

ME349

Engineering Design Projects

Concept Generation

This information corresponds to the material in: The Mechanical Design Process, Ullman, sections 7.1-7.5. It is suggested that the student read these sections to supplement this handout.

1) Background:

Once the customer needs and project specifications are identified, the work of determining the potential solution begins. This is where one begins to design the actual product. However, it is just as unwise to jump at the first potential solution, as it is to start without first understanding the true customer needs. With engineering design it usually pays to be patient and spend some quality time in up-front planning.

One step that many teams omit in the design process is that of developing a "body-of-facts" before setting out to generate alternatives. The design team should meet together and collect all the information that is available about the problem at hand to insure that they don't go off and try to re-invent the wheel. Good engineering practice builds on the basis of existing work.

During the collection of the body-of-facts, it is important to differentiate between what is "fact" and what is an "assumption". Design assumptions are critical to the understanding of the design objectives. Design assumptions may become facts over time. The engineering teams that can best forecast the assumptions about the future that become true usually have the winning products. The design assumptions, built on the foundation of the body-of-facts, become the basis for the product strategy.

Once the team has identified the critical parts of the design, it is time then to generate alternatives for the key parts of the design. Most teams stop too early in this process, and don't uncover the winning concept. Don't shortchange this process. Take the time to generate a large number of ideas before trying to narrow down to the final concept.

2) Documentation of Objectives:

Documentation of the Concept Generation and Selection Process is basically a record of the steps the team made in coming up with the final design concept. There are several reasons for capturing this information. The design team benefits from having a paper trail of their work. This allows them to look back at all their work and insures ideas don't get dropped through the cracks.

It also provides evidence that they have taken into account all the customer constraints in coming up with alternatives.

This document also provides a set of specifications, jointly agreed upon by the team, on what will be built. It documents the proposed solution to the customer need, just as the Customer's Functional Specifications documents the aspects of the problem being solved.

This information is also important to the management of the project. The data included in the document clearly shows how diligent the team was in evaluating different ideas. It also highlights the critical assumptions that the team is making about future events. This allows the management team to align the company objectives with those of the development team.

Document Requirements

The actual document should include the following information:

- Introduction and process description. This section briefly describes the process that the team used in completing the document.
- Summary of the body-of-facts. This section should highlight the key facts and assumptions that the team has gathered, upon which they are basing their design concept.
- Block diagram of the proposed solution. Alternative architectures considered by the team should also be included.
- Selection of which parts of the design are critical to the success of the project.
- For critical design areas, include:
 - Concept definition sheets. Here the team summarizes the key alternatives that were considered. This should include a brief description of each concept.
 - Concept evaluation worksheet. This section should include a write up of the selection method used to determine the concepts that best meet the product specifications. This forces the team to articulate the selection criteria, so that others can easily see the rationale behind their decision.
 - Chosen design concept. This is the last section, and it should summarize the design that the team will take into the actual development phase. It should clearly show why this design was chosen, and what information was used in the decision.
- For the remaining, non-critical design areas, document how those areas will be designed and what technologies will be used.

3) Concept generation process:

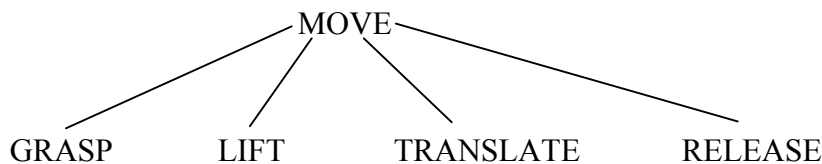
Function Determination

The following details a general process that may be used for concept generation. This process makes use of the customer and engineering requirements list you developed in the previous step (the QFD Method).

Generation of solution concepts requires understanding of the function(s) that your design must perform. Function is a statement of *what*, that is, what the system accomplishes. The usual form for a function is that of verb-noun. Examples of function statements would be; *transmit force* or *support load*. Remember that your functions should not attempt to tell *how* to accomplish something. We do not want the function to state *how* to transmit force for example; simply that it must be accomplished. Your text lists common function verbs in Figure 7.1.

The first step is to determine the overall function of your design. This is a statement of what your design/system will be used for. This statement needs to be the top level for function so it should be fairly general.

Next you need to decompose the overall function defined into smaller sub-functions. There may exist multiple sublevels to this decomposition. An example of a decomposition of function is given below. In this decomposition, the function MOVE is decomposed into the steps of GRASP, LIFT, TRANSLATE, and RELEASE. Note the nouns have been omitted from this example.



Make sure in your decomposition that you document only *what needs to happen* and not the *how it should happen*. If you must make some assumptions regarding design geometry (remember, we haven't chosen a solution yet), then list those assumptions.

Use standard notation in specifying your functions. Make use of the verb list given in the text. While it is not a comprehensive list, it does offer a large number of examples and will help you to determine other verbs as required. The nouns should be general enough that they do not presume a specific solution.

Consider the logical relationships between functions. Function for a design can be considered to be a flow, similar to that of energy flow. There are multiple functions being accomplished within a design and they relationships to one another.

The process for determining the relationship between functions is similar to flowcharting a computer program. You should use *and/or* branches to specify the flow of function within your design. Match inputs and outputs of functions at their junctures. This inputs and output can be material, energy, information, etc.

Be sure to decompose your functions as finely as possible. Break down each operation into as many steps as you can. This will simplify the function determinations phase. You will also be able to more easily define existing components that will satisfy functions within your system.

4) Concept Development

As opposed to the functions, concepts deal with *how* not the *what*. The idea of this stage is to develop as many concepts as possible and then to combine the concepts into designs that meet the customer/engineering requirements. The design team as a group should be involved in developing these concepts. Techniques for this procedure will be discussed later in this document.

Develop concepts for each of the functions defined previously. As many concepts as possible should be developed for each function. If only one function can be specified for a function then the function should be re-examined. There are very few functions for which only one concept exists. If you have this problem then consider the following:

- 1) Have you made a fundamental assumption without realizing it? Remember, all assumptions should be noted when defining functions.
- 2) The function does not specify *what* but rather *how*.
- 3) Not enough information is known of the area to which the function applies.

However, it is often the case that a single concept will solve more than one function.

It is suggested that you keep the concepts abstract and at the same level of abstraction. That is, do not specify some concepts broadly and others very detailed. Section 7.3.1 of Ullman gives an example of this on page 134.

Once individual concepts have been generated for each function, these concepts need to be combined into complete conceptual designs. You wish to use one concept from each function but when combining them you must use some structure. If you haphazardly combine concepts you will end up with designs containing unrelated ideas. Also since not every concept solves only one function it is possible to have redundant solutions within the conceptual design. Because of this, you should try to identify dependencies between concepts and try to combine these concepts into conceptual designs. You should also begin bringing graphics into your process at this stage. Begin generating thumbnail sketches of your conceptual designs. Make sure these are recorded within your design notebook.

Many of your concepts will be the result of the creativity of your design team. This is often a result of brainstorming. I suggest the 6-3-5 method detailed in section 7.4.5 of the Ullman text. If you use this technique, make sure you use it as detailed; do not modify the technique or omit steps. However, this is not the only source at your disposal. Concepts may also come from Patent searches, journal articles and various reference texts. Discussions and interviews with experts in the field will also yield design ideas. Be sure to detail these interviews in your design notebook.