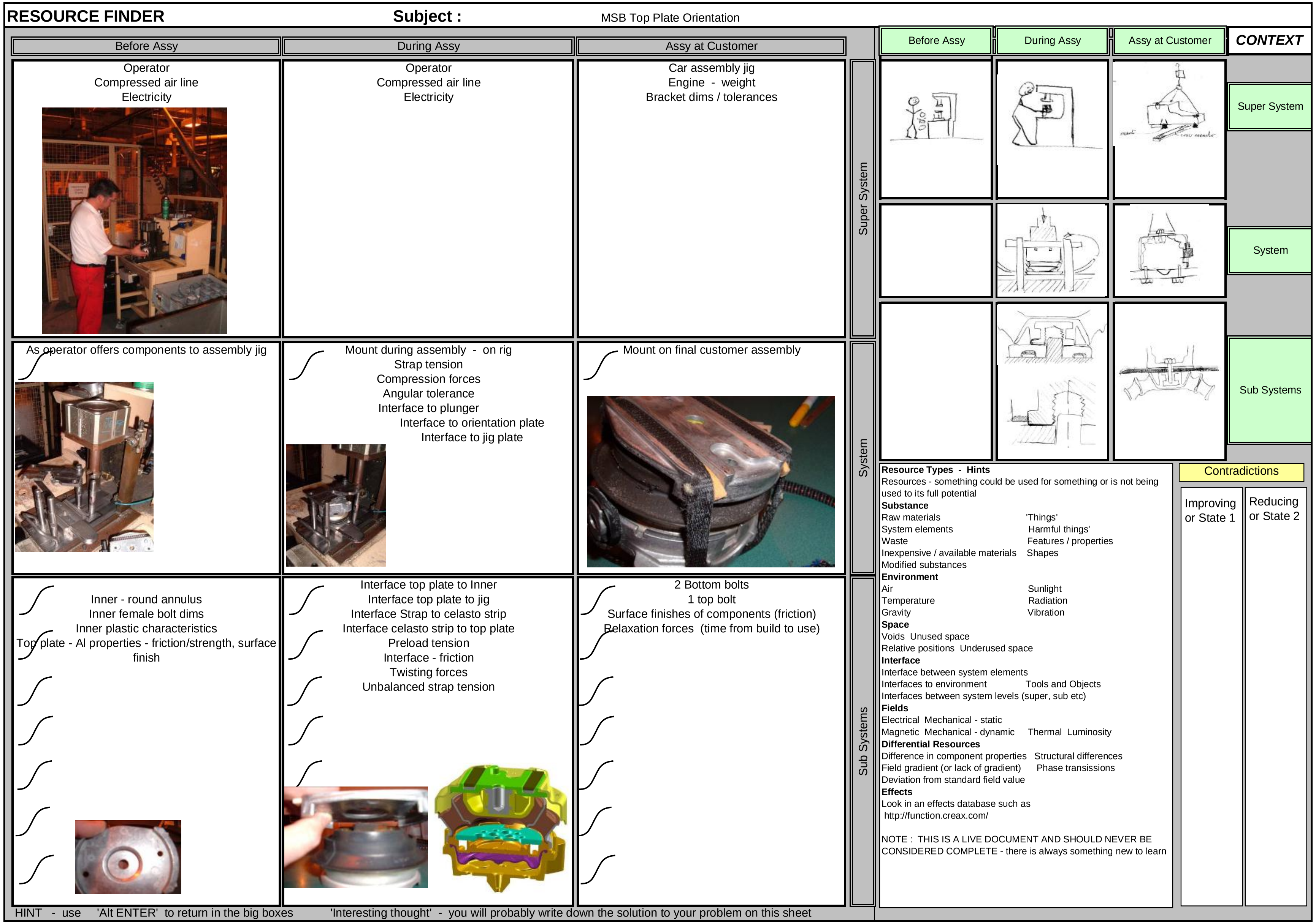
The trade-off contradictions identified :

- **Strap tension** vs. **torque** required to move plate
- **Interference** vs. **angular tolerance** (for the intended interlocking design)
- **Dimensional Tolerance** vs. **ease of assembly**

These contradictions focused the problem on the idea of reacting torque. They were then used as the input to the “matrix and 40 principles” during the second session after the team had read the Simplified TRIZ book, see Section 5.3.5.

5.3.3 Nine Windows and Resources

The group was divided into two teams, each taking part of the system to identify resources, and then present these back to the group as a whole. One team took the past, and present, the second took the present and future. The author wrote up the nine windows in the spreadsheet form in the fortnight between the workshop events and presented to the group in the second session. The majority of the content had however been derived during session one.



RESOURCE FINDER **Subject :** MSB Top Plate Orientation

	Before Assy	During Assy	Assy at Customer
Super System	Operator Compressed air line Electricity	Operator Compressed air line Electricity	Car assembly jig Engine - weight Bracket dims / tolerances
System	As operator offers components to assembly jig	Mount during assembly - on rig Strap tension Compression forces Angular tolerance Interface to plunger Interface to orientation plate Interface to jig plate	Mount on final customer assembly
Sub Systems	Inner - round annulus Inner female bolt dims Inner plastic characteristics Top plate - Al properties - friction/strength, surface finish	Interface top plate to Inner Interface top plate to jig Interface Strap to celasto strip Interface celasto strip to top plate Preload tension Interface - friction Twisting forces Unbalanced strap tension	2 Bottom bolts 1 top bolt Surface finishes of components (friction) Relaxation forces (time from build to use)

HINT - use 'Alt ENTER' to return in the big boxes 'Interesting thought' - you will probably write down the solution to your problem on this sheet

Resource Types - Hints
Resources - something could be used for something or is not being used to its full potential
Substance
Raw materials 'Things'
System elements Harmful things'
Waste Features / properties
Inexpensive / available materials Shapes
Modified substances
Environment
Air Sunlight
Temperature Radiation
Gravity Vibration
Space
Voids Unused space
Relative positions Underused space
Interface
Interface between system elements
Interfaces to environment Tools and Objects
Interfaces between system levels (super, sub etc)
Fields
Electrical Mechanical - static
Magnetic Mechanical - dynamic Thermal Luminosity
Differential Resources
Difference in component properties Structural differences
Field gradient (or lack of gradient) Phase transissions
Deviation from standard field value
Effects
Look in an effects database such as
http://function.creax.com/

NOTE : THIS IS A LIVE DOCUMENT AND SHOULD NEVER BE CONSIDERED COMPLETE - there is always something new to learn

Contradictions

Improving or State 1	Reducing or State 2

Figure 37. Nine Windows tool as completed for the MSB Engine Mount orientation problem

In the top right hand section, the definitions of time and space were made. The past, was considered to be point just prior to final assembly of the product. The Present was defined as the time during final assembly, and the future was defined as assembly at the customer. The system was defined as the Engine mount in its assembled state. This meant that system did not exist as a single entity in the "past" column, which is why these spaces are blank on the completed sheet sketch area at the top right hand corner. The super system was defined as the manufacturing systems around the assembly jig during each time period. The sub system was defined as the sub components. These systems were sketched, scanned and copied into the spreadsheet. Information on the resources was then added to the main body of the sheet. Photographs CAD images were incorporated to increase the detailed visualisation of the problem.

By using this tool, the team were able to consider the problem in space and time. Several ideas and insights started to be offered by the participants.

- use the packaging as a restraint to hold the top plate in position during transit.
- Pre-stretch the Kevlar straps to relieve any tension (It was suspected that the orientation was moving during transit due to uneven relaxation of the strap – at the sub system level).
- Interfaces between system elements were a key resource. This was because the traditional anti-rotation method used by designers to that time, make use of the interface between two sub components to provide anti-rotation features. As such the Poke Yoke philosophy was considered to be a good example of the TRIZ principle that an interface is a resource.

The ideas surrounding improved packaging did not solve the problem completely because they would require some level of spend. The ideality equation was therefore not improved sufficiently. But, the team felt that progress was being made in understanding the problem more deeply as they reflected on the workshop during the two week break between sessions.

5.3.4 Functional / Attribute Analysis (FAA)

The use of the 9 windows tool was a useful exercise to identify the relevant elements of the system to be modelled using the FAA tool. The first step was to list the elements as shown in table 6. This approach had not been seen by the author in training, or literature, but was added as a rigorous way of challenging each relationship between system elements.

Tools \ Objects	Strap	Cel Strip	Top Plate	Inner	Top /IVP Assy	Base cup	Orientation Plate (jig)	Pusher (jig)	Strap Holder (jig)
Strap	■	compresses	touches, wears			compresses			touches
Cel Strip	reacts	■	forces						
Top Plate		reacts	■	touches, holds				reacts, contacts	locates, orientates
Inner			reacts Contacts	■					
Top / VP Assy				orientates reacts	■	orientates, reacts	?		
Base Cup	Reacts, guides				Supports / orientates	■	reacts against	reacts against	
Orientation Plate (jig)							■		
Pusher (jig)						Pushes		■	
Strap Holder (jig)	guides		orientates						■

Table 6. Matrix of functional interactions between system elements of the MSB top plate.

From this matrix, the FAA diagram could be created using the CREAX Innovation suite software (CREAX, 2009)

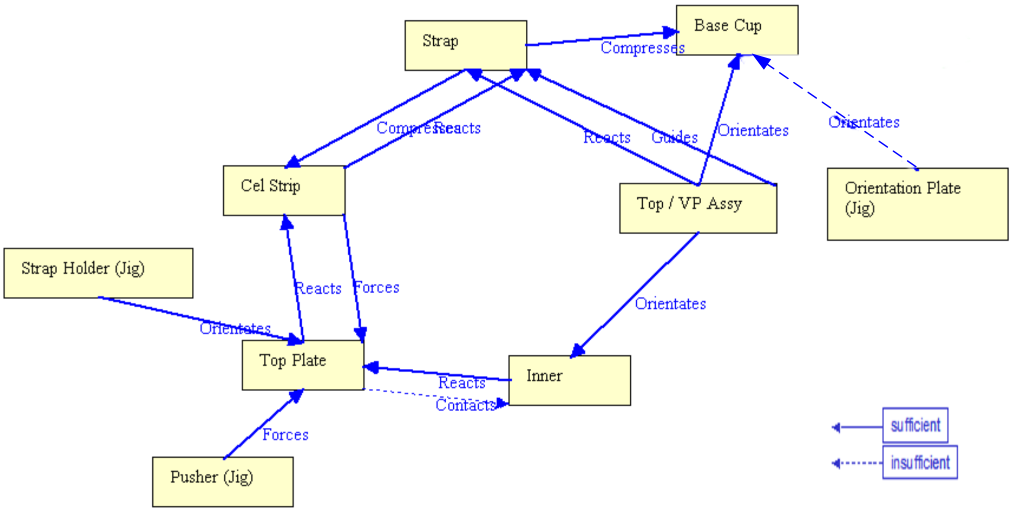


Figure 38. FAA model of the system during assembly.

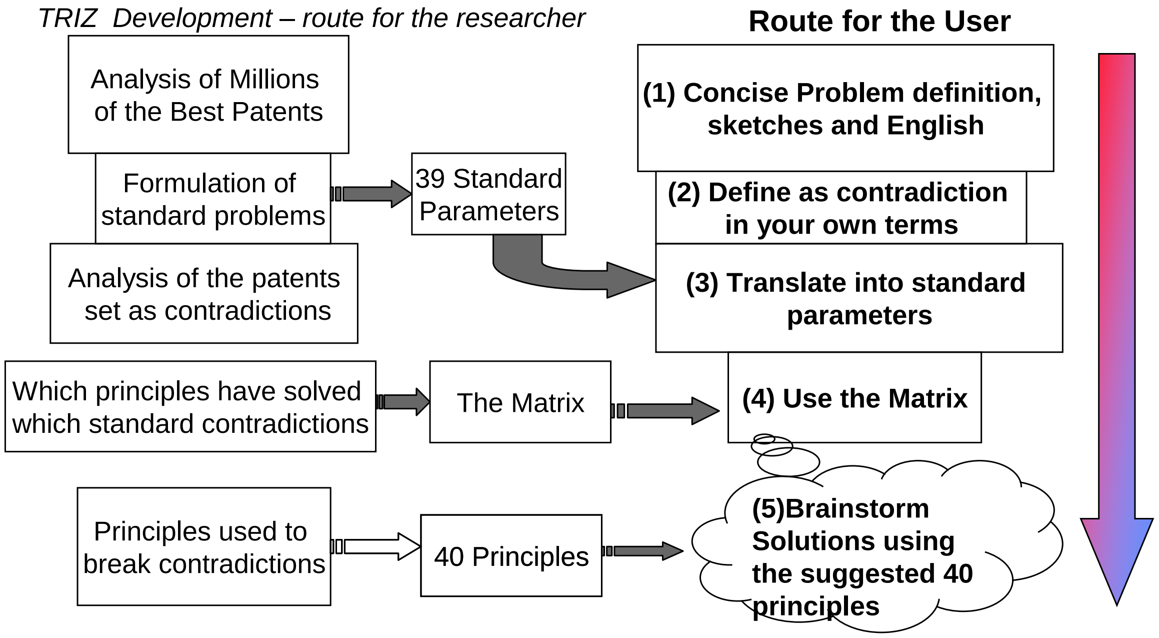
The FAA model shown in Figure 38 shows the functional relationship between the system element, with solid arrowed lines indicating an acceptable relationship. Dotted lines are used to indicate an insufficient relationship, and two of these were identified. Firstly the orientation function of the assembly jig was insufficient. Secondly that the problem could be defined as “insufficient torque resistance” – i.e. that if the top plate were positioned accurately, and if any torque from whatever source could be reacted without movement then the problem would be completely solved.

During a coffee break, team members briefly inspected the actual assembly jig, and found that further improvements could be made. These were immediately implemented using the on-site engineering workshop, with zero external spend. Later in that week the Quality Engineer was able to report a reduction of rework from typically between 20% to 30% to less than 5%. This suggested that the first insufficient relationship had been resolved, although was not conclusive.

An idea that resulted from using this tool was to use an adhesive to fix the top plate into position. This was considered to be viable, but would suffer the penalty of some increased cost. Adhesives are not generally well accepted in a production environment as they tend to create mess. It was therefore not considered to be the IFR.

5.3.5 Matrix and 40 Principles

The methodology that Altshullers researchers followed to develop the matrix tool (Lerner, 1991), together with a step by step instruction guide was presented to the workshop see Figure 39.



TRIZ Development – route for the researcher

Route for the User

Analysis of Millions of the Best Patents

Formulation of standard problems

39 Standard Parameters

Analysis of the patents set as contradictions

Which principles have solved which standard contradictions

The Matrix

Principles used to break contradictions

40 Principles

(1) Concise Problem definition, sketches and English

(2) Define as contradiction in your own terms

(3) Translate into standard parameters

(4) Use the Matrix

(5)Brainstorm Solutions using the suggested 40 principles

Figure 39. Slide from workshop showing the steps of using the contradiction matrix, and how each part of the system was derived by TRIZ researchers.

When trade-off contradictions have been identified in general language, the problem solver is required to make a connection or translation between these terms and the list of 39 parameters as shown in Table 7.

No	Parameter	No	Parameter
1	Weight of moving object	20	Use of energy by stationary object
2	Weight of stationary object	21	Power
3	Length of moving object	22	Loss of Energy
4	Length of stationary object	23	Loss of substance
5	Area of moving object	24	Loss of Information
6	Area of stationary object	25	Loss of Time
7	Volume of moving object	26	Quantity of substance/the matter
8	Volume of stationary object	27	Reliability
9	Speed	28	Measurement accuracy
10	Force	29	Manufacturing precision
11	Stress or pressure	30	External harm affects the object
12	Shape	31	Object-generated harmful factors
13	Stability of the object's composition	32	Ease of manufacture
14	Strength	33	Ease of operation
15	Duration of action by a moving object	34	Ease of repair
16	Duration of action by a stationary object	35	Adaptability or versatility
17	Temperature	36	Device complexity
18	Illumination intensity	37	Difficulty of detecting and measuring
19	Use of energy by moving object	38	Extent of automation
		39	Productivity

Table 7. The 39 standard parameters for formulating contradictions (Altshuller 1984).

In this case study, the workshop participants were required to take the contradictions as defined in their own words, (see section 5.3.2) and re-interpret them according to the most relevant of the 39 parameters. For instance one contradiction was defined as **angular tolerance** vs **ease of assembly**. *Angular tolerance*, was matched up to "*manufacturing precision*" (Number 29), which was considered to be a closely related term. The participants made the connection that angular tolerance in this case could be related to "*adaptability / versatility*". The reason for this was that the angular tolerance was only important because the engine mount needed to be *adapted* to either side of the engine. "Ease of assembly" was decided to be most closely interpreted as "ease of manufacture". Because the engine mount itself was causing manufacturing difficulties. "*object generated harmful factors*" was also considered appropriate.

Step 3 in the use of the tool (see Figure 39) is to use the matrix. The matrix is a 39 by 39 table, with each column, and each row allocated to one of the 39 parameters, as shown in figure 40.

	WORSENING FEATURE / IMPROVING FEATURE	WEIGHT OF MOVING OBJECT 1	WEIGHT of STATIONARY OBJECT 2	LECNGHT OF MOVING OBJECT 3	LENGTH OF STATIONARY OBJECT 4	AREA OF MOVING OBJECT 5	AREA OF STATIONARY OBJECT 6	VOLUME OF MOVING OBJECT 7	VOLUME OF STATIONARY OBJECT 8	SPEED 9	FORCE (INTESITY) 10	STRESS OR PRESSURE 11	SHAPE 12	STABILITY of OBJECT'S COMPOSITION 13	STRENGTH 14	DURATION of ACTION of MOVING OBJECT 15	DURATION of STATIONARY of MOVING OBJECT 16	TEMPERATURE 17	ILLUMINATION INTENSITY 18	USE of ENERGY by MOVING OBJECT 19	USE of ENERGY by STATIONARY OBJECT 20	POWER 21	LOSS of ENERGY 22	LOSS of SUBSTANCE 23	LOSS of INFORMATION 24	LOSS of TIME 25	QUALITY of SUBSTANCE / MATTER 26	RELIABILITY 27	MEASUREMENT ACCURACY 28	MANUFACTURING PRECISION 29	OBJECT-AFFECTED HARMFUL FACTORS 30	OBJECT-GENERATED HARMFUL FACTORS 31	EASE of MANYFACTURE 32	EASE of OPERATION 33	EASE of REPAIR 34	ADAPTABILITY or VERSATILITY 35	DEVICE COMPLEXITY 36	DIFFICULTY of DETECTING and MEASURING 37	EXTENT of AUTOMATION 38	PRODUCTIVITY 39
1	WEIGHT of MOVING OBJECT	+	-	15,8, 29,34	-	29,17, 38,34	-	29,2, 40,28	-	2,8, 15,38	8,10, 18,37	10,36, 37,4	10,14, 35,4	1,35, 19,39	28,27, 18,4	5,34, 31,35	-	6,29, 4,38	19,1, 32	35,12, 34,31	-	12,36, 18,31	6,2, 34,19	5,35, 3,31	10,24, 35	10,35, 20,28	3,26, 18,31	1,3, 11,27	28,27, 35,26	28,35, 26,18	22,21, 18,27	22,35, 31,39	27,28, 1,36	35,3, 2,24	2,27, 28,11	29,5, 15,8	26,30, 36,34	28,29, 26,32	26,35, 18,19	35,3, 24,37
2	WEIGHT of STATIONARY OBJECT	-	+	-	10,1, 29,35	-	35,30, 13,2	-	5,35, 14,2	-	8,10, 19,35	13,29, 10,18	13,10, 29,14	26,39, 1,40,	28,2, 10,27	-	2,27, 19,6	28,19, 32,22	19,32, 35	-	18,19, 28,1	15,19, 18,15	18,19, 28,15	5,8, 13,30,	10,15, 35	10,20, 35,26	19,6, 18,26	10,28, 8,3	18,26, 28	10,1, 35,17	2,19, 22,37	35,22, 1,39	28,1,9	6,13, 1,23	2,27, 28,11	19,15, 29	1,10, 26,39	25,28, 17,15	2,26, 35	1,28, 15,35
3	LENGTH of MOVING OBJECT	8,15, 29,34	-	+	-	15,17, 4	-	7,17, 4,35	-	13,4,8	17,10, 4	1,8,35	1,8, 10,29	1,8, 15,34	8,35, 29,34	19	-	10,15, 19	32	8,35, 24	-	1,35	7,2, 35,39	4,29, 23,1	1,24	15,2, 29	29,35	10,14, 29,4	28,32, 4	10,28, 29,37	1,15, 17,24	17,15	1,29, 17	15,29, 35,4	1,28, 10	14,15, 1,16	1,19, 26,24	35,1, 26,24	17,24, 26,16	14,4, 28,29
4	LENGTH of STATIONARY OBJECT		35,28, 40,29	-	+	-	17,7, 10,4	-	35,8, 2,14	-	28,1	1,14, 35	13,14, 15,7	39,37, 35	15,14, 28,26	-	1,10, 35	3,35, 38,18	3,25	-		12,8	6,28	10,28, 24,35	24,26,	30,29, 14		15,29, 28	32,28, 3	2,32, 10	1,18		15,17, 27	2,25	3	1,35	1,26	26		30,14, 7,26
5	AREA of MOVING OBJECT	2,17, 29,4	-	14,15, 18,4	-	+	-	7,14, 17,4		29,30, 4,34	19,30, 35,2	10,15, 36,28	5,34, 29,4	11,2, 13,39	3,15, 40,14	6,3	-	2,15, 16	15,32, 19,13	19,32	-	19,10, 32,18	15,17 30,26	10,35, 2,39	30,26	26,4	29,30, 6,13	29,9	26,28, 32,3	2,32	22,33, 28,1	17,2, 18,39	13,1, 26,24	15,17, 13,16	15,13, 10,1	15, 30	14,1, 13	2,36, 26,18	14,30, 28,23	10,26, 34,2
6	AREA of STATIONARY OBJECT	-	30,2, 14,18	-	26,7, 9,39	-	+	-		-	1,18, 35,36	10,15, 36,37		2,38	40	-	2,10, 19, 30	35,39, 38		-		17,32	17,7, 30	10,14, 18,39	30,16	10,35, 4,18	2,18, 40,4	32,35, 40,4	26,28, 32,3	2,29, 18,36	27,2, 39,35	22,1, 40	40,16	16,4	16	15,16	1,18, 36	2,35, 30,18	23	10,15, 17,7
7	VOLUME of MOVING OBJECT	2,26, 29, 40	-	1,7,4, 35	-	1,7,4, 17	-	+	-	29,4, 38,34	15,35, 36,37	6,35, 36,37	1,15, 29,4	28,10, 1,39	9,14, 15,7	6,35,4	-	34,39, 10,18	2,13, 10	35	-	35,6, 13,18	7,15, 13,16	36,39, 34,1	2,22	2,6, 34,1	29,30, 7	14,1, 40,11	26,26, 28	25,28, 2,16	22,21, 27,35	17,2, 40,1	29,1, 40	15,13, 30,12	10	15,29	26,1	29,26, 4	35,34, 16,24	10,6, 2,34
8	VOLUME of STATIONARY OBJECT	-	35,10, 19,14	19,14	35,8, 2,14	-		-	+	-	2,18, 37	24,35	7,2,35	34,28, 35, 40	9,14, 17,15	-	35,34, 38	35,6,4		-		30,6		10,39, 35,34		35,16, 32 18	35,3	2,35, 16		35,10, 25	34,39, 19,27	30,18, 35,4	35		1		1,31	2,17, 26		35,37, 10,2
9	SPEED	2,28, 13,38	-	13,14, 8	-	29,30, 34	-	7,29, 34	-	+	13,28, 15,19	6,18, 38,4	35,15, 18,34	28,33, 1,18	8,3, 26,14	3,19, 35,5	-	28,30, 36,2	10,13, 19	8,15, 35,38	-	19,35, 38,2	14,20, 19,35	10,13, 28,38	13,26		10,19, 29,38	11,35, 27,28	28,32, 1,24	10,28, 32,25	1,28, 35,23	2,24, 35,21	35,13, 8,1	32,28, 13,12	34,2, 28,27	15,10, 26	10,28, 4,34	3,34, 27,16	10,18	
10	FORCE (INTESITY)	8,1, 37,18	18,13, 1,28	17,19, 9,36	28, 10	19, 10, 15	1,18, 36,37	15,9, 12,37	2,36, 18,37	13,28, 15,12	+	18,21, 11	10,35, 40,34	35,10, 21	35,10, 14,27	19,2		35,10, 21	-	19,17, 10	1,16, 36,37	19,35, 18,37	14,15	8,35, 40,5		10,37, 36	14,29, 18,36	3,35, 13,21	35,10, 23,24	28,29, 37,36,	1,35, 40,18	13,3, 36,24	15,37, 18,1	1,28, 3,25	15,1, 11	15,17, 18,2	26,35, 10,18	36,37, 10,19	2,35	3,28, 35,37
11	STRESS or PRESSURE	10,36, 37,4	13,29, 10,18	35,10, 36	35,1, 14,16	10,15, 36,28	10,15, 36,37,	6,35, 10	35,24	6,35, 36	36,35, 21	+	35,4, 15, 10	35,33, 2, 40	9,18, 3, 40	19, 3, 27		35,39, 19,2	-	14,24, 10,37		10,35, 14	2,36, 25	10,36, 3,37		37,36, 4	10,14, 36	10,13, 19,35	6,28, 25	3,35	22,2, 37	2,33, 27,18	1,35, 16	11	2	35	19,1, 35	2,36, 37	35,24	10,14, 35,37
12	SHAPE	8,10, 29,4	15,10, 26,3	29,34, 5,4	13,14, 10,7	5,34, 4, 10		14,4, 15,22	7,2,35	35,15, 34,18	35,10, 37, 40	34,15, 10,14	+	33,1, 18,4	30,14, 10, 40	14,26, 9,25		22,14, 19,32	13,15, 32	2,6, 34,14		4,6,2	14	35,29, 3,5		14,10, 34,17	36,22	10,40, 16	28,32, 1	32,30, 40	22,1, 2,35	35,1	1,32, 17,28	32,15, 26	2,13,1	1,15, 29	16,29, 1,28	15,13, 39	15,1, 32	17,26, 34, 10
13	STABILITY of the OBJECT'S COMPOSITION	21,35, 2,39	26,39, 1, 40	13,15, 1,28	37	2,11, 13	39	28,10, 19,39	34,28, 35,4	33,15, 28,18	10,35, 21,16	2,35, 40	22,1, 18,4	+	17,9, 15	13,27, 10,35	39,3, 35,23	35,1, 32	32,3, 27,16	13,19	27,4, 29,18	32,35, 27,31	14,2, 39,6	2,14, 30,4		35,27	15,32, 35		13	18	35,24, 30,18	35,40, 27,39	35,19	32,35, 30	2,35, 10,16	35,30, 34,2	2,35, 22,26	35,22, 39,23	1,8,35	23,35, 40,3
14	STRENGTH	1,8, 40,15	40,26, 27,1	1,15, 8,35	15,14, 28,26	3,34, 40,29	9, 40, 28	10,15, 14,7	9,14, 17,15	8,13, 26,14	10,18, 3,14	10,3, 18, 40	10, 30, 35, 40	13,17, 35	+	27,3, 26		30,10, 40	35,19	19,35, 10	35	10,26, 35,28	35	35,28, 31,4		29,3, 28,1	29,10, 27	11,3	3,27, 16	3,27	18,35, 37,1	15,35, 22,2	11,3, 10,32	32,40, 25,2	27,11, 3	15,3, 32	2,13, 25,28	27,3, 15, 40	15	29,35, 10,14
15	DURATION of ACTION of MOVING OBJECT	19,5, 34,31	-	2,19,9	-	3,17, 19	-	10,2, 19, 30	-	3,35,5	19,2, 16	19,3, 27	14,26, 28,25	13,3, 35	27,3, 10	+	-	19,35, 39	2,19, 4,35	28,6, 35,18		19,10, 35,38		28,27, 3,18	10	20,10, 28,18	3,35, 10,4	11,2, 13	3	3,27, 16,4	22,15, 33,28	21,39, 16,22	27,1,4	12,27	29,10, 27	1,35, 13	10,4, 29,15	19,29, 39,35	6, 10	35,17, 14,19
16	DURATION of STATIONARY of MOVING OBJ,	-	6,27, 19,16	-	1, 40, 35	-		-	35,34, 38	-				39,3, 35,23		-	+	19,18, 36, 40		-		16		27,16, 18,38	10	28,20, 10,16	3,35, 31	34,27, 6, 40	10,26, 24		17,1, 40,33	22	35, 10	1	1	2		25,34, 6,35	1	20,10, 16,38
17	TEMPERATURE	36,22, 6,38	22,35, 32	15,19, 9	15,19, 9	3,35, 39,18	35,38	34,39, 40,18	35,6,4	2,28, 36,3	35, 10, 3,21	35,39, 19,2	14,22, 19,32	1,35, 32	10, 30, 22, 40	19,13, 39	19,18, 36, 40	+	32,30, 21,16	19,15, 3,17		2,14, 17,25	21,17, 35,38	21,36, 29,31		35,28, 21,18	3,17, 30,39	19,35, 3, 10	32,19, 24	24	22,33, 35,2	22,35, 2,24	26,27	26,27	4,10, 16	2,18, 27	2,17, 16	3,27, 35,31	26,2, 19,16	15,28, 35
18	ILLUMINATION INTENSITY	19,1, 32	2,35, 32	19,32, 16		19,32, 26		2,13, 10		10,13, 19	26,19, 6		32, 30	32,3, 27	35,19	2,19,6		32,35, 19	+	32,1, 19	32,35 1,15	32	13,16, 1,6	13,1	1,6	19,1, 26,17	1,19		11,15, 32	3,32	15,19	35,19, 32,39	19,35, 28,26	28,26, 19	15,17, 13,16	15,1, 1,19	6,32, 13	32,15	2,26, 10	2,25, 16
19	USE of ENERGY by MOVING OBJECT	12,18, 2,8,31	-	12,28	-	15,19, 25	-	35,13, 18	-	8,35, 35	16,26, 21,2	23,14, 25	12,2, 29	19,13, 17,24	5,19, 9,35	28,35, 6,18	-	19,24, 3,14	2,15, 19	+	-	6,19, 37,18	12,22, 15,24	35,24, 18,5		35,38, 19,18	34,23, 16,18	19,21, 11,27	3,1,32		1,35, 6,27	2,35,6	28,26, 30	19,35	1,15, 17,28	15,17, 13,16	2,29, 27,28	35,38	32,2	12,28, 35
20	USE of ENERGY by STATIONARY OBJ,	-	19,9, 6,27	-		-		-		-	36,37			27,4, 29,18	35				19,2, 35,32	-	+			28,27, 18,31			3,35, 31	10,36, 23			10,2, 22,37	19,22, 18	1,4					19,35, 16,25		1,6
21	POWER	8,36, 38,31	19,26, 17,27	1,10, 35,37		19,38	17,32, 13,38	35,6, 38	30,6, 25	15,35, 2	26,2, 36,35	22,10, 35	29,14, 2, 40	35,32, 15,31	26, 10, 28	19,35, 10,38	16	2,14, 17,25	16,6, 19	16,6, 19,37		+	10,35, 38	28,27, 18,38	10,19	35,20, 10,6	4,34, 19	19,24, 26,31	32,15, 2	32,2	19,22, 31,2	2,35, 18	26,10, 34	26,35, 10	35,2, 10,34	19,17, 34	20,19, 30,34	19,35, 16	28,2, 17	28,35, 34
22	LOSS of ENERGY	15,6, 19,28	19,6, 18,9	7,2,6, 13	6,38,7 10	15,26, 17, 30	17,7, 30,18	7,18, 23	7	16,35, 38	36,38			14,2, 39,6	26			19,38, 7	1,13, 32,15			3,38	+	35,27, 2,37	19, 10	10,18, 32,7	7,18, 25	11,10, 35	32		21,22, 35,2	21,35, 2,22		35,32, 1	2,19		7,23	35,3, 15,23	2	28,10, 29,35
23	LOSS of SUBSTANCE	35,6, 23,4	35,6, 22,32	14,29, 10,39	28,24 26	35,2, 10,31	10,18, 39,31	1,29, 30,36	3,39, 18,31	10,13, 28,38	14,15, 18, 40	3,36, 37,1	29,35, 3,5	2,14, 30, 40	35,28, 31, 40	28,27, 3,18	27,16, 18,38	21,36, 39,31	1,6,13	35,18, 24,5	28,27, 12,31	28,27, 18,38	35,27, 2,31	+		15,18, 35,1	6,3, 10,24	10,29, 39,35	16,34, 31,28,	35,10, 24,31	33,22, 30, 40	10,1, 34,29	15,34, 33	32,28, 2,24	2,35, 34,27	15,10, 2	35,10, 28,24	35,18, 10,13	35,10, 18	28,35, 10,23
24	LOSS of INFORMATION	10,24, 35	10,35, 5	1,26	30,24,	30,26	30,16		2,22	26,32						10	10		19			10,19	19,1		+	24,26, 28,32	24,28, 35	10,28, 23			22,10, 1	10,21, 22	32	27,22				35,33	35	13,23, 15
25	LOSS of TIME	10,20, 37,35	10,20, 26,5	15,2, 29	14,5	26,4, 5,16	10,35, 17,4	2,5, 34, 10	35,16, 32,18		10,37, 36,5	37 36,4	4, 10, 34,17	35,3, 22,5	29,3, 28,18	20,10, 28,18	28,20, 10,16	35,29, 21,18	1,19, 26,17	35,38, 19,18	1	35,20, 10,6	10,5, 18,32	35,18, 10,39	24,26, 28,32	+	35,38, 18,16	10,30, 4	24,34, 28,32	24,26, 28,18	35,18, 34	35,22, 18,39	35,28, 34,4	4,28, 10,34	32,1, 10	35,28	6,29,	18,28, 32, 10	24,28, 35, 30	
26	QUALITY of SUBSTANCE / MATTER	35,6, 18,31	27,26, 18,35	29,14, 35,18		15,14, 29	2,18, 40,4	15,20, 29		35,29, 34,28	35,14, 3	10,36, 14,3	35,14	15,2, 17, 40	14,35, 34, 10	3,35, 10, 40	3,35, 31	3,17, 39		34,29, 16,18	3,35, 31	35	7,18, 25	6,3, 10,24	24,28, 35	35,38, 18,16	+	18,3, 28, 40	13,2, 28	33, 30	35,33, 29,31	3,35, 40,39	29,1, 35,27	35,29, 25, 10	2,32, 10,25	15,3, 29	3,13, 27, 10	3,27, 29,18	8,35	13,29, 3,27
27	RELIABILITY	3,8, 10,4	3,10, 8,28	15,9, 14,4	15,29, 28,11	17,10, 14,16	32,35, 40,4	3,10, 14,24	2,35, 24	21,35, 11,28	8,28, 10,3	10,24, 35,19	35,1, 16,11		11,28	2,35, 3,25	34,27, 6, 40	3,35, 10	11,32, 13	21,11, 27,19	36,23	21,11, 26,31	10,11, 35	10,35, 29,39	10,28	10,30, 4	21,28, 40,3	+	32,3, 11,23	11,32, 1	27,35, 2, 40	35,2, 40,26		27,17, 40	1,11	13,35, 8,24	13,35, 1	27,40, 28	11,13, 27	1,35, 29,38
28	MEASUREMENT ACCURACY	32,35, 26,28	28,35, 25,26	28,26, 5,16	32,28, 3,16	26,28, 32,3	26,28, 32,3	32,13 6		28,13, 32,24	32,2	6,28, 32	6,28, 32	32,35, 13	28,6, 32	28,6, 32	10,26, 24	6,19, 28,24	6,1, 32	3,6,32		3,6,32	26,32, 27	10,16, 31,28		24,34, 28,32	2,6,32	5,11, 1,23	+		28,24, 22,26	3,33, 39, 10	6,35, 25,18	1,13, 17,34	1,32, 13,11	13,35, 2	27,35, 10,34	26,24, 32,28	28,2, 10,34	10,34, 28,32
29	MANUFACTURING PRECISION	28,32, 13,18	28,35, 27,9	10,28, 29,37	2,32, 10	28,33, 29,32	2,29, 18,36	32,23, 2	25,10, 35	10,28, 32	28,19, 34,36	3,35	32, 30, 40	30,18	3,27	3,27, 40		19,26	3,32	32,2		32,2	13,32, 2	35,31, 10,24		32,26, 28,18	32, 30	11,32, 1		+	26,28, 10,36	4,17, 34,26		1,32, 35,23	25, 10		26,2, 18		26,28, 18,23	10,18, 32,39
30	OBJECT-AFFECTED HARMFUL FACTORS	22,21, 27,39	2,22, 13,24	17,1, 39,4	1,18	22,1, 33,28	17,2, 39,35	22,23, 37,35	34,39, 19,27	21,22, 35,28	13,35, 39,18	22,2, 37	22,1, 3,35	35,24, 30,18	18,35, 37,1	22,15, 33,28	17,1, 40,33	22,33, 35,2	1,19, 32,13	1,24, 6,27	10,2, 22,37	19,22, 31,2	21,22, 35,2	33,22, 19,4	22,10, 2	35,18, 34	35,33, 29,31	27,24, 2,4	28,33 23,26	26,28, 10,18	+		24,35, 2	2,25, 28,39	35,10, 2	35,11, 22,31	22,19, 29, 40	22,19, 29, 40	33,3, 34	22,35, 13,24
31	OBJECT-GENERATED HARMFUL FACTORS	19,22, 15,39	35,22, 1,39	17,15, 16,22		17,2, 18,39	22,1, 40	17,2, 40	30,18, 35,4	35,28, 3,23	35,28, 1, 40	2,33, 27,18	35,1	35, 40 27,39	15,35, 22,2	15,22, 33,31	21,39, 16,22	22,35, 2,24	19,24, 39,32	2,35,6	19,22, 18	2,35, 18	21,35, 2,22	10,1, 34	10,21, 29	1,22	3,24, 39,1	24,2, 40,39	3,33, 26	4,17, 34,26		+					19,1, 31	2,21, 27,1	2	22,35, 18,39
32	EASE of MANYFACTURE	28,29, 15,16	1,27, 36,13	1,29, 13,17	15,17, 27	13,1, 26,12	16,4	13,29, 1, 40	35	35,13 8,1	35,12	35,19, 1,37	1,28, 13,27	11,13, 1	1,3, 10,32	27,1,4	35,16	27,26, 18	28,24, 27,1	28,26, 27,1	1,4	27,1, 12,24	19,35,	15,34, 33	32,24, 18,16	35,28, 34,4	35,23, 1,24		1,35, 12,18		24,2		+	2,5, 13,16	35,1, 11,9	2,13, 15	27,26, 1	6,28, 11,1	8,28,1	35,1, 10,28
33	EASE of OPERATION	25,2, 13,15	6,13, 1,25	1,17, 13,12		1,17, 13,16	18,16, 15,39	1,16, 35,15	4,18, 39,31	18,13, 34	28,13, 35	2,32, 12	15,34, 29,28	32,35, 30	32, 40, 3,28	29,3, 8,25	1,16, 25	26,27, 13	13,17, 1,24	1,13, 24		35,34, 2, 10	2,19, 13	28,32, 2,24	4, 10, 27,22	4,28, 10,34	12,35	17,27, 8,4	25,13, 2,34	1,32, 35,23	2,25, 28,39		2,5,12	+	12,26, 1,32	15,34, 1,16	32,26, 12,17		1,34, 12,3	15,1, 28
34	EASE of REPAIR	2,27, 35,11	2,27, 35,11	1,28, 10,25	3,18, 31	15,13, 32	16,25	25,2, 35,11	1	34,9	1,11, 10	13	1,13, 2,4	2,35	11,1, 2,9	11,29, 28,27	1	4, 10	15,1, 13	15,1, 28,16		15, 10, 32,2	15,1, 32,19	2,35, 34,27		32,1, 10,25	2,28, 10,25	11,10, 1,16	10,2, 13	25, 10	35,10, 2,16		1,35, 11, 10	1,12, 26,15	+	7,1,4, 16	35,1, 13,11		34,35, 7,13	1,32, 10
35	ADAPTABILITY or VERSATILITY	1,6, 15,8	19,15, 29,16	35,1, 29,2	1,35, 16	35,30, 29,7	15,16	15,35, 29		35,10, 14	15,17, 20	35,16	15,37, 1,8	35, 30, 14	35,3, 32,6	13,1, 35	2,16	27,2, 3,35	6,22, 26,1	19,35, 29,13		19,1, 29	18,15, 1	15,10, 2,13		35,28	3,35, 15	35,13, 8,24	35,5, 1,1		35,11, 32,31		1,13, 31	15,34, 1,16	1,16, 7,4	+	15,29, 37,28	1	27,34, 35	35,28, 6,37
36	DEVICE COMPLEXITY	26,30, 34,36	2,26, 35,39	1,19, 26,24	26	14,1, 13,16	6,36	34,26, 6	1,16	34, 10, 28	26,16	19,1, 35	29,13, 28,15	2,22, 17,19	2,13, 28	10,4, 28,15		2,17, 13	24,17, 13	27,2, 29,28		20,19, 30,34	10,35, 13,2	35,10, 28,29		6,29	13,3, 27,1	13,35, 1	2,26, 10,34	26,24, 32	22,19, 29, 40	19,1	27,26, 1,13	27,9, 26,24	1,13	29,15, 28,37	+	15,10, 37,28	15,1, 24	12,17, 28
37	DIFFICULTY of DETECTING and MEASURING	27,26, 28,13	6,13, 28,1	16,17, 26,24	26	2,13, 18,17	2,39, 30,16	29,1, 4,16	2,18, 26,31	3,4, 16,35,	30,28, 40,19	35,36, 37,32	27,13, 1,39	11,22, 39, 30	27,3, 15,28	19,29, 39,25	25,34, 6,35	3,27, 35,16	2,24, 26	35,38	19,35, 16	18,1, 16, 10	35,3, 15,19	1,18, 10,24	35,33, 27,22	18,28, 32,9	3,27, 29,18	27, 40, 28,8	26,24, 32,28		22,19, 29,28	2,21	5,28, 11,29	2,5	12,26	1,15	15,10, 37,28	+	34,21	35,18
38	EXTENT of AUTOMATION	28,26, 18,35	28,26, 35,1	14,13, 17,28	23	17,14, 13		35,13, 16		28, 10	2,35	13,35	15,32, 1,13	18,1	25,13	6,9		26,2, 19	8,32, 19	2,32, 13		28,2, 27	23,28	35,10, 18,5	35,33	24,28, 35,3	35,13	11,27, 32	28,26, 10,34	28,26, 18,23	2,33	2	1,26, 13	1,12, 34,3	1,35, 13	27,4, 1,35	15,24, 10	34,27, 25	+	5,12, 35,26
39	PRODUCTIVITY	35,26, 24,37	28,27, 15,3	18,4, 28,38	30,7, 14,26	10,26, 34,31	10,35, 17,7	2,6, 34, 10	35,37, 10,2		28,15, 10,36	10,37, 14	14, 10 34, 40	35,3, 22,39	29,28, 10,18	35,10, 2,18	20,10, 16,38	35,21, 28, 10	26,17, 19,1	35,10, 38,19	1	35,20, 10	28,10, 29,35	28,10, 35,23	13,15, 23		35,38	1,35, 10,38	1,10, 34,28	18,10, 32,1	22,35, 13,24	35,22, 18,39	35,28, 2,24	1,28, 7, 10	1,32, 10,25	1,35, 28,37	12,17, 28,24	35,18, 27,2	5,12, 35,26	+

Figure 40. The contradiction matrix (Altshuller 1971).

The improving standard parameter is then set against the worsening parameter, and at the intersection of the matrix there are numbers relating to the 40 inventive principles. For example in this case a parameter that we wish to improve is "*adaptability / versatility*", but when we do, "*ease of manufacture*" gets worse. The result is shown in figure 41.

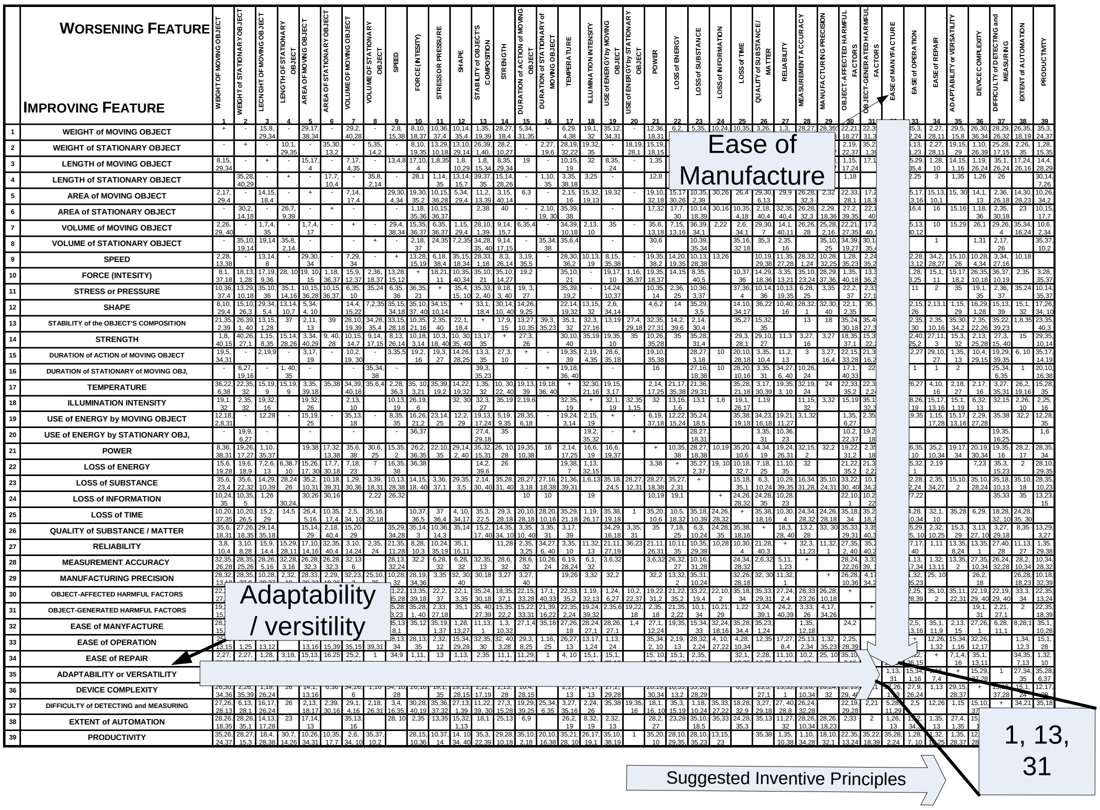


Figure 41. Use of the matrix for the top tlate orientation problem.

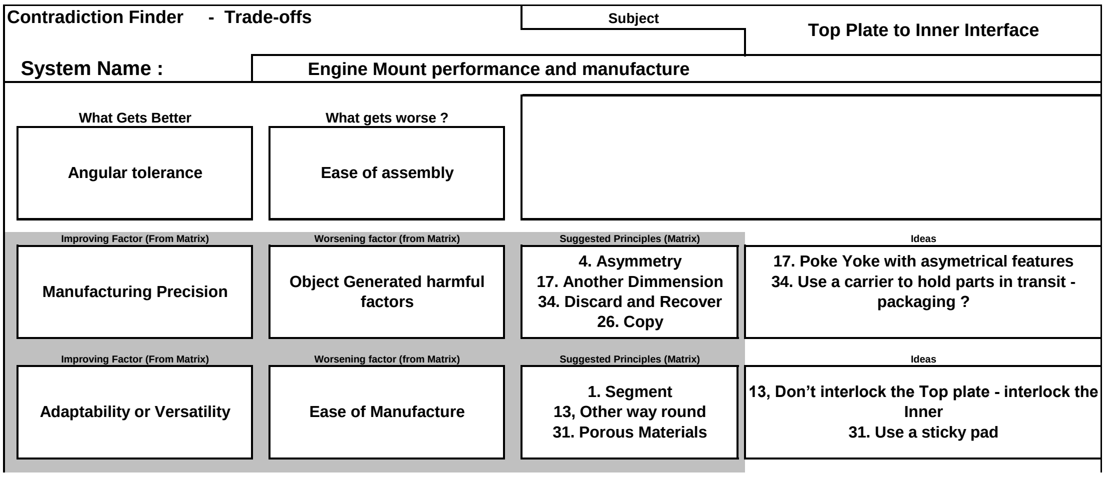
The numbers within each intersecting box relate to the inventive principles that Altshullers researchers had been found in the patent database to solve each contradiction pair. This was based upon over two million patents, and as such is a summarisation of how the world solves problems (Savransky, 2000, Altshuller, 1984).

A list of the 40 inventive principles with explanations is shown in Appendix 10.5. A summary is outlined in Table 8.

No	Inventive Principle	No	Inventive Principle
1	Segmentation	21	Skipping / Rushing through
2	Taking Out	22	Blessing in Disguise
3	Local Quality	23	Feedback
4	Asymetry	24	Intermediary
5	Merging	25	Self Service
6	Universality	26	Copying
7	Nested Doll	27	Cheap disposable / short living objects
8	Counter Balance / anti weight	28	Mechanics Substitution
9	Prior Counter action	29	Pneumatics and hydraulics
10	Prior Action	30	Flexible Shells and thin films
11	Before hand cushioning	31	Porous Materials
12	Equopotentiality / Remove Tension	32	Color Changes
13	The other way around	33	Homogenity
14	Curvature / spheroidality	34	Discarding and Recovering
15	Dynamization	35	Parameter Changes
16	A little less, a little more	36	Phase Transitions
17	Another Dimension	37	Thermal expansion
18	Vibration / Resonance	38	Strong Oxidants
19	Periodic Action	39	Intert atmosphere
20	Continuity of useful action	40	Composite materials

Table 8. List of the 40 inventive principles (Altshuller, 1984).

In this case, the matrix suggests the use of principles 1.*Segmentation*, 13.*Other way round* and 31.*Porous Materials.* This was structured using a tab on the spreadsheet "contradiction Finder" tool created for the workshop, as shown in Figure 43.



Contradiction Finder - Trade-offs

Subject: Top Plate to Inner Interface

System Name : Engine Mount performance and manufacture

What Gets Better	What gets worse ?
Angular tolerance	Ease of assembly

Improving Factor (From Matrix)	Worsening factor (from Matrix)	Suggested Principles (Matrix)	Ideas
Manufacturing Precision	Object Generated harmful factors	4. Asymmetry 17. Another Dimmension 34. Discard and Recover 26. Copy	17. Poke Yoke with asymetrical features 34. Use a carrier to hold parts in transit - packaging ?
Adaptability or Versatility	Ease of Manufacture	1. Segment 13, Other way round 31. Porous Materials	13, Don't interlock the Top plate - interlock the Inner 31. Use a sticky pad

Figure 42. "Contradiction finder", completed for the Top Plate orientation Problem.

The contradiction is entered into the cells headed “What gets better” and “What gets worse”, according to step one of Figure 40. Because there are multiple ways to interpret each contradiction, multiple cells are provided to record these interpretations, and the corresponding inventive principles suggested by the matrix. Finally, space is provided to record the ideas stimulated by the inventive principle. This tool encourages the problem solver to progress through the steps of using the matrix, and simultaneously record ideas in such a way as to be easily recorded and shared electronically.

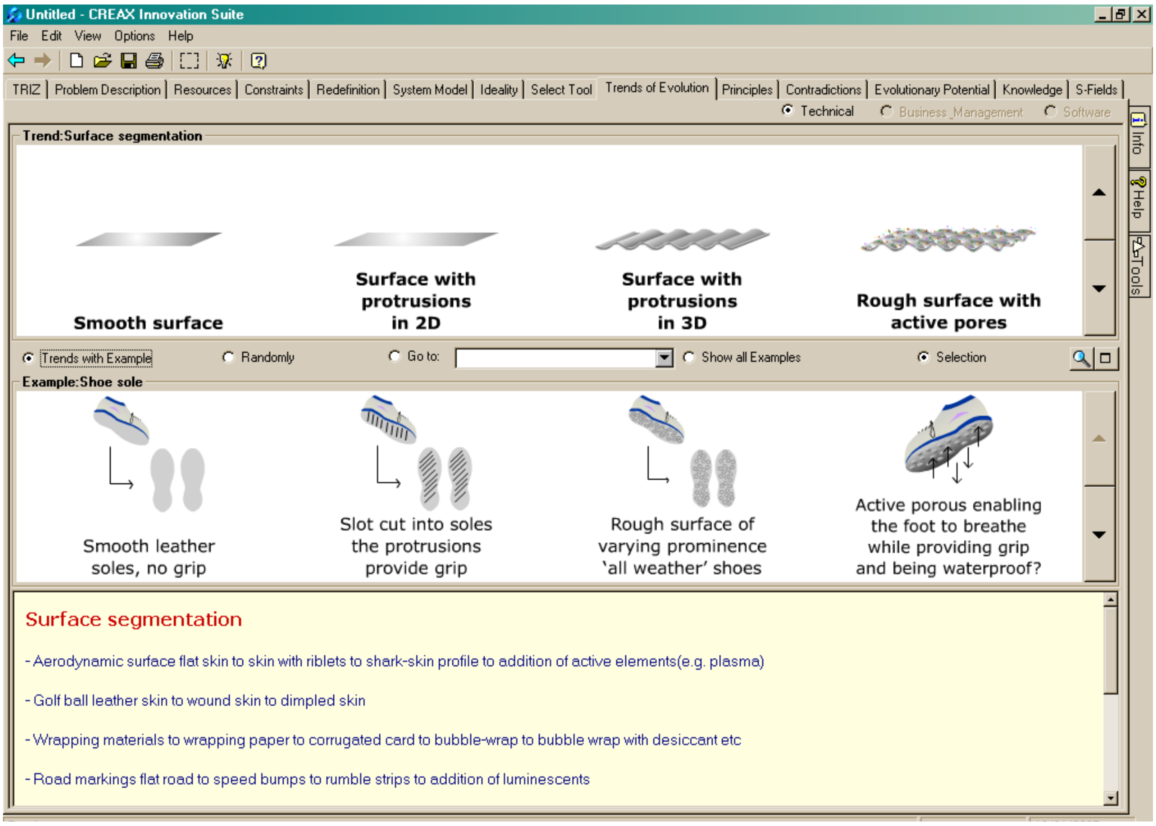
The principle “*Segmentation*” did not inspire any ideas, but participants thought that number 13 – “*Other way round*” suggested locking the inner to the top plate, rather than the top plate to the inner. The use of “*porous materials*” stimulated the idea of using a sticky pad to hold the top plate in place.

The matrix tool took some time to explain. Although it was anticipated that the participants would have read the Simplified TRIZ book (Rantanen, 2002), some had not read it all, others found they hadn’t grasped the matrix chapter and others had a working understanding of the tool. In this particular respect, the idea of having participants read the book between the two sessions was not helpful, as it created a wide range of abilities within the participants. Matching the workshop content and pace to satisfy these differing needs meant that the course slowed to the pace of the least capable person on the group.

Although the participants could have been asked to continue to add further contradiction pairs, time constraints required that the next tool be learned.

5.3.6 Trends of Evolution

The final tool taught in the workshop, the “trends of evolution” is based upon the patterns in which technology has been found to develop. Altshullers’ research outlined over 30 trends in which systems, and sub systems develop over time. Each step along the trend represents a patentable inventive step, where a problem solver has overcome a contradiction. Therefore, by positioning the specific problem onto a trend, one can start to determine how and why a jump along the trend could be beneficial. In relation to the MSB top mount orientation problem, the participants considered the “surface segmentation” trend, illustrated in Figure 43 :



Surface segmentation

- Aerodynamic surface flat skin to skin with riblets to shark-skin profile to addition of active elements(e.g. plasma)

- Golf ball leather skin to wound skin to dimpled skin

- Wrapping materials to wrapping paper to corrugated card to bubble-wrap to bubble wrap with desiccant etc

- Road markings flat road to speed bumps to rumble strips to addition of luminescents

Figure 43. Screen shot from the Creax innovation suite software showing the surface segmentation trend.

Because the interface between the top plate and the top of the engine mount spring moulding was the problem zone highlighted by the definition tools, the team were already zoomed into the problem. Within ten minutes of looking at this trend, and working alone independently, three people came up with potentially viable and very similar solutions. All were to do with increasing the grip between the mating – interface components, through roughening or adding bite, and grip to the plastic, the aluminium top plate or the rubber moulding. The selected solution to be trialled is described in Figure 44.

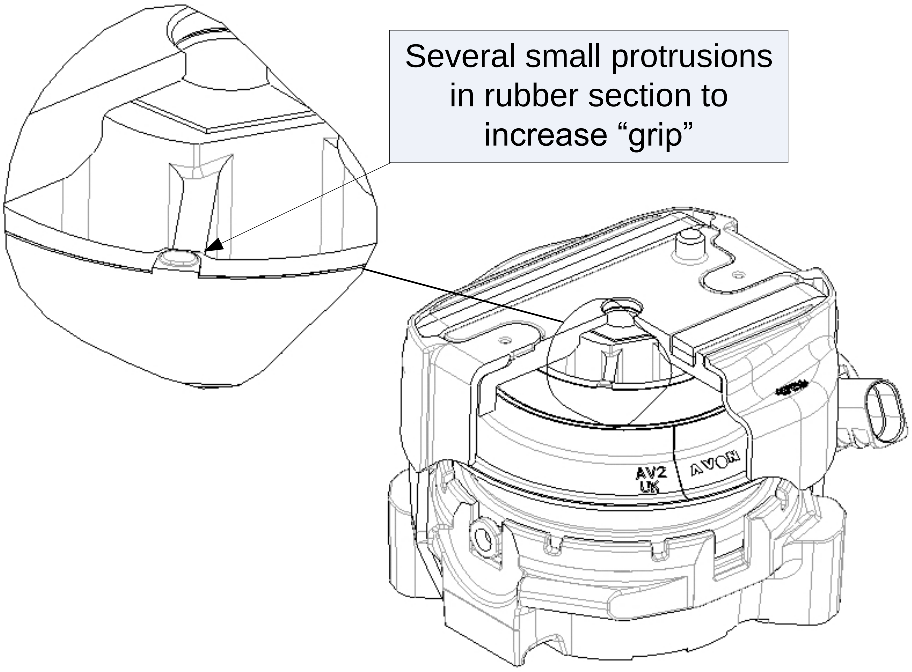


Figure 44. Illustration of one of the proposed solutions to the top plate orientation problem.

A very inexpensive modification was to be made to the rubber mould to create small "pips", which would resist the torque sufficiently, but have no other negative effects. Furthermore the cost of the modification was sub £1000. The idea was trialled subsequent to the workshop and found to be successful. In the unmodified state, the top plate could be rotated with manual force. With the "pips" the top plate could not be moved despite very significant manual force being applied using a lever. Although this force difference was not measured in terms of torque, it was clearly sufficient to keep the top plate in position when subject to loads likely to be subjected to, prior to assembly on the vehicle.

5.4 Reflection on Action Cycle 2

The reaction from the group was one of surprise. The "impossible" challenge of solving the problem had been met. This included the author of this thesis, who was relieved to have been able to see the TRIZ tools successfully applied to a problem that had been considered intractable.

For the workshop itself, the following reflections and learning were recorded :

- Timing was much improved.
- The "Avon Power Generation" problem was considered good (see Appendix 11.8).
- The Matrix split the group between those that "got it" and those that didn't, slowing things down in the second session.
- Those that read the book within the 2 weeks appeared to do the best in the workshop.
- The addition of the FAA tool was successful.
- There were 5 participants in the first workshop which seemed a workable group size.
- Some participants felt that there was too much to grasp in the timeframe.
- One participant felt that the folders used to add in the paperwork were distracting because they were asked to insert papers into pre-prepared sections – which took some concentration away from the training.

Actions arising from this reflection were that the MSB top plate project should be written up neatly and used as a case study in further workshops. The participants would not be exposed to the answer, in order to repeat the discovery "a-ha" moment with more people. The participants from the first workshop were instructed to not let the others know the solution to the problem.

5.5 Action Cycle 3 – Workshop 2 and 3

In workshops 2 and 3, the MSB top plate exercise was used as the main case study. In each of the two further workshops, at least half of the participants quickly came to the solution in the same way as the first workshop group.

However, the down-side to this, was that because the standard Power station / coal dust case study remained in the course material, there was no time left to add in further live difficult problems to work on. This restricted the ability of the attendees to generate new case study material.

6 *Results*

6.1 *Results from the Workshop Sessions*

A full copy of the workshop slides is shown in Appendix 11.9. During the times of reflection, participants were asked to rate the tools according to difficulty level in comparison to FMEA, and to also consider how often they thought they would use them in their job. They were asked to think about the response individually, but to present their answer publicly while the author created a tally chart of the responses, and made notes. Because the results were recorded at the time, all 17 participants responded. The results are presented in the following graphs :

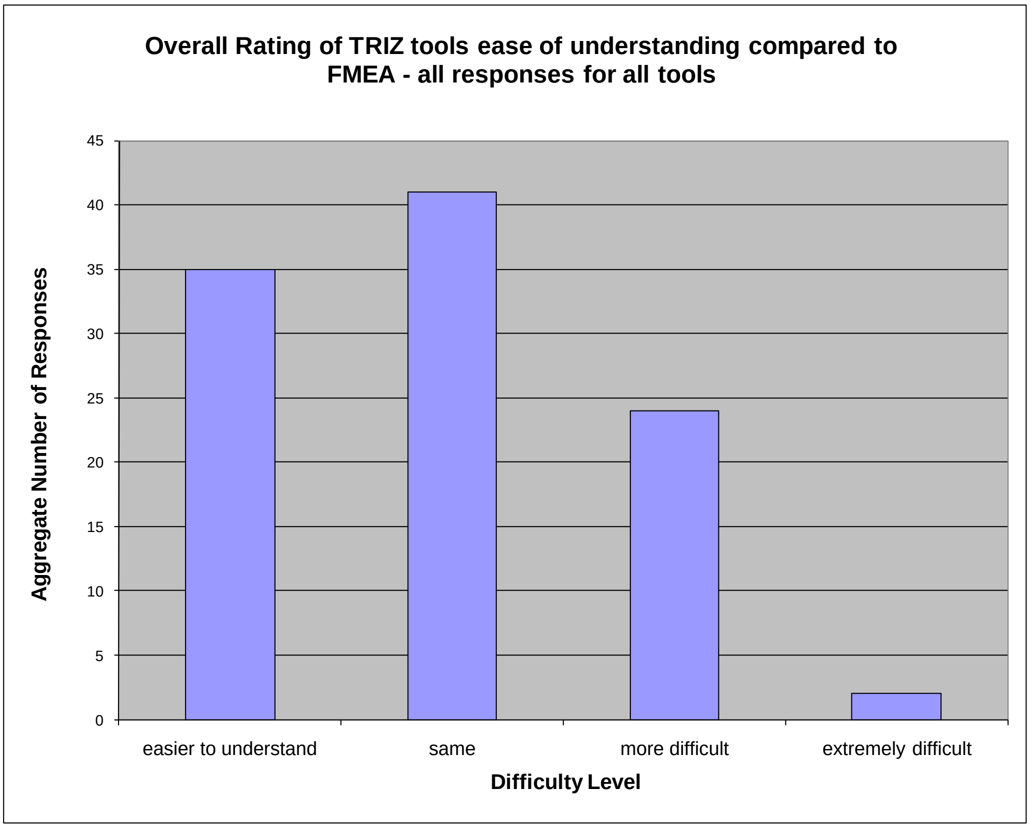


Figure 45. Overall rating of TRIZ tools in terms of ease of understanding compared to FMEA. (Aggregate score from all attendees across all tools 102 responses from 17 participants).

This shows that the participants found TRIZ to be overall slightly more easy to understand than FMEA. But most found it the same as FMEA.

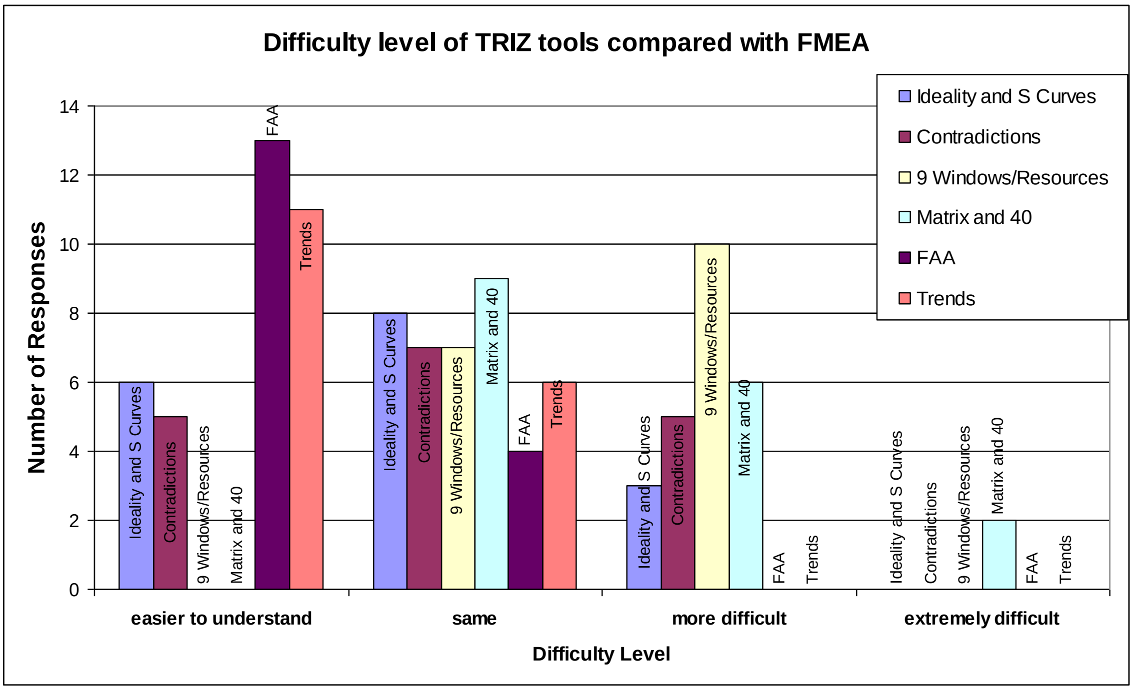


Figure 46. Chart showing difficulty level of each of the TRIZ tools compared to FMEA.

Figure 46 shows the breakdown of difficulty level between the tools. The tools fall into two groups. FAA, Ideality/S-curves, trends and contradictions were considered easier or similar in difficulty to FMEA, and the 9 Windows and the Matrix / 40 principles were considered more difficult.

FAA was the easiest tool according to the three groups, with 13 people rating this tool easier than FMEA. The "Matrix and 40 Principles" tool was the most difficult to grasp, with 8 people rating the tool as more difficult than FMEA or extremely difficult.

The groups were in closest agreement about FAA, Trends and the 9 Windows tools. The ratings in these categories span only two ratings levels. There was more variation in opinion between the members concerning Ideality / S-Curves, the Matrix and contradictions, with these tools spanning three rating levels.

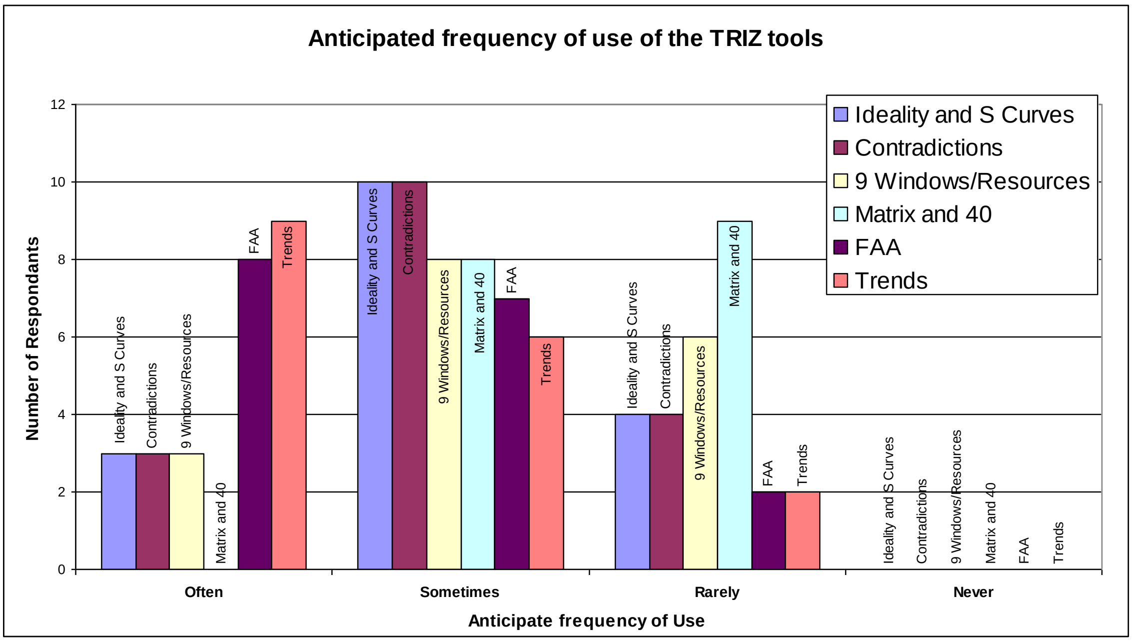


Figure 47. Chart showing responses from participants concerning their opinion on the likely frequency of use within their job.

The first point of note with the graph Figure 47, is that no tool was suggested to be ignored completely. There was also a wider range of opinions concerning this future use question. Only one tool, the Matrix and 40 Principles falls in only two ranking groups. The rest spanning three. Taking a ranking of both estimate of frequency of use, and difficulty level, Table 9 (Ranking of 1 = easiest, and most frequent use) can be drawn.

Rank	*Difficulty level*	*Frequency*
1	FAA	Trends
2	Trends	FAA
3	Ideality / S-Curves	Ideality / S-Curves
4	Contradictions	Contradictions
5	9 Windows	9 Windows
6	Matrix + 40 P's	Matrix + 40 P's

Table 09. Comparison of difficult levels and expected frequency of use according to feedback during workshop sessions.

It can be seen that the difficulty and frequency rankings are closely matched, with only the Trends and FAA being out of order between the two rankings.

Feedback Post Workshop

Sixteen of the possible seventeen post workshop feedback sheets were completed and returned. (See Appendix 11.9 for full responses). These were in three sections one concerned the overall course, and how well it was received, the second section repeated the question about frequency of use, and thirdly some suggestions were made about the future development of TRIZ, including “not at all”. Unlike the first questionnaire, the 40 principles and the matrix were separated in order to gauge opinion more specifically. The first group of questions were rated against a possible five categories, with increasingly positive statements. In analysing the results, these scores have been averaged, and then expressed as a percentage against the highest possible score, see Figure 48.

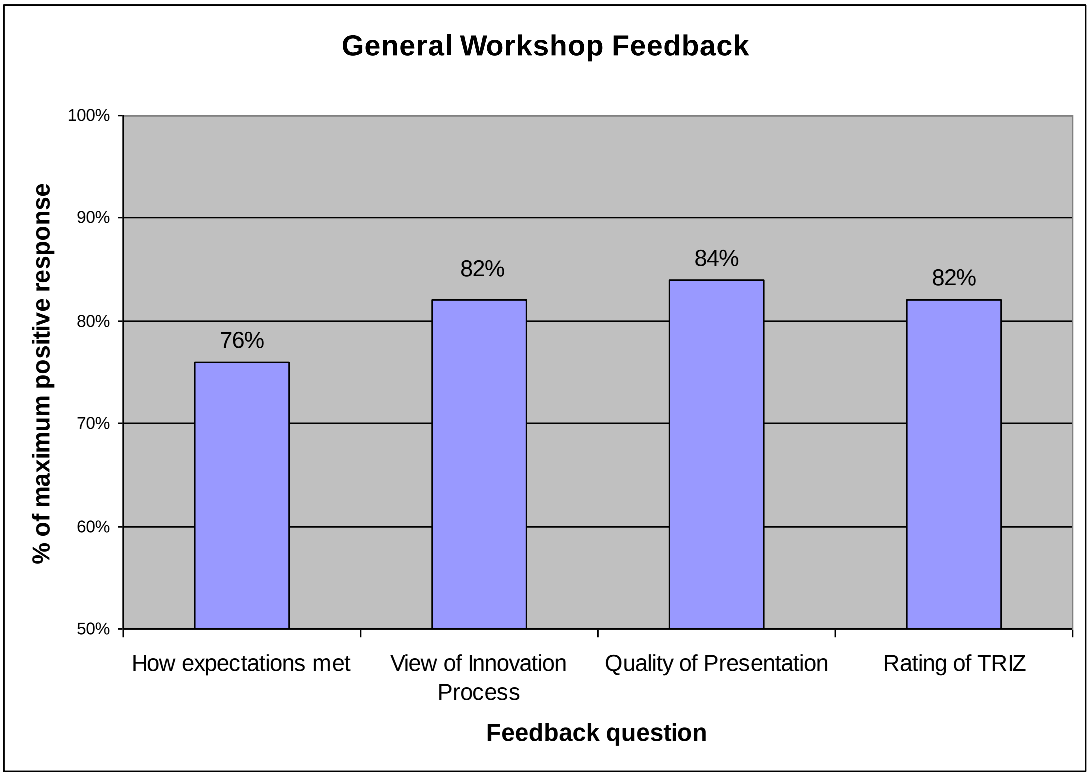


Figure 48. Overall workshop feedback.

Here we see that the course was generally well received, with participants rating all areas positively.

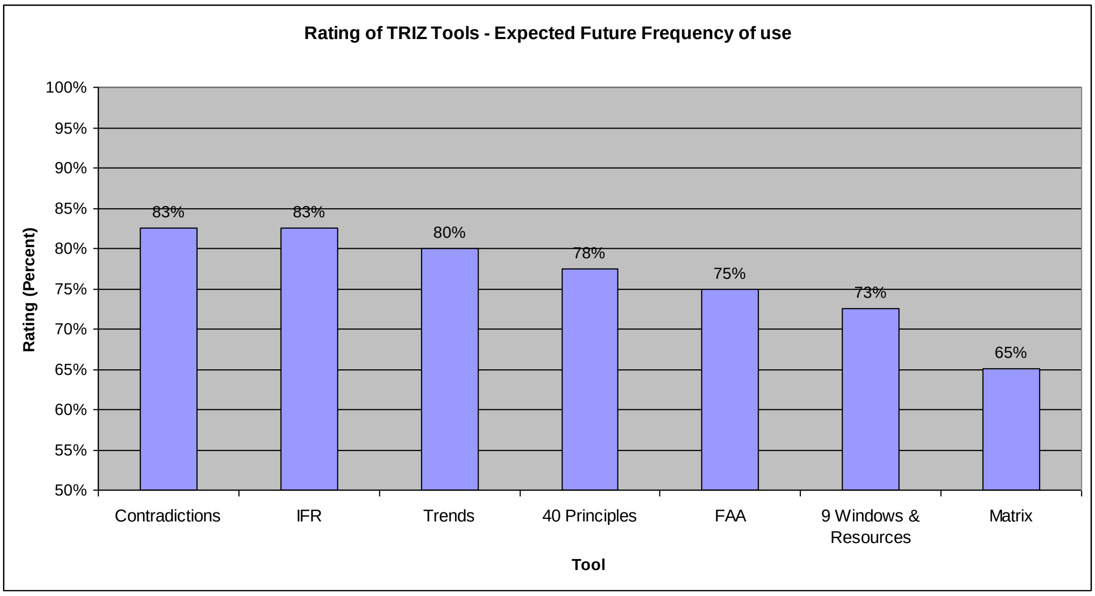


Figure 49. Post workshop feedback rating of TRIZ tools for frequency of use.

Tool	*Ranking Post Workshop*	*Ranking During Workshop*
Contradictions	1	4
IFR / S-Curves	1	3
Trends	3	1
40 Principles	4	(rated with Matrix)
FAA	5	2
9 Windows	6	5
Matrix	7	6

Table 10. Post workshop ranking of tools by participants view of their potential frequency of use in their job.

After a few days to dwell on their answers, the participants changed the order of popularity of the tools. Contradictions and the IFR tools were equal first, with a rating of 83%. It is the matrix that remains the least popular tool with 65%. In fact it can be seen in Figure 49, that the approval rating of the Matrix tool is significantly lower then the rest, with an eight point gap to the next most popular tool. The most important finding is that when the Matrix and 40 Principles are separated from each other, the 40 principles were rated almost as highly as the trends – in third position, with 83% approval rating.

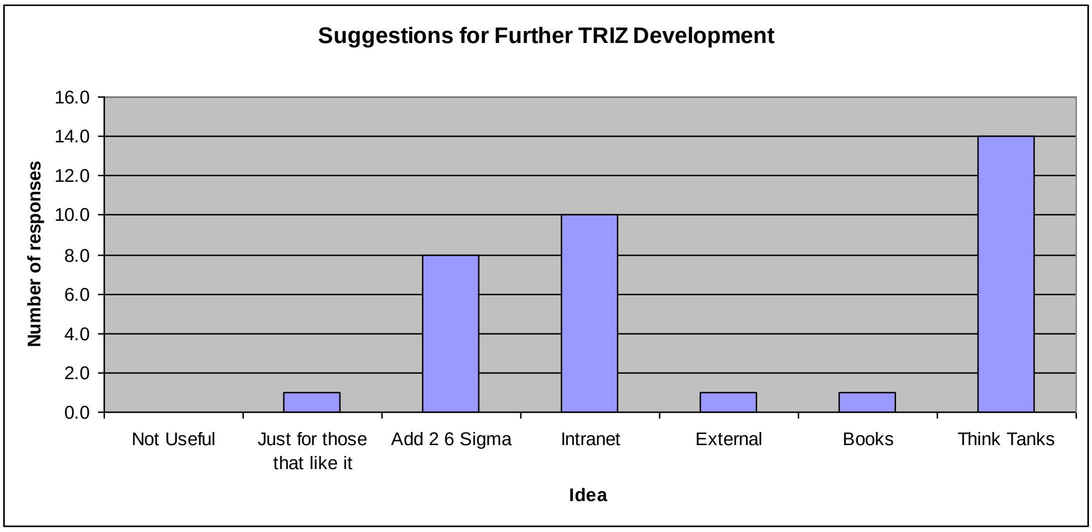


Figure 50. Suggestions from workshop participants for further development of TRIZ (16 out 17 participants responded).

It can be seen in Figure 50 that no-one suggested TRIZ was not useful at all in their job. Half of the respondents (eight) thought that TRIZ should be integrated into the standard Six Sigma toolkit. Over half felt that an on-line learning and sharing environment would be useful. This is one of the methods Samsung use for TRIZ training. (Feygenson; and Han, 2008, Platt, 2004). Finally almost all suggested the use of think tanks, where groups of interested innovators could spend time together, maybe at lunch times working on problems, with TRIZ experts on hand to give advice.

The clear message from the 16 respondents was that use of the TRIZ tools should be encouraged.

6.2 *Results from the IP Study*

A list was obtained of all the live patents filed from the inception of Avon VMS in the early 1980's, until 2005. These were scored by the author, and the lead engineer responsible for IP, who had been involved in the majority of the patent applications, the thought processes at the time of filing, and in reviewing competitor IP monthly.

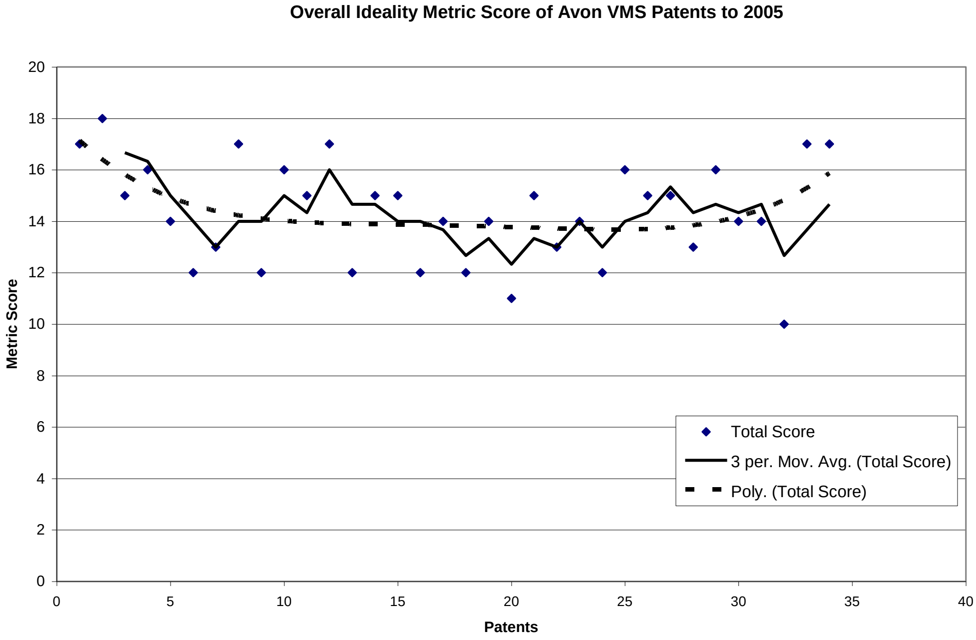


Figure 51. Graph showing Overall ideality score of patents in time sequence to 2005.

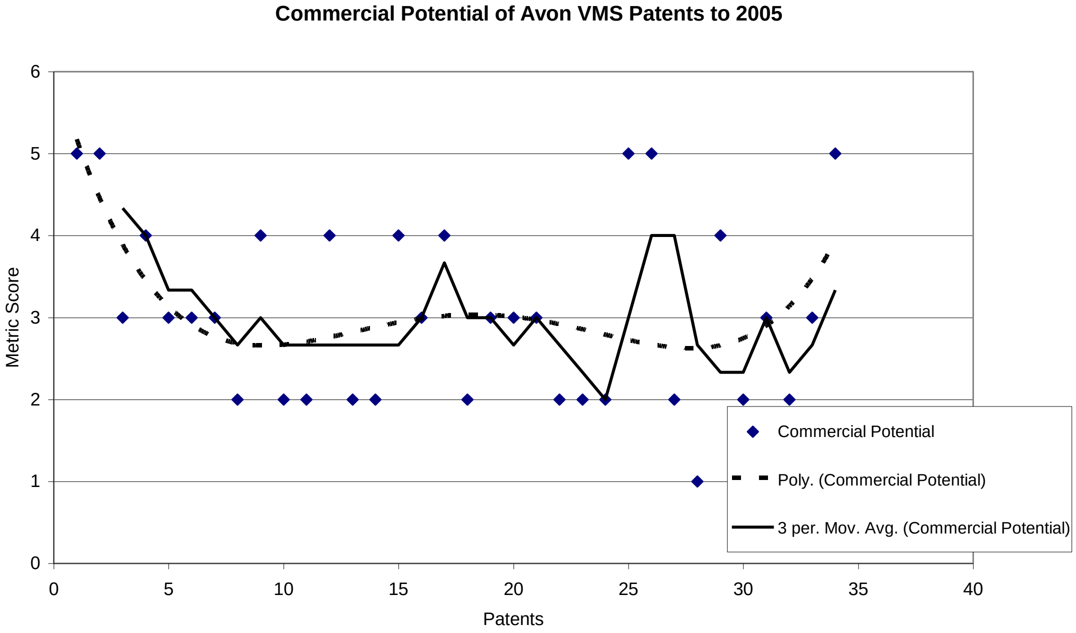


Figure 52. Graph showing commercial potential score of patents in time sequence to 2005.

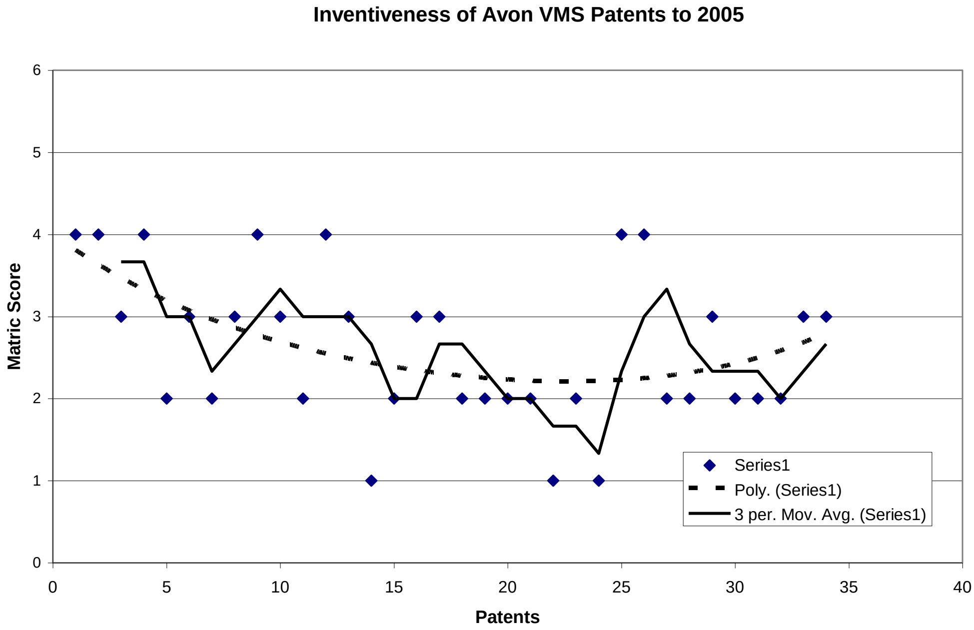


Figure 53. Graph showing inventiveness score of patents in time sequence to 2005.

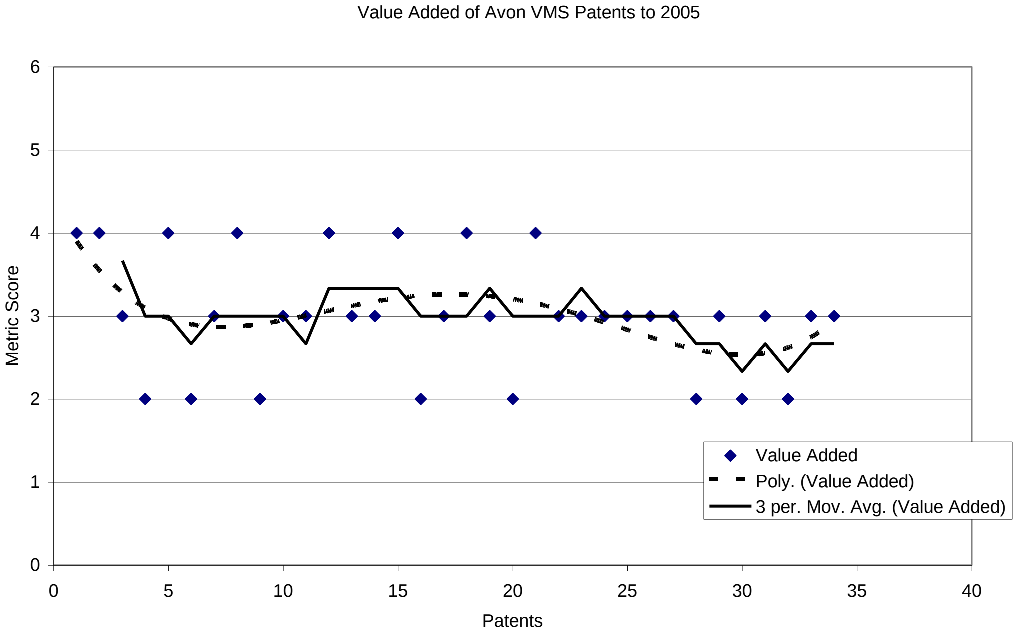


Figure 54. Graph showing value added score of patents in time sequence to 2005.

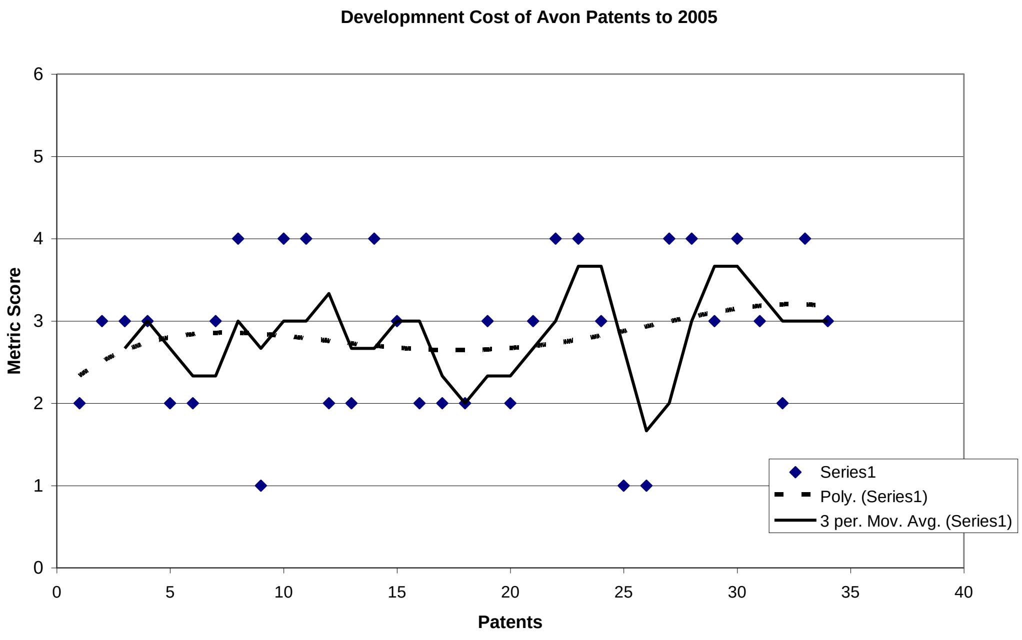


Figure 55. Graph showing development cost score of patents in time sequence to 2005.

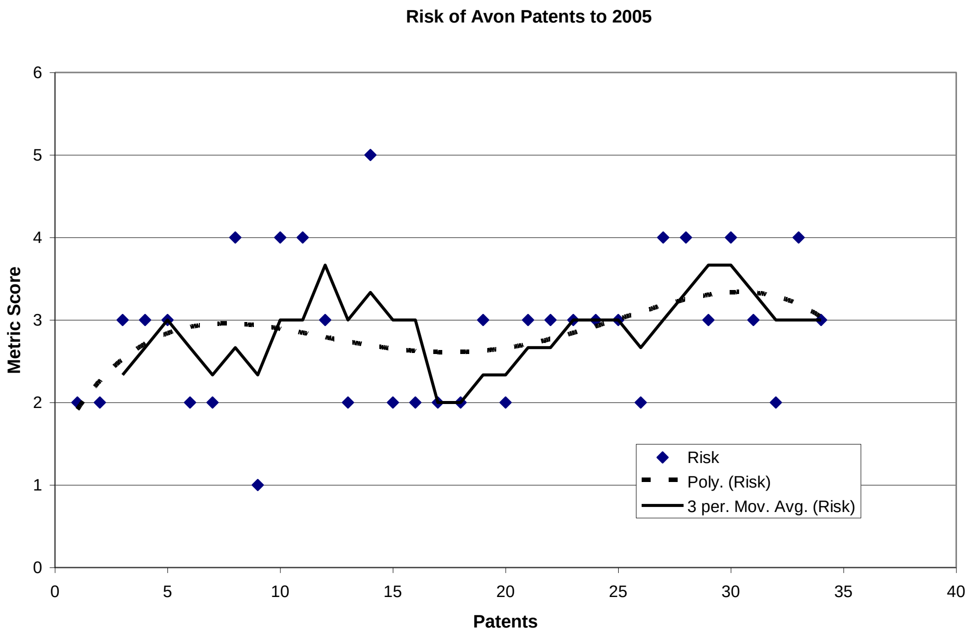


Figure 56. Graph showing risk score of patents in time sequence to 2005.

The graphs shown in Figures 51 to 56 include 3 point moving averages (solid lines) and 4th order polynomial lines of best fit (dotted lines) in order to uncover trends in the data. The trends identified are summarised in Table 11.

Measure	**Trend Observation**
Overall Ideality	Very slight downwards trend overall, although it is not clear if this is statistically significant.
Commercial Potential	Slight downward trend overall, with a slight recent increase.
Inventiveness	Downward trend until patents 23 / 24, followed by a rising trend.
Value Added	Downward trend.
Risk	Rising trend - i.e. to less risk.
Development Cost	Rising trend – i.e. lower development costs – with the exception of the active mount programme.

Table 11. Summary of trend observations from graphs shown in Figure s 52 to 57.

If the ideality equation is expanded for the data, the following equation is derived (Equation 3) :

$$\text{Ideality} = \frac{\sum CommercialPotential + AddedValue}{\sum DevelopmentCost + Risk}$$

Equation 3 Metric score categories applied to the ideality equation.

Plotting these combined factors we obtain the following graphs (Figures 57 and 58).

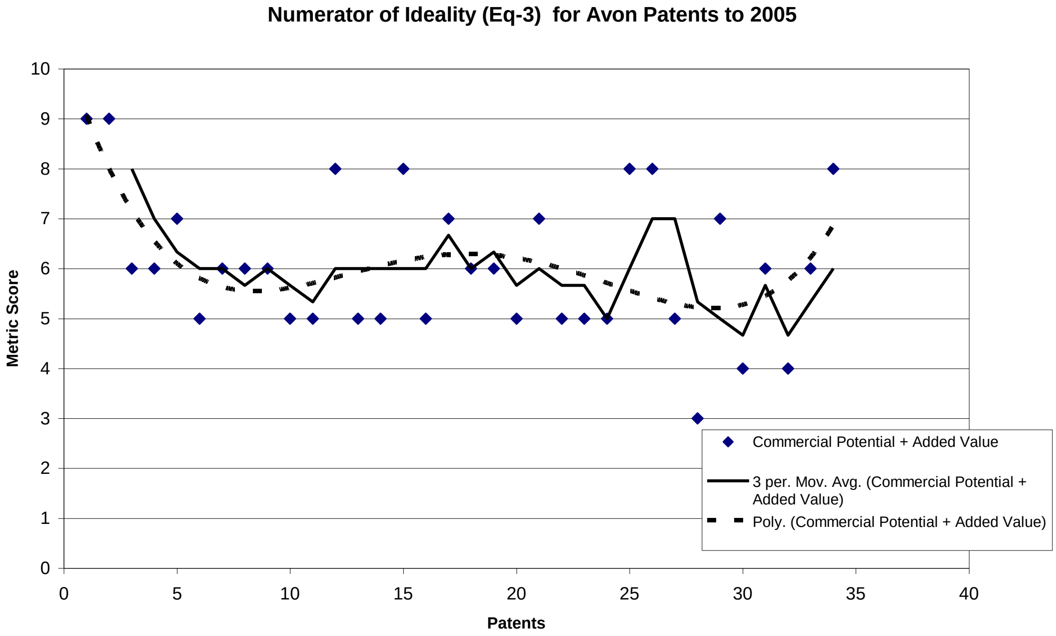


Figure 57. Graph showing the top line of the ideality equation for Avon Patents to 2005.

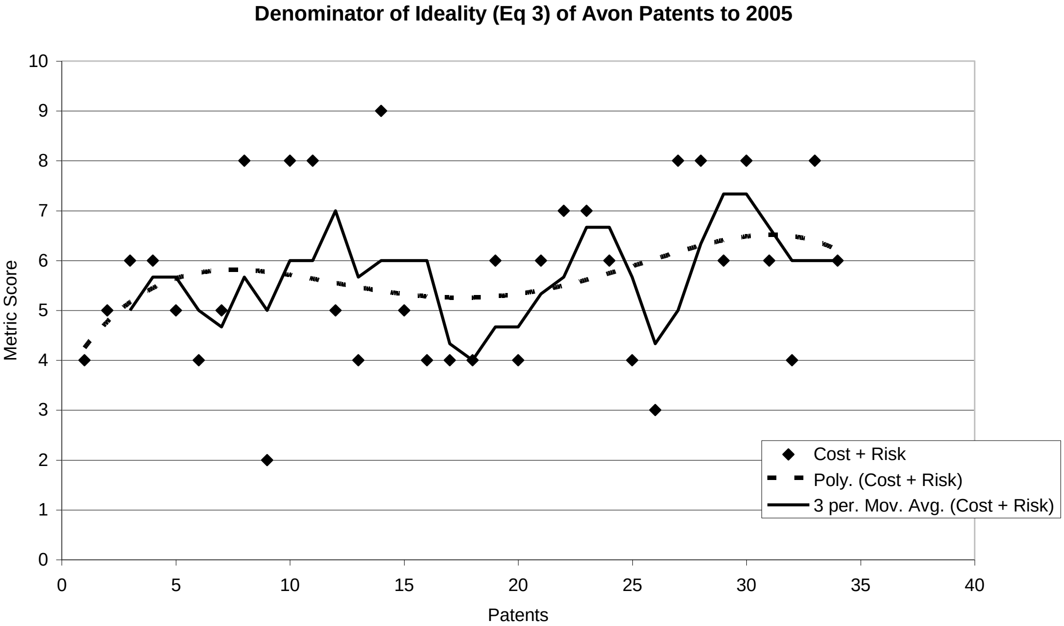


Figure 58. Graph showing the bottom line of the ideality equation for Avon Patents to 2005.

The top half of the ideality equation, shown in Figure 57 reveals a general falling trend in the metric score. The bottom half of the equation shown in Figure 58, shows a rising trend in metric score. This explains the broadly flat graph of the overall innovation ideality score in Figure 52, as one trend has tended to cancel the other out.

7 Discussion

In this section, each of the learning activities are discussed. Firstly, the modelling of innovation, then the measurement of the system and finally the workshop action cycle.

7.1 IDEF0 Model of Innovation

The literature review revealed a lack of clarity in the definition of the meaning of innovation. It is therefore unsurprising that there are many approaches to defining innovation as a business or creative process. Summarising and understanding the constituent parts of innovation – creativity, invention and application was useful, but it was a sense of dissatisfaction with the existing models of innovation that lead the author to consider modelling the process using IDEF0. But why did this need to be done at all ? The primary research question was aimed at the efficacy of TRIZ, rather than the definition of innovation. Considering the amount of research on the topic of innovation, and the importance of the subject to business and society in general, one would have expected that an "off the shelf" model would have been easily found. Perhaps the reason for this is the fundamental difference between IDEF0 and the other modelling techniques. If one considers Table 1a in chapter 3.3.1 (Howard, 2008b), one sees a stark similarity between all of the creativity methods described ie they are sequential, stepwise progressions from the left of the table to the right. IDEF0 is fundamentally different because it is not sequential. Maybe this is because although some of the aspects of creativity and problem solving are sequential, innovation as a whole is not, meaning that IDEF0 is a more appropriate modelling tool.

Clearly however, there are step by step elements within creativity, invention, design and implementation that can be applied and are useful. But innovation itself seems to defy that type of definition. The author proposes that an appropriate analogy of innovation is as an organism. Multiple sub systems interact with each other, working in parallel, and each being reliant on the other for the organism to thrive as an entity. Taking this analogy a stage further, one can imagine that measuring innovation of a company is similar to measuring the health and wellbeing of an organism. It is a measure of capability, of ability, of yield performance or the strength of affect on its environment.

Because innovation incorporates the application of creative / inventive ideas, it has to include all areas of the business, including those areas not normally associated with innovation at all. For instance accounting, IT, production operators and building facilities maintenance. All contribute in some way to the effectiveness of innovation of the organization, even if these are not part of the normally expected creative or inventing parts of the company. In order to explore this further, it is suggested that further work should be undertaken to evaluate innovation in the context of non linear modelling techniques such as IDEF0. This should be done more widely, across other fields and disciplines than the tight, single company, automotive environment of this research.

The lessons to be learned for innovation at Avon are considered, in the context of the IDEF0 diagram repeated here see Figure 59.

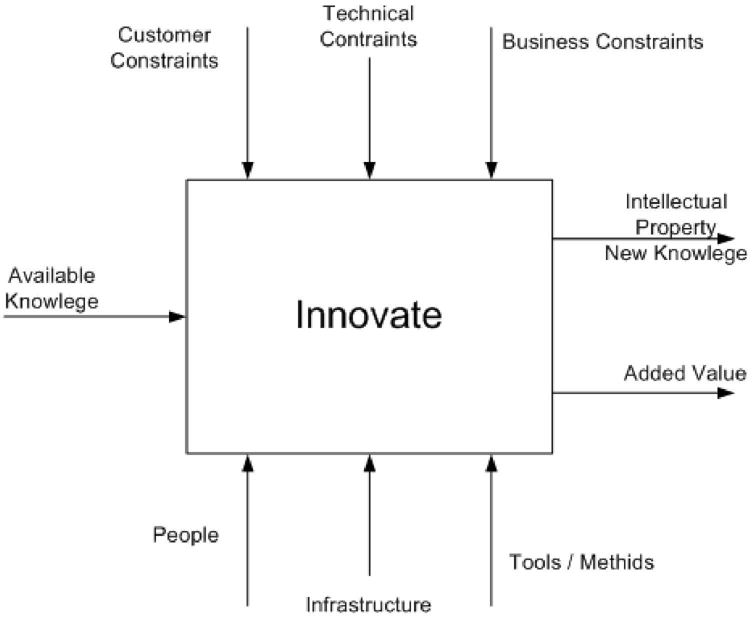


Figure 59. IDEF0 Innovation A-0 Diagram.

Available knowledge

In solving problems and developing new ideas, the team needs to have access to as much knowledge as possible – this includes deep knowledge from the domain, as well as relevant, or seemingly irrelevant knowledge from other fields. Knowledge Management (KM) is a rapidly developing field (Maier, 2004). There is much debate within the community on what KM is, and how it will develop as a subject in the future (Rees) However, IT will be the platform on which it is developed, and the extremely rapid development of company specific social networking and intranet based tools is evident. One of the most popular systems is called Yammer www.yammer.com which allows rapid sharing of information in a self organising network within an organisation. It is used by companies such as O_2, Xerox and Deloitte Digital. One can see the domains of KM, crowd-sourcing and open innovation merging in the long term. Companies such as Avon need to decide if, how and when to participate. Organisations need to maximise their ability to access knowledge, through databases, supplier networking, customers and any other source, but also to have a structure and method for assembling the knowledge so that it can be shared around the organisation.

Several of the TRIZ tools have a positive affect upon available knowledge. Firstly, the solution tools – the trends of technical evolution, and the 40 principles are summarisations of vast amounts of knowledge from all knowledge domains within the patent database. This knowledge is continuously being updated (Mann, 2003).

It is known that companies such as Samsung and Proctor and Gamble, who have adopted elements of TRIZ within their proprietary business systems, now evaluate how their businesses are solving problems by categorising them as contradictions and inventive principles. This helps to share learning across the organisation, as this is a continuously updated system (Cheong S, 2008)

During the workshop, several attendees suggested that the 9 Windows tool would be a useful database for capturing all the features and resources within standard products. For instance a 9 windows tool for the service life of an engine mount, or suspension bush. Learning could be added to these databases as it occurs, and referred to in any future problem solving situations and in designing future products. Likewise the FAA tool could be used as part of the FMEA process to show harmful, excessive, or insufficient interactions between system elements. Because a form of function analysis is already required as part of the FMEA process, this tool could be adopted very simply.

People

"Not utilizing human resources" is one of the deadly wastes according to lean thinking. In Chapter 3, Innovation best practice is shown to involve managing people, systems and roles to enhance creativity (Amabile, 1996). The work environment, provision of appropriate workloads, allocation of projects and encouragement and challenge all affect creativity. These aspects can only be addressed from the highest level leadership of the company. One of the responsibilities of leadership therefore is to make use of the skills and resources within the business. To fail in this responsibility is wasteful to the business and wider society.

From the literature survey outside of the TRIZ field, a short-list of important aspects can be compiled which should be considered to enhance creativity and innovation capability of the employees at Avon :

- de Bono – lateral thinking skills.
- Self awareness / learning styles.
- Awareness of the learning styles of other team members.
- Interpersonal skills.
- Self learning.
- How to sketch and make analogy.

Recruitment policy should also be considered based upon adding to the depth and breadth of the knowledge base of the company, through recruiting talent from different fields and industries. A further improvement to brainstorming and creativity is outlined by (Dorothy Leonard, 1999), which suggests using outsiders, or “aliens” within the problem solving team. This is claimed to increase the ability of groups to operate outside their normal thought patterns.

Infrastructure

Creating an iLab environment is somewhat impractical for most companies like Avon due to cost and space considerations. However thought should be given to improving the infrastructure and workplace environment, or the use of off-site meetings. The author is aware that companies such as O_2 are introducing flexible hot desking, where departmental and line management boundaries only exist virtually, and people are free each day to sit wherever makes most sense depending upon their project activities. Elements of this approach could be trialled without excessive spend

It is clear that the future direction of much of innovation is centred towards IT, using social networking type engines and platforms. Care must be taken to utilise these tools to advantage, particularly in terms of gathering information input, open sourcing and involvement of customers and suppliers.

Tools / Methods

From this study, the use of TRIZ tools is recommended for wider application within the business. This should not been seen as an alternative to the existing methods, but to build upon them. For instance, it has been concluded by (Howard, 2008a) that brainstorming is improved by the introduction of random stimuli into the sessions. But this research has also shown that the use of guided relevant stimuli such as the 40 principle or TRIZ trends is superior to random stimuli. Feedback from the workshops suggest that the popularity of trends of evolution, and the 40 inventive principles would improve the effectiveness of brainstorming, which is an accepted practice within the company. It is also suggested to investigate the Six Thinking Hats approach from de Bono, which is a credible method for improving the effectiveness of brainstorming.

It is noted that many of the participants that solved the MSB top plate problem, did so independently, in a way that they could have done at their desk. There is a potential therefore that an increased use of TRIZ, would require less use of brainstorming sessions.

Controls

In the book “Cradle to Cradle”(McDonough, 2002) the authors state:

> “*Innovation requires noticing signals outside the company itself: signals in the community, the environment and the world at large*”.

Customer Constraints

Understanding the needs of customers is crucial to business success. Automotive customers are usually very specific about their detailed requirements. In terms of long term product development, having a clear understanding of key contradictions, and how ideality looks to the customer is also important. Because customers will tend to ask for what they consider to be possible, being able to develop and then offer products with performance thought to currently be impossible gives a clear competitive advantage. Advanced use of the TRIZ tools can help to map out the technology development path needed to be followed to make that happen.

Also, there are some tools such at QFD that present data concerning customer requirements in very similar ways to contradiction statements in TRIZ. QFD is considered within Avon to be part of the six Sigma toolkit. It would be a simple and obvious step to use any QFD output to act as an input to the contradiction driven tools within TRIZ, such as the IFR, 40 principles and the Matrix.

Technical Constraints

Understanding technology in the context of contradictions is a key element of TRIZ. The trends of technical evolution and the 40 principles are powerful tools to understanding the constraints in the system. Understanding these contradictions helps to find alternative technologies from other industries that could potentially be used to resolve those contradictions and create new IP.

Business Constraints

A clear understanding of the constraints of the business are important to be communicated to all in the company. If for instance, capital investment is unavailable, multiple, large scale development programmes are not possible. This means that time expended on large proposals would effectively be wasted. However, the requirements of the business should constantly be challenged and questioned, meaning that such proposals should not be dismissed out of hand, should significant opportunities be identified. The IFR tool is useful for defining what is required by the business and why in such cases.

Outputs

Because the outputs of innovation – ‘new IP/Knowledge” and “added value” are a consequence of the inputs, controls and infrastructure of the innovation process, it could be argued that a company should concentrate on these contributory factors, rather than the outputs themselves. To an extent this is true, but if the outputs are not put to the best use, then this is wasteful. New ideas and creativity create opportunities for IP, but if these opportunities are lost, then potential value is lost also. As emphasised in section 3.3.3 on best inventive practice, organisations need to ensure staff are aware of the rules of confidentiality pertaining to dealings with outsiders, and also what does and does not constitute a patentable idea. New knowledge that is generated, even if not patentable needs to be recorded so that the benefits are transferred and realised around the company. For many companies this applies globally. Developments in the field of knowledge management therefore directly affect the value and efficiency of innovation.

When considering the flow of money through the innovation process as described in the second level A0 IDEF0 diagram in Section 4.1 (Figure 20), it can be noted that there is no feedback loop for added value. However, it should be considered that a proportion of the added value, or profit from the innovation process needs to be fed back, or re-invested into the process to make it self sustaining. As such this strategic decision about investment in the future vs profits for the short term is one that can only be taken at the most senior level of organisations. As such this thesis emphasises that responsibility for and ownership of the innovation process rests with the head of the organisation.

7.2 Measurement of the System

The analysis of the patent metric, shows that broadly speaking the earlier patents had the highest market potential, the largest inventive steps, and were the highest risk. As time has progressed, the patents have been applicable to sub systems and variants of the technology, and "improvement" patents, by their nature are consistent with incremental innovation (see Chapter 3.2.4). The disruptive innovations are highlighted in the metric as having the highest potential for application in wider markets, threatening competition and having higher inventiveness. These stand out in the data shown in Figure 21, as the initial hydramount patents (no's 1 and 2), The hydrabush bypass (no.8), vertical durabush (no.12), Radial Damping (no.15), Multi Axis II (no.17), High frequency dip suspension bush (no.21) and multi-axis Durabush (no.29). All of these have delivered a significant performance improvement for customer end products, and when realised give the company the ability to explore new customers and market segments within the automotive industry. The ideas in this list that have been taken to market are the hydramount, the hydrabush and the vertical fix durabush. These have all taken significant resource to develop, and were considered highly risky during the development and launch phases, but have allowed Avon to grow existing business significantly, and develop new customers. In particular the Durabush has allowed Avon to offer a bush that met or usually exceeded the dynamic performance characteristics of competitor parts, whilst having a durability life many times higher. At time of writing this thesis – the cars fitted with the Durabush are considered class leading for ride and handling, and field returns have been orders of magnitude lower that for competitor parts. In TRIZ terms, the Durabush has moved the contradiction of performance vs robustness further towards the IFR.

However, it is surprising that the "active mount" patents (no's 25, 26 and 34) were not highlighted in the metric as being disruptive. (see Figure 21). As outlined in the introduction to the company, Avon has achieved a world first in getting to market with a fully active, vibration cancelling engine mount. On reflection, it is likely that when scoring this project, the significant difficulties that were being experienced in perfecting the technology prior to launch coloured, the scorers opinions of the project. The market potential for this technology is very significant, and the scorers only rated it a three. This is because the focus is on refinement, and the difficulty in engineering the Active mount to meet robustness, size, and cost targets meant that in its first iteration, the active mount was not such a compelling proposition. However, with a more objective long term perspective, the TRIZ philosophy would tell us that the functions of the active mount can be delivered without the difficulties, and in which case the active mount should score much higher as a concept.

In fact, the active mount score seems to be a case study concerning the nature of disruptive innovation. A new system has been developed, that on existing “common sense” measures, such as cost is worse than the incumbent technology. But if investment is made in resolving the sub system contradictions, and is successful in developing the product along the S curve (Figure 60), then eventually a large slice of the most profitable parts of the market will be can be taken. (Christensen, 1997, Mann, 2002a).

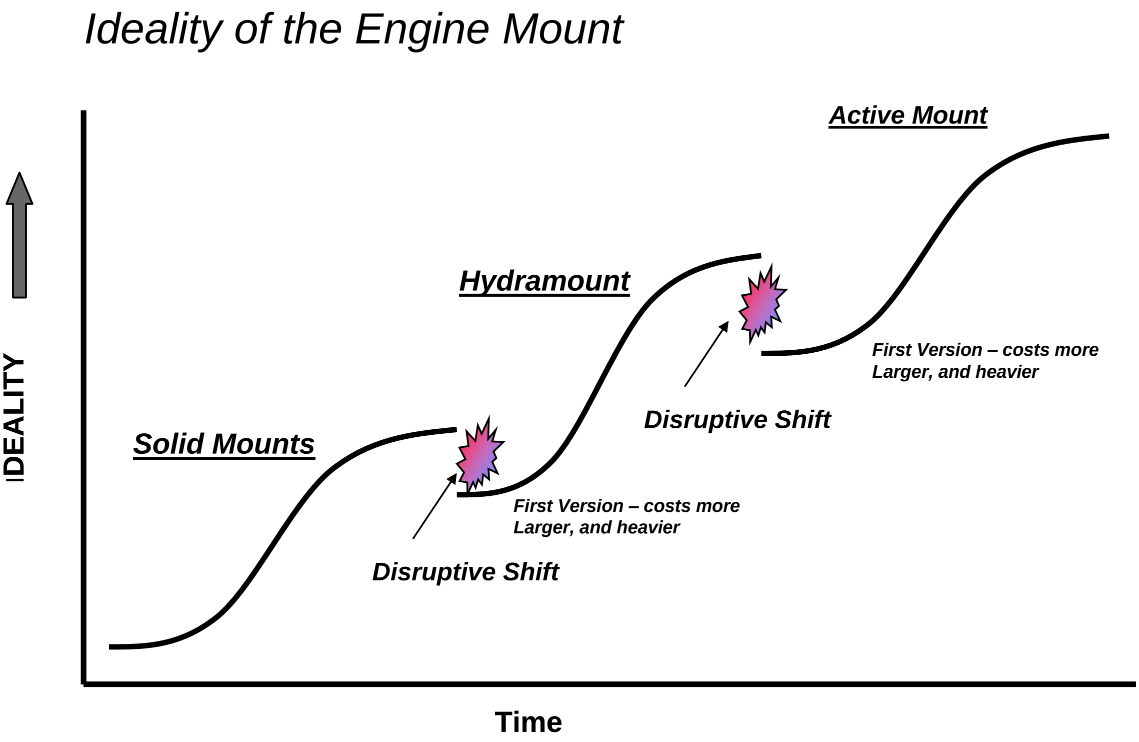


Figure 60. Graph showing the disruptive shifts in engine mount development.

Analysing the data, one particular patent stands out – number 33 – gap reducing feature. This scores highly, because it scores well in all sections. Normally, an inventive idea, with high commercial potential will have a downside of high risk, and high development cost. Without going into detail, this idea refers to a suspension bush, which is inserted into a housing in the chassis. Avon has pioneered the use of plastic in the outer sleeves of this type of suspension bush, which were traditionally steel. (no.27 – sub-frame bush retention, was an enabling patent for this technology – a snap fit arrangement). The gap reduction patent, allows the insertion process to locally deform the plastic, to the benefit of the performance and durability of the product. Although not developed using TRIZ, this demonstrates several TRIZ concepts and principles. Because this is a highly appealing feature for sub-frame bushes, it has good commercial potential, it requires little development, it actually improves riskiness, by improving the durability contradiction, and adds almost zero cost. It is therefore a good candidate for an example of an idea that looks like a simple incremental innovation, but could become disruptive, a tipping point (Gladwell, 2000).

It was anticipated that during the workshop, some intellectual property would be developed that could be rated using the scoring sheet, and compared to previous patents. Unfortunately this did not occur, primarily due to the need to cover so much material in a short time. Hence no TRIZ inspired patents were available for direct comparison with patents developed without TRIZ. Because of this, a wider rescoring of the patents, by a wider team was deemed to be unnecessary. The MSB engine mount case study allowed the affect of the TRIZ method to be assessed through comparison with the 8D and FMEA tools instead.

7.3 The TRIZ Training Workshops

The result of the MSB top plate was a success story. This feeling was echoed throughout most of the organisation. However, those of a more sceptical nature suggested that because the author, and some of the participants had been closely involved with the product introduction that it was not a true test of TRIZ, especially as in retrospect the solution seemed to be trivial, and somewhat obvious. Of course the counter argument to this was “if it was so obvious, why didn’t we think of that before?”. Furthermore, several workshop participants with no direct product knowledge also offered similar solutions.

The unexpected circumstance of the MSB top plate success gave an interesting opportunity to compare the 8D process with TRIZ. The 8D process did not help the team arrive at a satisfactory solution despite at least 60 person hours of meetings, 20 hours of CAD design work, and significant administrative effort in dealing with the customer concerns. Using the TRIZ method, several novice individuals whilst learning the method, generated promising solutions with only a few hours of work. A person familiar with TRIZ should be expected to achieve this result within an hour, assuming they are familiar with the problem. The 8D tool has been designed to investigate diagnostic type problems, not “day one” design problems. Therefore it may not be fair to compare its output in this case to TRIZ. However this does give one cause to question why the 8D process was used on the problem in the first place.

One reason that the 8D tool is so commonly used is that it is a formal requirement for reporting problems to customers in the automotive industry. Significant effort is therefore expended training staff in the method, and tools associated with it. The shortest course on 8D problem solving within Avon is the QA007 procedure, which is a full day of training and part of the company wide six sigma training package. As previously stated, there was no standard problem solving procedure for “day 1” type problems. Instead, it was assumed that such problems would be prevented through the use of the APQP procedures (see Section 3.3.3 and 5.3). The reason that the 8D methodology was used was simply that there was no alternative in place for “day one” problems. The author considers that the reason for this is that the impetus for business improvement was primarily through the Quality Director, who was more closely aligned with the operational management structure of the business, and separate to product development. Furthermore, the available tools within the Lean and Six Sigma toolkit were essentially missing for this type of problem situation.

Teaching Style and Methods and Implementation

The following points were considered successful :

- Starting with the Management workshop.
- Presentations to departments in advance of the workshop.
- Use of a single, realistic case study to act as a common thread through all tools.
- Teaching and use of the theory / action / reflection cycle .
- Individual and group activities for worked examples and reflections.
- Brief teaching sessions through power-point presentation (theorist style).
- Two week gap between workshop sessions.
- Reading Simplified TRIZ (Rantanen, 2002).
- Participants from multiple departments.

The points considered unsuccessful, or to be learned from :

- Time was too compressed. Two full days are needed.
- Not enough challenging problems were brought by participants to the workshop – these should be pre-prepared, and agreed with management in future workshops.
- The Matrix should not be taught – use software instead, or the book Matrix 2003 (Mann, 2003).
- There is a need for more follow up activities post workshop, and based upon the feedback from this thesis.

Since the completion of the workshop sessions in 2005, the use of TRIZ has not expanded within the organisation and is used only at the discretion of individuals. This is primarily due to significant changes within the business that have occurred over a relatively short period of time. The company directors that first instigated investigation of TRIZ left the company prior to commencement of the workshop series, and the Quality Director retired. The author left the company to pursue a business venture opportunity at the end of 2005, and several of the most ardent supporters of TRIZ from the workshops also moved outside of the company. As a result none of the recommended outcomes for future TRIZ development were adopted.

In 2006/7 Avon VMS was put up for sale by Avon Rubber PLC. In this period the company understandably focused on securing a positive future for the business and employees at the site. This was successful, and the company was purchased in December 2008 by Dongah Tire and Rubber company, a privately owned industrial and automotive company based in South Korea (Turnover $500M).

During the final months of writing up this thesis, the author returned to the company, now known as DTR VMS to assist with programme management on a part time basis. As the automotive industry is starting to recover from the significant recessionary shock in 2008/9, DTR are investing in new product development, and recruiting new talent into the business to support this strategy. It is still clear that many of the individuals exposed to TRIZ during the workshops in 2005 feel that its use should be encouraged. Because of the significant success of TRIZ adoption by Samsung, South Korea is forming an increasingly important role in TRIZ development globally, with most TRIZ texts now published in the Korean language. The author considers that as the new DTR company formulates its long term strategy for innovation, the learning from both this research, and the Samsung case study should be incorporated into its own bespoke vision of the future. There is an opportunity to bring the engineering cultures from the different teams together using a common set of tools, principles and language.

7.4 TRIZ Tools Review

It can be seen that several of the TRIZ tools generated useful insights and promising directions to the problem solving process for the engine mount orientation problem The contradiction tool, and 40 principles provoked several useful suggestions. The 9 windows tool identified “interfaces” as under used resources. However, all of the most ideal solutions, together with an “a-ha” moment were offered by participants when using the Trends of evolution tool. This tool clearly proved the most powerful for this type of mechanically based technical problem. Feedback during the workshop was that it was the second most easy to learn and understand, and significantly easier to learn than FMEA. Further analysis of the feedback data also suggests that the non-technical respondents rated this tool low, meaning that technical participants rated the tool very highly indeed. However, it is not known if participants would have offered such promising solutions without using the other tools on the problem first.

The IFR tool was popular with participants from all departments. It was also found to be useful because it helped to concentrate on what was most important, i.e. the main functions, and in defining the key contradictions within a problem situation. This led naturally to the formulation of contradictions, and the 40 principles, both of which were also well received by participants.

It is surprising that attendees found the 9-windows and resources TRIZ tool more difficult than FMEA, as it is essentially a simple concept. From notes made at the time and recollection of comments during the training, much of the difficulty in using the 9-windows centres around defining what is meant for each time period, and system level. People found this frustrating. However, part of the purpose of the tool is to challenge the user to re-frame their view of the problem, which could be considered a route cause of the frustration. It is considered that if a database of populated standard 9 windows were to be created for various product types, this frustration could be significantly reduced by learning through directly relevant case studies.

Clearly, the Matrix approach was not popular with participants. The function of the matrix is to direct the problem solver to consider the inventive principles most likely to generate a solution, and therefore simplify the problem solving task. But in the opinion of the majority of workshop participants, the approach of using the physical look-up table added complexity to the problem solving process. However, there are other approaches that allow filtering of the most relevant inventive principles, without the traditional matrix table. For instance the book Matrix 2003(Mann, 2003), or through using software tools. In fact there is a free online TRIZ matrix software tool – www.triz40.com (SolidCreativity, 2009) which uses the original 1971 matrix.

It was interesting to note that the FAA tool, having initially not been included, was found to be a necessary part of the TRIZ toolkit for the workshops. This leads to the suggestion that the various TRIZ tools work together to provide a range of different approaches to deepen understanding of problem scenarios, and prompting solutions from different directions. The author found that the tools included allowed the attendees to address a wide range of problem types fully.

During the feedback sessions it was decided to ask for comparative feedback on the TRIZ tools, using FMEA as a benchmark. As stated in Section 4.6, FMEA was known and understood throughout the organisation, and was part of the six Sigma toolkit. The majority of the participants in the TRIZ workshops had also undertaken 3rd party or in-house training on FMEA. Typically, these courses would be at least one full day duration. The TRIZ workshop described in this thesis was conducted in an equivalent timescale, and included several discrete tools, some of which can be argued were of equivalent complexity to FMEA. This suggests that the course was over ambitious in fitting the content into the allotted time. Despite this compressed timeframe, and familiarity with FMEA within Avon VMS, the workshop participants on balance found that the TRIZ tools were more powerful, easier to learn, use and understand than FMEA. Ease of understanding, or validity of individual tools therefore should not be considered to impair wider adoption of TRIZ in organisations similar to Avon VMS. This therefore raises the question as to why TRIZ is not more universally known and used. Many commentators and authors within the TRIZ community are concerned with this question (Mann, 2005).

This thesis may make some contribution into understanding this question. One approach is to take the advice of inventive principle number 13 (the other way around) and to ask this question of FMEA. Why is FMEA used so much in the automotive industry? The FMEA method is taught within Engineering degrees, and text books, it is integrated within the Six Sigma toolkit, which is associated with success stories such as Motorola and GE. As described in section 3.4, Six Sigma can trace its lineage to the post war Quality revolution, and the advances in lean manufacturing in Japan. FMEA therefore has credibility. Also, there are consultancies and training organisations that actively promote FMEA courses. But perhaps the overriding reason for the use of FMEA in the automotive industry is that it is a formal requirement by customers such as Ford, and is even accepted in law as evidence establishing culpability in negligence cases. Furthermore, FMEA is also a formal requirement within the quality standard ISO TS:16949. Automotive suppliers simply have no choice but to use it, and other methods such as the 8D process.

The author therefore contends that there are several reasons that TRIZ has not yet become widespread within Avon VMS, the automotive industry, and more widely :

- Originating in Russia it lacks the pedigree of tools developed and/or promoted through the lineage of Six Sigma and Lean, which is backed up by many credible business schools such as Harvard.
- Some of the on-line information pertaining to TRIZ is un-professional which can be off putting to some types of people, especially decision makers.
- Companies are still trying to digest the array of tools required as part of other initiatives. They are not ready for more.
- There is no major case study, or groundbreaking best selling book to act as a mainstream focal point.
- Innovation is still seen as a technical discipline, rather than a business process owned by the business leader, and involving the whole company.
- Lack of high quality TRIZ trainers, and training courses.
- Ideas generated by TRIZ, such as the engine mount case study contained in this research, can be seen in retrospect as obvious, leading to the criticism “well we didn’t need TRIZ to tell us that”.
- Although individual TRIZ tools are relatively simple to understand, practitioners need to be proficient in several tools in order to successfully tackle difficult problems.

However, this situation appears to be changing. The Institution of Mechanical Engineers now promotes TRIZ through TRIZ training courses. Several Universities have added TRIZ to the innovation and creativity modules of Engineering courses. Six Sigma practitioners sometimes now include some TRIZ tools within DFSS (Basem, 2009). It is also likely that the Samsung case study may result in TRIZ becoming more widely known, and as such demanded by business leaders.

This research has established a favourable comparison between FMEA / 8D / Brainstorming methods with TRIZ. However the comparison has not been made with other tools or methods. It has not for instance been compared with methods for enhancing brainstorming. The comparison has simply been made with the tools used by a single automotive supplier, albeit known as one of the most innovative in its field.

8 Conclusions and Contributions to Knowledge

The following is the broad statement describing the overall aim of the research :

"To gain greater understanding of the usefulness and effectiveness

of TRIZ at Avon VMS".

This has been achieved.

The research objectives of the project were :

1. *To propose and plan an acceptable way to introduce TRIZ at Avon VMS.*

Section 4.4 described the development of a bespoke workshop package. This included several TRIZ tools that were created as part of this research, and contribute to the body of knowledge concerning creative problem solving and TRIZ.

Section 5 details the development and use of the TRIZ tools in a practical workshop setting. The feedback and outcomes from the workshops were such that the implementation was considered successful. Lessons learned from the initial phase were applied to subsequent action cycles. Further learning was gained through reflection upon and analysis of the results of the three action cycles in this research. This learning has contributed to the body of knowledge concerning the presentation, teaching and use of the TRIZ tools.

2. *To Measure the effect of TRIZ implementation upon the company's innovation and problem solving capability.*

It can be concluded from this research that TRIZ is more effective at tackling "day one" problems than the TOPS 8D method or traditional brainstorming. Although a scientific comparison is inevitably disrupted by the industrial setting, sufficient evidence was generated through this research that this conclusion is valid within the limitations of the study identified in Section 2.1.4.

In order to derive a metric for comparative analysis of innovation, a new approach was taken to develop a definition of innovation using the IDEF0 modelling technique. This has added to the body of knowledge concerning the understanding of creativity, inventiveness and innovation, and is detailed in Section 4.1

3. *Record the lessons learned to form a useful case study, and add to the body of knowledge of the industrial use of TRIZ.*

The application of TRIZ through the workshop programme has provided a detailed real world case study, under academically supervised conditions that adds to the body of knowledge in the field of TRIZ, and TRIZ training.

It was concluded that the TRIZ tools were broadly found by the majority of workshop participants to be easier to understand, and more useful than the FMEA tool which is ubiquitous in the automotive industry.

It has been found that the most useful TRIZ tool for solving technical problems during this research was the "trends of evolution". The IFR tool was considered useful not just for technical, but also non-technical problems. The contradiction matrix proved to be the least favoured tool. This preference hierarchy feedback is detailed in section 6.1, and adds to the body of knowledge concerning the application and relative effectiveness of TRIZ tools.

The three research questions were :

1. *What is the best way to introduce TRIZ in an automotive engineering supplier?*

In Section 6.1, and the action reflections contained in this thesis, useful insights have been derived concerning the introduction of TRIZ. In summary:

- Start with Management.
- Create case studies around challenging real problems and opportunities.
- Allow two full days for introductory level training.
- Spread the learning over a period.
- Use software to teach the matrix – not the hard copy print out.
- Pre-prepare follow-up initiatives such as on-line resources and think tanks.
- Formalise the TRIZ tools within the official procedures of the company.

2. *How does the TRIZ method impact upon innovation?*

In Section 7.1 the IDEF0 model is used to show that TRIZ impacts positively upon the innovation process inputs (knowledge), the controls (contradictions) and the outputs of value added and new knowledge / IP.

In direct comparison to 8D and brainstorming on a real case study problem, TRIZ was shown to enable workshop participants to offer several effective solution ideas where alternative methods had not generated any. This research therefore concludes that for technical problems, the TRIZ methodology improves the quality and speed of the ideation part of the innovation process.

3. How does TRIZ compare to existing tools widely used within the automotive industry?

FMEA, TOPS 8D and Brainstorming are widely used in the automotive industry. This research has found that within Avon VMS, individual TRIZ tools were on balance easier to learn and understand than FMEA. It was also shown to be more effective at solving a “day one” problem than TOPS 8D and Brainstorming as applied and used within Avon VMS.

The specific tools developed during this research were :

- The “IFR” tool (Section 4.4.2) which takes the problem solver through a series of questions in order to explore the focal point of the problem, to expose concepts ready for the solution tools and postpone the acceptance of anything other than the idea solution.
- The contradiction finder tool (Section 4.4.3).
- The 9 Windows / Resources Sheet (Section 4.4.4), which separates the activity of defining the time / space columns from recording resources.

These tools add to the body of knowledge concerning TRIZ tools.

These research questions have been fully answered within the limitations identified in Section 2.1.4.

9 Recommendations for further work

This thesis has identified the following areas of further research:

1. The creation of a new model of innovation based upon and taking the IDEF0 model in this research further. This will look more deeply at innovation as an organism to be nurtured, rather than a procedure to be followed.
2. Develop the innovation metric contained in this thesis with more detail – adding weightings and splitting into more questions. Also testing validity within other companies and industries.
3. Consideration of the potential opportunity to use open innovation within the automotive supply industry, and the potential role of TRIZ within this.
4. To challenge a team to use the Avon TRIZ tools to solve intractable, impossible problems and to generate patentable solutions in a controlled research environment.

10 References

Oxford English Dictionary, 1999 Oxford University Press

ISOTS16949 - 2007

ACKOFF L, MAGIDSON J, ADDISON H. 2006. *Idealized Design Creating an organisations future,* Wharton School Publishing.

ALTSHULLER, G. 1984. *Creativity As an Exact Science: The Theory of the Solution of Inventive Problems,* New York, Gordon and Breach Science Publishing.

ALTSHULLER, G. 1999. *The Innovation Algorithm,* Worcester MA, Technical Innovation Center inc.

AMABILE M, MUELLER S, STRAW B 2005. Affect and Creativity at Work. *Administrative Science Quarterly,* , 50.

AMABILE M. 1996. *Creativity in context: Update to the Social Psychology of Creativity,* Boulder, CO, Westview Press.

BARKER, R. 2002a. Avon Rubber PLC Problem solving QA003 and QA007.

BARKER, R. 2002b. Six Sigma Breakthrough Green Belt Phase 3 Module 3 - Lean - FMEA - Control Plan - 5S- OEE - SMED

BARKER, R. 2005a. Internal Avon Rubber PLC Management Systems Manual - Benchmarking guidelines.: Avon Automotive.

BARKER, R. 2005b. Value Stream Mapping - Current and Future State Maps. *Six Sigma Breakthrough - Green Belt - Phase 3 Module 3.*

BASADUR, M, PRINGLE O, SPERANZINI G, BACOT M. 2000. Collaborative problem solving through creativity in problem definition: Expanding the pie. *Creativity and Innovation Management,* 9**,** 54-76.

BASEM, S. 2009. *Design for Six Sigma: A Roadmap for Product Development*, McGraw Hill.

BELL, W. L. F. C. 1995. *Organizational development: behavioural science interventions for organization improvement,* NJ, Prentice Hall.

BENTLEY, C. 2003. *Prince 2 - a practical handbook,* Oxford, Elsevier.

BODEN, M. 1990. *The creative mind myths and mechanisms,* New York, Routledge.

BRUE, G. 2002. *Six Sigma for Managers,* WI USA, McGraw-Hill.

BUZAN, T. 1984. Use your Head.

BYRD, J. 2003. *Building Creativity and Risk Taking in Your Organization,* CA, John Wiley &Sons Inc.

CREVELING C, SLUTSKY J, ANTIS D. 2003. *Design for Six Sigma,* New Jersey, Prentice Hall.

CHANG J. 2006. *Business Process Management Systems: Strategy and Implementation,* Fl USA, Aurbach Publications.

CHEONG S, KYNIN V, FEYGENSON A, 2008. TRIZ and innovation culture at Samsung Electro-Mechanics Company. *The Fourth TRIZ Symposium in Japan.* Japan.

CHESBROUGH, H. 2006. *Open innovation: the new imperative for creating and profiting from technology,* Massachusetts, Harvard Business School Publishing.

CHRISTENSEN C. 1997. *The Inventors Dilemma*, Harvard Business School Press.

COOPER D. S. 2008. Stage-Gate® - Your Roadmap for New Product Development Product Development Institute Inc.

CREAX 2005. Function Database. *http://function.creax.com/*. Creax nv.

CREAX. 2009. *Innovation Suite Software* [Online]. Belgium CREAX nv. Available: http://www.creax.com/innovation_software.htm [Accessed 5/11/09 2009].

DE-BONO, E. 1992. *SurPetition*, Toronto, HarperCollins Pulishers.

DE-BONO, E. 1998. *Simplicity,* London, Penguin Books.

DE-BONO, E. 2007. Dr Edward de Bono opens the world's first Six Thinking Hats® Room. Online - www.prlog.org: Holst Group.

LEONARD D, 1999. *When Sparks Fly: Igniting Creativity in Groups,* MA, Harvard Business School Press.

FELDER R. 1988. Learning and Teaching Styles in Engineering Education. *Engr. Enduction*, 78**,** 674-681.

FILMORE, P. 2008. A comparison of the Problem Solving and Creativity Potential of Engineers between using TRIZ and Lean / Six Sigma.

FRESE M. 2008. The impact of emotions, moods and other affect-related variables on creativity, innovation and initiative in organizations.

FROBISHER P, DEKONINK E, MILEHAM AR. 2006. Improving Manufacturing and Process innovation at an automotive component manufacturer. *IDMME 1006.* Grenoble.

GILBERT, E. 2009. Nurturing Creativity. TED2009.

GLADWELL, M. 2000. *The Tipping Point - How Little Things can make a big difference*, Abacus Books.

GOLDSCHMIDT, G. 1991. The Dialectics of Sketching. *Creativity Research Jounal*.

HILL, D. 1990. Teaching Company Scheme- Induction Course Training - David Hill Associates

HIPPLE, J. 2003. The Integration Of TRIZ Problem Solving Techniques

With Other Problem Solving And Assessment Tools. *triz-journal.com*.

HOSNEDL W. 2008. *Design Engineering A manual for Enhanced Creativity*, FL, CRC Press.

HOWARD T J. 2008a. *Information Management for creative stimuli in engineering design.* Phd, Universtiy of Bath.

HOWARD T J. 2008b. Overview of creative methods.

IDEF0. 2005. IDEF0 Oveview. Available: http://www.idef.com/IDEF0.html [Accessed Nov 2005].

ISAKENSEN S. 1998. A Review of Brainstorming Research: Six Critical Issues for Inquiry. Available: http://www.cpsb.com/resources/downloads/public/302-Brainstorm.pdf.

JOHNSON R, KNOWLES P, SAXBERG B 1976. *Management, Systems, and Society: An Introduction* California, Goodyear Publishing.

JOLLY A. 2004. *A handbook of intellectual property management: protecting, developing and exploiting your assets,* London Kogan Page Ltd.

JOY. 2002. *8D Process* [Online]. isixsigma.com. Available: http://www.12manage.com/methods_ford_eight_disciplines_8D.html [Accessed Nov 2009].

KIM H J. 2003. How to implement TRIZ at Samsung.

KOCK N, BAKER M, MCQUEEN R, ROUSE, A. Year. Negotiation in Information Systems Action Research. *In:* SALIS, P., ed. 1st Information Systems Conference of New Zealand, 1996. Computer Society Press, 164-173.

KRAEV, V. 2007. Kraev's Korner: Problem Solving Process - Lesson 12. *triz-journal.com*.

LERNER, L. 1991. Genrich Altshuller: Father of TRIZ. Available: http://www.aitriz.org/articles/altshuller.pdf.

MAIER, R. 2004. *Knowlege Managment Systems,* Berlin, Springer-Verlag.

MANDEL, G. N. 2008. The Non-Obvious Problem: How the Indeterminate Non-Obvious Standard Produces Excessive Patent Grants. *Social Science Research Network* [Online].

MANN, D. 2002a. *Hands On Systematic Innovation,* Belgium, CREAX nv.

MANN, D. 2002b. Hands On Systematic Innovation.

MANN, D. 2002c. TRIZ for everyone: even those who don't want to spend a year learning it. *TRIZ Journal online www.triz-journal*.

MANN, D. 2004. *Hands on Systematic Innovation for Business and Management*.

MANN, D. 2005. If TRIZ is so Good, Why isnt Everyone Using It ? Part 7: Plausible Deniability & Spiral Dynamics.

MANN D, ZLOTIN B, ZUSMAN A. 2003. *Matrix 2003 - Updating the Contradiction Matrix* Belgium, CREAX Press.

MAY, M. E. 2007. *The Elegant Solution - Toyotas Formula for Mastering Innovation,* New York, Free Press.

MCDONOUGH, W. B., M 2002. *Cradle to Cradle, Remaking the way we make things*, North Point PRess.

MIZUNO S. 1994. *Quality Function Depoyment: The Customer-Driven approach to Quality Planning and Deployment,* Tokyo, Asian Productivity Organisation.

OHNO, T. 1988. *Toyota Production System Beyond Large-Scale Production,* New York, Productivity Press.

OSBORN, A. F. 1963. *Applied Imagination: Principles and procedures for creative problem solvin(Third edition),* NY, Charles Scribner's Sons.

PANDE P, CAVANAGH R. 2000. *The Six Sigma Way : How GE, Motorola and other top companies are honing their performance,* New York, McGraw Hill.

PANDE P S, CAVANAGH, R 2000. *The Six Sigma Way : How GE, Motorola and other top companies are honing their performance,* New York, McGraw Hill.

PISANO G. 1991. *Manufacturing Renaissance*, Harvard Business Review.

PLATT, R. 2004. *RE: Conversation concerning TRIZ use and adoption at Intel and Samsung.*

PORRAS J, 2000. *Built To Last – Successful Habits of Visionary Companies*, Random House Business Books.

RANTANEN K, DOMB E. 2002. *Simplified TRIZ: New Problem Solving Applications for Engineers & Manufacturing Professionals'*, CRC Press.

REES, J. 2008. *Notes from Summary of Issues Raised at ECKM 08* [Online]. Academic Conferences International. Available: http://www.academic-conferences.org/pdfs/ECKM_08_Summary_Issues_Raised.pdf [Accessed].

REID J. 1987. The learning style preferences of ESL students 87. *TESOL Quarterly,* 21.

REUTERS, T. 2009. Analysis of 2008 World Patent activity finds U.S. market infused with Asian Innovations Thomson Reuters.

ROSEWELL, J. 2004. Learning Styles. Available: http://openlearn.open.ac.uk/file.php/1715/Learning%20styles.pdf.

SAJAL, D. 1982. *Patterns of Technological Innovation,* Massachusetts. , Addison-Wesley Publishing Company

SAVRANSKY, S. D. 2000. *Engineering of Creativity,* Florida, CRC Press LLC.

SCOTT A, Q., RONALD R. SIMS 2008. *Ethical Dilemas and Challenges for the C-Suite*, Information age Publishing ltd.

SHAVININA, L. V. 2003. *The international handbook of innovation*.

SOLIDCREATIVITY. 2009. *Interactive TRIZ Matrix & 40 Principles* [Online]. Available: http://www.triz40.com/ [Accessed December 2009].

STAMATIS, D. H. 1997. *TQM Engineering Handbook,* New York, Marcel Dekker Inc.

STAMM, B. V. 2008. *Managing Innovation, Design and Creativity,* Chichester, John Wiley & Sons Ltd.

ULWICK, A. W. 2002. Turn Customer Input into Innovation Vol. 80.

VERSTIJNEN, WAGEMANS J 2004. Sketching, Analogies, and Creativity.

WOLFE, I. S. 2008. Innovation: the act of introducing something new. *Totalview* [Online].

WOMACK D. 1990. *The Machine that changed the world,* New York, Macmillion Publishing Company.

ZUSMAN A, ZLOTIN B 1999. Overview of Creative Methods. *The TRIZ Journal*.

11 Appendices

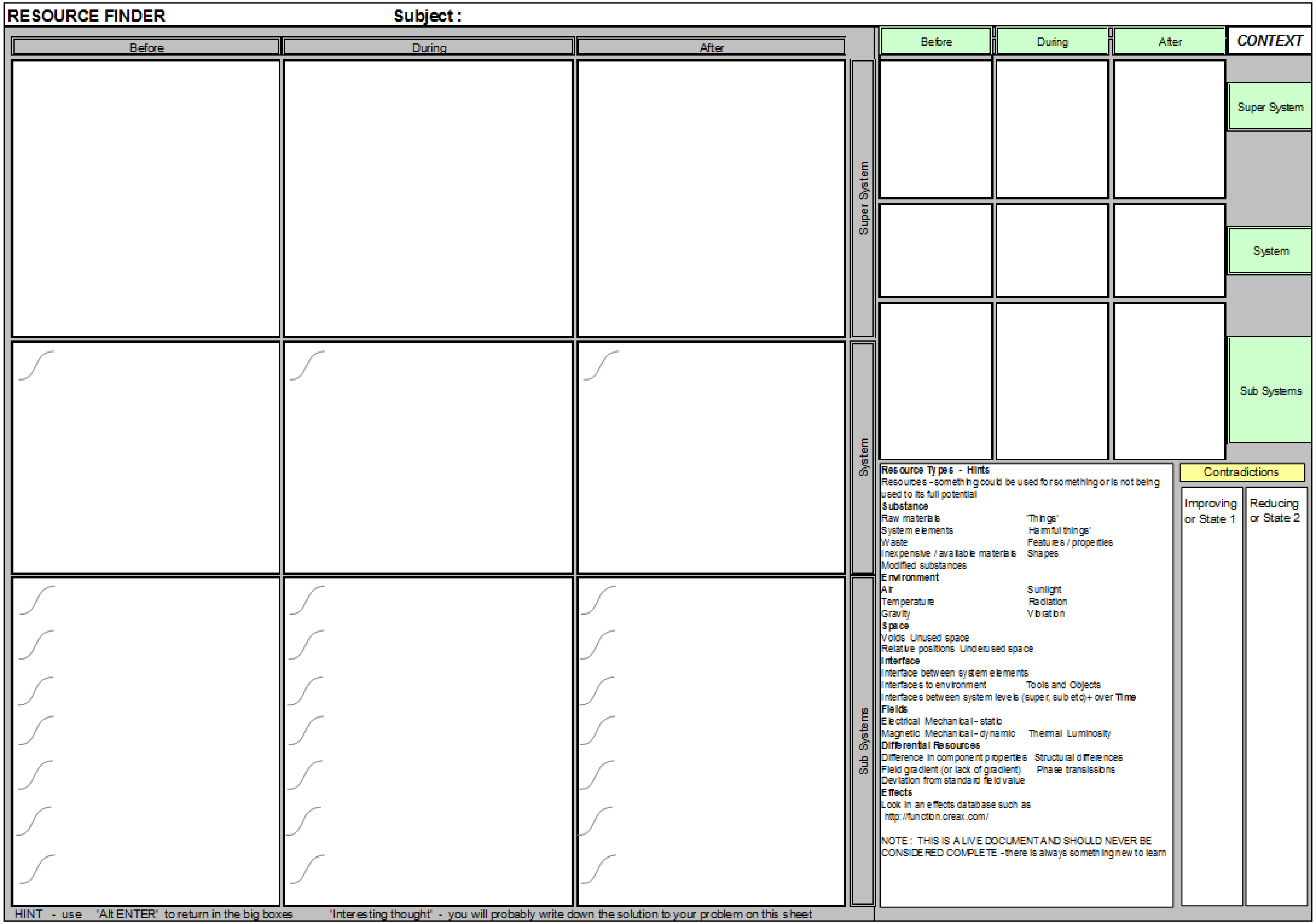
11.1 Day 1 Training Plan and Guidelines

Start	End	Phase	Description	Outcome	Notes	Resources	Who
8:30	8:45	Reflection	Warmup	Disengage from normal.. Generate interest. Emphasise the importance of innovation. Focus on what is required, in terms of effort, and the final outcome - what will be taught	Find a few inspirational quotes. Get people to TWS their expectations of the workshop	Powerpoint, Pro-forma sheet for recording thoughts.	PF
8:45	9:00	Reflection	Introduction to Group problem - in groups of 3 - discuss hose problem - how Avon would appoach it today, and brainstorm some solutions.	Understanding of a real problem, and how we would approach it. Team gets in the groove		Flip Chart (Pre-prepared with problems)	All
9:00	9:25	Theory	Importance of Innovation to Avon, and defining Innovation as a process	Context and importance of innovation is understood		Modified Etria Paper - Powerpoint	PF
9:25	9:30	Reflection	Reflection	People record their thoughts so far		Pro forma - with hit questions	all
9:30	9:50	Theory	Ideality and the S Curve	Functions delivered with min cost. Understanding of S curve development	Emphasise magic wand. Take the team though the standard problem	Powerpoint	PF
9:50	10:00	Action	ACTION : Place own system onto S-Curve	First try at thinking about the IFR and where a real system is on it	May extend into coffee break	Pro forma - with hints and S curve	all
10:00	10:10	Action	ACTION : Place own system onto S-Curve	Practice the team problem	Think about this whilst	Blank sheets @A1 Sise	PF
10:10	10:20		Coffee				
10:20	10:30	Theory	Contradictions	Understanding of 2 types of contradiction and why it is so important	Compare route contradiction to route cause in 8D problem solving. Compare to	Powerpoint	PF
10:30	10:45	Action	Practice finding contradictions	Understanding of how to find contradictions.	Take team through	Pre-prepared cards - laminated pictures - with worked solution handouts for after	
10:45	11:00	Reflection	TWS about contradictions	Learn from self and others the issues about contradiction finding, and what it means	Emphasise that breaking the contradiction is how to increase ideality - reflect back to this	Pro-forma	All
11:00	11:20	Theory	Resources	Understanding importance of mapping resources. Underutilised resources can be used to break contraditions	Need a good example - removing pepper cores ?	Powerpoint	PF
11:20	11:50	Action	Practice finding resources	Practice the difficult task of defining what is meant in each box, and identifying each one	9 Windows is a living document to be added to as you go. Doesn't have to be 100% complete before moving on. Use same example as card picked up before	Pre-prepared cards - laminated pictures - with worked solution handouts for after	all
11:50	12:00	Reflection	TWS about resources				all
12:00	12:15	Theory	Set homework	People read Simplified TRIZ - minimum = chapter on contradictions and 40 principles			PF
12:15	12:30	Reflection	TWS	Did Well - Do Better	Did well - Do Better		
12:30			Finish				

11.2Day 2 Training Plan and Guideline

Start	End	Phase	Description	Outcome	Notes	Resources
8:30	8:50	Reflection	Warmup (Book review)	Disengage from normal.. Generate interest. Form a group consensus on the Book, and 40 principles	Get people to write down their thoughts about the book, and share with the group.	Powerpoint, Pro-forma sheet for recording thoughts.
8:50	9:00	Reflection	Review of Session 1	Re-enforcement of S-Curves, resources and contradictions + process of innovation	Group Brainstorm about last time. Go through each tool, and write down the applications for each tool.	MSB - IFR Sheet, Resources, Contradications
9:00	9:10	Theory	Re-enforcement of S-Curves, resources and contradictions	Understand the work sheets, with some worked examples	Refer back to points raised in previous reflection session	Powerpoint
9:10	9:25	Theory	40 principles	Understand how to use 40 principles and the Matrix on worked example	Explain about the 40 principles + the Matrix - use a worked example	Use Powerpoint.
9:25	9:45	Action	Practice using the 40 principles	As a group - understand how to go from contradiction finder to matrix	As a group, go through a worked example + present homework	Powerpoint.
9:45	9:55	Coffee				
9:55	10:15	Action	Practice using the 40 principles	Individually - understand how to go from contradiction finder to matrix		Powerpoint
10:15	10:20	Reflection				
10:20	10:45	Theory	Functional Analysis	Understand how TRIZ approaches functional analysis	How it is used in TRIZ	Powerpoint
10:45	11:00	Theory	Trends	Know how to use Trends, on Avon style problems	emphasis sub , super system etc	Powerpoint
11:00	11:30	Action	Practice Trends	Get some real examples		
11:30	12:00	Theory and reflection	Putting it all together + where do we go from here	How to use the tools in order. How will TRIZ actually improve Innovation - the roll of the individual in the big picture	model of innovation	Powerpoint
12:00	12:30	Finishing / Feedback	Did well / do better	Consensus on what can be done to move forward.		

11.3 Resource Finder Template



RESOURCE FINDER **Subject :**

Before | During | After

Super System

System

Sub Systems

HINT - use 'Alt ENTER' to return in the big boxes 'Interesting thought' - you will probably write down the solution to your problem on this sheet

Before | During | After | *CONTEXT*

Super System

System

Sub Systems

Contradictions

Improving or State 1

Reducing or State 2

Resource Types - Hints
Resources - something could be used for something or is not being used to its full potential
Substance
Raw materials 'Things'
System elements 'Harmful things'
Waste Features / properties
Inexpensive / available materials Shapes
Modified substances
Environment
Air Sunlight
Temperature Radiation
Gravity Vibration
Space
Voids Unused space
Relative positions Underused space
Interface
Interface between system elements
Interfaces to environment Tools and Objects
Interfaces between system levels (super, sub etc)+ over Time
Fields
Electrical Mechanical - static
Magnetic Mechanical - dynamic Thermal Luminosity
Differential Resources
Difference in component properties Structural differences
Field gradient (or lack of gradient) Phase transissions
Deviation from standard field value
Effects
Look in an effects database such as
http://function.creax.com/

NOTE : THIS IS A LIVE DOCUMENT AND SHOULD NEVER BE CONSIDERED COMPLETE - there is always something new to learn

No.	Title	Explanation
	Moving objects	Objects which can easily change position in space, either on their own, or as a result of external forces. Vehicles and objects designed to be portable are the basic members of this class.
	Stationary objects.	Objects which do not change position in space, either on their own, or as a result of external forces. Consider the conditions under which the object is being used.
1	Weight of moving object	The mass of the object, in a gravitational field. The force that the body exerts on its support or suspension.
2	Weight of stationary object	The mass of the object, in a gravitational field. The force that the body exerts on its support or suspension, or on the surface on which it rests.
3	Length of moving object	Any one linear dimension, not necessarily the longest, is considered a length.
4	Length of stationary object	Same.
5	Area of moving object	A geometrical characteristic described by the part of a plane enclosed by a line. The part of a surface occupied by the object. OR the square measure of the surface, either internal or external, of an object.
6	Area of stationary object	Same
7	Volume of moving object	The cubic measure of space occupied by the object. Length x width x height for a rectangular object, height x area for a cylinder, etc.
8	Volume of stationary object	Same
9	Speed	The velocity of an object; the rate of a process or action in time.
10	Force	Force measures the interaction between systems. In Newtonian physics, force = mass X acceleration. In TRIZ, force is any interaction that is intended to change an object's condition.
11	Stress or pressure	Force per unit area. Also, tension.
12	Shape	The external contours, appearance of a system.
13	Stability of the object's composition	The wholeness or integrity of the system; the relationship of the system's constituent elements. Wear, chemical decomposition, and disassembly are all decreases in stability. Increasing entropy is decreasing stability.
14	Strength	The extent to which the object is able to resist changing in response to force. Resistance to breaking .
15	Duration of action by a moving object	The time that the object can perform the action. Service life. Mean time between failure is a measure of the duration of action. Also, durability.
16	Duration of action by a stationary object	Same.
17	Temperature	The thermal condition of the object or system. Loosely includes other thermal parameters, such as heat capacity, that affect the rate of change of temperature.
18	Illumination intensity * (jargon)	Light flux per unit area, also any other illumination characteristics of the system such as brightness, light quality, etc..
19	Use of energy by moving object	The measure of the object's capacity for doing work. In classical mechanics, Energy is the product of force times distance. This includes the use of energy provided by the super-system (such as electrical energy or heat.) Energy required to do a particular job.
20	Use of energy by stationary object	same
21	Power * (jargon)	The time rate at which work is performed. The rate of use of energy.
22	Loss of Energy	Use of energy that does not contribute to the job being done. See 19. Reducing the loss of energy sometimes requires different techniques from improving the use of energy, which is why this is a separate category.
23	Loss of substance	Partial or complete, permanent or temporary, loss of some of a system's materials, substances, parts, or subsystems.
24	Loss of Information	Partial or complete, permanent or temporary, loss of data or access to data in or by a system. Frequently includes sensory data such as aroma, texture, etc.
25	Loss of Time	Time is the duration of an activity. Improving the loss of time means reducing the time taken for the activity. "Cycle time reduction" is a common term.
26	Quantity of substance/the matter	The number or amount of a system's materials, substances, parts or subsystems which might be changed fully or partially, permanently or temporarily.
27	Reliability	A system's ability to perform its intended functions in predictable ways and conditions.
28	Measurement accuracy	The closeness of the measured value to the actual value of a property of a system. Reducing the error in a measurement increases the accuracy of the measurement.
29	Manufacturing precision	The extent to which the actual characteristics of the system or object match the specified or required characteristics.
30	External harm affects the object	Susceptibility of a system to externally generated (harmful) effects.
31	Object-generated harmful factors	A harmful effect is one that reduces the efficiency or quality of the functioning of the object or system. These harmful effects are generated by the object or system, as part of its operation.
32	Ease of manufacture	The degree of facility, comfort or effortlessness in manufacturing or fabricating the object/system.
33	Ease of operation	Simplicity: The process is NOT easy if it requires a large number of people, large number of steps in the operation, needs special tools, etc. "Hard" processes have low yield and "easy" process have high yield; they are easy to do right.
34	Ease of repair	Quality characteristics such as convenience, comfort, simplicity, and time to repair faults, failures, or defects in a system.
35	Adaptability or versatility	The extent to which a system/object positively responds to external changes. Also, a system that can be used in multiple ways for under a variety of circumstances.
36	Device complexity	The number and diversity of elements and element interrelationships within a system. The user may be an element of the system that increases the complexity. The difficulty of mastering the system is a measure of its complexity.
37	Difficulty of detecting and measuring	Measuring or monitoring systems that are complex, costly, require much time and labor to set up and use, or that have complex relationships between components or components that interfere with each other all demonstrate "difficulty of detecting and measuring." Increasing cost of measuring to a saticfactory error is also a sign of increased difficulty of measuring.
38	Extent of automation	The extent to which a system or object performs its functions without human interface. The lowest level of automation is the use of a manually operated tool. For intermediatel levels, humans program the tool, observe its operation, and interrupt or re-program as needed. For the highest level, the machine senses the operation needed, programs itself, and monitors its own operations.
39	Productivity *	The number of functions or operations performed by a system per unit time. The time for a unit function or operation. The output per unit time, or the cost per unit output.

11.5 The 40 Inventive Principles

Principle 1. Segmentation

A. Divide an object into independent parts.
   - *Replace mainframe computer by personal computers.*
   - *Replace a large truck by a truck and trailer.*
   - *Use a work breakdown structure for a large project.*

B. Make an object easy to disassemble.
   - *Modular furniture*
   - *Quick disconnect joints in plumbing*

C. Increase the degree of fragmentation or segmentation.
   - *Replace solid shades with Venetian blinds.*
   - *Use powdered welding metal instead of foil or rod to get better penetration of the joint.*

Principle 2. Taking out

A. Separate an interfering part or property from an object, or single out the only necessary part (or property) of an object.
   - *Locate a noisy compressor outside the building where compressed air is used.*
   - *Use fiber optics or a light pipe to separate the hot light source from the location where light is needed.*
   - *Use the sound of a barking dog, without the dog, as a burglar alarm.*

Principle 3. Local quality

A. Change an object's structure from uniform to non-uniform, change an external environment (or external influence) from uniform to non-uniform.
   - *Use a temperature, density, or pressure gradient instead of constant temperature, density or pressure.*

B. Make each part of an object function in conditions most suitable for its operation.
   - *Lunch box with special compartments for hot and cold solid foods and for liquids*

(Part C continued on the next page.)

C. Make each part of an object fulfill a different and useful function.
   - *Pencil with eraser*
   - *Hammer with nail puller*
   - *Multi-function tool that scales fish, acts as a pliers, a wire stripper, a flat-blade screwdriver, a Phillips screwdriver, manicure set, etc.*

Principle 4. Asymmetry

A. A. Change the shape of an object from symmetrical to asymmetrical.
   - *Asymmetrical mixing vessels or asymmetrical vanes in symmetrical vessels improve mixing (cement trucks, cake mixers, blenders).*
   - *Put a flat spot on a cylindrical shaft to attach a knob securely.*

B. If an object is asymmetrical, increase its degree of asymmetry.
   - *Change from circular O-rings to oval cross-section to specialized shapes to improve sealing.*
   - *Use astigmatic optics to merge colors.*

Principle 5. Merging

A. Bring closer together (or merge) identical or similar objects, assemble identical or similar parts to perform parallel operations.
   - *Personal computers in a network*
   - *Thousands of microprocessors in a parallel processor computer*
   - *Vanes in a ventilation system*
   - *Electronic chips mounted on both sides of a circuit board or subassembly*

B. Make operations contiguous or parallel; bring them together in time.
   - *Link slats together in Venetian or vertical blinds.*
   - *Medical diagnostic instruments that analyze multiple blood parameters simultaneously*
   - *Mulching lawnmower*

Principle 6. Universality

A. Make a part or object perform multiple functions; eliminate the need for other parts.
   - *Handle of a toothbrush contains toothpaste*
   - *Child's car safety seat converts to a stroller*
   - *Mulching lawnmower (Yes, it demonstrates both Principles 5 and 6, Merging and Universality.)*
   - *Team leader acts as recorder and timekeeper.*
   - *CCD (Charge coupled device) with micro-lenses formed on the surface*

Principle 7. "Nested doll"

A. Place one object inside another; place each object, in turn, inside the other.
   - *Measuring cups or spoons*
   - *Russian dolls*
   - *Portable audio system (microphone fits inside transmitter, which fits inside amplifier case)*

B. Make one part pass through a cavity in the other.
   - *Extending radio antenna*
   - *Extending pointer*
   - *Zoom lens*
   - *Seat belt retraction mechanism*

  - *Retractable aircraft landing gear stow inside the fuselage (also demonstrates Principle 15, Dynamism).*

Principle 8. Anti-weight

A. To compensate for the weight of an object, merge it with other objects that provide lift.
  - *Inject foaming agent into a bundle of logs, to make it float better.*
  - *Use helium balloon to support advertising signs.*

B. To compensate for the weight of an object, make it interact with the environment (e.g. use aerodynamic, hydrodynamic, buoyancy and other forces).
  - *Aircraft wing shape reduces air density above the wing, increases density below wing, to create lift. (This also demonstrates Principle 4, Asymmetry.)*
  - *Vortex strips improve lift of aircraft wings.*
  - *Hydrofoils lift ship out of the water to reduce drag.*

Principle 9. Preliminary anti-action

A. If it will be necessary to do an action with both harmful and useful effects, this action should be replaced with anti-actions to control harmful effects.
  - *Buffer a solution to prevent harm from extremes of pH.*

B. Create beforehand stresses in an object that will oppose known undesirable working stresses later on.
  - *Pre-stress rebar before pouring concrete.*
  - *Masking anything before harmful exposure: Use a lead apron on parts of the body not being exposed to X-rays. Use masking tape to protect the part of an object not being painted*

Principle 10. Preliminary action

A. Perform, before it is needed, the required change of an object (either fully or partially).
  - *Pre-pasted wall paper*
  - *Sterilize all instruments needed for a surgical procedure on a sealed tray.*

B. Pre-arrange objects such that they can come into action from the most convenient place and without losing time for their delivery.
  - *Kanban arrangements in a Just-In-Time factory*
  - *Flexible manufacturing cell*

Principle 11. Beforehand cushioning

A. Prepare emergency means beforehand to compensate for the relatively low reliability of an object.
  - *Magnetic strip on photographic film that directs the developer to compensate for poor exposure*

  - *Back-up parachute*
  - *Alternate air system for aircraft instruments*

Principle 12. Equipotentiality

A. In a potential field, limit position changes (e.g. change operating conditions to eliminate the need to raise or lower objects in a gravity field).
  - *Spring loaded parts delivery system in a factory*
  - *Locks in a channel between 2 bodies of water (Panama Canal)*
  - *"Skillets" in an automobile plant that bring all tools to the right position (also demonstrates Principle 10, Preliminary Action)*

Principle 13. 'The other way round'

A. Invert the action(s) used to solve the problem (e.g. instead of cooling an object, heat it).
  - *To loosen stuck parts, cool the inner part instead of heating the outer part.*
  - *Bring the mountain to Mohammed, instead of bringing Mohammed to the mountain.*

(Part B continued on the next page.)

B. Make movable parts (or the external environment) fixed, and fixed parts movable).
  - *Rotate the part instead of the tool.*
  - *Moving sidewalk with standing people*
  - *Treadmill (for walking or running in place)*

C. Turn the object (or process) 'upside down'.
  - *Turn an assembly upside down to insert fasteners (especially screws).*
  - *Empty grain from containers (ship or railroad) by inverting them.*

Principle 14. Spheroidality - Curvature

A. Instead of using rectilinear parts, surfaces, or forms, use curvilinear ones; move from flat surfaces to spherical ones; from parts shaped as a cube (parallelepiped) to ball-shaped structures.
  - *Use arches and domes for strength in architecture.*

B. Use rollers, balls, spirals, domes.
  - *Spiral gear (Nautilus) produces continuous resistance for weight lifting.*
  - *Ball point and roller point pens for smooth ink distribution*

C. Go from linear to rotary motion, use centrifugal forces.
  - *Produce linear motion of the cursor on the computer screen using a mouse or a trackball.*
  - *Replace wringing clothes to remove water with spinning clothes in a washing machine.*
  - *Use spherical casters instead of cylindrical wheels to move furniture.*

Principle 15. Dynamics

A. Allow (or design) the characteristics of an object, external environment, or process to change to be optimal or to find an optimal operating condition.
    - *Adjustable steering wheel (or seat, or back support, or mirror position...)*

(Part B continued on the next page.)

B. Divide an object into parts capable of movement relative to each other.
    - *The "butterfly" computer keyboard, (also demonstrates Principle 7, "Nested doll".)*
C. If an object (or process) is rigid or inflexible, make it movable or adaptive.
    - *The flexible boroscope for examining engines*
    - *The flexible sigmoidoscope, for medical examination*

Principle 16. Partial or excessive actions

A. If 100 percent of an object is hard to achieve using a given solution method then, by using 'slightly less' or 'slightly more' of the same method, the problem may be considerably easier to solve.
    - *Over spray when painting, then remove excess. (Or, use a stencil--this is an application of Principle 3, Local Quality and Principle 9, Preliminary anti-action).*
    - *Fill, then "top off" when filling the gas tank of your car.*

Principle 17. Another dimension

A. To move an object in two- or three-dimensional space.
    - *Infrared computer mouse moves in space, instead of on a surface, for presentations.*
    - *Five-axis cutting tool can be positioned where needed.*
B. Use a multi-story arrangement of objects instead of a single-story arrangement.
    - *Cassette with 6 CD's to increase music time and variety*
    - *Electronic chips on both sides of a printed circuit board*
    - *Employees "disappear" from the customers in a theme park, descend into a tunnel, and walk to their next assignment, where they return to the surface and magically reappear.*
C. Tilt or re-orient the object, lay it on its side.
    - *Dump truck*
D. Use 'another side' of a given area.
    - *Stack microelectronic hybrid circuits to improve density.*

Principle 18. Mechanical vibration

A. Cause an object to oscillate or vibrate.
    - *Electric carving knife with vibrating blades*

B. Increase its frequency (even up to the ultrasonic).
  - *Distribute powder with vibration.*
C. Use an object's resonant frequency.
  - *Destroy gall stones or kidney stones using ultrasonic resonance.*
D. Use piezoelectric vibrators instead of mechanical ones.
  - *Quartz crystal oscillations drive high accuracy clocks.*
E. Use combined ultrasonic and electromagnetic field oscillations.
  - *Mixing alloys in an induction furnace*

Principle 19. Periodic action

A. Instead of continuous action, use periodic or pulsating actions.
  - *Hitting something repeatedly with a hammer*
  - *Replace a continuous siren with a pulsed sound.*
B. If an action is already periodic, change the periodic magnitude or frequency.
  - *Use Frequency Modulation to convey information, instead of Morse code.*
  - *Replace a continuous siren with sound that changes amplitude and frequency.*
C. Use pauses between impulses to perform a different action.
  - *In cardio-pulmonary respiration (CPR) breathe after every 5 chest compressions.*

Principle 20. Continuity of useful action

A. Carry on work continuously; make all prts of an object work 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.*
  - *Run the bottleneck operations in a factory continuously, to reach the optimum pace. (From theory of constraints, or takt time operations)*
B. Eliminate all idle or intermittent actions or work.
  - *Print during the return of a printer carriage--dot matrix printer, daisy wheel printers, inkjet printers.*

Principle 21. Skipping

A. Conduct a process , or certain stages (e.g. destructible, harmful or hazardous operations) at high speed.
  - *Use a high speed dentist's drill to avoid heating tissue.*
  - *Cut plastic faster than heat can propagate in the material, to avoid deforming the shape.*

Principle 22. "Blessing in disguise" or "Turn Lemons into Lemonade"

A. Use harmful factors (particularly, harmful effects of the environment or surroundings) to achieve a positive effect.
  - *Use waste heat to generate electric power.*

    - *Recycle waste (scrap) material from one process as raw materials for another.*

B. Eliminate the primary harmful action by adding it to another harmful action to resolve the problem.
    - *Add a buffering material to a corrosive solution.*
    - *Use a helium-oxygen mix for diving, to eliminate both nitrogen narcosis and oxygen poisoning from air and other nitrox mixes.*

Amplify a harmful factor to such a degree that it is no longer harmful.

- *Use a backfire to eliminate the fuel from a forest fire.*

Principle 23. Feedback

A. Introduce feedback (referring back, cross-checking) to improve a process or action.
    - *Automatic volume control in audio circuits*
    - *Signal from gyrocompass is used to control simple aircraft autopilots.*
    - *Statistical Process Control (SPC) -- Measurements are used to decide when to modify a process. (Not all feedback systems are automated!)*
    - *Budgets --Measurements are used to decide when to modify a process.*

B. If feedback is already used, change its magnitude or influence.
    - *Change sensitivity of an autopilot when within 5 miles of an airport.*
    - *Change sensitivity of a thermostat when cooling vs. heating, since it uses energy less efficiently when cooling.*
    - *Change a management measure from budget variance to customer satisfaction.*

Principle 24. 'Intermediary'

A. Use an intermediary carrier article or intermediary process.
    - *Carpenter's nailset, used between the hammer and the nail*

B. Merge one object temporarily with another (which can be easily removed).
    - *Pot holder to carry hot dishes to the table*

Principle 25. Self-service

A. Make an object serve itself by performing auxiliary helpful functions
    - *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.*
    - *To weld steel to aluminum, create an interface from alternating thin strips of the 2 materials. Cold weld the surface into a single unit with steel on one face and copper on the other, then use normal welding techniques to attach the steel object to the interface, and the interface*

to the aluminum. (This concept also has elements of Principle 24, Intermediary, and Principle 4, Asymmetry.)

B. Use waste resources, energy, or substances.
   - *Use heat from a process to generate electricity: "Co-generation".*
   - *Use animal waste as fertilizer.*
   - *Use food and lawn waste to create compost.*

Principle 26. Copying

A. Instead of an unavailable, expensive, fragile object, use simpler and inexpensive copies.
   - *Virtual reality via computer instead of an expensive vacation*
   - *Listen to an audio tape instead of attending a seminar.*

B. Replace an object, or process with optical copies.
   - *Do surveying from space photographs instead of on the ground.*
   - *Measure an object by measuring the photograph.*
   - *Make sonograms to evaluate the health of a fetus, instead of risking damage by direct testing.*

C. If visible optical copies are already used, move to infrared or ultraviolet copies.
   - *Make images in infrared to detect heat sources, such as diseases in crops, or intruders in a security system.*

Principle 27. Cheap short-living objects

A. Replace an inexpensive object with a multiple of inexpensive objects, comprising certain qualities (such as service life, for instance).
   - *Use disposable paper objects to avoid the cost of cleaning and storing durable objects. Plastic cups in motels, disposable diapers, many kinds of medical supplies.*

Principle 28 Mechanics substitution

A. Replace a mechanical means with a sensory (optical, acoustic, taste or smell) means.
   - *Replace a physical fence to confine a dog or cat with an acoustic "fence" (signal audible to the animal).*
   - *Use a bad smelling compound in natural gas to alert users to leakage, instead of a mechanical or electrical sensor.*

B. Use electric, magnetic and electromagnetic fields to interact with the object.
   - *To mix 2 powders, electrostatically charge one positive and the other negative. Either use fields to direct them, or mix them mechanically and let their acquired fields cause the grains of powder to pair up.*

C. Change from static to movable fields, from unstructured fields to those having structure.
   - *Early communications used omnidirectional broadcasting. We now use antennas with very detailed structure of the pattern of radiation.*

D. Use fields in conjunction with field-activated (e.g. ferromagnetic) particles.

    - *Heat a substance containing ferromagnetic material by using varying magnetic field. When the temperature exceeds the Curie point, the material becomes paramagnetic, and no longer absorbs heat.*

Principle 29. Pneumatics and hydraulics

A. Use gas and liquid parts of an object instead of solid parts (e.g. inflatable, filled with liquids, air cushion, hydrostatic, hydro-reactive).
    - *Comfortable shoe sole inserts filled with gel*
    - *Store energy from decelerating a vehicle in a hydraulic system, then use the stored energy to accelerate later.*

Principle 30. Flexible shells and thin films

A. Use flexible shells and thin films instead of three dimensional structures
    - *Use inflatable (thin film) structures as winter covers on tennis courts.*

B. Isolate the object from the external environment using flexible shells and thin films.
    - *Float a film of bipolar material (one end hydrophilic, one end hydrophobic) on a reservoir to limit evaporation.*

Principle 31. Porous materials

A. Make an object porous or add porous elements (inserts, coatings, etc.).
    - *Drill holes in a structure to reduce the weight.*

B. If an object is already porous, use the pores to introduce a useful substance or function.
    - *Use a porous metal mesh to wick excess solder away from a joint.*
    - *Store hydrogen in the pores of a palladium sponge. (Fuel "tank" for the hydrogen car--much safer than storing hydrogen gas)*

Principle 32. Color changes

A. Change the color of an object or its external environment.
    - *Use safe lights in a photographic darkroom.*

B. Change the transparency of an object or its external environment.
    - *Use photolithography to change transparent material to a solid mask for semiconductor processing. Similarly, change mask material from transparent to opaque for silk screen processing.*

Principle 33. Homogeneity

A. Make objects interacting with a given object of the same material (or material with identical properties).
    - *Make the container out of the same material as the contents, to reduce chemical reactions.*
    - *Make a diamond cutting tool out of diamonds.*

Principle 34. Discarding and recovering

A. Make portions of an object that have fulfilled their functions go away (discard by dissolving, evaporating, etc.) or modify these directly during operation.
    - *Use a dissolving capsule for medicine.*
    - *Sprinkle water on cornstarch-based packaging and watch it reduce its volume by more than 1000X!*
    - *Ice structures: use water ice or carbon dioxide (dry ice) to make a template for a rammed earth structure, such as a temporary dam. Fill with earth, then, let the ice melt or sublime to leave the final structure.*

B. Conversely, restore consumable parts of an object directly in operation.
    - *Self-sharpening lawn mower blades*
    - *Automobile engines that give themselves a "tune up" while running (the ones that say "100,000 miles between tune ups")*

Principle 35. Parameter changes

A. A. Change an object's physical state (e.g. to a gas, liquid, or solid.
    - *Freeze the liquid centers of filled candies, then dip in melted chocolate, instead of handling the messy, gooey, hot liquid.*
    - *Transport oxygen or nitrogen or petroleum gas as a liquid, instead of a gas, to reduce volume.*

B. Change the concentration or consistency.
    - *Liquid hand soap is concentrated and more viscous than bar soap at the point of use, making it easier to dispense in the correct amount and more sanitary when shared by several people.*

C. 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.*
    - *Vulcanize rubber to change its flexibility and durability.*

D. Change the temperature.
    - *Raise the temperature above the Curie point to change a ferromagnetic substance to a paramagnetic substance.*
    - *Raise the temperature of food to cook it. (Changes taste, aroma, texture, chemical properties, etc.)*
    - *Lower the temperature of medical specimens to preserve them for later analysis.*

Principle 36. Phase transitions

A. Use phenomena occurring during phase transitions (e.g. volume changes, loss or absorption of heat, etc.).
    - *Water expands when frozen, unlike most other liquids. Hannibal is reputed to have used this when marching on Rome a few thousand years ago. Large rocks blocked passages in the Alps. He poured water on them at night. The overnight cold froze the water, and the expansion split the rocks into small pieces which could be pushed aside.*

    - *Heat pumps use the heat of vaporization and heat of condensation of a closed thermodynamic cycle to do useful work.*

Principle 37. Thermal expansion

A. Use thermal expansion (or contraction) of materials.
    - *Fit a tight joint together by cooling the inner part to contract, heating the outer part to expand, putting the joint together, and returning to equilibrium.*

B. If thermal expansion is being used, use multiple materials with different coefficients of thermal expansion.
    - *The basic leaf spring thermostat: (2 metals with different coefficients of expansion are linked so that it bends one way when warmer than nominal and the opposite way when cooler.)*

Principle 38. Strong oxidants

A. Replace common air with oxygen-enriched air.
    - *Scuba diving with Nitrox or other non-air mixtures for extended endurance*

B. Replace enriched air with pure oxygen.
    - *Cut at a higher temperature using an oxy-acetylene torch.*
    - *Treat wounds in a high pressure oxygen environment to kill anaerobic bacteria and aid healing.*

C. Expose air or oxygen to ionizing radiation.

D. Use ionized oxygen.
    - *Ionize air to trap pollutants in an air cleaner.*

E. Replace ozonized (or ionized) oxygen with ozone.
    - *Speed up chemical reactions by ionizing the gas before use.*

Principle 39. Inert atmosphere

A. Replace a normal environment with an inert one.
    - *Prevent degradation of a hot metal filament by using an argon atmosphere.*

B. Add neutral parts, or inert additives to an object.
    - *Increase the volume of powdered detergent by adding inert ingredients. This makes it easier to measure with conventional tools.*

Principle 40. Composite materials

A. Change from uniform to composite (multiple) materials.
    - *Composite epoxy resin/carbon fiber golf club shafts are lighter, stronger, and more flexible than metal. Same for airplane parts.*
    - *Fiberglass surfboards are lighter and more controllable and easier to form into a variety of shapes than wooden ones.*

11.6 Results from Feedback forms (Within 3 Days of Workshop)

TRIZ TRAINING FEEDBACK - Groups A, B and C

group	**Dept**	**Name**	How expectations met	View of Innovation Process	Quality of Presentation	Rating of TRIZ	IFR	9 Windows & Resources	Contradictions	40 Principles	Matrix	FAA	Trends		Not Useful	Just for those that like it	Add 2 6 Sigma	Intranet	External	Books	Think Tanks
a	Quality	CB	Feedback missing																		
a	Marketing	RW	4	5	4	5	4	3	4	2	2	2	2				1	1			1
a	Design	MK	3	4	4	3	2	2	2	2	2	2	2								1
a	Design	AB	4	4	4	4	4	3	3	4	2	3	4				1	1			1
a	Design	MR	4	4	5	4	3	3	3	4	3	3	2				1	1			1
b	Test	CI	4	4	4	4	3	3	4	2	3	2	4				1	1			1
b	Design	PW	3	3	4	3	3	3	3	3	2	4	4					1			1
b	Prod Eng	BW	4	5	5	5	3	3	4	4	3	4	3			1	1	1			1
b	Design	JG	3	4	4	5	3	3	3	3	3	3	4				1	1	1		1
b	Prod Eng	JC	4	4	4	4	4	3	3	3	3	3	3				1				1
b	Design	JM	5	4	4	4	4	3	4	4	3	4	4					1		1	
c	Prog Man	UH	3	4	3	3	3	3	3	2	1	3	3								1
c	Prod Eng	MJ	3	3	3	3	3	2	3	2	2	2	2								1
c	QA	BF	2	3	2	3	2	2	2	2	2	2	2								1
c	Materials	SK	4	4	4	4	2	2	2	2	2	2	2								1
c	Prod Eng	SM	3	4	3	3	3	2	2	2	2	3	3					1			
c	Prod Eng	AS	3	4	4	5	2	2	2	2	2	2	2				1	1			1
	Average Score		3.8	4.1	4.2	4.1	3.3	2.9	3.3	3.1	2.6	3.0	3.2	Total	0.0	1.0	8.0	10.0	1.0	1.0	14.0
	Max Pos Score		5	5	5	5	4	4	4	4	4	4	4								
	Percent		76%	82%	84%	82%	83%	73%	83%	78%	65%	75%	80%								

11.7 Response form Participants during the Workshop

Tools	**Ease of understanding compared to FMEA**				**How Often would Use**			
Total Score	easier to understand	same	more difficult	extremely difficult	Often	Sometimes	Rarely	Never
Ideality and S Curves	6	8	3	0	3	10	4	0
Contradictions	5	7	5	0	3	10	4	0
9 Windows/Resources	0	7	10	0	3	8	6	0
Matrix and 40	0	9	6	2	0	8	9	0
FAA	13	4	0	0	8	7	2	0
Trends	11	6	0	0	9	6	2	0
Total Score	35	41	24	2	26	49	27	0
Group A								
Ideality and S Curves	2	2	1		1	3	1	
Contradictions	1	3	1			5		
9 Windows/Resources		3	2		1	2	2	
Matrix and 40		4	1			2	3	
FAA	3	2			2	3		
Trends	4	1			3	2		
Group B								
Ideality and S Curves	2	3	1		1	3	2	
Contradictions	2	3	1		1	2	3	
9 Windows/Resources		3	3			3	3	
Matrix and 40		3	3			2	4	
FAA	4	2			2	3	1	
Trends	3	3			3	2	1	
Group C								
Ideality and S Curves	2	3	1		1	4	1	
Contradictions	2	1	3		2	3	1	
9 Windows/Resources		1	5		2	3	1	
Matrix and 40		2	2	2		4	2	
FAA	6				4	1	1	
Trends	4	2			3	2	1	

Number of Responses

11.8 Example team Problem – Avon Power Generation

Avon have recently acquired a company that has its own coal fired power station. It uses this for its own needs and also supplies the National grid. The management have decided to keep this facility within the business in order to offset future increases in electricity costs. Unfortunately, due to years of underinvestment, there is much work to be done to bring the generation facility up to Avon H+S standards. In particular, measurements show that airborne coal dust particle levels are far too high, and action must be taken.

A report from the previous owners showed that 90% of the dust came from the coal feed system. In order for the burners to work at maximum efficiency, coal is fed in the form of fine coal particles (<6mm). This ensures maximum generation efficiency, minimum emissions, and ash waste. Because the coal is procured in various lump sizes, a pulveriser is used on- site, to obtain a consistent fine grading.

Unfortunately, the rubber belt conveyor system is open to the atmosphere, and this is where the dust is primarily generated. The vibration in the conveyor creates the dust. The coal is dried prior to the pulveriser, and immediately afterwards, using waste heat from the furnace. It is continuously fed to 8 burners on separate conveyors of different lengths. If the coal is damp, it does not form dust, but causes feed problems due to stickiness.

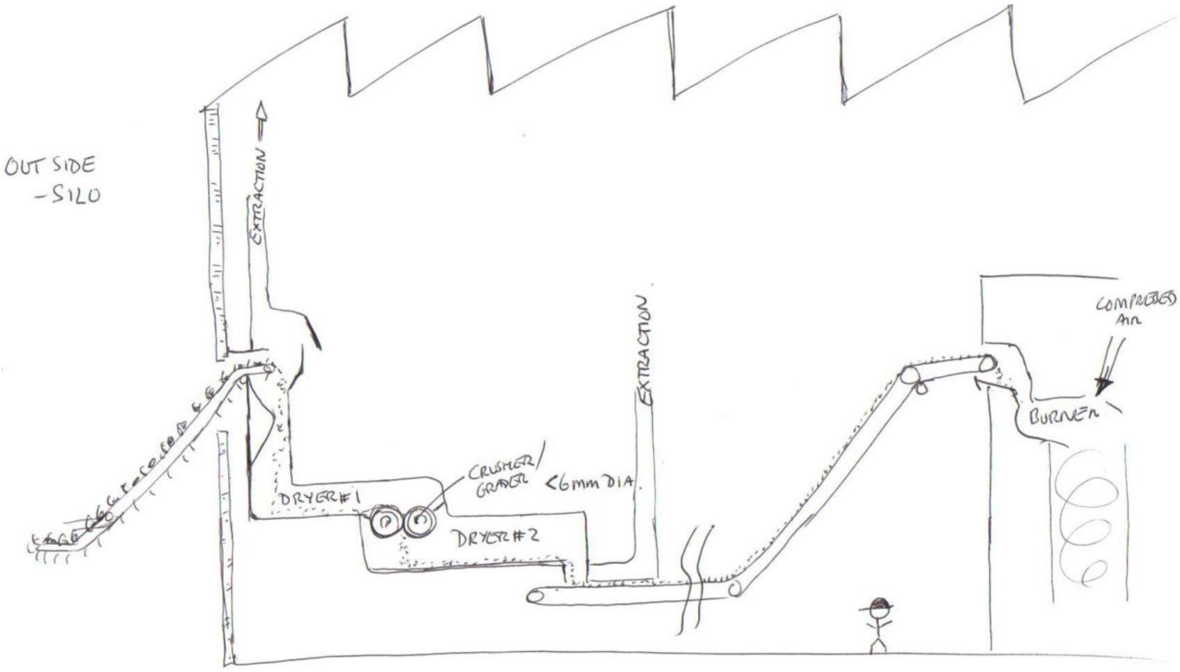
The previous company could not afford the significant investment in enclosing, and extracting the conveyors. Instead they had attempted to control the moisture content of the coal dust. Operators sample the moisture content, and adjust the drier settings according to experience. Too much moisture creates stickiness, too little causes dust.

What approach would Avon take to solving this problem ?

What methods / tools would be used ?

What would be the end result ?

Brainstorm some possible solutions (For Information, the management team have rejected a proposal of £730k for an extraction system around the conveyors – target budget is only £50k - everyone thinks this is totally unrealistic)



11.9 Example Workshop Feedback Form

Feedback is essential in order to understand how to present and apply TRIZ to the benefit of AVON. Please take a minute to fill in following, Place a tick in front of the most fitting expression.

How did the session meet your expectations :

- ☐ Not at all
- ☐ A little
- ☐ Mostly
- ☐ Completely
- ☑ Exceeded

Comments…**A set of useful tools that are actually enjoyable to use!**

Did the workshop change your view of the Innovation Process and how you contribute ?

- ☐ No, I do not consider Innovation to be a process - it just happens naturally, and my role does not contribute to Innovation in any tangible way
- ☐ No, I already understood what innovation was about, and my views have not been changed
- ☐ A little - it changed my view on how I contribute
- ☑ Yes, I understand significantly more about the <u>Innovation process</u>
- ☐ Significantly, and I would like to learn more

Comments…**Innovation does not have to be confined to the walls of your skull**

How well was the material presented

- ☐ Unacceptable
- ☐ Poorly
- ☐ Average
- ☑ Well
- ☐ Excellent

Specific comments/ suggestions for improvement……….

From your perspective how do you rate TRIZ ?

- ☐ Irrelevant, I will never use it.
- ☐ I understand that others may be interested, but it is not for me
- ☐ Of some interest, I will probably use some tools occasionally.
- ☐ Interesting, I can see me using some aspects regularly in my job
- ☑ Very interesting I want to use it, and learn more tools

Specific comments / suggestions for ideal projects to work with……………..

From your perspective, please rate the following TRIZ tools :

Tool	Of no use to me	Infrequent use (< once per 2	Frequent use (> than once	Very frequent use – extremely	Comments
IFR				✓	
Resources			✓	✓	
Contradictions					
40 Principles				✓	
Matrix				✓	
FAA			✓		
Trends				✓	**The CREAX software looks very useful. Can we all have access to it or create an excel or PowerPoint version?**

How would you like to see TRIZ methods developed in Avon ? (Tick the ones that you agree with) :

- ☐ Not at all
- ☐ Just for those that will find it useful - let them learn for themselves
- ☐ Add the tools into the six sigma / quality toolkit
- ☑ Intranet site - showing the tools and examples of real use
- ☐ External Training courses
- ☑ Books / other.
- ☐ TRIZ / Innovation think tanks / work groups
- ☐ Any other suggestions…………………………………..

Thankyou for your time.

Name :…**Julian Makinson**…………………………..

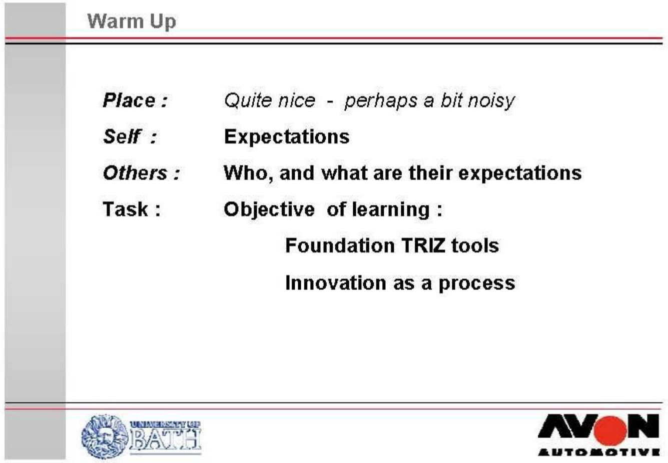
11.10 Avon VMS TRIZ Workshop PowerPoint Slides

AVON AUTOMOTIVE

Improving Innovation using TRIZ

'There are no strategies for creating wealth in the long term, that are not driven by Innovation'

- Gary Hamel



Warm Up

Place : *Quite nice - perhaps a bit noisy*

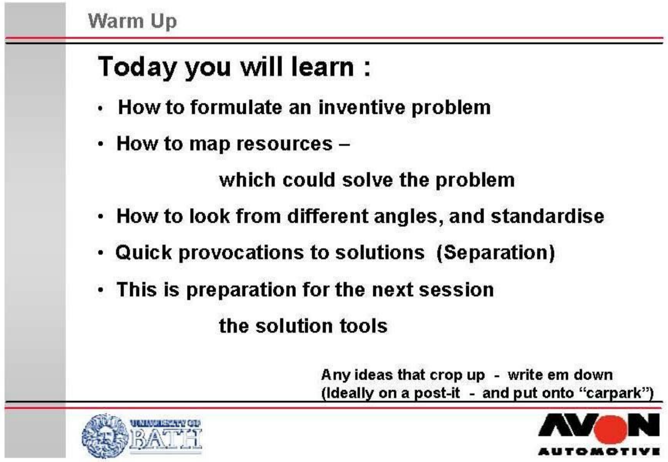
Self : Expectations

Others : Who, and what are their expectations

Task : Objective of learning :

Foundation TRIZ tools

Innovation as a process

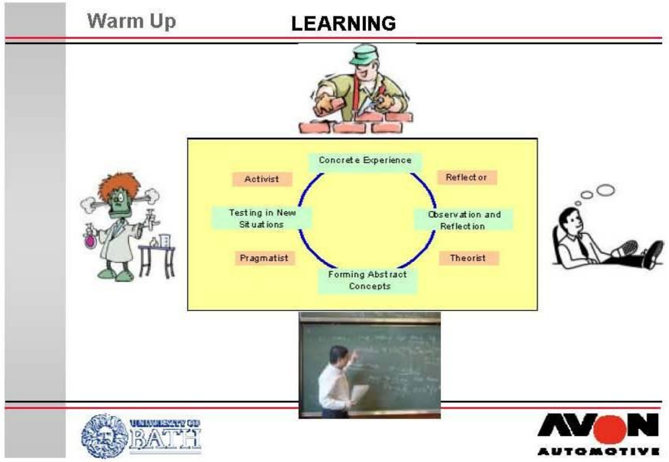


Warm Up

Today you will learn :

- How to formulate an inventive problem
- How to map resources –
  which could solve the problem
- How to look from different angles, and standardise
- Quick provocations to solutions (Separation)
- This is preparation for the next session
  the solution tools

Any ideas that crop up - write em down
(Ideally on a post-it - and put onto "carpark")



Warm Up

LEARNING

Mission Statement

Avon VMS will be recognised in the automotive vibration management system market as the benchmark in:

- Product Technology
- Low cost manufacturing excellence
- Customer support

We will profitably grow our business through a culture of Learning, Teamwork and Innovation.

Problem Solving

Problem Type	***Response***	***Available Tools***
Something Went Wrong	*We correct it*	*6Sigma Toolkit* *8D* *QA 007* *QA 003*
Something Might go Wrong	*We Prevent it*	*APQP* *DFMEA* *PFMEA*
We need something We do not have	*We invent it*	*Brainstorming* *FPISA*

We can at least say that we don't have much of a toolbox for Innovation

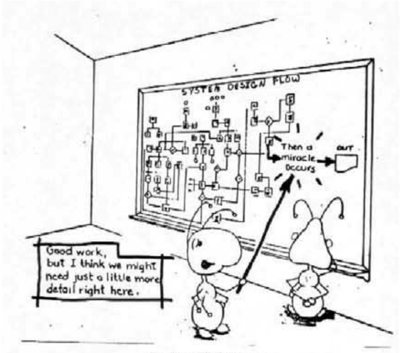
Problem Solving

' 95% of CEO's polled, identified innovation as concern no 1 '

- Business week 2004

We need 'out of the box' thinking !!

Innovation tools for AVON

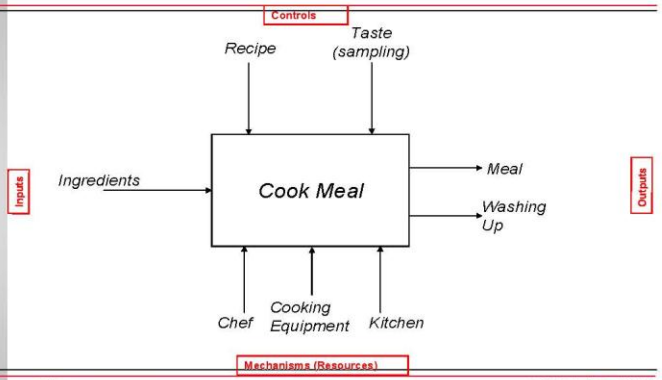


Source Unknown

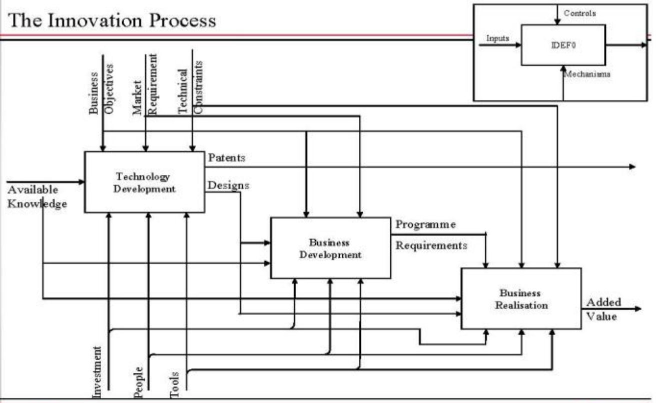
Generic Problem Solving Process

Common Sense	Six Sigma	FPISA	TRIZ (ARIZ)
Define Problem	Define Measure	F (Facts) P (Problem)	
Think up solutions	Analyse	I (Ideas)	
Choose the best	Analyse	S (Solution)	
Implement	Implement Control Transfer	A (Acceptance)	

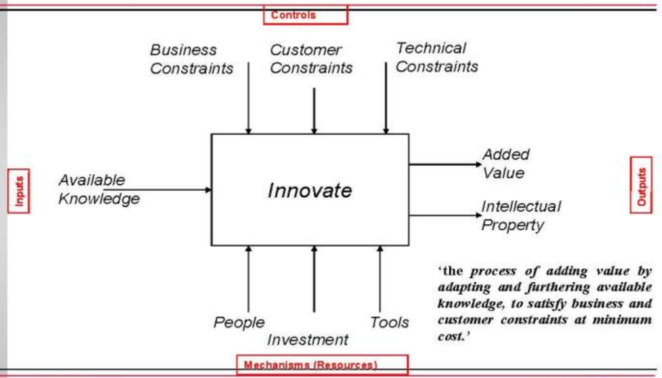
Innovation Definition



The Innovation Process

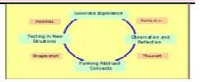


Innovation Definition



'*the process of adding value by adapting and furthering available knowledge, to satisfy business and customer constraints at minimum cost.*'

Reflection



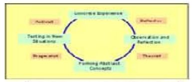
'We are all just a moment from 'commodity hell', where you compete only on price, where your share goes to the least common denominator, and where you're working for your customers instead of you investors and you cannot build a business for the future.'

2003 Jeff Immelt - CEO GE

Second thoughts ?

Theory

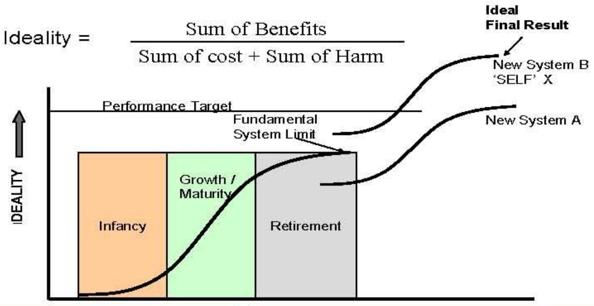
1st TRIZ Tool



S Curves and Ideal Final Result (IFR)

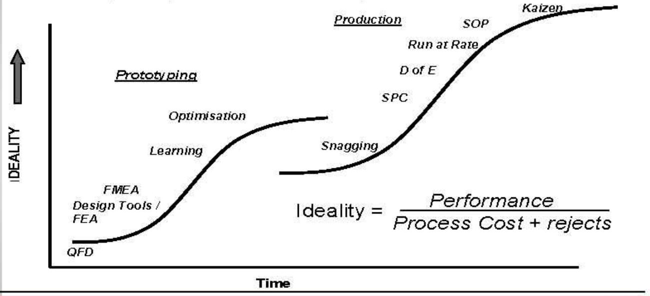
S Curves and Ideal Final Result (IFR)

- Ideality = $\dfrac{\text{Sum of Benefits}}{\text{Sum of cost + Sum of Harm}}$



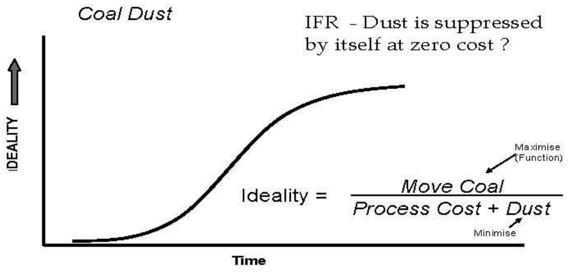
S Curves and Ideal Final Result (IFR)

Ideality of a product from Concept to Production



Ideality = $\dfrac{\textit{Performance}}{\textit{Process Cost + rejects}}$

S Curves and Ideal Final Result (IFR)



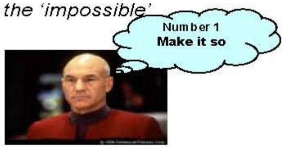
IFR - Dust is suppressed by itself at zero cost ?

$$\text{Ideality} = \frac{\text{Move Coal}}{\text{Process Cost + Dust}}$$

S Curves and Ideal Final Result (IFR)

Using the S Curve and Ideality as a definition tool

Purpose - To get around Psychological Inertia
by working back from the 'impossible'

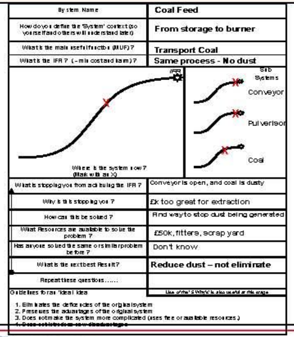


Imagine you are in Sci Fi world

If you have a magic wand !

Functions remain. Form follows function.
IFR means a function is performed for free,
perfectly and now…………….

S Curves and Ideal Final Result (IFR)



System Name	**Coal Feed**
How do you define the 'System' context (so yourself and others will understand later)	**From storage to burner**
What is the main useful function (MUF) ?	**Transport Coal**
What is the IFR ? (- min cost and harm) ?	**Same process - No dust**
What is stopping you from achieving the IFR ?	Conveyor is open, and coal is dusty
Why is this stopping you ?	£k too great for extraction
How can this be solved ?	Find way to stop dust being generated
What Resources are available to solve the problem ?	£50k, fitters, scrap yard
Has anyone solved the same or similar problem before ?	Don't know
What is the next best Result?	**Reduce dust – not eliminate**
Repeat these questions……	
Guidelines for an 'Ideal' idea	Use of the '5 Why's' is also useful at this stage

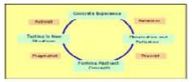
1. Eliminates the deficiencies of the original system
2. Preserves the advantages of the original system
3. Does not make the system more complicated (uses free or available resources.)
4. ~~Does not introduce new disadvantages~~

This is a definition tool, not a solution tool. If you forget this, you may get frustrated. Go as far as you can, and then move on. You can always come back to this later

It is always useful to use this to benchmark potential solutions later on

---

!!!!!!! ACTION !!!!!!!!



ACTION !!!

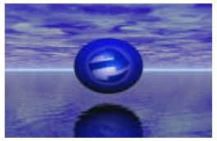
OBJECTIVE - Get familiar with the IFR tool

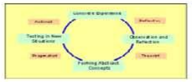
First - work through your individual problem

Complete the sheet as far as you can, and then, in two's compare notes

TEAM PROBLEM TIME

Reflection





Reflect on Ideality
And S Curves

'Removing the faults in a stage-coach may produce a perfect stage coach, but it is unlikely to produce the the first motor car ' - Edward de Bono

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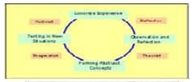
Theory

2nd TRIZ Tool

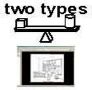


CONTRADICTIONS

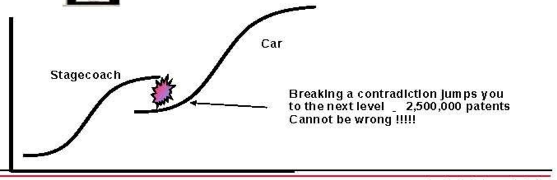
Contradictions

Contradictions are a cornerstone of TRIZ Theory.
As important to TRIZ as route cause analysis to 8D

There are two types of contradiction :



- Trade-off
- Physical / Inherent Contradictions



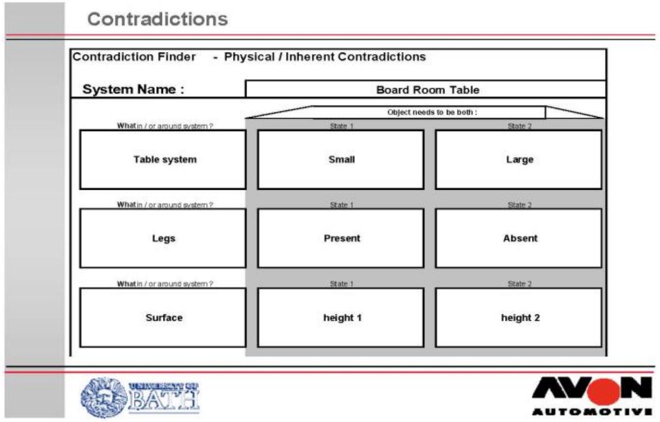
Breaking a contradiction jumps you to the next level _ 2,500,000 patents Cannot be wrong !!!!!

Contradictions

Contradiction Finder - Trade-offs

System Name : Board Room Table

Where in / or around system ?	What gets Better ?	What Gets Worse ?
Table Top	Strength	Weight
Where in / or around system ?	What gets Better ?	What Gets Worse ?
Legs	More legs = greater stability	Cost
Where in / or around system ?	What gets Better ?	What Gets Worse ?
Material	Cosmetics	Cost



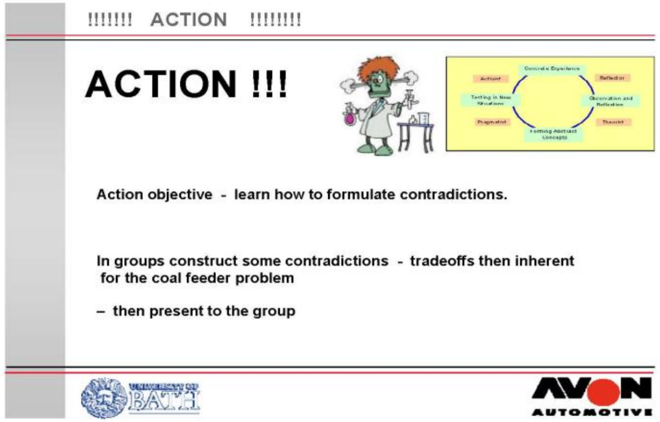
Contradictions

Contradiction Finder - Physical / Inherent Contradictions

System Name : Board Room Table

Object needs to be both :

What in / or around system ?	State 1	State 2
Table system	Small	Large
Legs	Present	Absent
Surface	height 1	height 2



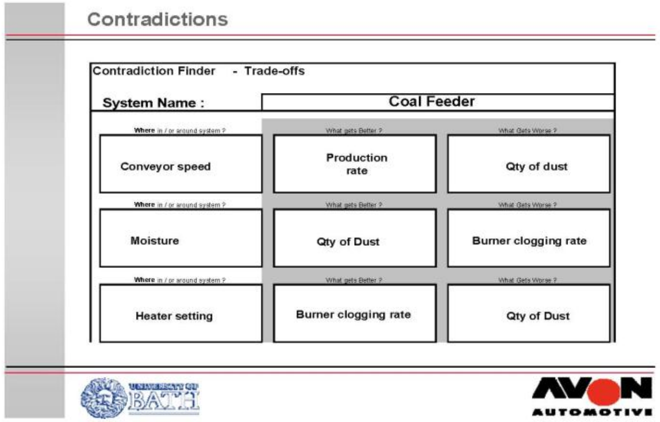
!!!!!!! ACTION !!!!!!!!

ACTION !!!

Action objective - learn how to formulate contradictions.

In groups construct some contradictions - tradeoffs then inherent for the coal feeder problem

– then present to the group

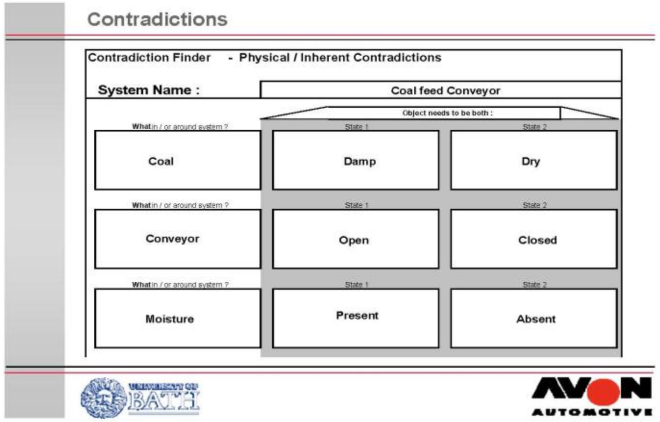


Contradictions

Contradiction Finder - Trade-offs

System Name : Coal Feeder

Where in / or around system ?	What gets Better ?	What Gets Worse ?
Conveyor speed	Production rate	Qty of dust
Moisture	Qty of Dust	Burner clogging rate
Heater setting	Burner clogging rate	Qty of Dust



Contradictions

Contradiction Finder - Physical / Inherent Contradictions

System Name : Coal feed Conveyor

Object needs to be both :

What in / or around system ?	State 1	State 2
Coal	Damp	Dry
Conveyor	Open	Closed
Moisture	Present	Absent

Contradictions

Contradiction Finder Trade-offs

System Name : Hose Manufacture

	Where is / or around system ?	What gets Better ?	What Gets Worse ?
1	**Bends**	**tighter bend radius**	**assembly effort / damage to hose (kinks / creases)**
2	**Assembly of hose onto mandrel**	**assembly effort**	**tolerance**
3	**end caps**	**ease of fitting**	**tolerance**
4	**Bend Radius**	**Package / routing in some vehicle applications**	**Fluid flow losses**

Contradictions

Contradiction Finder Physical / Inherent Contradictions

System Name : Hose Manufacture

	Object needs to be both :	
What in / or around system ?	State 1	State 2
Mandrel	Loose fit (for assembly)	Tight fit (for tolerance)
Lubricant	Present (to enable sliding)	Not present (to improve environment)
Lubricant	low viscosity for application	high viscosity - to creat a good barrier (lubricity)
Bend Radius	tight for some applications	low radius for manufacture

---

Contradictions

Separation Principles

- A SOLUTION TOOL for Physical / Inhenrent contradictions

Separate in :

Space

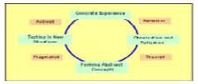
Time

Condition

More on these in the next session +
The 40 principles to break
contradictions

	Object needs to be both :	
What in / or around system ?	State 1	State 2
Coal	damp	dry

Reflection

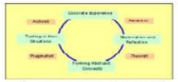


Reflect on Contradictions

'First things first - but not necessarily in that order ' - Dr Who

Theory

3rd TRIZ Tool



RESOURCES

Resources

So, what do we know so far ?

IFR and Ideality :

Good ideas achieve a function - with less cost / harm
There IS an Ideal result to work back from

Contradictions :

When tradeoffs / contradictions are broken, ideality increases

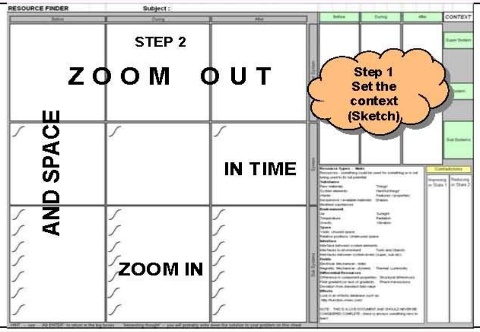
HOW ? THE USE OF *RESOURCES*

A resource can be defined as - *'something available to, or within the system not being used to its full potential'*

The best resource to use for solving a problem, is one you already have. The resource tool, is a way of overcoming psychological inertia to find these things – if they exist.

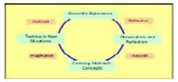
The resource tool, is both a definition, and a solve tool.

Resources



!!!!!!! ACTION !!!!!!!!

ACTION !!!

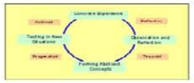



Action objective - to gain experience of mapping resources.

To solve the team problems

Suggestion - 1 member of each team picks a super/system/sub
and fills in the sheet

Reflection

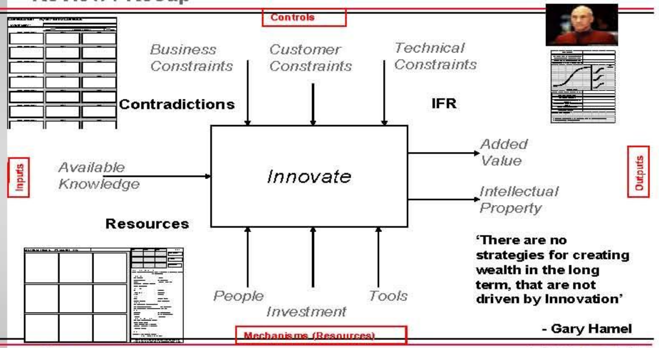


Reflect on Resources

'To be thrown upon ones own resources, is to be cast into the very lap of fortune; for our faculties then undergo a development and display an energy of which they were previously unsusceptible'

Benjamin Franklin

Review / Recap



'There are no strategies for creating wealth in the long term, that are not driven by Innovation'

- Gary Hamel

Review / Recap

You have now learned the key TRIZ Definition Tools

S-Curves / IFR

- Gives direction / context
- Stretches you to believe in the impossible
- Helps you to solve the 'right' problem
- Introduces the idea of maintaining the main function

Resources / 9 Windows

- Thinking in time and space
- Zooming in and out of the problem
- Listing / looking for un-utilised, or under-utilised things / effects
- A database of possible sources of solutions

Review / Recap

Contraditions

- Simple formulation of the problem
- Looking at the problem from different angles
- The first stage of abstraction of your problem – making it into a standard format
  - Trade-offs - one variable against another
  - Inherent / Physical - one STATE vs another

Separation Principles

- The first solution tool
- Can you separate in TIME SPACE on CONDITION

AVON AUTOMOTIVE

Improving Innovation using TRIZ
Welcome to day 2

'There are no strategies for creating wealth in the long term, that are not driven by Innovation'

- Gary Hamel

Warm Up

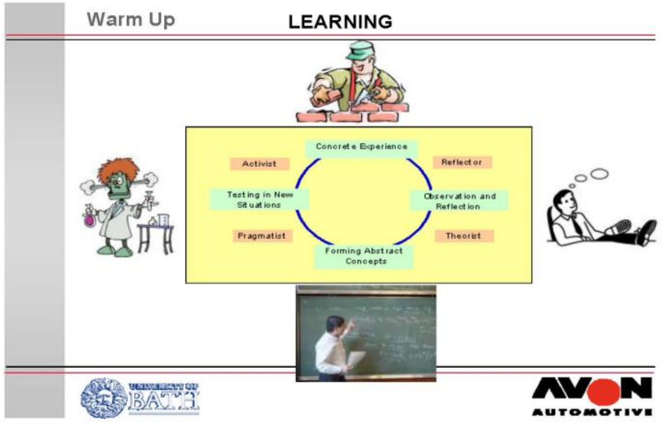
Welcome to Session 2

Hope you liked the first one

Useful - inspiring - at least interesting

Place :	*Same as last time*
Self :	**Expectations**
Others :	**Share expectations**
Task :	**Objective of learning :**

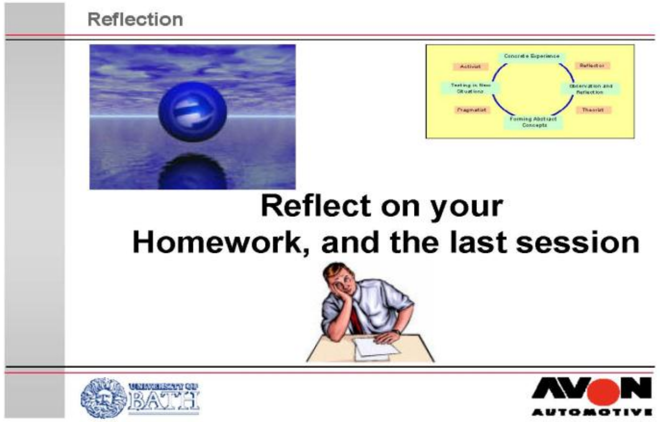
Re-enforce session 1
Gain 3 more tools
Get ready to use it for real



Warm Up

LEARNING

Concrete Experience
Reflector
Observation and Reflection
Theorist
Forming Abstract Concepts
Pragmatist
Testing in New Situations
Activist



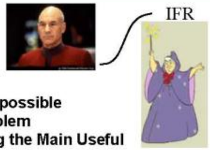
Reflection

Reflect on your Homework, and the last session

Review / Recap

From Session 1

S-Curves / IFR



- Gives direction / context
- Stretches you to believe in the impossible
- Helps you to solve the 'right' problem
- Introduces the idea of maintaining the Main Useful Function

Resources / 9 Windows

- Thinking in time and space
- Zooming in and out of the problem
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Review / Recap

Contraditions

- Simple formulation of the problem
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- The first stage of abstraction of your problem – making it into a standard format
  - Trade-offs - one VARIABLE vs another 
  - Inherent / Physical - one STATE vs another 

Separation Principles

- The first solution tool
- Can you separate in TIME ? SPACE ? on CONDITION ?

Theory

4th TRIZ Tool

40 Principles and the Matrix

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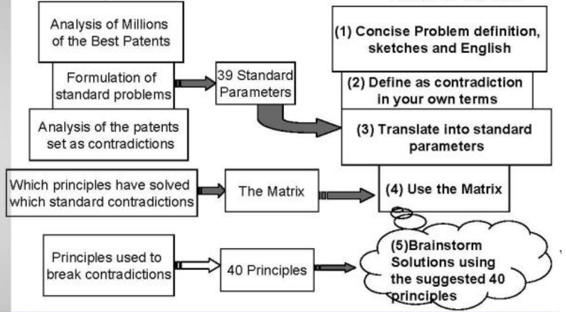
40 Principles and the Matrix



TRIZ Development – route for the researcher

Analysis of Millions of the Best Patents

Formulation of standard problems

39 Standard Parameters

Analysis of the patents set as contradictions

Which principles have solved which standard contradictions

The Matrix

Principles used to break contradictions

40 Principles

Route for the User

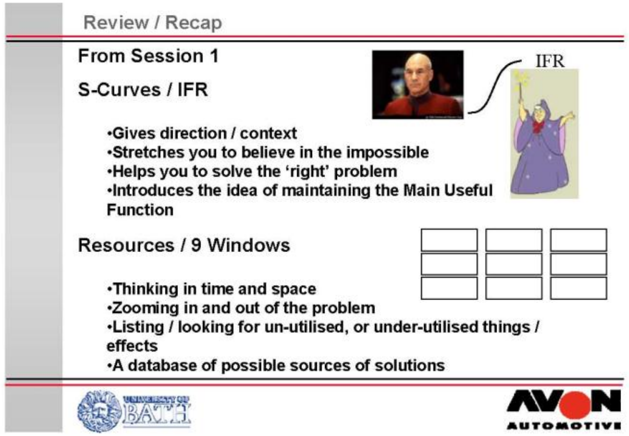
(1) Concise Problem definition, sketches and English

(2) Define as contradiction in your own terms

(3) Translate into standard parameters

(4) Use the Matrix

(5)Brainstorm Solutions using the suggested 40 principles



Review / Recap

From Session 1

S-Curves / IFR

- Gives direction / context
- Stretches you to believe in the impossible
- Helps you to solve the 'right' problem
- Introduces the idea of maintaining the Main Useful Function

Resources / 9 Windows

- Thinking in time and space
- Zooming in and out of the problem
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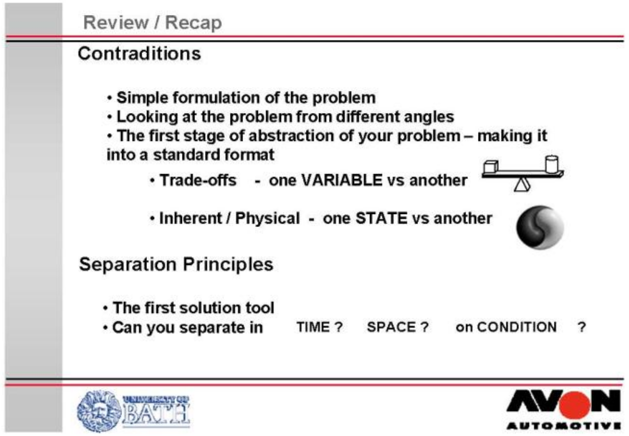

Review / Recap

Contradictions

- Simple formulation of the problem
- Looking at the problem from different angles
- The first stage of abstraction of your problem – making it into a standard format
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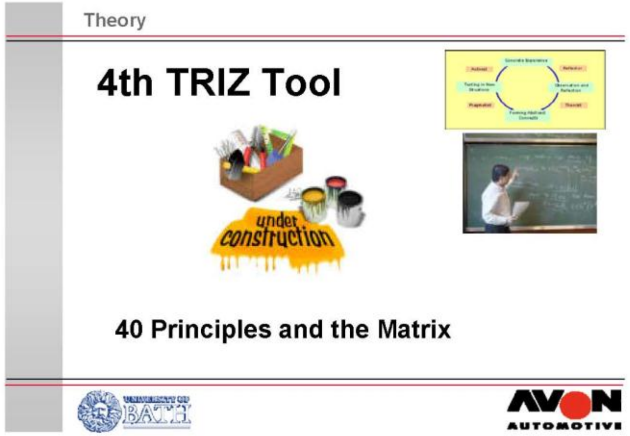
  - Inherent / Physical - one STATE vs another

Separation Principles

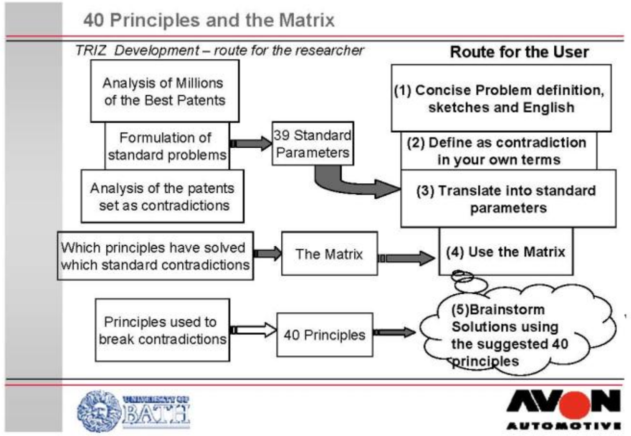
- The first solution tool
- Can you separate in TIME ? SPACE ? on CONDITION ?



Theory

4th TRIZ Tool

40 Principles and the Matrix



40 Principles and the Matrix

TRIZ Development – route for the researcher

Route for the User

40 Principles and the Matrix

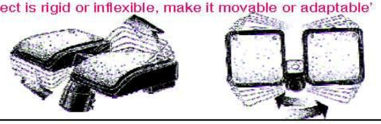
Contradiction matrix step-by-step
Step 5: Generate ideas

Look up the principles and use each principle to generate and record some solution ideas

⇩

Solution Ideas **13: ‘The Other Way Round’**
‘make movable objects fixed, and fixed objects movable’

15: Dynamization
‘divide an object into parts capable of moving relative to each other’
‘if an object is rigid or inflexible, make it movable or adaptable’



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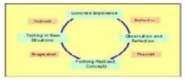
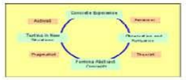


ACTION !!!

Work through the MSB top plate worksheet in pairs.

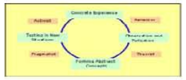
Reflection



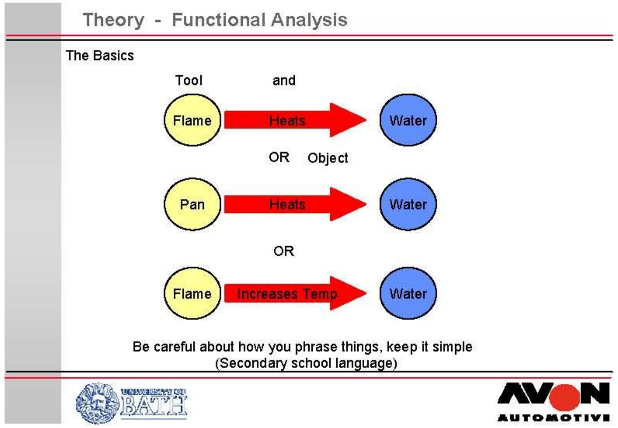
Reflect on 40 Principles

Theory

5th TRIZ Tool



Functional Analysis



Theory - Functional Analysis

The Basics

Tool and

Flame → Heats → Water

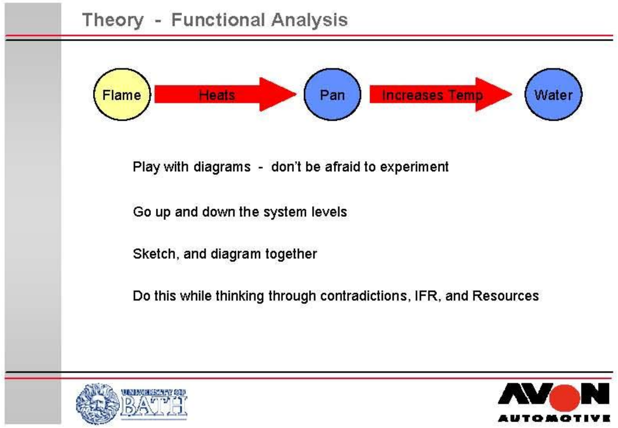
OR Object

Pan → Heats → Water

OR

Flame → Increases Temp → Water

Be careful about how you phrase things, keep it simple
(Secondary school language)



Theory - Functional Analysis

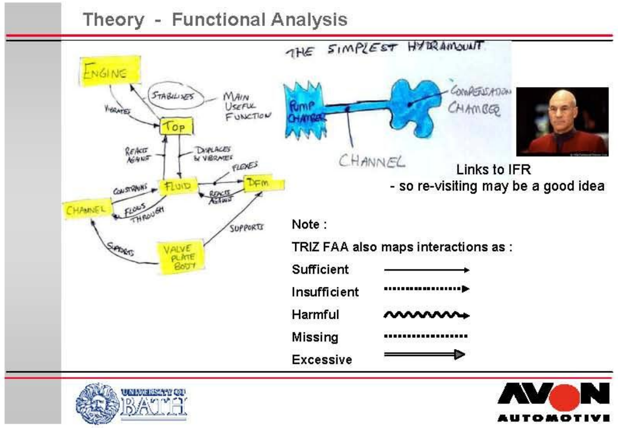
Flame → Heats → Pan → Increases Temp → Water

Play with diagrams - don't be afraid to experiment

Go up and down the system levels

Sketch, and diagram together

Do this while thinking through contradictions, IFR, and Resources



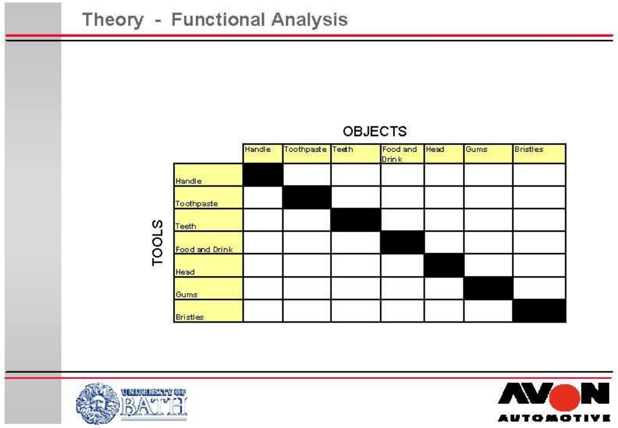
Theory - Functional Analysis

Links to IFR
- so re-visiting may be a good idea

Note :

TRIZ FAA also maps interactions as :

Sufficient ⟶
Insufficient ⇢
Harmful ⇝
Missing ┈┈┈
Excessive ⟹



Theory - Functional Analysis

OBJECTS

TOOLS

	Handle	Toothpaste	Teeth	Food and Drink	Head	Gums	Bristles
Handle	■						
Toothpaste		■					
Teeth			■				
Food and Drink				■			
Head					■		
Gums						■	
Bristles							■

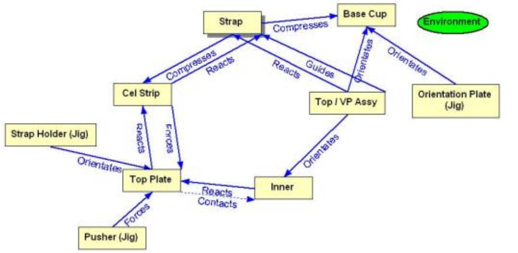
Theory - Functional Analysis

MSB Engine Mount - During Assembly - Have a go

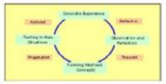
	Strap	Cel Strip	Top Plate	Inner	Top /VP Assy	Base cup	Orientation Plate (jig)	Pusher (jig)	Strap Holder (jig)
Strap	■								
Cel Strip		■							
Top Plate			■						
Inner				■					
Top / VP Assy					■				
Base Cup						■			
Orientation Plate (jig)							■		
Pusher (jig)								■	
Strap Holder (jig)									■

Theory - Functional Analysis

MSB Engine Mount - During Assembly



Reflection



Reflect on FAA

Learn it yourself

Keep it simple

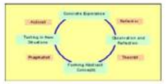
Coloured pencils

Experiment / doodle / imagine

It does not have to be right before moving on (come back to it later)

Theory

6th TRIZ Tool



Trends of Evolution

Theory - Trends of Evolution

Trends - The Basics

Align a trend with something in the system, and try to evolve in the direction of increasing ideality - many other people have generated benefit from this - the chances are good that you will too !!

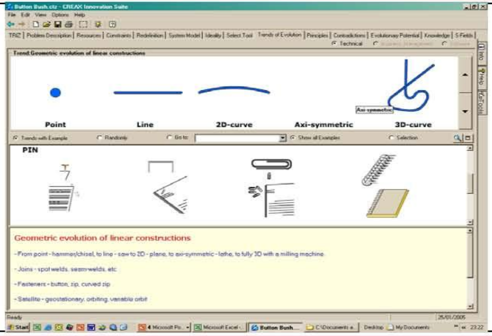
Hints :

Helps to have IFR, S-curves, resources sheets first. At least partially completed - so that you have a good understanding of the system.

Work up and down the system / sub systems, focus in and out.

Get to know the trends, it helps to know which apply to you

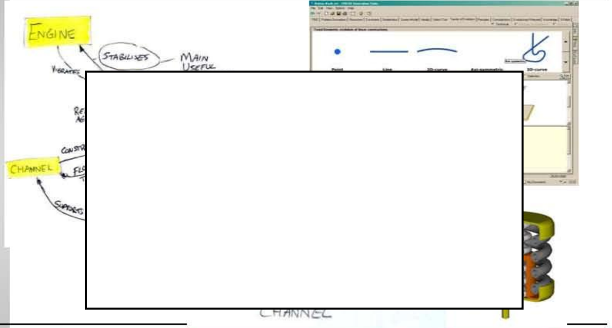
Theory - Trends of Evolution



Geometric evolution of linear constructions

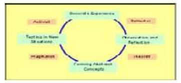
- From point - hammer/chisel, to line - saw to 2D - plane, to axi-symmetric - lathe, to fully 3D with a milling machine
- Joins - spot welds, seam-welds, etc
- Fasteners - button, zip, curved zip
- Satellite - geostationary, orbiting, variable orbit

Theory - Trends of Evolution



!!!!!!! ACTION !!!!!!!!

ACTION !!!



Worked Avon example
MSB Orientation - in pairs

Reflection

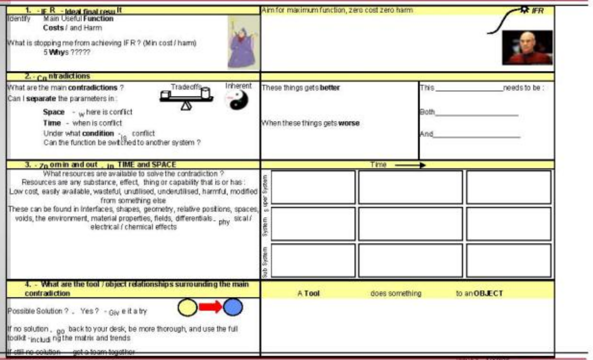
Reflect on Trends

Putting it all together

TRIZ is Powerful

People tend to notice the horns, but it's the more 'boring' definition tools that lead to the killer ideas !!

Putting it all together



1. - IFR - Ideal final result

Identify Main Useful **Function**
Costs / and Harm

What is stopping me from achieving IFR ? (Min cost / harm)
5 **Whys** ?????

Aim for maximum function, zero cost zero harm

2. - Contradictions

What are the main **contradictions** ?
Can I **separate** the parameters in :
Space - where is conflict
Time - when is conflict
Under what **condition** - is conflict
Can the function be switched to another system ?

These things gets **better**

When these things gets **worse**

This ________________ needs to be :
Both ________________
And ________________

3. - Zoom in and out - in TIME and SPACE

What resources are available to solve the contradiction ?
Resources are any substance, effect, thing or capability that is or has :
Low cost, easily available, wasteful, unutilised, underutilised, harmful, modified from something else
These can be found in Interfaces, shapes, geometry, relative positions, spaces, voids, the environment, material properties, fields, differentials - physical / electrical / chemical effects

Time →			
Super System			
System			
Sub System			

4. - What are the tool / object relationships surrounding the main contradiction

Possible Solution ? - Yes ? - Give it a try

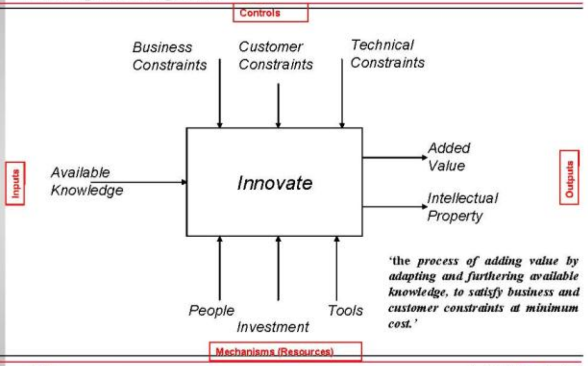
If no solution - go back to your desk, be more thorough, and use the full toolkit - including the matrix and trends

If still no solution – get a team together

A **Tool** does something to an **OBJECT**

Issue 1 - 13/8/05

Putting it all together



'the process of adding value by adapting and furthering available knowledge, to satisfy business and customer constraints at minimum cost.'

Putting it all Together

Problem Type	***Response***	***Available Tools***	
Something Went Wrong	*We correct it*	*6Sigma Toolkit* *8D* *QA 007* *QA 003*	
Something Might go Wrong	*We Prevent it*	*APQP* *DFMEA* *PFMEA*	
We need something We do not have	*We invent it*	*Brainstorming* *FPISA* *TRIZ*	

We can at least say that we have a toolbox started for Innovation

---

Review / Recap

You have now learned the key TRIZ Definition Tools

S-Curves / IFR

- **Gives direction / context**
- **Stretches you to believe in the impossible**
- **Helps you to solve the 'right' problem**
- **Introduces the idea of maintaining the main function**

Resources / 9 Windows

- **Thinking in time and space**
- **Zooming in and out of the problem**
- **Listing / looking for un-utilised, or under-utilised things / effects**
- **A database of possible sources of solutions**

Review / Recap

Contraditions

- **Simple formulation of the problem**
- **Looking at the problem from different angles**
- **The first stage of abstraction of your problem – making it into a standard format**
  - **Trade-offs - one variable against another**
  - **Inherent / Physical - one STATE vs another**

Separation Principles

- **The first solution tool**
- **Can you separate in TIME SPACE on CONDITION**

Review / Recap

You have now learned the key TRIZ Definition Tools

FAA

- **Identifies Tools and Object**
- **Interations - good and bad (ideality equation)**
- **Simplifies the problem**

Matrix , 40 Principles , Trends - TRIZ Solve Tools

- **Guided brainstorming – with hints from global excellence**
- **Solving Contraditions**
- **Evolving in good directions**
- **(But power is derived in combination with problem definition)**