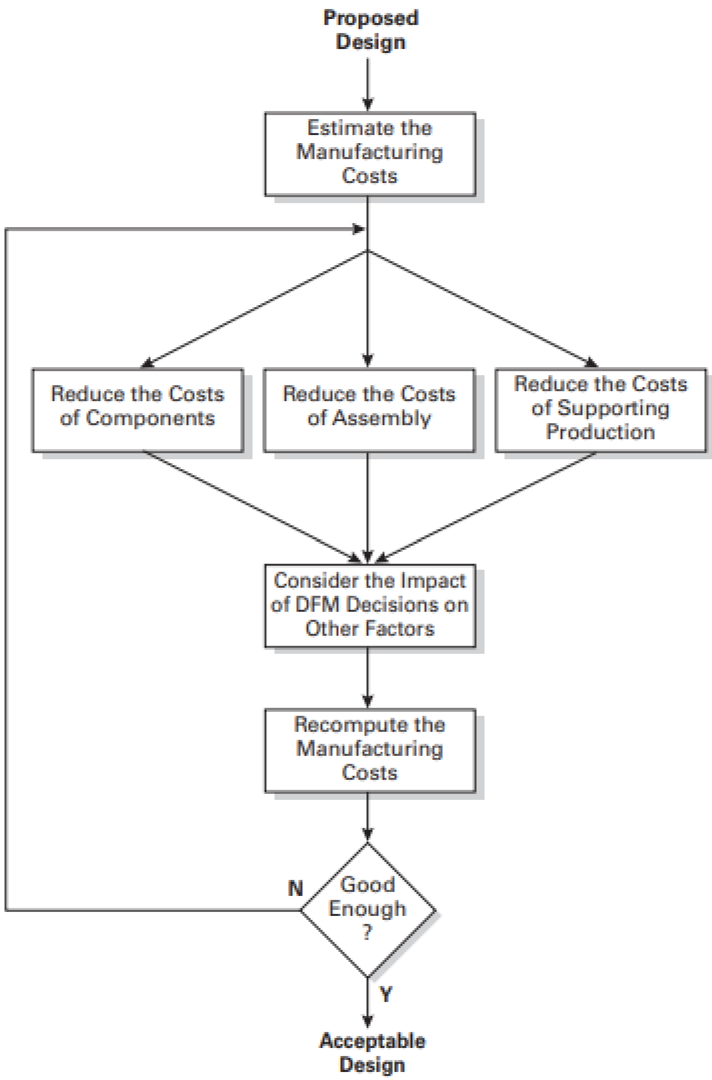
## 1.Illustrate the design for manufacturing (DFM) process with block diagram.

Design for Manufacturing (DFM) is the process of designing parts, components or products for ease of manufacturing with an end goal of making a better product at a lower cost. This is done by simplifying, optimizing and refining the product design.




The five steps of DFM process are as follows:

**Step 1: Estimate the Manufacturing Costs:**
The DFM method begins with the estimation of the manufacturing cost of the proposed design. This helps the team to determine at a general level which aspects of the design—components, assembly, or support—are most costly. The team then directs its attention to the appropriate areas in the subsequent steps. This process is iterative.

**Step 2: Reduce the Costs of Components:**
For most highly engineered discrete goods the cost of purchased components will be the most significant element of the manufacturing cost. This section presents several strategies for minimizing these costs. Many of these strategies can be followed even without the benefit of accurate cost estimates. In this case, these strategies become design rules, or rules of thumb, to guide DFM cost reduction decisions.

**Step 3: Reduce the Costs of Assembly:**
Design for assembly (DFA) is a fairly well-established subset of DFM that involves minimizing the cost of assembly. For most products, assembly contributes a relatively small fraction of the total cost. Nevertheless, focusing attention on assembly costs yields strong indirect benefits. Often as a result of emphasis on DFA, the overall parts count, manufacturing complexity, and support costs are all reduced along with the assembly cost.

**Step 4: Reduce the Costs of Supporting Production:**
A reduction in assembly content reduces the number of workers required for production and therefore reduces the cost of supervision and human resource management. Standardized components reduce the demands on engineering support and quality control. There are, in addition, some direct actions the team can take to reduce the costs of supporting production. It is important to remember that manufacturing cost estimates are often insensitive to many of the factors that actually drive overhead charges. Nevertheless, the goal of the design team in this respect should be to reduce the actual costs of production support even if overhead cost estimates do not change.

**Step 5: Consider the Impact of DFM Decisions on Other Factors:**
Minimizing manufacturing cost is not the only objective of the product development process. The economic success of a product also depends on the quality of the product, the timeliness of product introduction, and the cost of developing the product. There may also be situations in which the economic

success of a project is compromised in order to maximize the economic success of the entire enterprise. In contemplating a DFM decision, these issues should be considered explicitly:

- The Impact of DFM on Development Time
- The Impact of DFM on Development Cost
- The Impact of DFM on Product Quality
- The Impact of DFM on External Factors

## 2.What is prototyping? Illustrate the different steps of prototyping.

We define prototype as “an approximation of the product along one or more dimensions of interest”. Prototyping is the process of developing such an approximation of the product.

Prototypes can be usefully classified along two dimensions.

The first dimension is the degree to which a prototype is **physical** as opposed to **analytical**. The second dimension is the degree to which a prototype is **comprehensive** as opposed to **focused**.

**Physical prototypes** are tangible artifacts created to approximate the product. Aspects of the product of interest to the development team are actually built into an artifact for testing and experimentation. Examples of physical prototypes include models that look and feel like the product, proof-of-concept prototypes used to test an idea quickly, and experimental hardware used to validate the functionality of a product.

**Analytical prototypes** represent the product in a nontangible, usually mathematical or visual, manner. Interesting aspects of the product are analyzed, rather than built. Examples of analytical prototypes include computer simulations, systems of equations encoded within a spreadsheet, and computer models of three-dimensional geometry.

**Comprehensive prototypes** implement most, if not all, of the attributes of a product. A comprehensive prototype corresponds closely to the everyday use of the word prototype, in that it is a full-scale, fully operational version of the product. An example of a comprehensive prototype is one given to customers in order to identify any remaining design flaws before committing to production.

**Focused prototypes** implement one, or a few, of the attributes of a product. Examples of focused prototypes include foam models to explore the form of a product and hand-built circuit boards to investigate the electronic performance of a product design.

## 3.Discuss the different steps in robust design process.

Robust design is the product development activity of improving the desired performance of the product while minimizing the effects of noise.

**The Robust Design Process has the following seven steps:**

**Step 1: Identify Control Factors, Noise Factors, and Performance Metrics:** The robust design procedure begins with identification of three lists: control factors, noise factors, and performance metrics for the experiment.

• **Control factors**: These are the design variables to be varied in a controlled manner during the experiment, in order to explore the product's performance under the many combinations of parameter setpoints.

• **Noise factors**: Noise factors are variables that cannot be explicitly controlled during the manufacturing and operation of the product. Noise factors may include manufacturing variances, changes in materials properties, multiple user scenarios or operating conditions, and even deterioration or misuse of the product.

• **Performance metrics**: These are the product specifications of interest in the experiment. Usually the experiment is analyzed with one or two key product specifications as the performance metrics in order to find control factor setpoints to optimize this performance.

**Step 2: Formulate an Objective Function:** The experiment's performance metric(s) must be transformed into an objective function that relates to the desired robust performance. Several objective functions are useful in robust design for different types of performance concerns. They can be formulated either as functions to be maximized or minimized, and they include,

• **Maximizing**: This type of function is used for performance dimensions where larger values are better, such as maximum deceleration before belt slippage.
• **Minimizing**: This type of function is used for performance dimensions where smaller values are better, such as back angle at peak deceleration.
• **Target value**: This type of function is used for performance dimensions where values closest to a desired setpoint or target are best, such as amount of belt slackening before restraint.
• **Signal-to-noise ratio:** This type of function is used particularly to measure robustness. Taguchi formulates this metric as a ratio with the desired response in the numerator and the variance in the response as the denominator.

**Step 3: Develop the Experimental Plan:** Statisticians have developed many types of efficient experimental plans. These plans lay out how to vary the factor levels (values of the control factors and possibly also some of the noise factors) in a series of experiments in order to explore the system's behavior.

**Step 4: Run the Experiment:** To execute the experiment, the product is tested under the various treatment conditions described by each row in the experimental plan. Randomizing the sequence of the experimental runs ensures that any systematic trend over the duration of the experiment is not correlated with the systematic changes to the levels of the factors.

**Step 5: Conduct the Analysis:** There are many ways to analyze the experimental data. For all but the most basic analysis, the team benefits from consulting with a DOE expert or from referring to a good book on statistical analysis and experimental design.

**Step 6: Select and Confirm Factor Setpoints:** Analysis of means and the factor effects charts help the team determine which factors have a strong effect on mean performance and variance, and therefore how to achieve robust performance. These charts help to identify which factors are best able to reduce the product's variance (robustness factors) and which factors can be used to improve the performance (scaling factors). By choosing setpoints based on these insights, the team should be able to improve the overall robustness of the product.

**Step 7: Reflect and Repeat:** One round of experiments may be sufficient to identify appropriately robust setpoints. Sometimes, however, further optimization of the product's performance is worthwhile, and this may require several additional rounds of experimentation.

## 4.Demonstrate the principles of prototyping during the product development.

Several principles are useful in guiding decisions about prototypes during product development. These principles inform decisions about what type of prototype to build and about how to incorporate prototypes into the development project plan.

- **Analytical Prototypes Are Generally More Flexible Than Physical Prototypes:** Because an analytical prototype is a mathematical approximation of the product, it will generally contain parameters that can be varied in order to represent a range of design alternatives. In most cases, changing a parameter in an analytical prototype is easier than changing an attribute of a physical prototype.
- **Physical Prototypes Are Required to Detect Unanticipated Phenomena:** A physical prototype often exhibits unanticipated phenomena completely unrelated to the original objective of the prototype. One reason for these surprises is that all of the laws of physics are operating when the team experiments with physical prototypes. Physical prototypes intended to investigate purely geometric issues will also have thermal and optical properties. Some of the incidental properties of physical prototypes are irrelevant to the final product and act as annoyances during testing.
- **A Prototype May Reduce the Risk of Costly Iterations:** In many situations, the outcome of a test may dictate whether a development task will have to be repeated. The anticipated benefits of a prototype in reducing risk must be weighed against the time and money required to build and evaluate the prototype. This is particularly important for comprehensive prototypes. Products that are high in risk or uncertainty, because of the high costs of failure, new technology, or the revolutionary nature of the product, will benefit from such prototypes.
- **A Prototype May Expedite Other Development Steps:** Sometimes the addition of a short prototyping phase may allow a subsequent activity to be

completed more quickly than if the prototype were not built. If the required additional time for the prototype phase is less than the savings in duration of the subsequent activity, then this strategy is appropriate. One of the most common occurrences of this situation is in mold design.

- **A Prototype May Restructure Task Dependencies:** It may be possible to complete some of the tasks concurrently by building a prototype. For example, a software test may depend on the existence of a physical circuit. Rather than waiting for the production version of the printed circuit board to use in the test, the team may be able to rapidly fabricate a prototype and use it for the test while the production of the printed circuit board proceeds.

## 5.Demonstrate the block diagram elements of the manufacturing cost of a product.

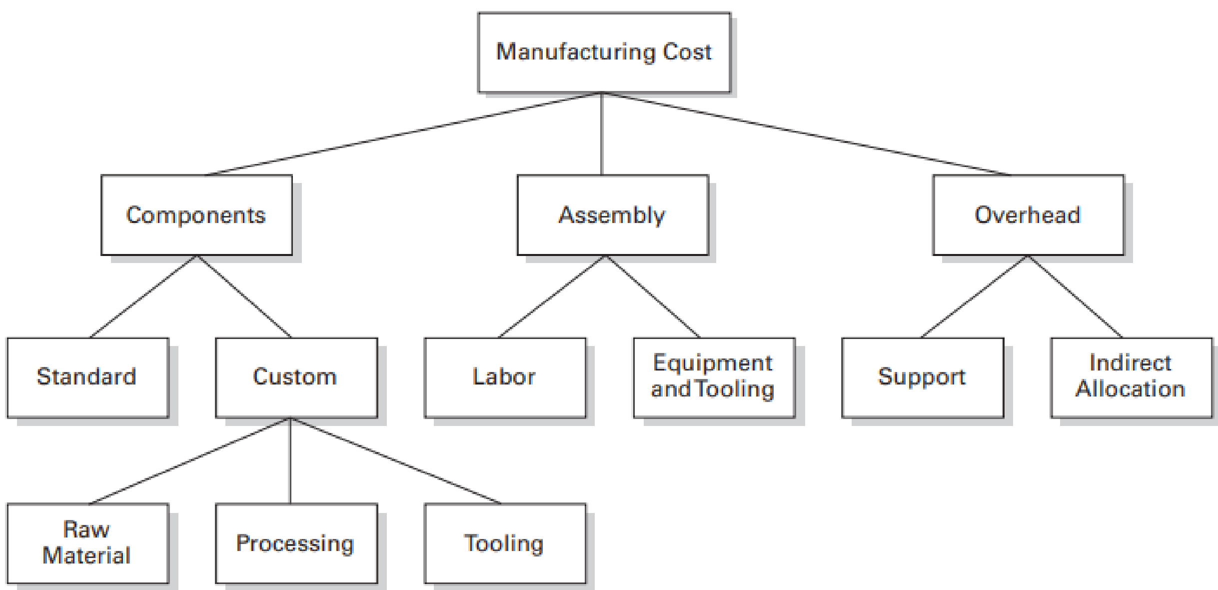



**Fig:** Elements of manufacturing cost of a product

**Component costs:** The components of a product may include standard parts purchased from suppliers. Examples of standard components include motors, switches, electronic chips, and screws. Other components are custom parts, made according to the manufacturer’s design from raw materials, such as sheet steel, plastic pellets, or aluminum bars. Some custom components are made in the manufacturer’s own plant, while others may be produced by suppliers according to the manufacturer’s design specifications.

**Assembly costs:** Discrete goods are generally assembled from parts. The process of assembling almost always incurs labor costs and may also incur costs for equipment and tooling.

**Overhead costs:** Overhead is the category used to encompass all of the other costs. We find it useful to distinguish between two types of overhead: support costs and other indirect allocations. Support costs are the costs associated with materials handling, quality assurance, purchasing, shipping, receiving, facilities, and equipment/tooling maintenance (among others). These are the support systems required to manufacture the product, and these costs do greatly depend upon the product design. Indirect allocations are the costs of manufacturing that cannot be directly linked to a particular product but that must be paid for to be in business. For example, the salary of the security guard and the cost of maintenance to the building and grounds are indirect costs because these activities are shared among several different products and are difficult to allocate directly to a specific product.

## 6.Summerize how to reduce cost of assembly in DFM.

Design for assembly (DFA) is a fairly well-established subset of DFM that involves minimizing the cost of assembly. For most products, assembly contributes a relatively small fraction of the total cost. Nevertheless, focusing attention on assembly costs yields strong indirect benefits. Often as a result of emphasis on DFA, the overall parts count, manufacturing complexity, and support costs are all reduced along with the assembly cost. we have the following principles useful to guide DFA decisions.

**Keeping Score:** Boothroyd and Dewhurst (1989) advocate maintaining an ongoing estimate of the cost of assembly. In addition to this absolute score, they propose the concept of assembly efficiency. This is measured as an index that is the ratio of the theoretical minimum assembly time to an estimate of the actual assembly time for the product. This concept is useful in developing an intuition for what drives the cost of assembly. The expression for the DFA index is

$$\text{DFA index} = \frac{(\text{Theoretical minimum number of parts})(3\ \text{seconds})}{\text{Estimated total assembly time}}$$

**Integrate Parts:** If a part does not qualify as one of those theoretically necessary, then it is a candidate for physical integration with one or more other parts. The resulting multifunctional component is often very complex as a result of the integration of several different geometric features that would otherwise be separate parts. Nevertheless, molded or stamped parts can often incorporate additional features at little or no added cost.

**Maximize Ease of Assembly:** Two products with an identical number of parts may nevertheless differ in required assembly time by a factor of two or three. This is because the actual time to grasp, orient, and insert a part depends on the part geometry and the required trajectory of the part insertion. The ideal characteristics of a part for an assembly are (adapted from Boothroyd and Dewhurst, 1989):

- Part is inserted from the top of the assembly
- Part is self-aligning
- Part does not need to be oriented
- Part requires only one hand for assembly
- Part requires no tools
- Part is assembled in a single, linear motion
- Part is secured immediately upon insertion

**Consider Customer Assembly:** Customers may tolerate completing some of the product assembly themselves, especially if doing so provides other benefits, such as making the purchase and handling of the packaged product easier. However, designing a product such that it can be easily and properly assembled by the most inept customers, many of whom will ignore directions, is a substantial challenge in itself.