ME0613
Rapid Prototype & Tooling (DE-II)

B. Tech Mechanical Semester-6

Chapter-1-Introduction

- Need for time compression in product development
- Product development
  - Conceptual design development
  - Detail design
  - Prototype
  - Tooling
- Applications of Rapid Prototyping

Need for the compression in the product development

- To increase effective communication.
- To decrease development time.
- To decrease costly mistakes.
- To minimize sustaining engineering changes.
- To extend product life time by adding necessary features & eliminating redundant features early in the design.

product development

- **Product:**

A product is a item/thing/solution that satisfies the needs of end users for certain period of time.

- **Product Development:**

It is a process of development of a conceptual idea to the real product.

- Phase 0
  - Planning
- Phase 1
  - Concept Development
- Phase 2
  - System Level Design
- Phase 3
  - Detail Design
- Phase 4
  - Testing & Refinements
- Phase 5
  - Production Ramp-up

product development

Phase 0: Planning:

- It is should be done before the approval of product development project.
- It is done in two steps:
  - **Step:1**
  - Quick investigation and scoping of the project to determine the possible markets and whether the product is in alignment with the corporate strategic plan.
  - It involves a preliminary engineering assessment to decide technical and manufacturing features.
  - Preliminary investigation usually completed in a month
  - **Step:2**
  - If everything looks good the planning phase step in to step 2 where planning operation goes into detailed investigation to build ***"the business case"****.*
  - *It takes few months to be completed.*

product development

- **In making business case**
- Marketing completes a detailed marketing analysis which involves, identification of target market, product positioning and product benefits
- Design digs more deeply to evaluate technical capability, possibly include ***proof of concept*** and validate some very preliminary design concepts
- Manufacturing identifies possible production constraints, costs and supply chain strategy.
- Financial analysis is made which uses sales and cost projections from marketing and profitability of the project. This also involves cash flow analysis, sensitivity analysis and possible risks

- If the project becomes considerable, it advances to Phase-1 and a multifunction team with designated leaders is established.
- The project is now be in formally on way.

product development

Phase 1: Concept Development

- It considers the different ways the product and each subsystems can be designed.
- Team takes potential customers from phase-0, adds its own knowledge base and fashions this into carefully crafted ***product design specification (PDS)***
- It is aided by using tools such as surveys and focus groups, benchmarking and quality function deployment.
- The generation of numbers of concepts follows:
  - Designer's creative instincts must be stimulated and assisted with development tools to produce promising concepts
  - At arriving to small set of feasible concepts, the one best suited for development into a product must be determined using selection methods.
- Conceptual design is the heart of the product development process.

product development

Phase 2: System Level Design

- It is where the function of the product are examined, leading to the division of the product into various subsystems.
  - Alternatives ways of arranging the subsystems into a product architecture are studied
  - The interface of subsystems are identified and studied
  - The forms and features of product begins to take shape, it is often called as embodiment design.
  - Selection of materials, configuration and dimensions of parts are established.
  - Critical parts are identified and checked for reliability, it is called as design robustness.
  - Legal formality and patents licensing issues are looked after.

product development

Phase 3: Detail Design

- It is where the design is brought to the state of the complete engineering description of a tested and producible product.
  - Missing information is added on the arrangement, form, dimensions, tolerances, surface properties, materials and manufacturing of each part in the product.
  - Design engineers are wrapping up all these details
  - Manufacturing engineers are finalizing a process plan for each part along tooling to make parts
  - All contracts with suppliers and outsourcing agencies are done in this phase.
  - All documentation are prepared and finalized to trigger Phase-4 and Phase-5.

product development

Phase 4: Testing and refinements

- It is concerned with making and testing man pre-production versions of the product.
- ***The first (alpha) Prototypes*** are usually made form the parts with same dimensions and material as a production version of the product, not necessarily made with the same process used for actual production, to minimize production cost.
  - The purpose to make alpha version is to determine whether actual product will work as designed and will satisfy the prime need or not.
- Then ***Beta versions*** are produced with the process and tooling which will be actually used for production and supplied to selected customers to in-house use.
  - The purpose is to check and receive feed backs of customers to make necessary changes before releasing product to general market.

product development

Phase 4: Testing and refinements

- At the end of Phase-4 a major review is carried out to determine whether the work has been done in a quality way and whether the developed product is consistent with original intent.
- Because large monetary sums must be committed beyond this point, a careful update is made of the financial estimates and the market prospects before funds are committed for production.

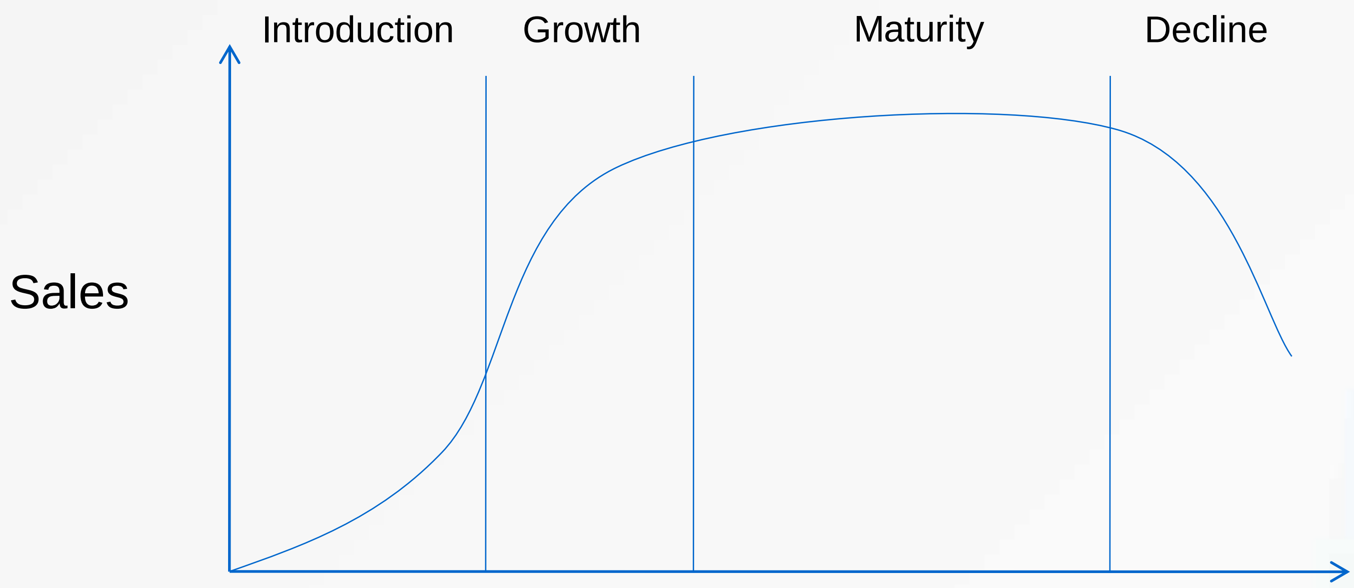
product development

Phase 5: Production Ramp-up

- It is the phase where manufacturing operations begins to make and assemble the product using the intended production system.
- Most likely they will go through a learning curve as they work out any production yield and quality problems
- Often product produced during ramp-up are also supplied to preferred customers and studied carefully to find any defects.
- Production is increased gradually until the full production is reached and then product is launched and made available to general market.

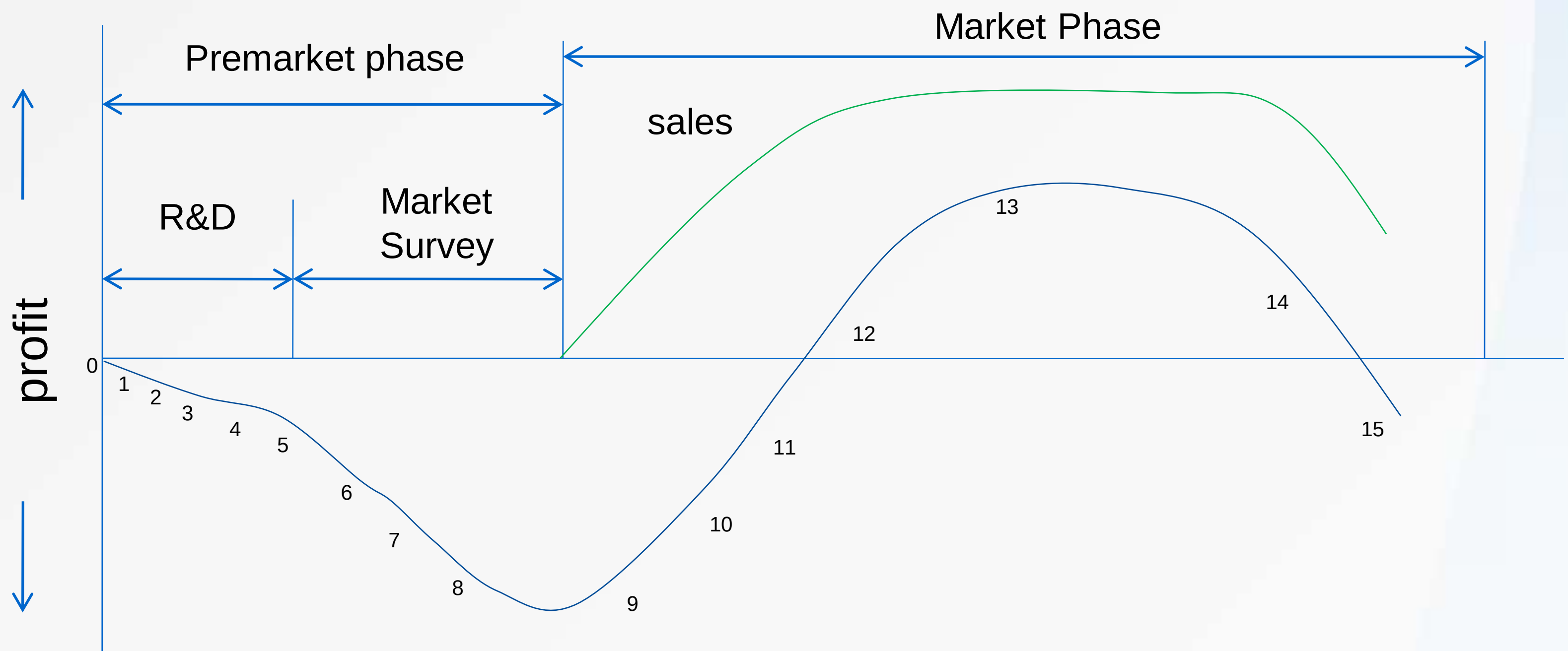
Stages in product life cycle

- Product life cycle is a representation of product whole life from conceptual idea to the demises of product from market.



- The product can be developed in only pre-market phase due to cost consideration and risk estimation.
- Hence, prototyping and testing play crucial role in product development.

Stages in product development & Product Life cycle



Premarket phase

1. Idea generation
2. Idea Evaluation
3. Feasibility analysis
4. Technical R&D
5. Product R&D
6. Preliminary Production
7. Market testing
8. Commercial production

Market Phase

9. Product Introduction
10. Market Development
11. Rapid Growth
12. Competitive market
13. Maturity
14. Decline
15. Abandonment

Engineering Design Process

Identifying Customer’s need

↓

Converting Needs into Product Design Specifications

↓

Engineering Design

↓

Product Prototyping

Prototyping and Its impact

- ***Impact on prototype design and innovation***
  - Design is to invent. As one thinks about the essential nature of an alternative design, one mentally formulates an invention.
  - In the product invention process, many technical problems need to be resolved.
  - Most technical problems have alternative solutions, and often there are several solutions and trade-offs associated with each solution.
  - A viable solution is simple, easy to produce with good quality, and low cost.
  - Product prototyping can be used as an evaluation tool in the engineering design process.
  - Prototyping plays a key role in product innovation.
  - Prototyping helps to quickly develop a product by providing a good tool for problem solving and can validate a concept.
  - Also a prototype can play a vital role in innovation because it can be used as a visual to help communicate the product's purpose and feel.

Prototyping and Its impact

- ***Impact on prototype design and innovation***
  - By doing this, different teams can look at the prototypes and use them as a stepping stone to further develop new product.
  - The engineer's way is to design with drawings while the artist's way is to design without them.
  - Both an engineer and an artist start with a blank page, and transfer to it the vision in his or her mind's eye.
  - An engineer's goal may be reached by many different paths, and none of which is in all aspects the one best way.
  - An engineer's decision will need to be based on intuition, a sense of fitness, and a personal preference made in the course of working through a particular design.
  - New product development is a complex, costly, and time-consuming process. There are many challenges.
  - In fact the national average success rate for start-up companies is about 10%!
  - Therefore, to start a new company requires a lot of planning, effort, and creativity.

Prototyping and Its impact

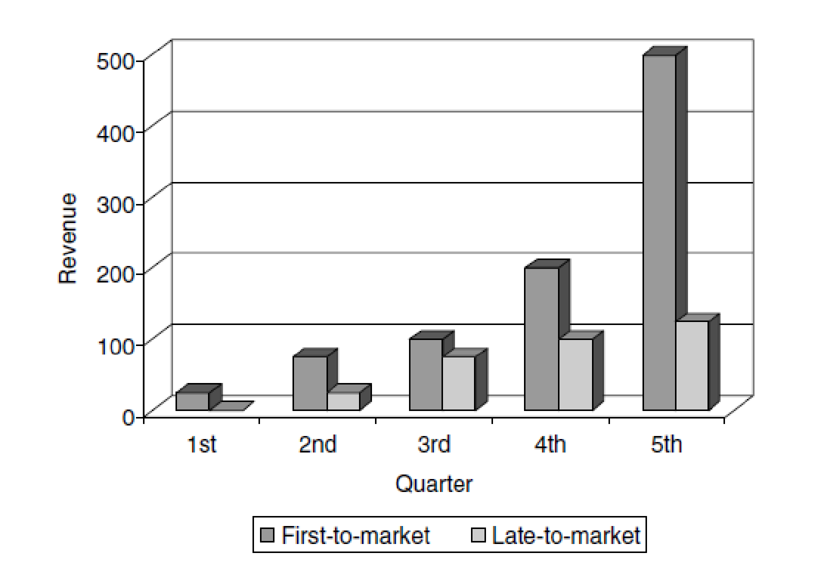
- ***Impact on prototype design and innovation***

Issues That Cause Product Innovation Failures

Rank/Issues	Role	Causes	Comments
1. Market obstacles	Major	Missing demands	Need
		Product pricing	Cost
		Late-to-market	Time
2. Management issues	Medium	Poor market analysis	Need
		Understaffing	Time/cost
		Lack of capital resources	Cost
3. Technology issues	Minor	Dated technical approach	Performance Quality
		Design problems	Performance Quality
		Poor quality	Quality
4. Others	Minor		Other

Prototyping and Its impact

- ***Impact on quality, cost and time***
  - The direct impact of a shorter product development time includes the opportunity to sell the product at premium prices early in the life cycle, and enjoy longer market life cycle.
  - In addition the benefits include faster breakeven on development, investment and lower financial risk, which leads to greater overall profits and higher return on investment (ROI).
  - Figure further illustrates this concept.



Prototyping and Its impact

- ***Impact on quality, cost and time***
  - To illustrate the importance of time-to-market, here a simple model is used to observe the impact of time-to-market.
  - The rate of ROI is an important index for the success of a product innovation project.
  - The ROI of the a product can be estimated as

$$\frac{Net\ Profit}{(Development\ cost)\ x\ (Time-to-market)} = \frac{[(Total\ Profit)-(Development\ cost)]}{[(Development\ cost)\ x\ (Time-to-market)]}$$

$$\frac{Net\ Profit}{(Development\ cost)\ x\ (Time-to-market)} = \frac{[(Total\ Profit)-(Time-to-market)\ x\ (annual\ development\ cost)]}{(Time-to-market)\ x\ (annual\ development\ cost) x\ (time-to-market)}$$

  - Time-to-market normally refers to the time needed for a new product to be sufficiently debugged, so that the development personnel can be allocated to develop another product.

Prototyping and Its impact

- ***Impact on quality, cost and time***
  - From Equation, it can be seen that the product development cost is very critical to the ROI.
  - As time-to-market can significantly impact product development cost and can even be more critical to the ROI, it is the most important factor which needs to be addressed.
  - The critical issues in innovation are related to cost, quality, and time-to-market.
  - Product definition is key to the success in the product development process, and among the activities, prototyping is the most time-consuming task.
  - Design is an iterative process in which two or more iterations may be needed. This makes the prototyping task even longer.
  - It is therefore very critical to be able to reduce prototyping time to shorten the entire product development cycle.

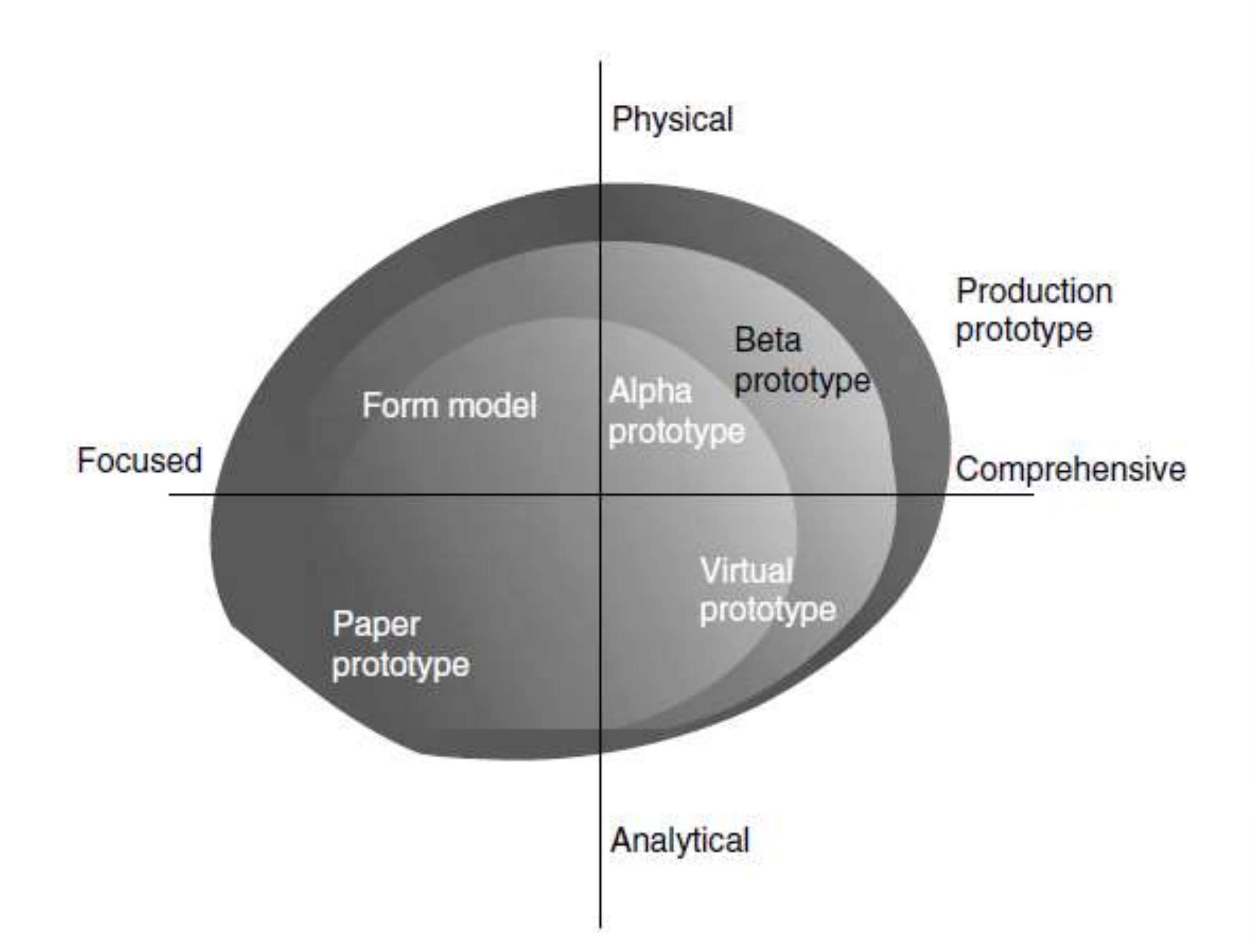
Prototyping and Its impact

- Traditional design ideologies require that engineers construct a variety of physical prototypes to test and evaluate design concepts.
- Due to the nature of such a process, the design and analysis of new products can become very time-consuming and expensive.
- Therefore, a traditional product design approach often yields very long product development time.
- Currently, new technologies involving rapid and virtual prototyping are revolutionizing the way products are designed.

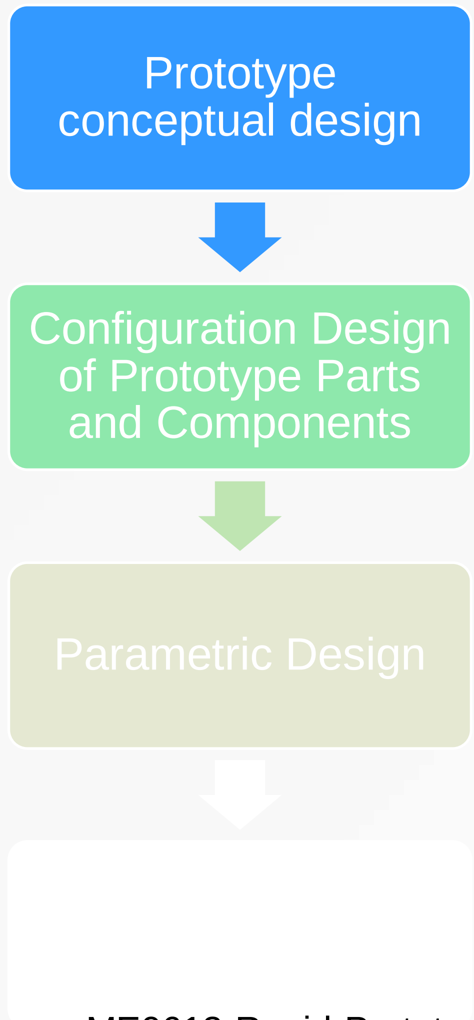
Application of Prototyping

- Before a prototype is made, it is very important to define the goal of the prototype so that the level of detail of the prototype can be determined.
- A prototype can be used for many purposes, such as
  - Gather initial user requirements
  - Show proof of concept to senior management
  - Validate system specifications
  - Explore solutions to specific usability or design problems
  - Deliver early proof of concept
  - Resolve fuzziness in early stages of design
  - Manage change requests
  - Validate evolving user requirements
  - Increase constructive user participation
  - Customer acceptance
  - Product invisibility
  - Quality assurance
  - Pertain users or to create a marketing demo

Types of prototype

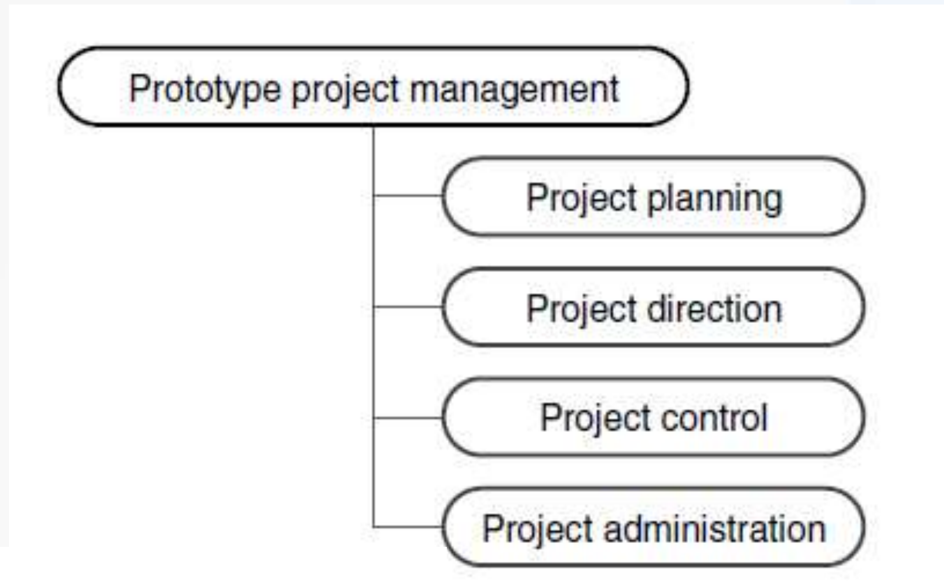


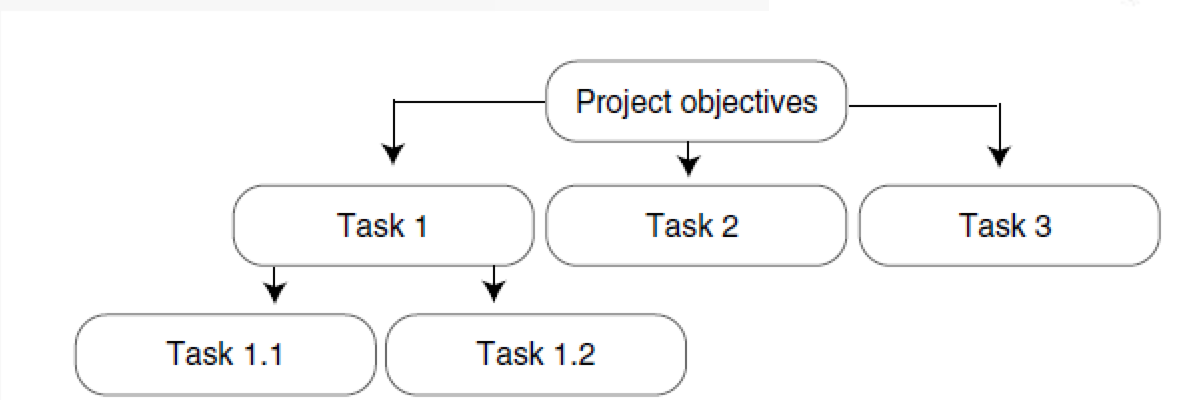
Physical prototype design



Prototype project management

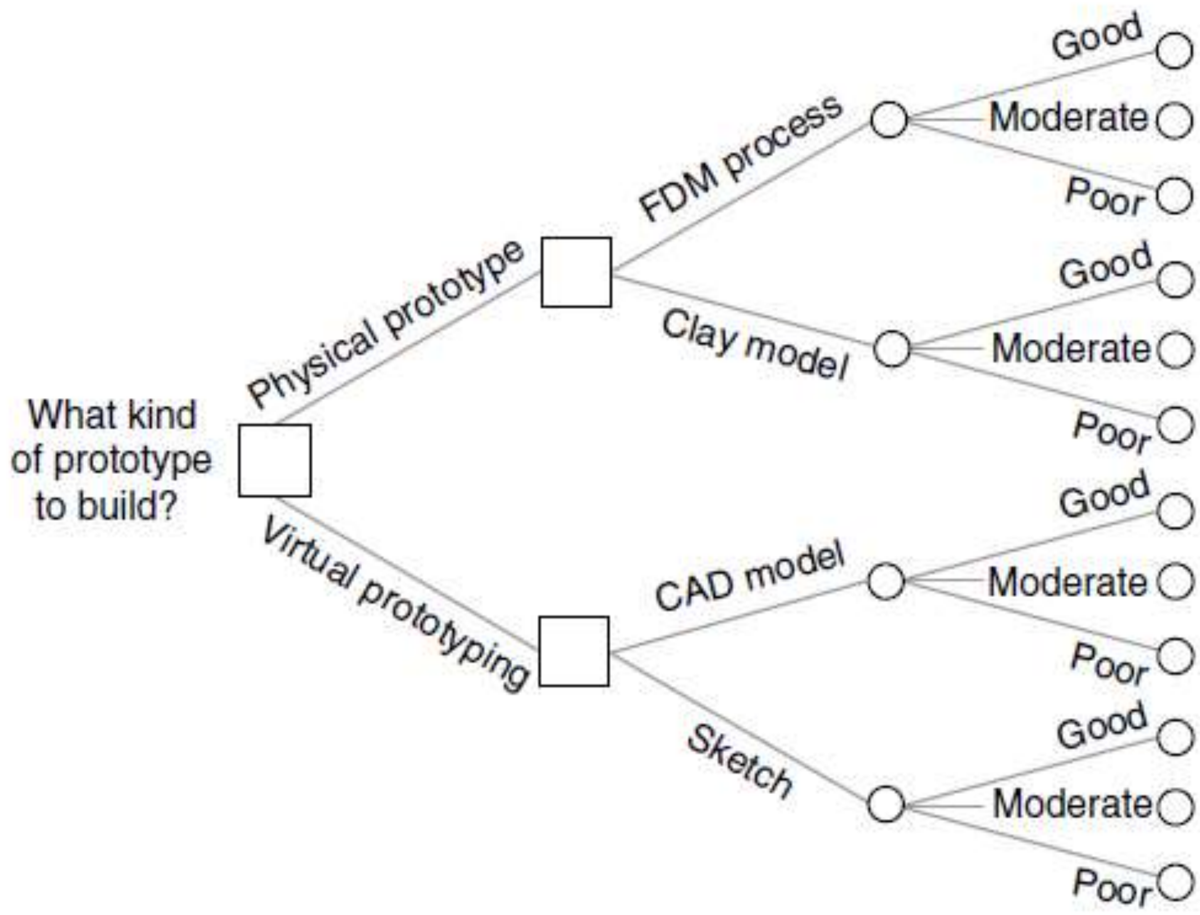
- PROJECT VISION IN PROJECT MANAGEMENT
  - Specific
  - Measurable
  - Achievable
  - Relevant
  - Time dimensioned



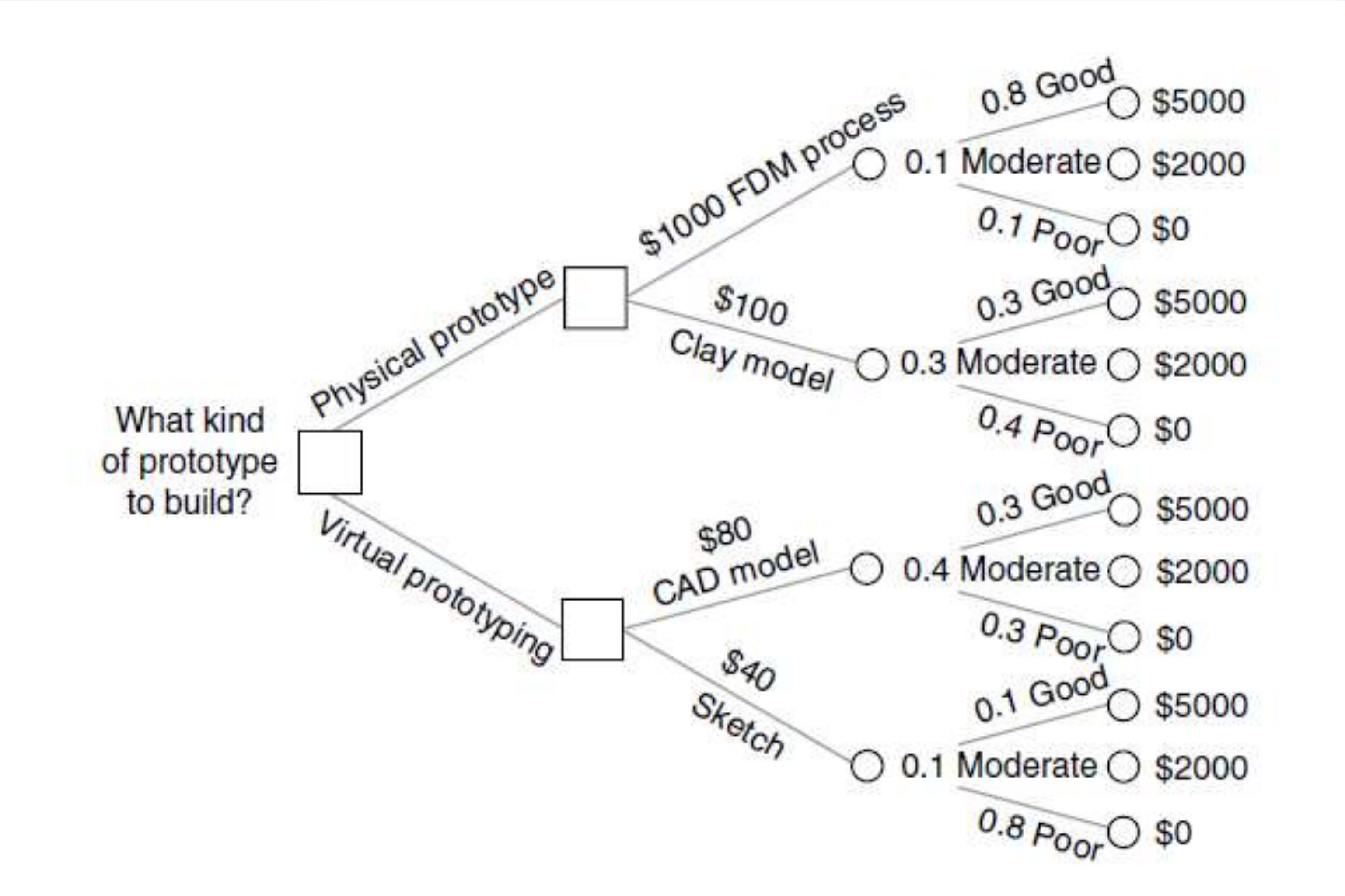


Tooling

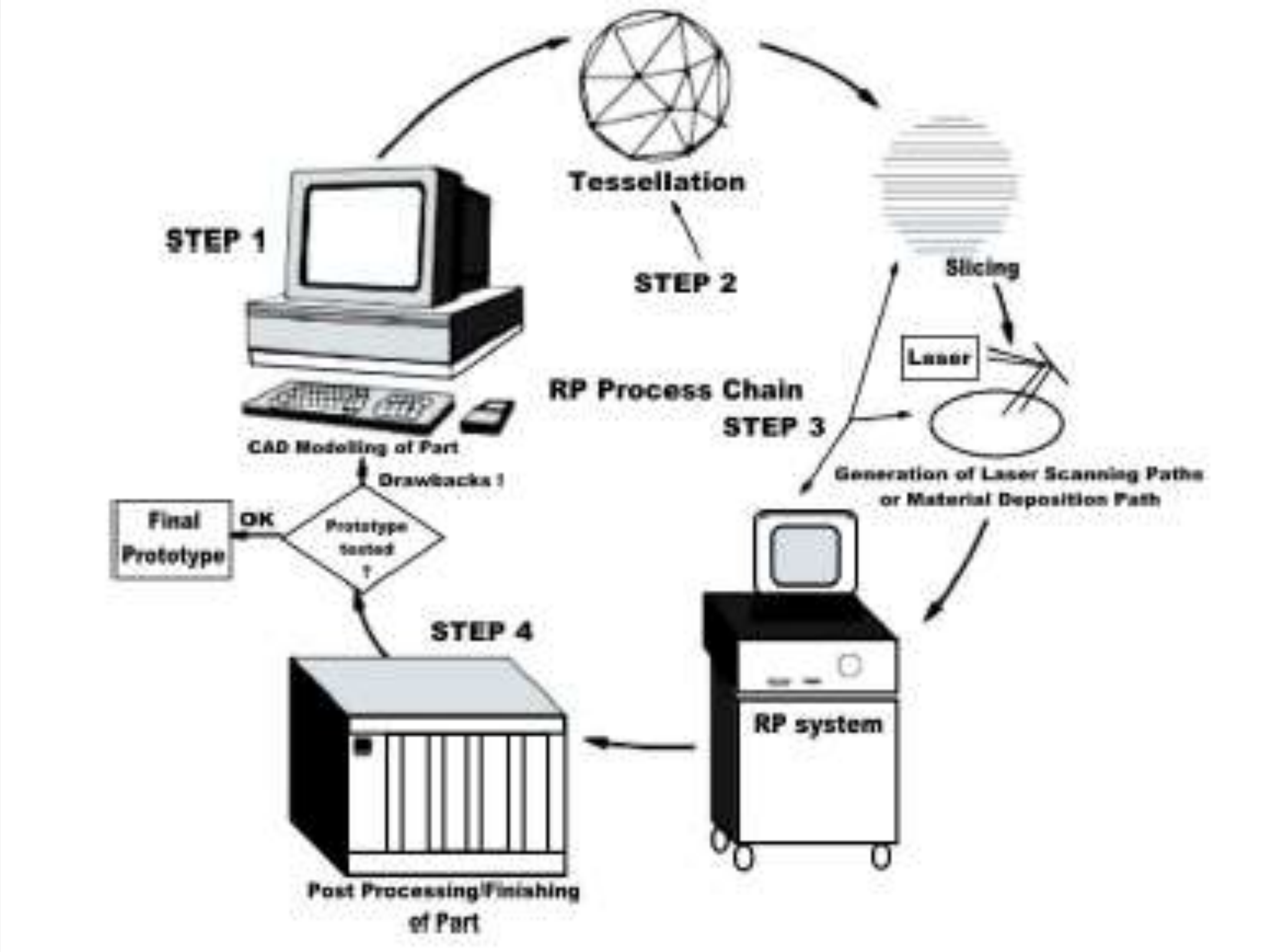
Project Risk Management



Project Risk Management



Methodology of Rapid Prototyping



Methodology of Rapid Prototyping

1. Development of CAD model

The process begins with the generation CAD model of the desired object which can be done by one of the following ways;

- Conversion of an existing two dimensional (2D) drawing
- Importing scanned point data into a CAD package
- Creating a new part in CAD in various solid modeling packages
- Altering an existing CAD model

RP has traditionally been associated with solid rather than surface modelling but the more recent trends for organic shapes in product design is increasing the need for free flowing surfaces generated better in surface modelling.

Methodology of Rapid Prototyping

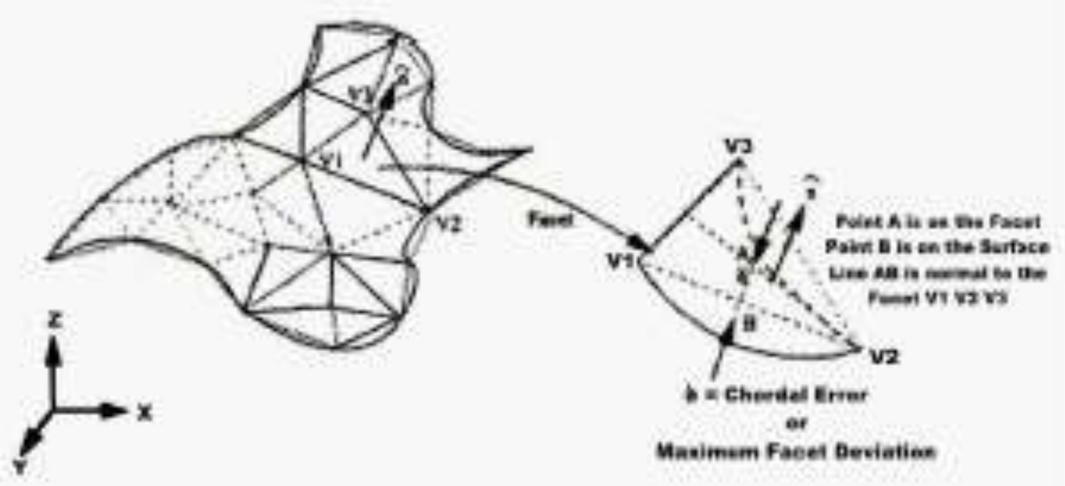
2. Generation of Standard triangulation language (STL) file

- The developed 3D CAD model is tessellated and converted into STL files that are required for RP processes.
- Tessellation is piecewise approximation of surfaces of 3D CAD model using series of triangles.
- Size of triangles depends on the chordal error or maximum fact deviation.
- For better approximation of surface and smaller chordal error, small size triangle are used which increase the STL file size.

Methodology of Rapid Prototyping

2. Generation of Standard triangulation language (STL) file

- This tessellated CAD data generally carry defects like gaps, overlaps, degenerate facets etc which may necessitate the repair software.
- These defects are shown in figure below.



Methodology of Rapid Prototyping

2. Generation of Standard triangulation language (STL) file

- The STL file connects the surface of the model in an array of triangles and consists of the X, Y and Z coordinates of the three vertices of each surface triangle, as well as an index that describes the orientation of the surface normal.

Methodology of Rapid Prototyping

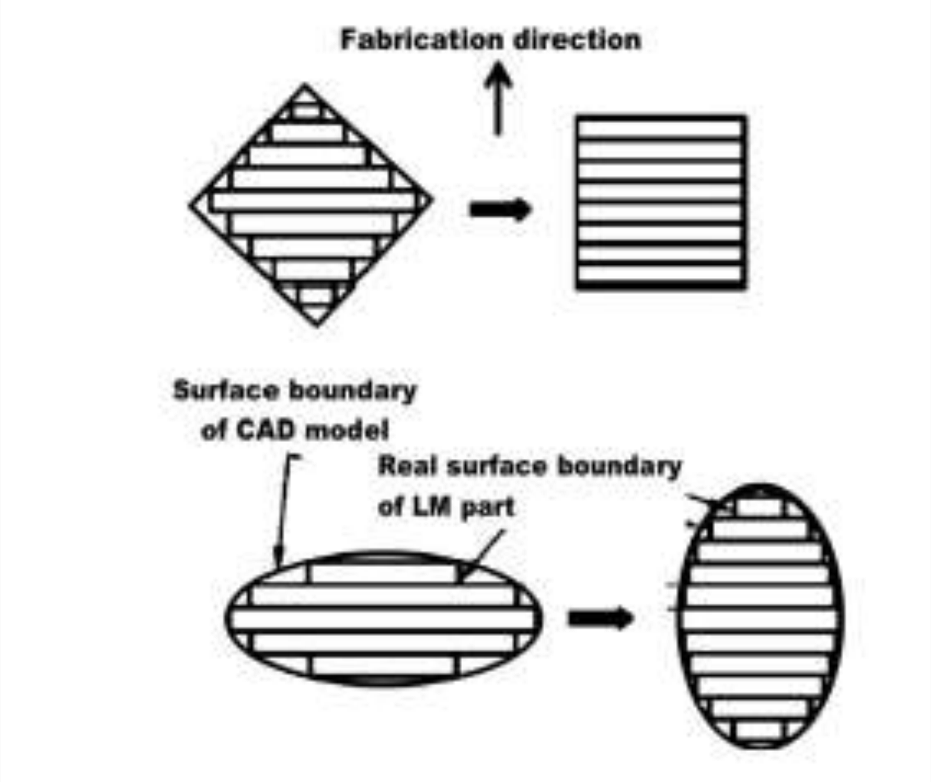
3. Slicing the STL file

- Slicing is defined as the creating contours of sections of the geometry at various heights in the multiples of layer thickness.
- Once the STL file has been generated from the original CAD data the next step is to slice the object to create a slice file (SLI).
- This necessitates the decision regarding part deposition orientation and then the tessellated model is sliced.

Methodology of Rapid Prototyping

3. Slicing the STL file

- Part orientation will be showing considerable effect on the surface as shown in the figures.



Methodology of Rapid Prototyping

3. Slicing the STL file

- The thickness of slices is governed by layer thickness that the machine will be building in, the thicker the layer the larger the steps on the surface of the model when it has been built.
- After the STL file has been sliced to create the SLI files they are merged into a final build file.
- This information is saved in standard formats like SLC or CLI (Common Layer Interface) etc.

Methodology of Rapid Prototyping

4. Support Structures

- As the parts are going to be built in layers, and there may be areas that could float away or of overhang which could distort.
- Therefore, some processes require a base and support structures to be added to the file which are built as part of the model and later removed.

Methodology of Rapid Prototyping

5. Manufacturing

- As discussed previously, RP process is addative i.e., it built the parts up in layers of material from bottom.
- Each layer is bonded automatically to the layer below and the process is repeated till the whole part is built.
- This process of bonding is undertaken in different ways for the various material to be used.

Methodology of Rapid Prototyping

6. Post processing

- The parts are removed from the machine and post processing operations are performed sometimes to add extra strength to the part by filling process voids or finish the curing of a part or to hand finish the parts to the desired level.
- The level of post processing will depend greatly on the final requirements of the parts produced, for example,

metal tooling for injection molding will require extensive finishing to eject the parts but a prototype part manufactured to see if it will physically fit in a space will require little or no post processing.

Classification of Rapid Prototyping