ME349
Engineering Design Projects

Concept Evaluation Techniques

The evaluation of design concepts implies and involves both *comparison* and *decision making*. Evaluation techniques require a comparison between the concepts developed and the requirements they must meet along with decisions regarding how well they meet those requirements. It is recommended that you follow a procedural approach to evaluation in order to better determine which concepts will best meet your design goals.

The concept evaluation stage represents the convergence stage of design development so we will start by evaluating the concepts developed for the lowest level of function decomposition. As we progress, we will begin to combine the best concepts into sub-systems and then to evaluate the sub-systems using the same procedures. In this fashion, we will converge upon our "best" design.

Feasibility Judgment

The first step in the judgment of feasibility is to eliminate those concepts that are deemed "not feasible" under any conditions. Many times these judgments are based upon "gut feel", however as trained engineers, our "gut feel" is usually rooted in technological knowledge. The not feasible concepts are not considered further but still remain recorded in your design notebooks as reference.

Sometimes a concept is deemed as "conditionally feasible". This occurs when it is determined that a concept is workable if something else happens. This "something else" may involve the obtaining of currently unavailable information or the development of some other component. Conditionally feasible concepts will require further determination. They may fail later evaluations such as technological readiness or more information may be learned which will determine their fate.

The hardest concepts to evaluate are those where it is not immediately evident whether the idea is good or not, but the concept is "worth considering". These ideas (along with the conditionally feasible) will be evaluated through the decision making techniques given below.

Technology-Readiness Assessment

The second major evaluation should be to determine the readiness of the technologies that may be used in the concept. These technologies can include but are not restricted to, materials, manufacturing techniques, theoretical principals. Examine each concept with regard to the following questions. While a single "no" response is not enough to exclude a concept, it does mean that the concept may require re-examination.

Do reliable and reasonable manufacturing processes exist?

Do appropriate material choices for the solution exist and are they readily available?
While you may not be making material choices yet, be careful of counting on using a specific exotic or difficult to fabricate material.

Does my team have sufficient technological expertise for the solution considered?

Does the solution make use of mature and developed technologies?
Do similar applications exist that demonstrate the technology's readiness?

Go/No-Go Screening

This is a relatively easy procedure to implement. The first step is to return to the set of customer requirements developed during the early stages of design development. Transform each of the customer requirements into a yes/no question. For example, "is this concept light weight?" Apply the question to each of the surviving concepts. Answer each question as yes, no, or maybe. If the answers are "yes" or "maybe", then the concept is a "Go", and it proceeds to the next stage of evaluation; if the answer is "no", then the concept is a "No-Go". Before discarding the no-go concepts, make the following determination; can No-Go concepts be modified for a Go? If so, then the modified concepts are advanced to the next step.

Decision Matrix

Our final level of evaluation is by the decision matrix. In order to evaluate concepts effectively, some form of criteria are needed against which concepts can be evaluated in a quantitative fashion. Within the decision matrix, the concepts are not compared to one another, but only to the criteria of evaluation. These criteria provide a constant "yardstick" against which meaningful comparisons can be made. The selection criteria for the decision matrix are based on the functional requirements and/or the objectives of the problem.

Establishing the criterion weighting factors is a very important part of the decision matrix. The weights for each criterion quantitatively describe how important each criterion is with respect to the other criteria. Obviously required features (as determined by your analysis of customer requirements) are of the greatest importance, so have the highest weight. There are many different scales that can be used for assigning weights, but very few hard and fast rules exist for deciding which scale is best. Generally, one wants as coarse a scale as possible (because, after all, the concepts are only vaguely defined), and as simple a scale as possible.

Many companies use a weighting scale based upon a ten point system. The highest weighted criteria are given a ten, the lowest a one. This scale does ten to bias toward the positive and hence will result in higher scores.

Another commonly used scale is linear five point scale shown below. This scale is symmetrical about the origin (0) and linear. That is, it will not bias the results of assigning a weight. Such scales are often used in the automotive industry.

Rating	*Meaning*
-2	Greatly inferior compared to the criterion
-1	Somewhat inferior
0	Satisfactory
1	Somewhat superior
2	Greatly Superior

Some industries prefer a non-linear or asymmetrical scale. For example, some aerospace firms use a scale containing the values {0, 1, 3, 9}. It has been suggested that this scale, which biases strongly to the positive, is common in the aerospace industry because aerospace engineers tend to be too conservative (compared to, say, automotive engineers).

A rating is assigned to each concept by the design team (that is, ratings are decided collaboratively). The rating is also usually taken from a simple linear scale, often ranging between -2 (very bad) and 2 (very good). In the case of the example, a scale of 1-5 was used.

The ratings should be agreed upon by the design team as a whole, either by democratic vote or some other mechanism.

The weighted score is simply the product of the rating and the weight for a given concept and criterion.

The weighted scores are then summed, and the concept with the highest score is selected.

The decision matrix and iterative design

The decision matrix can be used as a tool to guide iterative design processes, by structuring the way that concepts are identified, specified and evaluated.

The following steps can be used.

1.) Establish the concept selection criteria and list them in the appropriate column of a decision matrix.

2.) Establish the weights of the selection criteria and list them in the matrix.

3.) Develop a set of initial concepts (4 or 5 are usually enough).

4.) Set up a column for each concept in the decision matrix.

5.) Evaluate each concept with respect to the selection criteria and calculate the ranking of each concept.

6.) Identify concepts that your team will no longer pursue and mark them as "dead ends." Do not remove the columns of the terminated concepts from the decision matrix. Rather, mark those columns in some way; mark the date that the concepts were terminated. This kind of information is invaluable for maintaining a history or "paper trail" of how your design process progressed with time.

7.) Consider adding 1 or 2 new concepts that are combinations or improvements on the remaining concepts in the decision matrix. There are two techniques that are useful for doing this:

> Fix low-scoring aspects of highly ranked concepts. Usually, even a winning concept will score poorly with respect to one or two criteria. What can be done to improve those aspects?
>
> Consider the highest-scoring aspects of concepts that were terminated. Usually, even the worst concept will have some redeeming aspect or other. Is it possible to "transplant" those good aspects of otherwise bad concepts into other concepts?

In either case, changes to any concept constitute the creation of a new concept. The new concept is added as a new column in the decision matrix (such as concept DF in the example); it must be evaluated as a separate concept with respect to the criteria, independent of the evaluation of other concepts from which it was derived.

8.) Return to the first step and continue until:

One concept emerges as a clear winner with a very high overall ranking, or you run out of time or resources to continue the iteration - in which case an arbitrary decision to choose a final concept must be performed.

Finally, you want to eliminate more concepts on each iteration than are added. In this way, you will eventually converge on a "best" design.

It should be clear that the decision matrix is not a static document, but one that can change and evolve in parallel to both your understanding of the design problem and the development of the design itself. Therefore, it's important to keep old versions of the decision matrix, to track the history of the design.

As a team moves from one level of detail to the next in a design project, recursion occurs. That is, once the design process has been carried out at a highly conceptual level, the "winning" concept is detailed out to another level, and the entire process is carried out again.