Topic 4: Generating Design Alternatives

Introduction to the Topic

Having identified the market segment that the product must compete in and the functional outcomes/customer requirements that the product must satisfy to meet the needs of the specific market segment, it becomes important to generate designs that will satisfy these demands.

There are a number of ‘generic’ approaches that can be applied to help generate alternative ways of meeting these outcomes, namely:

- **Research and Development**: a review of scientific journals, patents and research projects may lead to breakthrough innovations.

- **Engineering Experience**: a good scientific and engineering understanding of a product/process can lead to the generation of enhanced properties or a superior performance and potentially the generation of a platform of superior products.

- **Brainstorming**: perhaps the best known method for using the knowledge of a PDT is through the application of structured brainstorming procedures

- **Benchmarking**: often a comparative evaluation of competitive products can highlight new approaches/features that can be applied during the generation of new products.

- **Researching Other Industries**: investigating similar products from non-competitive industries may offer alternative solutions to problems that have been traditionally difficult to achieve in the past.

Learning Outcomes

Upon successful completion of this Topic you will be able to:

- discuss the various ways that alternative design ideas can be generated

- apply brainstorming methods to generate new ideas

- discuss the Theory of Inventive Problem Solving (TRIZ)

- apply the Stuart Pugh Concept Selection System to generate new ideas

- apply Customer Competitive Benchmarking methods to identify new ideas.
Session 4.1: Brainstorming

One of the most effective ways of expanding the creativity of the group and for the generation of new ideas is the process of brainstorming.

There are a number of reasons for brainstorming, namely:

- increases the involvement and participation of the members in the PDT
- frees the imagination
- generates many creative ideas and solutions
- helps to build upon ideas
- reduces inhibition by overcoming the need to give the ‘right answer’.

Although there are a number of variations to the practice of brainstorming, there are two basic categories: structured and unstructured.

The approach most commonly used in the manufacturing industry is the structured version.

A structured approach to brainstorming will cover four basic phases, namely:

1. Listing:
   - everybody suggests an idea *in turn*
   - all ideas are clearly recorded – no matter how absurd
   - no comments or evaluations are allowed at this stage
   - exaggeration and freewheeling is encouraged
   - interruptions are avoided.

2. Clarifying:
   - participants clarify their ideas
   - repetitions and obviously irrelevant ideas may be eliminated at this stage.

3. Classifying:
   - common headings or groupings are introduced
   - duplication is eliminated
   - a cause/effect diagram is often used at this stage.
4. Evaluating:

- set criteria direct the evaluation
- potential alternatives may be considered for combination with other ideas.

It is beneficial for the main topic to be clearly highlighted and explained at the start of the brainstorming session. Diagrams, illustrations, parts etc, can be effective at focusing the attention of the participants in this way.

Importantly the ‘synergy’ that arises from the listing phase should not be interrupted. This phase will normally last for about 20 minutes until no more ideas are forwarded by the participants. Once this is completed the session can return to a less formal mode.

**Session 4.2: Theory of Inventive Problem Solving (TRIZ)**

TRIZ (an acronym translated from Russian to mean Theory of Inventive Problem Solving) is a technique used to generate innovative solutions to problems.

Genrich Altshuller is generally accredited as the inventor of TRIZ. He observed that successful inventions conform to an ‘analogical’ trend where the solution to a problem can be reached by comparing the inventions used to solve other similar conditions.

In his capacity as a patents investigator for the Russian Navy in the 1940s, he recognized that most inventions can be classified into 5 basic categories (levels), namely:

- **Level 1 – Apparent**: inventive solutions that fall well within the normal understanding of existing experience, e.g. increasing insulation by increasing thickness.
- **Level 2- Improvement**: inventions achieved within an existing system with the addition of new features, e.g. use of reflected light to produce better vision
- **Level 3 – Inventions within existing paradigms**: inventions achieved within an existing system through the interaction of other technologies, e.g. vehicle safety improved with the application of air bags
School of Aerospace, Mechanical and Manufacturing Engineering

- **Level 4 – Inventions outside the paradigm**: inventions outside the paradigm of the system through the application of accepted (but new) scientific principles, e.g. the use of superconductors to propel vehicles

- **Level 5 – New Discoveries**: inventions of new systems through the application of new scientific systems, e.g. digital technology, lasers, nano technology etc.

That is, successful inventions represent one point along repeatable lines of development. After studying numerous patents (over 1,500,000 have been reviewed to date) he observed that the same solutions to problems are used over and over again. He reasoned that if pertinent information from various inventions can be extracted and summarized it would overcome the need to have to analyse thousands of separate experiments to find a suitable analogy.

An evaluation of over 40,000 patents identified 39 technical parameters and 40 inventive principles that could be used in conjunction with a ‘Contradiction Matrix’, to identify the inventive principles that could be applied to guide the user to a speedy resolution.

Altschuller also realized that all inventive problems contain at least one contradiction and that patents can provide solutions to the contradictions.

That is, as one parameter increases the other parameter decreases, e.g. high strength V’s low weight, high speed V’s low fuel consumption etc.

![Figure 4.1 The TRIZ approach to Inventive Problem Solving](image)

Figure 4.1 The TRIZ approach to Inventive Problem Solving, copyright RMIT (Jacinta Eccles),
A “Contradiction Matrix” comprised of $39 \times 39$ Technical Parameters can be cross-referenced to target the contradictions, while the 40 Inventive Principles can then be used to generate a list of appropriate inventive principles. In this way a speedy resolution to a design problem can be identified.

Figure 4.2 Identifying the inventive parameters from the contradiction matrix, copyright RMIT (Jacinta Eccles), adapted from Step-by-Step QFD: J Terninko, St Lucie Press: 1997; page138

While this approach forces the user to condense a problem into predefined engineering parameters and identify solutions that have been applied elsewhere, more unique problems that require unique solutions have also been addressed by applying a further range of techniques, namely:

- ARIZ (Algorithm for Inventive Problem Solving
- Su-Field Analysis
- AFD (Anticipatory Failure Determination
- DPE (Direct Product Evolution
Session 4.3: Pugh Concept Selection

A very simple method analysing potential concepts and developing design alternatives is the Pugh Concept Selection Technique. This technique is particularly useful for evaluating a large range of competitive products/processes when the functional requirements have been identified.

The steps that are taken to apply this technique are:

- develop a set of simple sketches outlining alternative concepts to the same level of detail - being careful not to favour any particular concept

- generate a list of relevant criteria for comparison purposes. This may be a mix of customer wants, company interests, and engineering requirements. A good cross-functional team using sound brainstorming techniques can be very effective at generating this list.

- select one alternative as the datum - usually the existing product

- evaluate each alternative to the datum for each appropriate criteria using the following assessment:
  - + for clearly better
  - - for clearly worse
  - S for about the same

- total the pluses and minuses to provide a general quantitative overview of the overall analysis

- consider alternatives for potential product improvements by determining how all the pluses can be accommodated into the one design proposal.

Throughout this procedure, discussions will arise as to which alternatives should be considered for improvement. These issues should be noted for further evaluation when the analysis has been completed, but the original concept should not be changed. Another similar analysis can be conducted at a later stage for new alternatives.

However crude this approach appears to be, through the Pugh Concept Selection technique a better product than the original can be usually synthesized to provide design direction and to target areas for potential research on future programs.
Session 4.4: Competitive Company Benchmarking

The primary aim of this technique is to generate a design that provides the same (or better) functional outcomes at a lower cost.

Like the Pugh Concept Selection technique, the competitive benchmarking approach uses a matrix format to analyse competitive products and incorporating the best features of the competitive designs.

In this approach the functional requirements of the design (generated from a function tree) are allocated to the left side of a matrix, while the top of the matrix refers to all the component parts (generated from the bill of materials) that are required to achieve the allocated functions. A separate matrix is generated for each separate competitive design. Where the design is very complex it is appropriate to divide the design into systems and sub-systems.
This process may identify functions that may not have been previously considered, or parts that may be redundant etc., and these anomalies should be carefully evaluated by the design team.

A closer comparison can be achieved by allocating the costs needed to meet the desired functions at a component level. For this comparison the fully burdened costs should be used.

This analysis enables the PDT to identify the most cost effective design and to generate a superior design by applying the best features into one singular product.

![Table showing competitive company benchmarking exercise for a door assembly.](image_url)

*Figure 4.4: Competitive company benchmarking exercise for a door assembly. Reprinted with permission from the American Supplier Institute: QFD Training Manual (1992) (permission being sought)*
Activity 4 A

Generating design ideas

Reading:
- Please refer to the bibliography at the start of the programme and read the articles referring to TRIZ.

Website:
- [http://www.mazur.com](http://www.mazur.com) and be prepared to discuss how you would apply TRIZ to improve the design of a binder for your lecture notes (as discussed previously in section 3).

Activity:
1. Utilizing the results of the previous QFD exercise, develop a list of requirements that would be used to conduct a competitive benchmarking analysis for three different binder designs.
2. Discuss the difference between the Pugh Concept Selection process and the Competitive Benchmarking process.
3. Why you would use one in preference to another?

Discussion:
- Participate in groupwork during lectures and online discussions concerning the Pugh Concept Selection Technique
- Participate in the brainstorming plenary exercise.
Summary and Outcome Checklist

This Topic introduced you to generating design alternatives.

Tick the box for each statement with which you agree:

☐ I can discuss the various ways that alternative design ideas can be generated.

☐ I can apply brainstorming methods to generate new ideas.

☐ I can discuss the Theory of Inventive Problem Solving (TRIZ).

☐ I can apply the Stuart Pugh Concept Selection System to generate new ideas.

☐ I am able to apply Customer Competitive Benchmarking methods to identify new ideas.

Assessment

Assessment for this Topic will be included in Assignment 1.