INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN

ICED 81

ROME - ITALY 9-13 MARCH 1981

CONCEPT SELECTION - A METHOD THAT WORKS

STUART PUGH

One of the most difficult, sensitive and critical problems in design, both in teaching and in practice, is the selection of the best concept with which to proceed to detail design and ultimately manufacture. This paper deals with the question of conceptual choice and discusses in detail a method which has been evolved over a period of years, and which has been tested and used effectively by postgraduate students in pursuance of competitive designs.
Primarily concerned with the avoidance of conceptual vulnerability brought about by lack of thoroughness in conceptual approach, this, by definition, means the emergence and selection of the best and strongest concepts. The effectiveness of the method, which is strictly non-numeric, is illustrated by an example of its use. The paper concludes with a discussion of the method against the background of others purporting to have the same objective.

Eines der schwersten Probleme in der Maschinenkonstruktion, sowohl in der Belehrung als auch in der Praxis, ist die Wahl des besten Planes der die Grundlage der Konstruierung und Hervorbringung wird. Diese Abhandlung enthält eine Diskussion der Methode die es ermöglicht den besten Konstruktionsbegriff aus zu wählen, und die auch auf nützliche Weise während einigen Jahren angewendet und geprüft wurde.
Sie bezieht sich vor Allem auf die Vermeidung der Begriffsverwundbarkeit auf Grund des Vollständigkeitsmangels der verschiedenen Konstruktionsbegriffe und der schliesslichen Wahl der besten Begriffe.
Die Wirksamkeit dieser Methode, die keine Berechnungen benötigt, wird mit einem Bespiel erläutert.
Die Abahndlung wird mit einer Diskussion, die verschiedene Methoden welche das gleiche Ziel haben mit einander vergleicht, abgeschlossen.

The postgraduate course in Engineering Design has been in operation at Loughborough for some 12 years and is primarily concerned with providing students with a sound professional approach to and competence in design suitable for today's needs. Based firmly on design in practice, a major component of the course is a group design project provided by industry the outcome of which is an attempt to produce a competitive product design(1). During the evolution of the course particular attention has been paid to the testing and evaluation of existing design methods in the real-life situation and many of the so called methods have been found wanting when applied in these situations(2). A repetitive, particular difficulty always occurs at that point in the design activity when solutions to the particular problem in hand have been generated and the question arises as to how to select the best concept(s) with which to proceed. One thing is certain, it is extremely easy to select the wrong concept and difficult to select the best one. If the wrong one is chosen, the design may be said to suffer from conceptual weakness, the design may be said to be conceptually vulnerable. This paper is concerned with a method developed to minimise such vulnerability.

EXISTENCE OF CONCEPTUAL VULNERABILITY

Conceptual weakness in any design usually manifests itself in two ways:-

1. The final chosen concept is weak due to lack of thoroughness in conceptual approach. Thereafter, no amount of attention to detail requirements, technical requirements and the like, will recoup the situation.

2. The final chosen concept is strong and the best possible within the constraints but, due to lack of thoroughness in conceptual approach and selection, alternatives suggested, say, by others, cannot be refuted by sound technical argument and debate. In other words the concept is the best available, it is strong, but the reasons for its strength are not known or fully understood.

So here we have, by definition, two cases of conceptual weakness, the former being truly weak, the latter being strong but lacking thoroughness in approach is apparently weak. The above hypothesis has been arrived at in creating and evaluating designs for products covering a wide range of industry and, as a result of continual evolution and refinement, an approach has been formulated to eliminate or at least minimise such weakness; this approach has been tested and proved effective in many design situations.

Bearing in mind that in the absolute sense it is impossible to evolve and evaluate all possible solutions to a particular problem and in order to minimise the possibility of the wrong choice of conept, it becomes essential to carry out concept formulation and evaluation in a progressive and disciplined manner. This disciplined approach necessitates a number of rules and a procedure, which, if followed, leads to significant improvements, not only in concept formulation but also in selection.

PROCEDURE FOR MINIMISING CONCEPTUAL VULNERABILITY

In the teaching phase of our course students have this discipline and procedure impressed upon them and obtain practice in usage, based upon relatively (apparently) simple examples. The basic rules and procedure are as follows:

1. Having established a number of embryonic solutions to the problem in hand, these solutions are produced in sketch form to the same level of detail in each case.

2. A concept comparison and evaluation matrix is established which compares the generated concepts, one with the other, against the criteria for evaluation. A skeleton of the matrix is shown in Fig.1.

CONCEPT / CRITERIA	1	2	3	4	5	6	7	8	9	10	11
A	+	–	+	–	+	–	D	–	+	+	+
B	+	S	+	S	–	–	A	+	–	+	–
C	–	+	–	–	S	S	T	+	S	–	–
D	–	+	+	–	S	+	U	S	–	–	S
E	+	–	+	–	S	+	M	S	+	+	+
F	–	–	S	+	+	–		+	–	+	S

FIGURE 1

3. It is essential that the matrix has all the 'visuals' (sketches) of all the concepts incorporated into it in order that the participants witness the patterns of emergence.

4. Ensure that the comparison of the different concepts is valid i.e. that

all are to the same basis and at the same generic level.

5. Criteria against which the concepts will be evaluated are chosen. Usually these are based upon the detailed requirements of the product specification i.e. established before solution generation commences[(3)]. It is essential that the criteria chosen are unambiguous and understood by all participants in the evaluation.

6. A datum is chosen with which all the other concepts will be compared. If a design or designs already exist for the product area under consideration these must be included in the matrix and always form a useful first datum choice.

7. In considering each concept/criteria against the chosen datum, the following legend should be used:-

   + (plus) meaning better than, less than, less prone to, easier than, etc. relative to the datum.

   - (minus) meaning worse than, more expensive than, more difficult to develop than, more complex than, more prone to, harder than, etc. relative to the datum.

   Where any doubt exists as to whether a concept is better or worse than the datum, then use:-

   S meaning same as datum.

8. Having selected a datum, an initial comparison of the other concepts is made using (7); this establishes a score pattern in terms of the number of +, -, and S's achieved relative to the datum.

9. Assess the individual concept scores. If certain concepts exhibit exceptional strength, re-run the matrix with the strengths removed. If, as a result of running the matrix several times, the initial high scorers persist i.e. (1),(1),(1),(1), they are likely to be the best concepts with which to proceed.

10. If a strng pattern of concept(s) does not emerge in (9) i.e. all appear to have uniformity of strength (which is very unusual), change the datum and re-essess the pattern.

11. If, for example, one particular concept persists, change the datum and repeat. If the result remains the same, let the emergent strong concept assume the role of datum, re-run the matrix and again assess the result.

It is preferable that the course of action detailed in (1) to (11) be carried out on a large blackboard or similar display unit as it is considered essential that all participants to the evaluation take part in the usually hectic discussions on each point and that each sees the complete picture for the whole of the period.

Having completed what might be called the initial evaluation comprising a number of 'runs', the participants will have acquired:-

a) greater insight into the requirements of the specification,
b) greater understanding of the problem,
c) greater understanding of the potential solutions,
d) an understanding of the interaction between the proposed solutions, which can give rise to additional solutions.
e) a knowledge of the reasons why one concept is stronger or weaker than another.

If additional solutions arise, the comparison and evaluation procedure should be repeated. Note: In conducting the comparison and evaluation just described, the tutor/project leader will have to control the questioning of concepts and maintain a tight discipline on the participants. Reaching this point in an evaluation should be construed as being the end of the first phase.

PHASE II

The decision is taken to proceed to develop the strongest concepts emerging from the initial evaluation in Phase I. This entails further work on these concepts, to engineer them to a higher level and in more detail than was carried out in Phase 1. Again, care should be taken to ensure that each one remains comparable with the others. The additional work, involving finer detail, results in even greater understanding of the problem and its projected solutions, and such understanding also leads to a refinement and expansion of the criteria for evaluation. The matrix is reformed to incorporate the enhanced concepts and also the revised/expanded criteria, and the mechanism of the first phase is repeated. The outcome of this re-evaluation will either confirm the pattern established previously or will give rise to a re-ordered set of concepts. In each case, the reasons for the emergent pattern and the relative strengths and weaknesses should be questioned deeply.

It is interesting to note that students invariably develop a critical awareness of the whole procedure and particularly if a strong concept emerges and stays, as it were, in the lead, they now begin to have doubts over the whole matter and usually suggest that many of the concepts generated initially are far better than the emergent leader. This becomes a particular problem with strong-willed individuals whose initial concepts have not emerged in the final selection; they then commence a defence based upon emotion and may prefer to ignore the facts of the situation.

It is recommended that at this stage, all concepts are placed in a re-formed matrix with the revised criteria, and a comparison is carried out and assessed. Almost without exception, the results of Phase I and II will be confirmed which inspires a confidence in the procedure. It should always be borne in mind that with the method just described, the choice of concept remains with the participants, the matrix does not take the decisions. It is simply a procedure for controlled convergence on to the best possible concept and is not composed of absolutes in the mathematical sense, the decisions remain with the user.

SUBSEQUENT PHASES

As design work proceeds on the chosen concept(s) it may become necessary to repeat the continually refined procedure several times in order to confirm the approach adopted. Depending upon the complexity of the project, it is not untypical in our experience to carry our 5 or 6 evaluations and comparisons before a single concept emerges, which is then carried through to final design, detailing and manufacture. A single typical matrix run may take anything up to a whole day to complete and in a recent project 32 different concepts were evaluated in arriving at the solution. What is particularly heartening about the whole procedure is that conceptually (i.e. approaches to the solution of the problem), in dealing with a variety of companies, not one has been able to seriously fault or cause to be altered the chosen concept which leads to the final design. Bearing in mind the expertise and experience present in those companies, if a student group, on the basis of the foregoing, can defend their designs in a sound and logical manner when confronted by such expertise and not be faulted conceptually, then the procedure underwriting this situation may be deemed not only to have some merit but also to have minimised conceptual vulnerability.

AN EXAMPLE OF USAGE

In the first term of our course as a first exercise in the procedure, students are given the task of generating embryonic solutions (concepts) for an audible means of approach for a motor car (car horn). They develop their own initial product specification and using this as a basis, produce a variety of concepts with the ultimate capability of effectively satisfying this specification. Fig.2 shows 14 comparable concepts produced by a student group. 11 others generated at the same time have not been included since they all, in principle, required a major additional component to achieve the same function and therefore were evaluated separately.

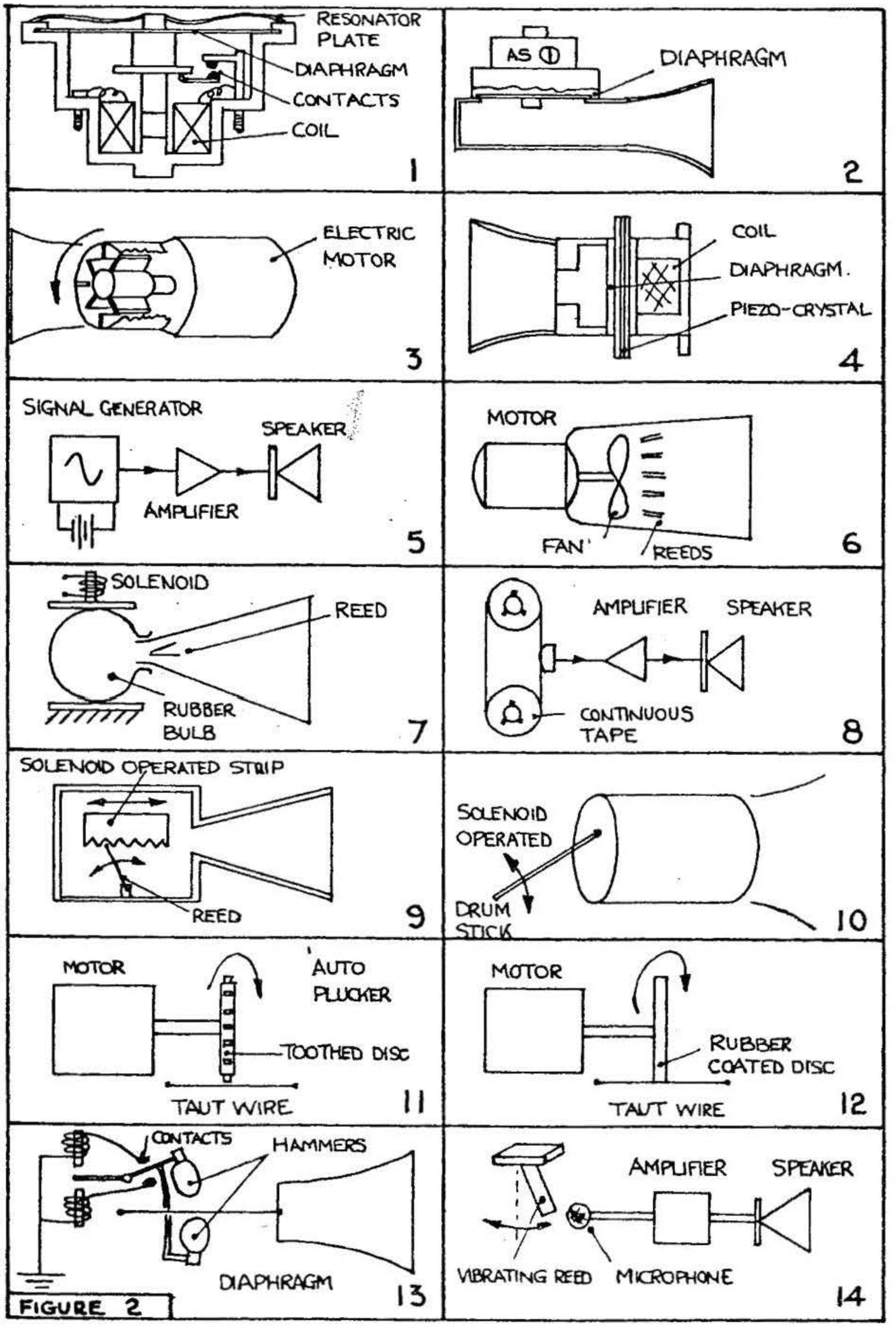
The writer apologises for the fact that within the limited space allowed for this paper it is not possible to portray the matrix including drawings of the concept in the same figure and remain meaningful. Fig.3 shows the evaluation chart for the 14 comparable concepts. A word of explanation; the chosen datum, Concept 1, is the traditional motor horn which has been developed over many years and is fitted to millions of cars today. Whilst it is debatable whether the relative order of merit for the different concepts is correct, the almost overwhelming strength of Concept 5 is not only extremely interesting, it is perhaps a foretaste of future car horn design and development. The reader is recommended to ask himself the question, "Does a vehicle audible means of approach, as outlined in Concept 5, exist at the present time?" Certainly not to the writers' knowledge!

Subsequently, further exercises are carried out on more difficult and complex products in order to gain familiarity with and confidence in the procedure and to prepare the students for the main group project where it will be used with intent in a real situation.

DISCUSSION AND CONCLUSIONS

The establishment of the procedure described has been found necessary and desirable for a number of reasons, the main ones being:-

1. The inadequacy of existing methods to produce effective and best solutions.
2. The constraints to creativity imposed either knowingly or subliminally by these methods.
3. A desire to formalise and establish a procedure that not only works effectively in practice but is also teachable.


RESONATOR PLATE
DIAPHRAGM
CONTACTS
COIL
1
AS ①
DIAPHRAGM
2
ELECTRIC MOTOR
3
COIL
DIAPHRAGM.
PIEZO-CRYSTAL
4
SIGNAL GENERATOR
SPEAKER
AMPLIFIER
5
MOTOR
FAN
REEDS
6
SOLENOID
REED
RUBBER BULB
7
AMPLIFIER
SPEAKER
CONTINUOUS TAPE
8
SOLENOID OPERATED STRIP
REED
9
SOLENOID OPERATED
DRUM STICK
10
MOTOR
AUTO PLUCKER
TOOTHED DISC
TAUT WIRE
11
MOTOR
RUBBER COATED DISC
TAUT WIRE
12
CONTACTS
HAMMERS
DIAPHRAGM
13
AMPLIFIER
SPEAKER
VIBRATING REED
MICROPHONE
14
FIGURE 2

CONCEPT / CRITERIA	1	2	3	4	* 5	6	7	8	9	10	11	12	13	14
Ease of achieving 105 - 125 DbA		S	-		+	-	+	+	-	-	-	-	S	+
Ease of achieving 2000 - 5000 Hz		S	S	N	+	S	S	+	S	-	-	-	S	+
Resistance to corrosion, erosion and water		-	-	O	S	-	-	S	-	+	-	-	-	S
Resistance to vibration, shcok, acceleration	D	S	-	T	S	-	S	-	-	S	-	-	-	-
Resistance to temperature	A	S	-		S	-	-	-	S	S	-	-	S	S
Response time	T	S	-		+	-	-	-	-	S	-	-	-	-
Complexity: number of stages	U	-	+	E	S	+	+	-	-	-	+	+	-	-
Power consumption	M	-	-	V	+	-	-	+	-	-	-	-	S	+
Ease of maintenance		S	+	A	+	+	+	-	-	S	+	+	S	-
Weight		-	-	L	+	-	-	-	S	-	-	-	-	+
Size		-	-	U	S	-	-	-	-	-	-	-	-	-
Number of parts		S	S	A	+	S	S	-	-	+	-	-	S	-
Life in service		S	-	T	+	-	S	-	-	-	-	-	-	-
Manufacturing cost		-	S	E	-	+	+	-	-	S	-	-	-	-
Ease of installation		S	S	D	S	S	+	-	S	-	-	-	S	-
Shelf life		S	S		S	S	-	-	S	S	S	S	S	S
FIGURE 3		0 + 6 -	2 + 9 -		8 + 1 -	3 + 9 -	5 + 7 -	3 + 12 -	0 + 11 -	2 + 8 -	2 + 13 -	2 + 13 -	0 + 8 -	4 + 9 -

4. The necessity to avoid the false confidence which many methods give to the user[2].

In using this procedure many times in practice to establish new or improved products it has been found that constraints to creative thinking are minimised. The fundamental difficulty, particularly in a teaching situation, of lack of convergence on the best solution is avoided whilst the participants remain open-minded in approach. In other words, having converged on to a solution in a controlled manner they are still capable of divergent thinking about the same problem.

A particular difficulty which arises in practice comes with a group which contains people with long experience of design in industry. They exhibit an impatience 'to get on with it' and may consider that the procedure holds them back from arriving at a solution. However, exposure to the full procedure usually convinces them of the error of their ways, particularly when asked if the solution, as it emerged, was ever likely to have arisen with their random, intuitive approach. The procedure positively stimulates creative, unconstrained thinking due to its lack of rigorous structure. For instance, it takes a lot of thought to establish in the first place and yet in the writers experience avoids the rigidity and false confidence instilled by numeric rating/weighting matrices.

Whilst this paper has been concerned with a procedure for minimising conceptual vulnerability, it should be pointed out that as an approach it can be used at any level in design from the most complex concept to the simplest detail component.

In conclusion, it offers many opportunities to improve design teaching and practice and will remain under continual scrutiny and development.

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ENGINEERING DESIGN CENTRE, LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY, LEICESTER.