Product Design and Development (315367)

Model Question Paper — Set A · Model Answers

Q.1

a) Customer need identification and its importance. 2 M

Customer need identification is the process of finding out, by interviews, focus groups and observation of the product in use, what the customers really want from a product, and writing these wants as clear **need statements** in terms of *what* the product has to do (not *how*).

Importance: it makes sure the product is focused on customers, hidden and latent needs are not missed, it gives the basis for target specifications and concept generation, and it creates a record (archive) of needs for the whole team.

(Definition 1 M, importance 1 M)

b) Product architecture. 2 M

Product architecture is the scheme by which the **functional elements** of a product are arranged into **physical chunks** (building blocks) and by which these chunks **interact** with each other.

Example: a desktop computer — functions such as processing, storage, display and input are carried out by separate chunks (motherboard, hard disk, monitor, keyboard) connected by standard interfaces; this is a *modular* architecture.

(Definition 1 M, example 1 M)

c) Design by evolution. 2 M

Design by evolution: the design of a product developed slowly over a long period through small, gradual improvements of the earlier design, based on experience, user feedback and trial and error — without any sudden or radical change.

Example: the bicycle — from the wooden "dandy horse" to the high-wheel bicycle, then the chain-driven safety bicycle with equal wheels and pneumatic tyres, and today's geared bicycle.

(Definition 1 M, example 1 M)

d) Types of consumer products. 2 M

Type	Meaning	Example
Convenience products	Bought frequently, with little effort and comparison	Soap, toothpaste, bread
Shopping products	Bought less often; customer compares quality, price and style	Television, furniture, clothes
Specialty products	Unique features / brand; buyer makes special effort	Luxury car, branded watch
Unsought products	Customer does not normally think of buying them	Fire extinguisher, life insurance

(Each type ½ M)

e) Value of a product and its types. 2 M

Value = Function (worth) / Cost, i.e. V = F / C. Value increases when the required function is obtained at a lower cost or a better function at the same cost.

Types of value: (i) Use value — properties that make the product perform its function; (ii) Esteem value — features that make the product attractive / prestigious to own; (iii) Cost value — total cost of producing the product; (iv) Exchange value — properties that make it possible to exchange it for something else (resale).

(Expression 1 M, any two types 1 M)

f) Needs of QFD in new product development. 2 M

1. To translate the voice of the customer into measurable technical requirements.
2. To focus the design on features that are most important to customers.
3. To reduce design changes late in development, which shortens development time and cost.
4. To improve communication and team work between marketing, design and manufacturing; it also documents the reasons for design decisions.

(Any four, ½ M each)

g) FDM vs SLA. 2 M

Point	FDM	SLA
Raw material	Thermoplastic filament (PLA, ABS, PETG, nylon)	Liquid photopolymer resin
Principle	Molten plastic extruded through a heated nozzle, bead by bead	UV laser cures (solidifies) resin layer by layer
Resolution / accuracy (typical)	Lowest; about ± 0.2 – 0.5 mm	Highest; about ± 0.05 – 0.1 mm
Surface finish	Rough, layer lines visible	Very smooth

(Any two points, 1 M each)

Q.2

a) Five-step concept generation method. 4 M

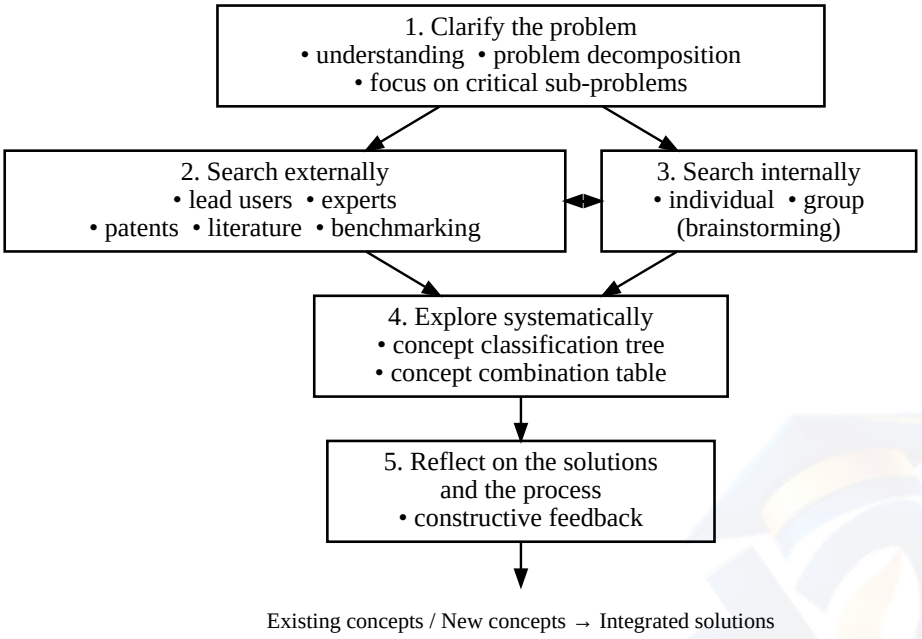


Fig.: Five-step concept generation method

1. **Clarify the problem:** understand the problem and break it into simpler sub-problems (functional decomposition); focus on the critical sub-problems.
2. **Search externally:** find existing solutions — interview lead users, consult experts, search patents and literature, benchmark related products.
3. **Search internally:** use the knowledge and creativity of the team — individual and group brainstorming to create new concepts.
4. **Explore systematically:** organise and combine the concept fragments using a concept classification tree and a concept combination table.
5. **Reflect on the solutions and the process:** check whether the solution space is fully explored and how the process can be improved.

(Flow chart 1 M, five steps 3 M)

b) Principles of good product design. 4 M

1. **Functional requirement:** the product must perform its intended function effectively and reliably (e.g. a pressure cooker must cook safely under pressure).
2. **Simplicity:** minimum number of parts and simple shapes — easy to make, assemble, use and repair.
3. **Ergonomics (ease of use) and safety:** designed to suit the human body and to protect the user (guards, rounded edges, safety valve).
4. **Aesthetics:** pleasing appearance — form, colour and finish attract customers.
5. **Economy and manufacturability:** low cost; uses standard parts and available processes and materials.

6. **Reliability, durability and maintainability:** long life, easy servicing; environment-friendly (recyclable materials).

(Any four principles, 1 M each)

c) Slot, bus and sectional modular architectures. 4 M

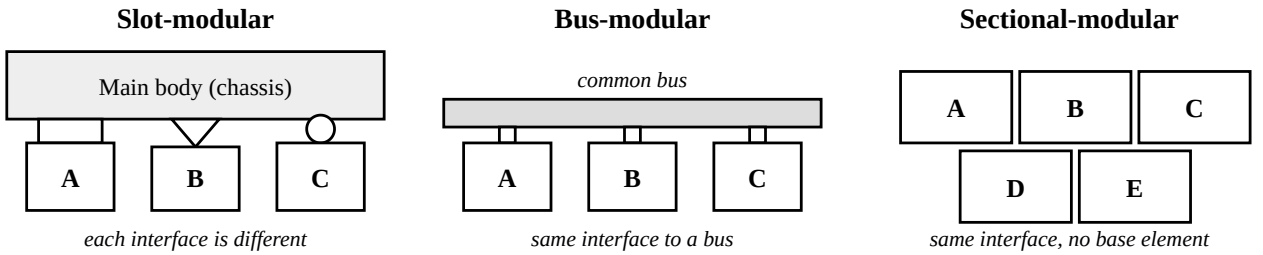


Fig.: Types of modular product architecture

- **Slot-modular:** each interface between a chunk and the rest of the product is of a *different type*, so each chunk fits only in its own slot and chunks cannot be interchanged. Example: car dashboard — radio, speedometer and air-conditioner controls each have their own mounting.
- **Bus-modular:** there is a common *bus* to which other chunks connect through the *same type of interface*. Example: expansion cards on a computer motherboard, lights on a track-lighting rail, shelves on a slotted rack.
- **Sectional-modular:** all interfaces are of the same type, but there is no single element (bus) to which the others attach; the product is built by joining chunks to each other. Example: office partition panels, sectional sofa, piping systems.

(Each type with sketch and example, 1⅓ M)

d) Aspects of aesthetics: form, proportion, contrast, surface finish. 4 M

1. **Form:** the overall shape and outline of the product. A form that expresses its function (e.g. streamlined form of a motorcycle tank) looks attractive and creates the first impression.
2. **Proportion:** the relation of size of one part to another and to the whole. Well-proportioned products look balanced; the golden ratio (about 1 : 1.618) is often used for rectangles, panels and screens.
3. **Contrast:** a deliberate difference in colour, shape, texture or size used to draw attention to important features (e.g. red emergency-stop button on a grey machine panel); too much contrast looks disturbing.
4. **Surface finish:** texture and quality of the surface — polished, matt, textured, painted, chrome-plated. It affects the look, feel (touch) and perceived quality and also protects against corrosion and wear.

(Each aspect 1 M)

Q.3

a) DFM flow chart and steps. 4 M

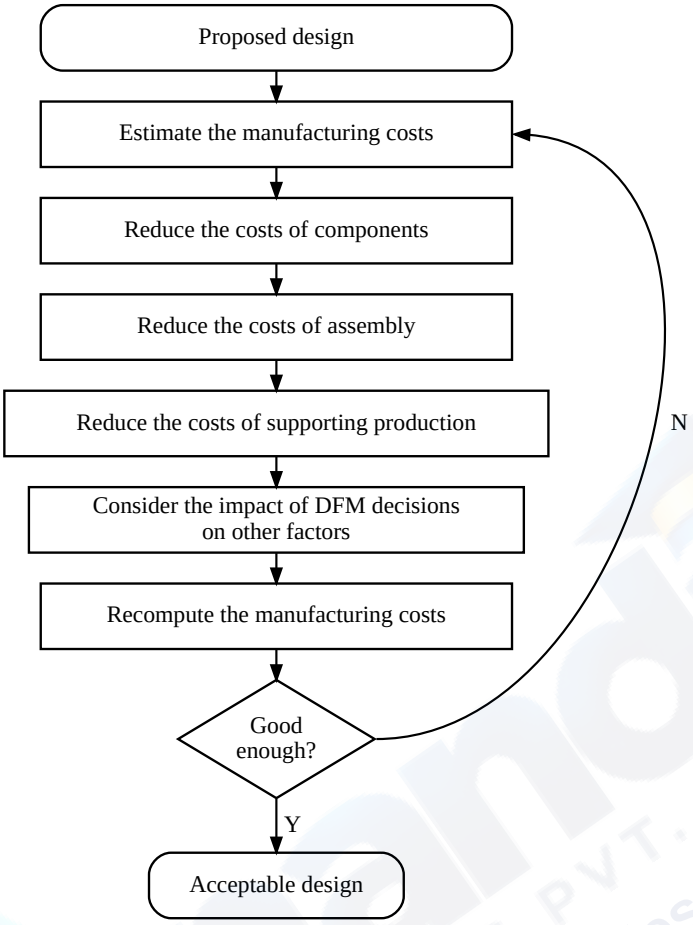


Fig.: Flow chart of the Design for Manufacturing (DFM) method

DFM is a design approach in which the product is designed so that it is easy and economical to manufacture, keeping the required quality.

- **Estimate the manufacturing costs:** list the bill of materials and estimate the cost of standard and custom components, assembly cost and overhead cost.
- **Reduce the costs of components:** simplify part shapes, choose cheaper suitable processes and materials, use standard components, avoid tight tolerances.
- **Reduce the costs of assembly:** reduce part count, make parts self-aligning, avoid separate fasteners (snap fits), design for top-down assembly.
- **Reduce the costs of supporting production and consider other factors:** fewer part numbers and less inventory; check that DFM changes do not hurt development time, quality or reuse.

(Flow chart 2 M, any two steps 2 M)

b) Importance of VOC in QFD. 4 M

Voice of Customer (VOC) is the customer's own description of what he wants (needs, expectations, complaints) collected by interviews, surveys, complaint records and focus groups. It is the starting point of QFD.

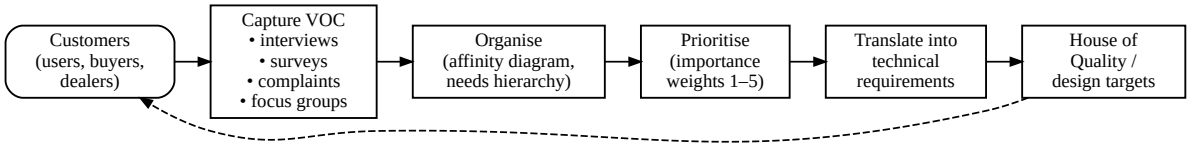


Fig.: Voice of Customer (VOC) in QFD — block diagram (dashed: product that meets the needs returns to a satisfied customer)

Importance:

1. Gives the real "WHATs" for the House of Quality, so the product is designed for customers and not from the designer's assumption.
2. Helps rank needs by importance, so effort is spent on the features that matter most.
3. Reduces the risk of product failure in the market and costly late changes.
4. Increases customer satisfaction and loyalty; gives a common language to marketing and engineering.

(Meaning 1 M, block diagram 2 M, importance 1 M)

c) Concept of rapid prototyping and its general process. 4 M

Rapid prototyping (RP) is a group of techniques used to make a physical model (prototype) of a part quickly and **directly from its 3-D CAD data**, by **adding material layer by layer** (additive manufacturing), without any tools, dies or fixtures.

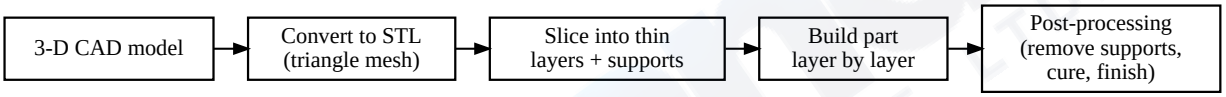


Fig.: General process of rapid prototyping / 3-D printing

- **Additive, layer-by-layer approach:** the part is built by adding material one thin layer (cross-section) at a time, instead of removing material (machining).
- **CAD-driven (digital) fabrication:** the part is made directly from a 3-D CAD model converted to an STL file and sliced into layers — no tooling, dies or fixtures.
- **Iterative development:** design → print → test → modify CAD → reprint; many quick, cheap iterations improve the design early.
- **Speed and automation:** the machine works unattended; a prototype is ready in hours/days instead of weeks.
- **Geometric freedom:** complexity is almost "free" — internal channels, lattices and undercuts can be built.

(Concept 1 M, process diagram 2 M, principles 1 M)

d) Concept screening — kitchen vegetable chopper. 4 M

Concept screening (Pugh method) is a quick, approximate evaluation used to narrow down many concepts. Each concept is compared with a **reference concept** for each criterion and rated "+" (better than), "0" (same as) or "−" (worse than); the net score (+'s − −'s) is used to rank, combine/improve and select concepts.

Selection criteria	A: Knife + board (reference)	B: Pull-cord rotary	C: Plunger press	D: Electric mini

Ease of use	0	+	+	+
Ease of cleaning	0	0	−	−
Cutting speed	0	+	+	+
Safety of user	0	+	+	0
Portability	0	+	0	−
Low manufacturing cost	0	0	0	−
Durability	0	0	−	0
Sum +'s	0	4	3	2
Sum 0's	7	3	2	2
Sum −'s	0	0	2	3
Net score	**0**	**+4**	**+1**	**-1**
Rank	**3**	**1**	**2**	**4**

Result: concept **B: Pull-cord rotary** has the highest net score (+4), rank 1, so it is selected for further development (concept scoring). Concept D can be improved (lower cost) or dropped.

(Meaning 1 M, matrix 2 M, selection 1 M)

Q.4

a) PLC curve and stages. 4 M

Product life cycle (PLC) is the series of stages a product passes through from its introduction into the market until it is withdrawn, shown by the change of sales (and profit) with time.

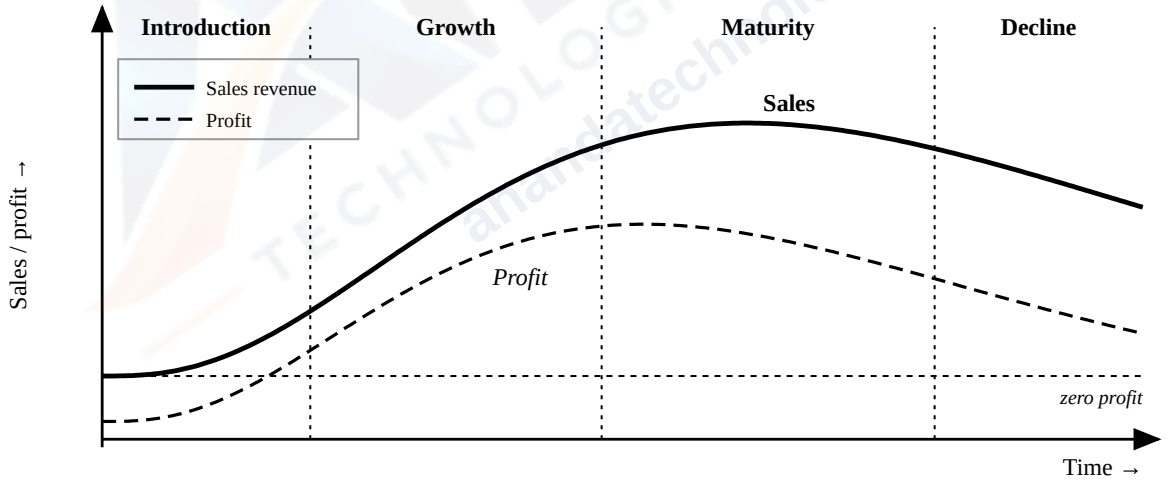


Fig.: Product life cycle (PLC) curve

Stage	Sales	Profit	Competition	Typical strategy
Introduction	Low, slow rise	Negative / low (high development & promotion cost)	Few or none	Create awareness, trial, remove defects

Growth	Rapid rise	Rising, becomes highest towards end	Increasing	New features, more dealers, build brand
Maturity	Peak, levels off	High then falling (price war)	Maximum	Variants, cost reduction, defend share
Decline	Falling	Low / falling	Competitors leave	Cut cost, phase out or rejuvenate

(Curve 2 M, stages 2 M)

b) Man–machine closed loop system. 4 M

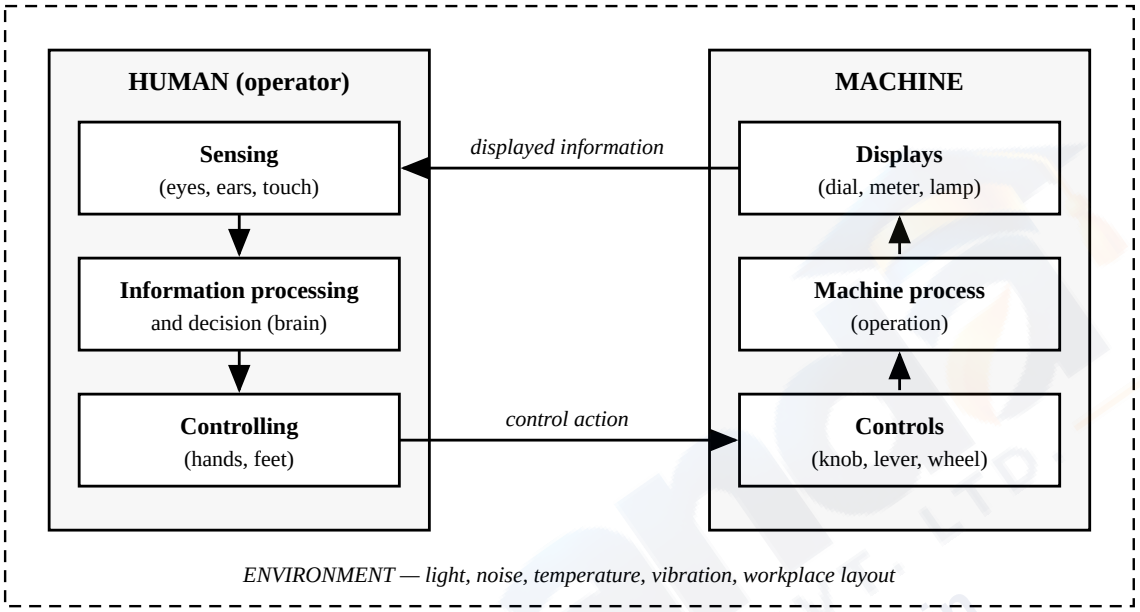


Fig.: Man–machine closed loop system (information → decision → control → machine → display → back to human)

In any man–machine system the human and the machine form a **closed loop**:

1. The machine shows its condition through **displays** (dial, meter, lamp, sound).
2. The operator **senses** this information (eyes, ears, touch) and the brain **processes** it and takes a **decision**.
3. The operator acts on the **controls** (knob, lever, hand wheel, pedal).
4. The control action changes the **machine process**, whose new state is again shown on the displays — the loop is closed. Example: driver – car (speedometer → brain → accelerator/brake → speed).

The whole loop works within an **environment** (light, noise, temperature). Ergonomics designs displays, controls and workplace so that the loop works with minimum error and fatigue.

(Sketch 2 M, explanation 2 M)

c) Steps for establishing architecture — trailer. 4 M

1. **Create a schematic of the product:** show the functional (and physical) elements and the flows (material, energy, signal) between them. Trailer: protect cargo from weather, connect to vehicle, minimise air drag, support cargo loads, suspend trailer structure, transfer loads to road.
2. **Cluster the elements of the schematic:** assign each element to a chunk. In a modular trailer each function gets its own chunk — box, hitch, fairing, bed, springs and wheels.

3. **Create a rough geometric layout:** place the chunks in 2-D / 3-D to check that they fit and that interfaces are feasible (box on bed, springs and wheels below, hitch in front, fairing on top/front).
4. **Identify the fundamental and incidental interactions:** fundamental — the planned flows (cargo load from box to bed, force from bed through springs to wheels, pull from hitch); incidental — unplanned effects such as vibration or heat between chunks.

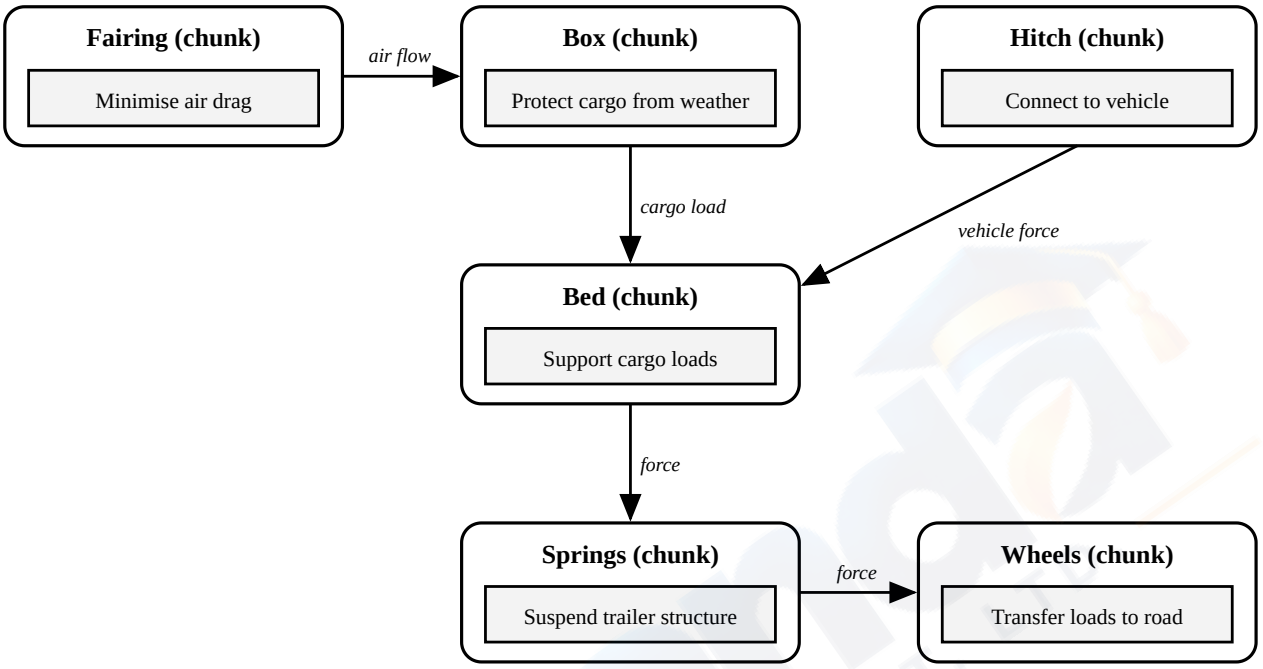


Fig.: Schematic of a trailer clustered into chunks (modular: each function is carried out by one chunk)

(Four steps 3 M, example/schematic 1 M)

d) Criteria of patentability and benefits of patent. 4 M

Criteria (Patents Act, 1970, India):

1. **Novelty (new):** the invention must not be published or used anywhere in the world before the filing (priority) date.
2. **Inventive step (non-obvious):** it must involve a technical advance or economic significance that is not obvious to a person skilled in that field.
3. **Industrial applicability:** it must be capable of being made or used in an industry.
4. **Patentable subject matter:** it must not fall in the non-patentable list of Sections 3 and 4 (e.g. discovery of a natural law, mere new use of a known substance, methods of agriculture, mathematical methods, atomic energy inventions).

Benefits of patent: (i) exclusive right to make, use, sell and import the invention for 20 years — protection from copying; (ii) income by licensing or selling the patent, and better value of the company for investors.

(Criteria 3 M, benefits 1 M)

e) SLS 3-D printer. 4 M

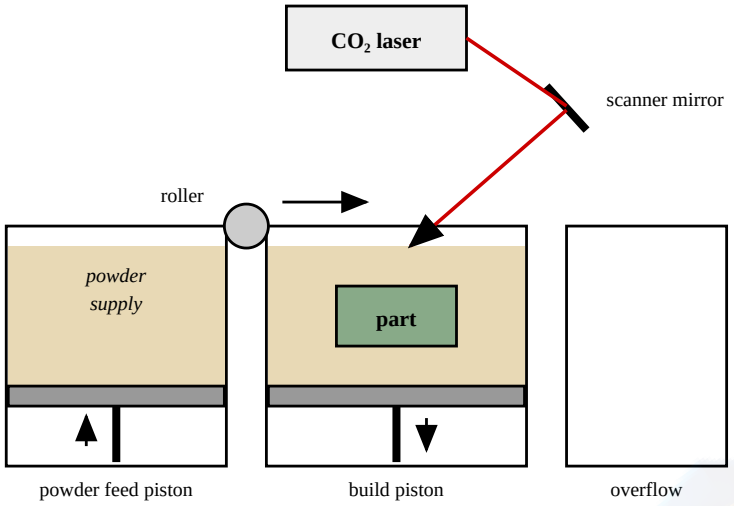


Fig.: Selective Laser Sintering (SLS) — schematic

Construction: powder-feed piston with powder supply, build piston (build chamber), counter-rotating roller (or blade), CO_2 laser with X–Y scanner mirrors, heated closed chamber filled with nitrogen, and an overflow bin.

Working:

1. The 3-D CAD model is sliced into thin layers (≈ 0.1 mm).
2. The build chamber is heated to just below the melting point of the powder (e.g. nylon PA12).
3. The roller spreads a thin layer of powder from the feed piston over the build piston.
4. The laser scans the cross-section of the layer and **sinters** (fuses) the powder particles together.
5. The build piston moves down by one layer thickness and the feed piston moves up; a new layer is spread and sintered. Steps repeat until the part is complete.
6. The part cools inside the powder cake; it is removed and cleaned by brushing / bead blasting. Unsintered powder supports the part, so no support structures are needed; loose powder is partly reused.

(Sketch 2 M, working 2 M)

Q.5

a) Tyco product development process. 6 M

Tyco International is a manufacturer of sensors and controls, including home and industrial security systems (e.g. wireless security-alarm control panels). Tyco is a **market-pull** company: projects start from a market need and use new or established technology. Its products are made from components produced by conventional processes (moulding, machining, electronics assembly) and are customised for each customer at the time of sale and installation; therefore its development process mainly aims at creating **new product models**.

Tyco set up a common, phased process called the **“Rally Point” process**, similar to the generic process. It has **nine phases**; each phase ends with a critical review called a **Rally Point (RP)** — a gate where management approval is needed to proceed.

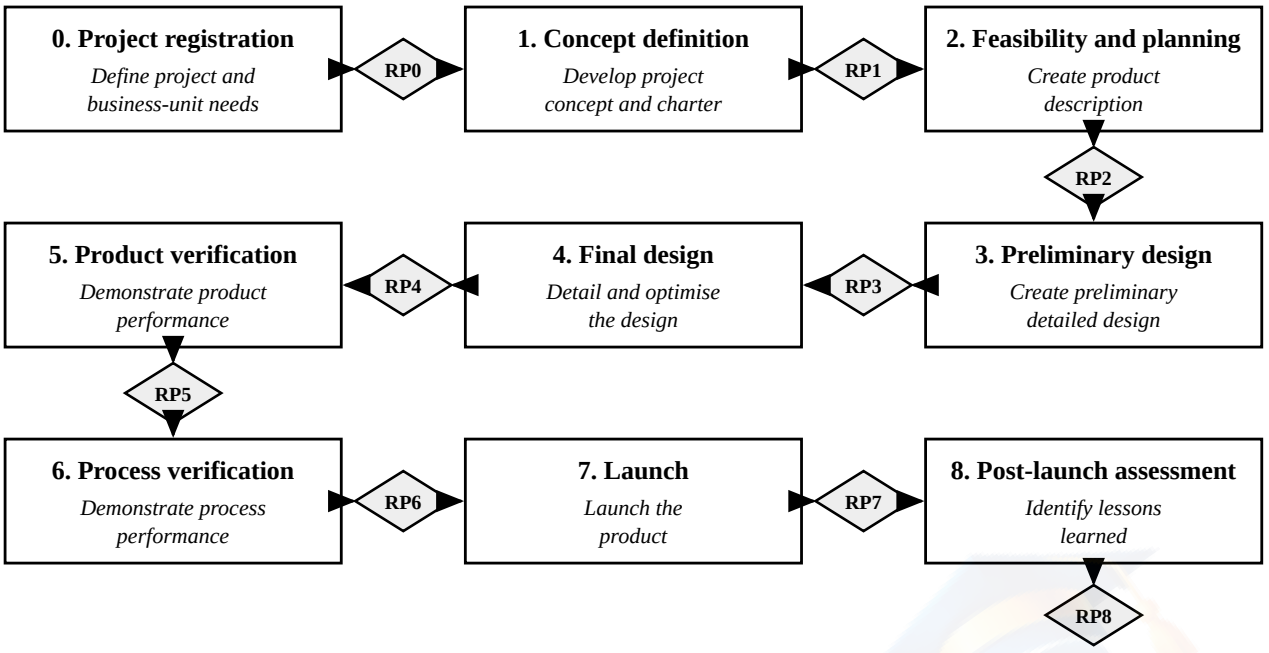


Fig.: Tyco "Rally Point" product development process — nine phases, each ending in a rally point (RP), a review gate for approval

Phase	Primary goal / key activities
0. Project registration	Define project and business-unit needs; register the project.
1. Concept definition	Develop project concept and charter; capture voice of customer; identify market size; select a Rally Point variant.
2. Feasibility and planning	Create product description; develop and select concepts; identify target cost, risks, long-lead items.
3. Preliminary design	Create preliminary detailed design; define product architecture; build and test alpha prototypes.
4. Final design	Detail and optimise design; freeze design; finalise bill of materials; test beta prototypes.
5. Product verification	Demonstrate product performance — complete beta-prototype testing, start field trials, apply for regulatory approvals.
6. Process verification	Demonstrate process performance — manufacturing pilot runs, process verification tests, complete field trials, obtain approvals.
7. Launch	Launch product; complete sales and service training; finalise pricing.
8. Post-launch assessment	Identify lessons learned; measure sales vs. forecast; customer feedback.

Example: a new wireless alarm control panel is registered (RP0), its concept and customer needs are approved (RP1), feasibility and plan (RP2), preliminary design with alpha prototypes (RP3), final design with beta prototypes (RP4), product verification and field trials (RP5), pilot production runs (RP6), launch (RP7) and review of sales and feedback (RP8). For simple derivative products Tyco uses a shorter variant called **Rally Point EZ**.

(Introduction 1 M, flow chart 2 M, phases 3 M)

b) Industrial design process. 6 M

Industrial design (ID) is the professional service of creating and developing concepts and specifications that optimise the function, value and appearance of products for the mutual benefit of user and manufacturer.

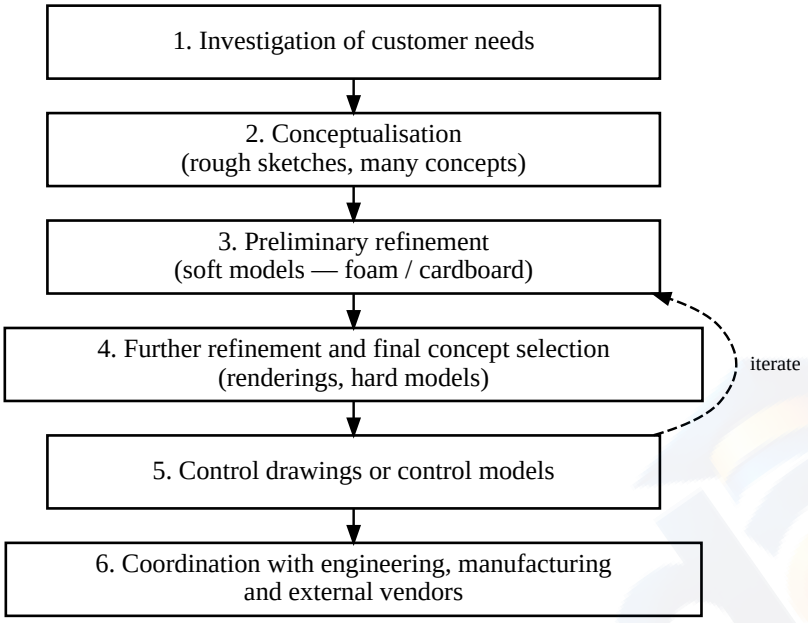


Fig.: Industrial design process

1. **Investigation of customer needs:** industrial designers (IDs) study how users use the product, its look and ergonomics problems, together with the team.
2. **Conceptualisation:** many ideas are sketched quickly (thumbnail sketches) for form, user interaction and features.
3. **Preliminary refinement:** the best concepts are built as *soft models* (foam, cardboard, clay) to check size, proportion and feel.
4. **Further refinement and final concept selection:** concepts are compared using renderings and *hard models* (realistic look and feel); the final concept is chosen.
5. **Control drawings or models:** the chosen concept is documented — functions, features, sizes, colours, surface finishes and key dimensions.
6. **Coordination with engineering, manufacturing and external vendors:** IDs work with engineers and suppliers to make sure the design intent is kept through detail design and production.

(Block diagram 2 M, six steps 4 M)

c) Value engineering and VEJP — bicycle side stand. 6 M

Value engineering (VE) is a systematic, function-oriented, team approach to obtain the required functions of a product at the **lowest total cost**, without reducing its quality, reliability, performance or safety. Value = Function (worth) / Cost.

Value Engineering Job Plan (VEJP) is the organised step-by-step procedure followed by the VE team:

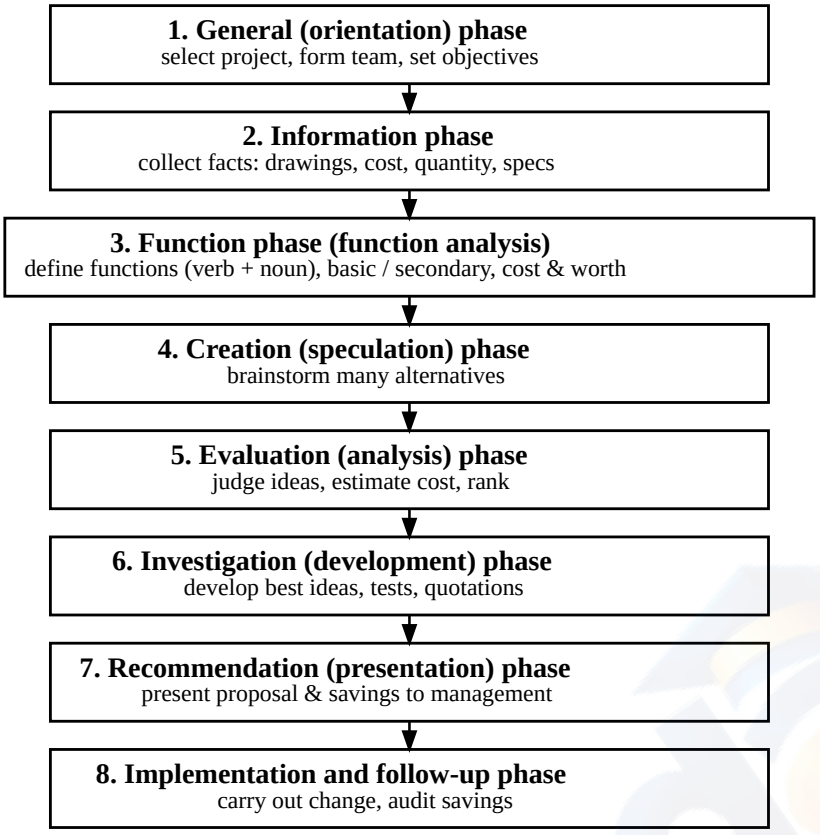


Fig.: Value Engineering Job Plan (VEJP) — phases

1. **General / orientation phase:** select the product or part (high cost, high volume, many complaints), form a team, fix objectives and target saving.
2. **Information phase:** collect all facts — drawings, specifications, quantities, cost break-up, customer complaints; ask "What is it? What does it cost?".
3. **Function phase:** define each function in two words (verb + noun), separate basic and secondary functions, find the cost and worth of each function (value index).
4. **Creation (speculation) phase:** generate many alternative ways to perform the function — brainstorming, SCAMPER; no criticism at this stage.
5. **Evaluation phase:** screen and rank the ideas for cost, feasibility and performance; select the best few.
6. **Investigation (development) phase:** develop the selected ideas in detail — drawings, tests, supplier quotations, cost estimates.
7. **Recommendation (presentation) phase:** present the proposal with savings, investment and benefits to management for approval.
8. **Implementation and follow-up:** carry out the approved change, monitor the actual savings and quality.

Example — bicycle side stand (cost and worth assumed for illustration):

Component	Function (verb + noun)	Basic / Secondary	Cost ₹	Worth ₹	Value index = Worth / Cost	Saving potential ₹
Leg (tube)	Support bicycle	Basic	60	50	0.83	10

Mounting bracket (forged)	Hold leg	Secondary	45	20	0.44	25
Return spring	Retain position	Secondary	12	10	0.83	2
Bolt and nut	Fasten bracket	Secondary	10	6	0.60	4
Rubber foot	Protect floor	Secondary	8	4	0.50	4

Total cost = ₹135; total worth = ₹90; overall value index = 90/135 = **0.67**. The component with the lowest value index (**Mounting bracket (forged)**, 0.44) is the first target for value improvement.

Creation and evaluation: replace the forged bracket by a pressed-steel bracket welded to the frame plate (removes machining and the separate bolt-and-nut); use a moulded rubber foot.
Recommendation / implementation: estimated cost of bracket + fasteners falls from ₹55 to about ₹25 while the basic function "support bicycle" is unchanged — value is increased.

(VE definition 1 M, phases 4 M, example 1 M)

Q.6

a) House of Quality — ceiling fan. 6 M

The **House of Quality (HoQ)** is the first matrix of QFD. It relates the customer requirements (WHATs) to the technical requirements (HOWs) and shows which technical requirements are most important.

1. List customer requirements (WHATs) on the left wall and give each an importance rating (1 = low, 5 = very high).
2. List measurable technical requirements (HOWs) on the ceiling with the direction of improvement (▲ / ▼ / ◎).
3. Fill the relationship matrix (body): ● strong = 9, ○ medium = 3, △ weak = 1.
4. Fill the roof (correlation matrix) to show how technical requirements support (+) or conflict (−) with each other.
5. Compare our product with a competitor (customer rating 1–5) in the right wall.
6. Body ranking: technical importance of each HOW = Σ (importance × relationship weight); convert to % and rank.

Ceiling fan

	Sweep size (mm)	Blade pitch angle (deg)	Motor efficiency (%)	Bearing life (h)	Noise level (dB)	Finish / colour options (no.)	Customer rating (1–5)	
Customer requirements *(WHATs) ↓ HOWs →*	Importance (1–5)						Ours	Comp.
Direction of improvement	◎	◎	▲	▲	▼	▲		
Low noise	**4**		○		○	●	3	4
High air delivery	**5**	●	●	○			4	4
Low power consumption	**5**	△	○	●			2	4
Long life	**3**			○	●		3	3
Attractive look	**2**	△				●	3	4
Technical importance (absolute)		52	72	69	39	36	18	
Relative importance (%)		18.2	25.2	24.1	13.6	12.6	6.3	
Rank (body ranking)		**3**	**1**	**2**	**4**	**5**	**6**	

Relationship: ● strong = 9, ○ medium = 3, △ weak = 1. ▲ maximise, ▼ minimise, ◎ target.
Roof: ++ strong positive, + positive, − negative, −− strong negative correlation.

Fig.: House of Quality — Ceiling fan

Calculation of technical importance (body ranking):

Technical requirement	Σ importance × weight	Relative %	Rank
Sweep size (mm)	5×9 + 5×1 + 2×1 = **52**	18.2	3
Blade pitch angle (deg)	4×3 + 5×9 + 5×3 = **72**	25.2	1
Motor efficiency (%)	5×3 + 5×9 + 3×3 = **69**	24.1	2
Bearing life (h)	4×3 + 3×9 = **39**	13.6	4
Noise level (dB)	4×9 = **36**	12.6	5
Finish / colour options (no.)	2×9 = **18**	6.3	6

Result: the design team should give first priority to **Blade pitch angle (deg)** (rank 1), then **Motor efficiency (%)**. Blade pitch angle and motor efficiency (e.g. an energy-efficient BLDC motor) have almost equal importance — together they decide air delivery and power consumption.

Roof ranking (trade-offs): negative correlations exist between Blade pitch angle (deg) ↔ Noise level (dB); Blade pitch angle (deg) ↔ Motor efficiency (%). For each such pair, improving one

makes the other worse, so a balanced target value must be chosen (or a new technology used).

Positive correlations: Motor efficiency (%) ↔ Bearing life (h); Bearing life (h) ↔ Noise level (dB); Sweep size (mm) ↔ Blade pitch angle (deg) (improving one helps the other).

(Customer and technical requirements 1 M, relationship matrix 2 M, roof 1 M, technical importance / ranking 2 M)

b) Concept scoring — hospital-bed back-rest mechanism. 6 M

Concept scoring is used when finer resolution is needed to choose among a few concepts. Each selection criterion is given a **weight** (%) according to its importance, each concept is rated on a **1–5 scale** (1 much worse, 3 same as reference, 5 much better), and the **weighted score** = Σ (rating × weight) is calculated. The concept with the highest total is selected (after combining and improving concepts).

Purpose: to make a careful, objective and documented choice of the final concept and to see the strengths and weaknesses of each concept.

Steps: 1) prepare the selection matrix (criteria, weights, reference) 2) rate the concepts 3) rank the concepts 4) combine and improve the concepts 5) select one or more concepts 6) reflect on the results and the process.

Selection criteria	Weight	A: Screw jack Rating · Weighted	B: Gas spring Rating · Weighted	C: Ratchet-and-pawl Rating · Weighted
Ease of operation (patient / nurse)	25%	2 · 0.50	5 · 1.25	4 · 1.00
Safety (no sudden fall)	25%	5 · 1.25	4 · 1.00	2 · 0.50
Low cost	20%	3 · 0.60	2 · 0.40	5 · 1.00
Durability	15%	4 · 0.60	3 · 0.45	3 · 0.45
Ease of manufacture	15%	3 · 0.45	4 · 0.60	4 · 0.60
Total score	100%	**3.40**	**3.70**	**3.55**
Rank		**3**	**1**	**2**

Weighted score example: concept B = 0.25×5 + 0.25×4 + 0.20×2 + 0.15×3 + 0.15×4 = **3.70**.

Result: B: Gas spring scores the highest (3.70) and is selected. Its lower score on cost can be improved by using a standard gas spring.

(Concept scoring and purpose 2 M, matrix with calculation 3 M, selection 1 M)

c) Impact of DFM decisions. 6 M

DFM decisions change the cost of the product, but they also affect other goals of the project:

1. **Impact on development time:** time is very valuable. A DFM effort that is done in parallel with design saves time by avoiding late changes and tooling rework. But excessive cost-reduction iterations, or very complex integral parts (e.g. a large multi-function moulding needing complex dies), can delay the project. The DFM decision must not be made at the expense of the launch date.
2. **Impact on development cost:** development cost closely follows development time. Products designed for low manufacturing cost are not necessarily costly to develop; an integrated DFM

team usually keeps development cost the same or lower. Extra tooling or analysis for a cost reduction must be paid back by savings in volume.

3. **Impact on product quality:** fewer parts and simpler assembly usually improve reliability and reduce defects (e.g. snap-fit housing instead of 8 screws). However, some decisions may reduce quality — e.g. a cheaper material may lower durability, or integrating parts may make servicing and repair difficult. Quality must be checked before accepting a DFM change.
4. **Impact on external factors:** (i) *component reuse* — a low-cost standard part may also be used in other products of the company; (ii) *life-cycle costs* — warranty, service, environmental and disposal costs should be considered, not only the factory cost.

Example: replacing a welded steel bracket by a single die-cast part reduces assembly cost and improves quality, but the die takes 8 weeks to make — the team must judge whether this delay is acceptable.

(Development time 1½ M, development cost 1½ M, quality 2 M, external factors 1 M)

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