PRODUCT DESIGN AND DEVELOPMENT

DIPLOMA WALLAH

MECHANICAL

Unit - IV Value Engineering

JHARKHAND UNIVERSITY OF TECHNOLOGY (JUT)

◆ 4.1 Concept of Value Engineering, Steps in Value Engineering, Creative Thinking, Problem Identification and Value Engineering Job Plan (VEJP)

📃 Definition (Expanded)

Value Engineering (VE) is a structured, systematic method used to improve the "value" of a part, product, system or process. In mechanical engineering this means analysing the functions a component or system performs, the cost (including material, manufacturing, assembly, lifecycle maintenance) and then optimizing so that the same (or better) function is delivered for lower cost — or more function is delivered for the same cost. VE emphasises early involvement (design stage) so that large cost decisions (e.g., materials, processes, tooling) are made optimally. The "value = function ÷ cost" concept is key. Federal Highway Administration+3investopedia.com+3Indeed+3

The Value Engineering Job Plan (VEJP) is the roadmap or phase-by-phase plan that a VE study follows. It breaks down the process into manageable stages, from selecting the target component/system, gathering data, identifying functions, generating alternatives, analysing and implementing improvements. Federal Highway Administration+1

🧩 Steps / Phases (Detailed)

In mechanical engineering environments you'll often see these steps:

1. Selection / Project identification – Choose the component, subsystem or process for VE study. In mechanical engineering this might be a pump housing, gearbox casing, weld fixture, etc. The criteria: high cost, high volume, high maintenance, recurring failure. Federal Highway Administration+1
2. Information Phase – Gather all relevant data: material costs, manufacturing cost (casting/machining/assembly), lifecycle costs (maintenance, repair), failure history, customer/operational requirements. Function analysis begins: ask *What does this do?*

What is it required to do? What could it do? What must it not do? McGill University+1

3. Function Analysis / Problem Identification – Define functions explicitly (in mechanical terms): e.g., “contain pressure of 10 bar”, “allow fluid flow at 50 L/min”, “resist corrosion for 10 years”. Evaluate cost vs worth of each function; separate essential vs non-essential functions.

4. Creative Phase (Ideation) – Brainstorm alternatives: different materials, alternate manufacturing methods (sheet-metal vs casting, additive manufacturing vs machining), part consolidation (reduce part count), standardisation. Mechanical engineers here may use FAST (Function Analysis System Technique) diagrams to visualise functions.

5. Evaluation Phase – Assess each alternative: manufacturing feasibility, cost reduction, impact on function, reliability, maintenance. For example: switching bearing from forged to standard off-the-shelf may reduce cost but check reliability under fatigue.

6. Development Phase – Develop recommended alternatives into detailed proposals: new drawings/specs, cost/benefit calculation, implementation plan (tooling changes, process changes, supplier changes).

7. Presentation Phase – Present findings to decision-makers: show cost savings, improved function/quality, any trade-offs.

8. Implementation & Follow-up – Implement the approved changes, monitor actual savings, track performance over lifecycle. The VEJP emphasises follow-up to ensure proposed savings are realised. Federal Highway Administration+1

Mechanical Engineering-Specific Considerations

- When selecting candidate parts: high manufacturing cost (machining hours, material wastage), high scrap/repair rate, parts with frequent maintenance or downtime.
- In function analysis: emphasise physical/mechanical functions (load carrying, stiffness, fatigue life, thermal behavior, corrosion resistance).
- In creative phase: mechanical engineers might consider alternative manufacturing methods (e.g., injection moulding vs die casting vs

machined) or use topology optimisation (lightweighting) to reduce material cost while maintaining structural integrity.

- Manufacturing constraints: tooling cost, machine setup, tolerance requirements, finishing processes, assembly time all feed into cost.
- Lifecycle cost: in mechanical engineering, maintenance/repair/operational efficiency (e.g., energy consumption) matter a lot. VE must account for these, not just initial cost.

✅ Why it's Valuable

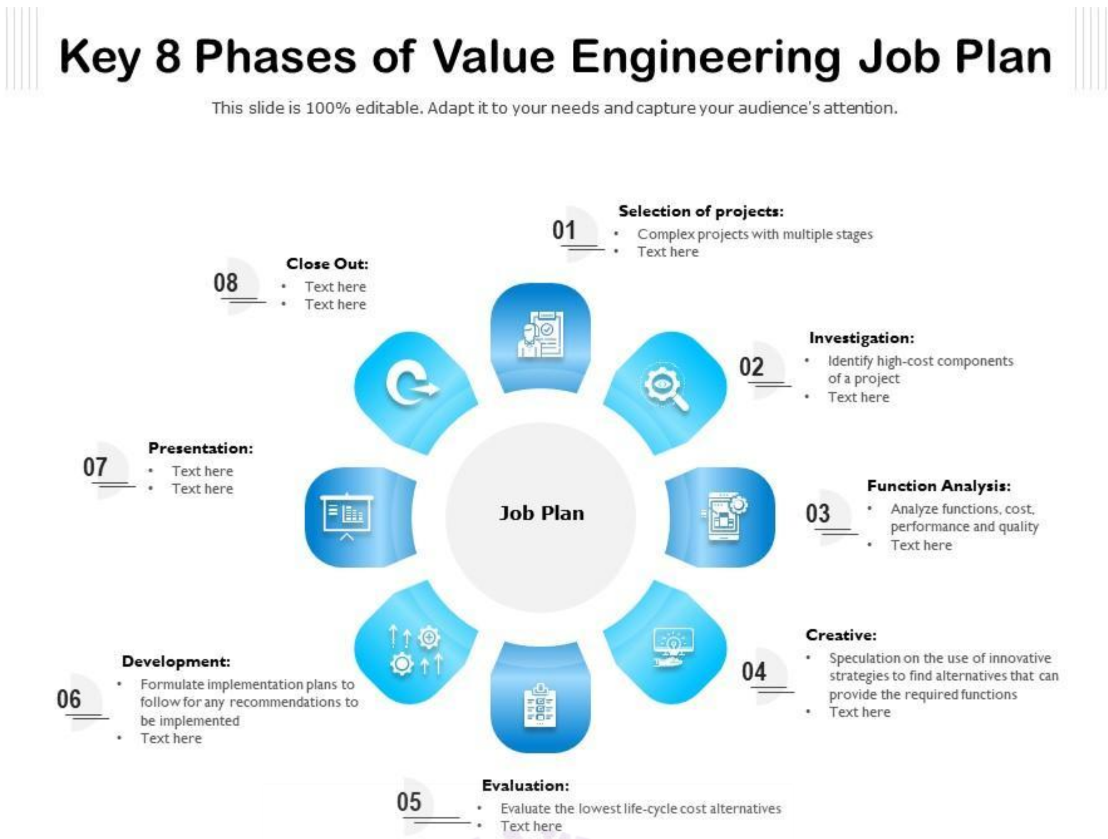
- Early cost decisions matter: studies show large portion of product cost is determined in early design. VE addresses this.
- Helps reduce cost without degrading function (or preferably improving it).
- Encourages cross-functional teamwork (design, manufacturing, procurement, maintenance).
- Can improve reliability, maintainability, ease of production.

❌ Risks / Pitfalls

- If reduction of cost comes at the expense of function or reliability, product quality may suffer.
- If implemented late (after tooling/foundation completed), cost of change may be too high.
- Requires data, cross-functional team and discipline — not just ad-hoc cost cutting.
- For specialised low-volume mechanical products, cost/benefit of VE may be marginal.

🗣️ Summary (Hinglish)

Mechanical part ya system ko samjho — kya karna hai, kya kar raha hai. Fir creative socho ki kaise same ya better kaam kam cost me ho sakta hai. VEJP ek roadmap hai jo ideation se implementation tak lead karta hai.


Key 8 Phases of Value Engineering Job Plan
This slide is 100% editable. Adapt it to your needs and capture your audience's attention.
Job Plan
01
Selection of projects:
Complex projects with multiple stages
Text here
02
Investigation:
Identify high-cost components of a project
Text here
03
Function Analysis:
Analyze functions, cost, performance and quality
Text here
04
Creative:
Speculation on the use of innovative strategies to find alternatives that can provide the required functions
Text here
05
Evaluation:
Evaluate the lowest life-cycle cost alternatives
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06
Development:
Formulate implementation plans to follow for any recommendations to be implemented
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07
Presentation:
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Close Out:
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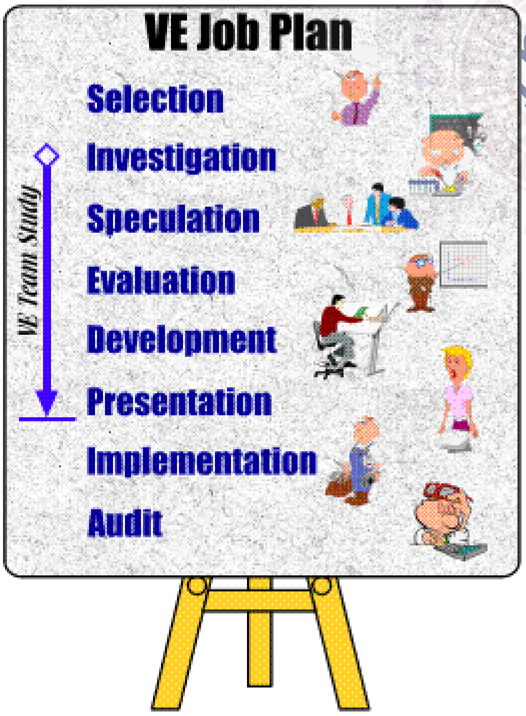
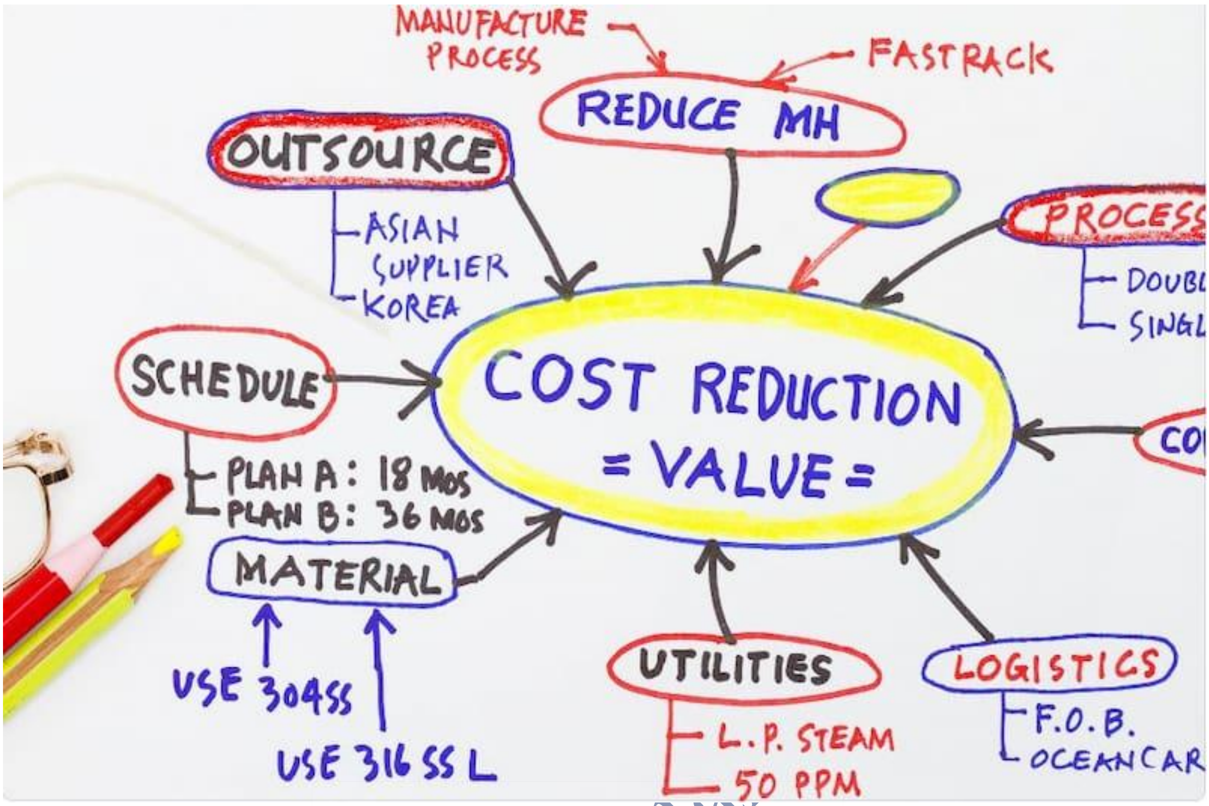

VE Job Plan
VE Team Study
Selection
Investigation
Speculation
Evaluation
Development
Presentation
Implementation
Audit



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🔹 4.2 Quality Function Deployment (QFD) Process – Need, Importance with Example, Symbols of QFD, VOC, VOC Analysis, Quality-QFD Relationship Matrix, Roof Ranking, Body Ranking, Importance of QFD

📃 Definition (Expanded)

Quality Function Deployment (QFD) is a methodology used in product development (including mechanical engineering) to translate customer requirements (Voice of the Customer, VOC) into measurable engineering and technical specifications. It ensures that the product design and manufacturing process remain aligned with what customers truly value. The central tool is the House of Quality, a matrix that links customer "Whats" to engineering "Hows". rcet.org.in

🧩 Detailed Explanation & Elements

Need & Importance in Mechanical Engineering:

- Mechanical products often have many features, but the customer may care only about a few (e.g., reliability, low maintenance, low noise, lightweight). Without QFD, design teams may focus on irrelevant specs.

- QFD helps ensure that engineering effort is focused on what matters (e.g., fatigue life, weight reduction, manufacturing cost) by linking to customer needs.
- It supports concurrent engineering: design, manufacturing, suppliers can all understand priorities early. ifm.eng.cam.ac.uk+1

Key Steps and Components:

1. Voice of Customer (VOC): Collect customer/user needs, complaints, expectations—via surveys, interviews, observation. Example in mechanical domain: "Machine downtime < 2 hours/year", "Weight of assembly < 20 kg", "Noise < 75 dB at full load".
2. VOC Analysis & Prioritisation: Sort, group similar needs, assign importance weights (e.g., 1–5 or percentage).
3. Technical/Engineering Requirements ("Hows"): Identify measurable design/process characteristics that can meet the VOC. E.g., "Bearing lifetime > 10000 hours", "Use aluminium alloy with yield strength ≥ 300 MPa", "Cooling fan speed < 2000 rpm".
4. Create Relationship Matrix (Body): Build matrix with rows = customer needs (Whats), columns = engineering requirements (Hows). Use symbols/numbers to show strength of relationship: strong (9), medium (3), weak (1) or other convention. ConceptDraw+1
5. Roof / Correlation Matrix: Above the columns, show inter-relationships between "Hows" (technical requirements)—highlight synergistic or conflicting interactions (e.g., improving (reducing) weight may conflict with increasing stiffness). ifm.eng.cam.ac.uk
6. Body Ranking / Priority Setting: Multiply importance of each customer need × relationship strength for each technical requirement; sum for each technical requirement to get priority score. This helps decide which technical specs to focus on in design.
7. Benchmarking & Targets: Include competitor performance, set target values for each technical requirement (e.g., target noise level = 70 dB when competitor is 80 dB).
8. Implementation: Use outputs from QFD to guide design, manufacturing planning, supplier specification, testing and validation.

Symbols of QFD:

- A common convention: Solid dot or ● or number 9 = strong relation; ○ or number 3 = moderate; △ or number 1 = weak; blank = no relation. ConceptDraw+1

🧩 Example in Mechanical Context

Imagine designing a new industrial gearbox for a machine:

- VOC (Whats): "Quiet operation at full load", "Minimal oil leakage", "Compact size for retrofit", "Long service interval".
- Engineering Requirements (Hows): "Gear tooth deviation ≤ 10 µm", "Bearing clearance ≤ 0.02 mm", "Housing volume ≤ 0.015 m^3", "Sealing flanges with 4 bar pressure rating".
- Relationship matrix: "Quiet operation" strongly relates to "Gear tooth deviation" (9); moderately relates to "Housing volume" (3). "Minimal oil leakage" strongly relates to "Sealing flanges pressure rating" (9) and moderately to "Bearing clearance" (3).
- Roof: "Housing volume ≤ 0.015 m^3" may conflict with "Bearing clearance ≤ 0.02 mm" (negative sign).
- After ranking, you find "Gear tooth deviation" and "Sealing flanges pressure rating" have highest scores → focus design efforts there.

✅ Why It's Important

- Focuses engineering resources on what gives maximum customer value.
- Helps avoid "over-engineering" features customers don't care about.
- Facilitates communication between marketing/user-needs side and engineering/manufacturing side.
- Improves time-to-market and reduces redesign because designers are clearer about targets early.

❌ Challenges

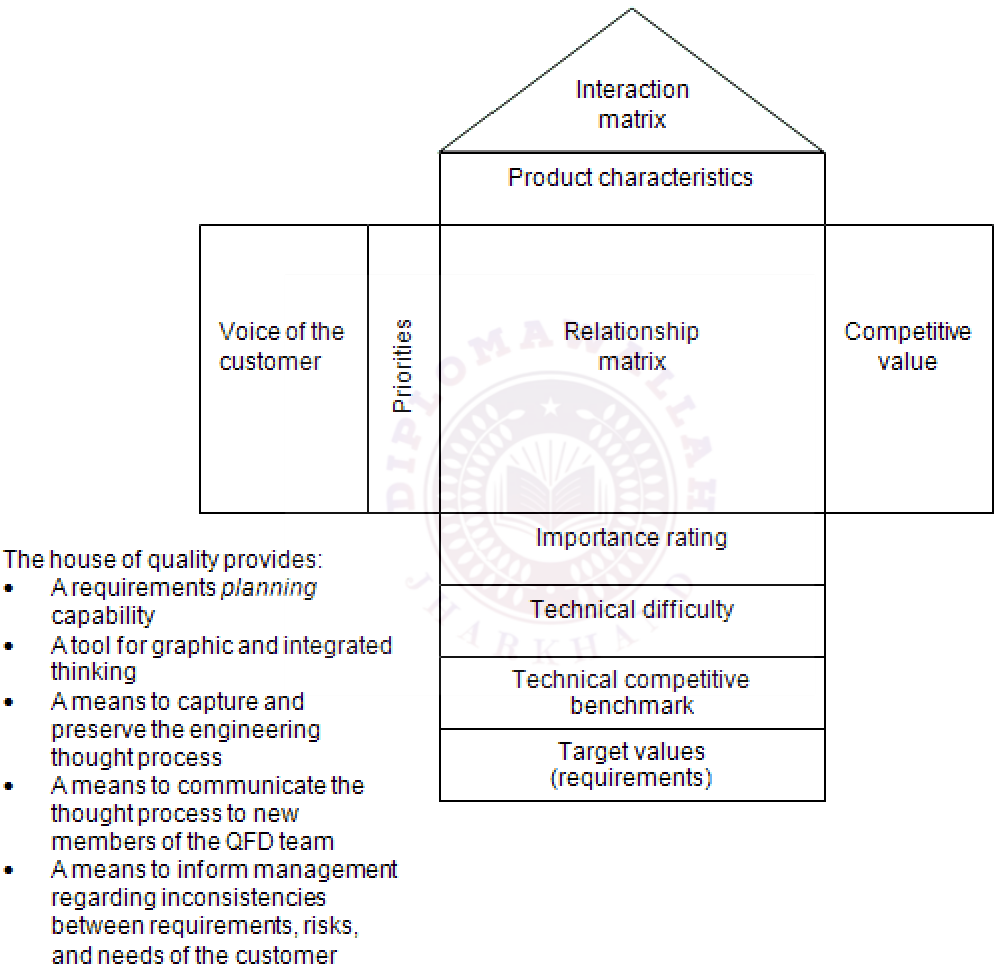
- Building a full QFD/HOQ can be resource intensive (data collection, cross-functional workshops).
- Requires good, accurate customer data (if VOC is flawed, then matrix results will be flawed).
- Relationship scoring can be subjective; team bias may affect results.

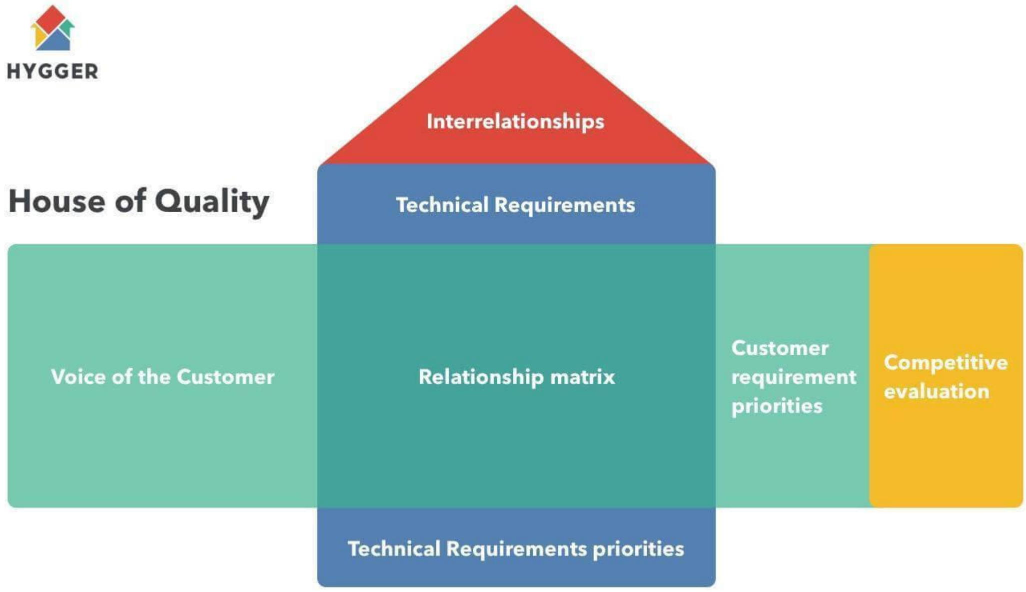
- For highly innovative or rapidly changing mechanical markets, the time and rigidity may reduce flexibility.

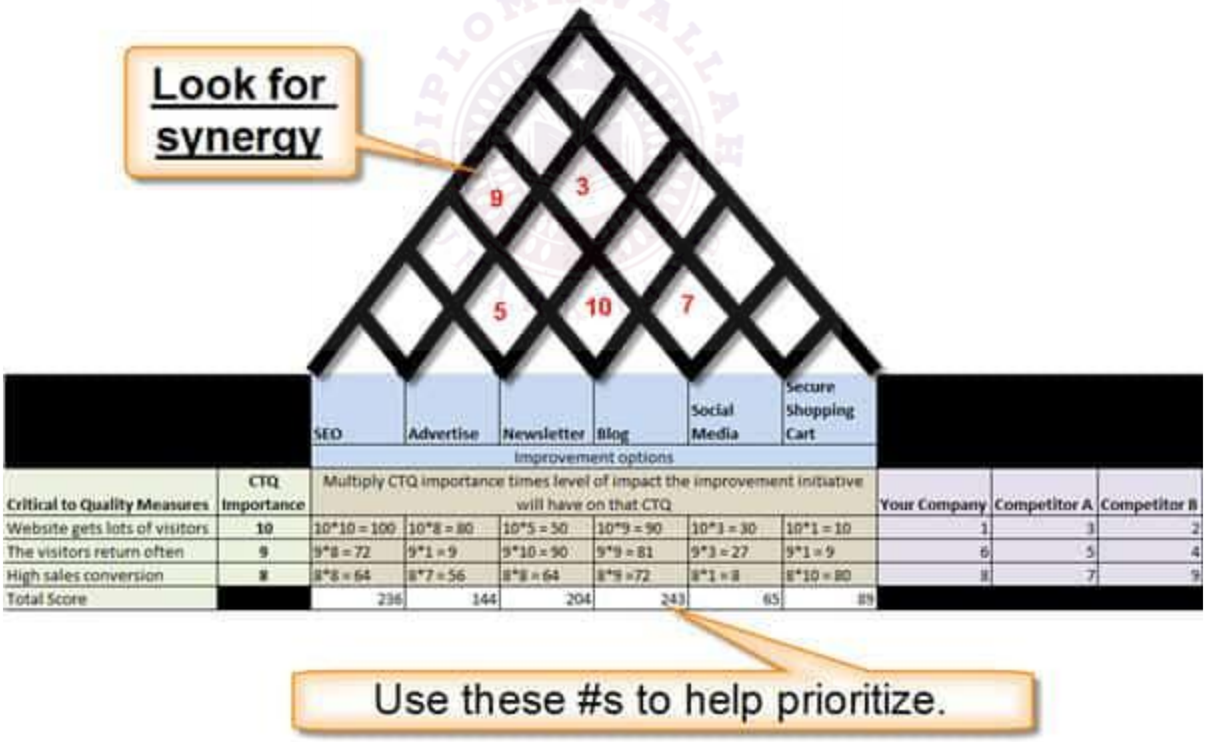
🗣 Summary (Hinglish)

QFD ka matlab hai "customer jo chahte hain usko engineering requirements me badlo" — uske baad design aur manufacturing yahi specs ke according chalein. Mechanical design me yeh bahut important hai kyunki bahut saare technical specs hote hain aur hume unme se sabse important ones pe focus karna hai.

Figure 1 — House of quality template and benefits







		SEO	Advertise	Newsletter	Blog	Social Media	Secure Shopping Cart			
		Improvement options								
Critical to Quality Measures	CTQ Importance	Multiply CTQ importance times level of impact the improvement initiative will have on that CTQ						Your Company	Competitor A	Competitor B
Website gets lots of visitors	10	10*10 = 100	10*8 = 80	10*5 = 50	10*9 = 90	10*3 = 30	10*1 = 10	1	3	2
The visitors return often	9	9*8 = 72	9*1 = 9	9*10 = 90	9*9 = 81	9*3 = 27	9*1 = 9	6	5	4
High sales conversion	8	8*8 = 64	8*7 = 56	8*8 = 64	8*9 = 72	8*1 = 8	8*10 = 80	8	7	9
Total Score		236	144	204	243	65	89			

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◆ 4.3 House of Quality – Linking Customer Complaints to Technical Requirements

📃 Definition (Expanded)

The House of Quality (HOQ) is the central matrix tool in QFD used for translating customer-oriented requirements/complaints into engineering/design parameters. In mechanical engineering, HOQ is used not just for new product design but for improvement/feedback loops — linking "customer complaints" or maintenance issues (e.g., high vibration, failure, noise, overheating) to changes in technical specs. The visual layout resembles a house (rows = customer needs, columns = engineering specs, roof = correlations) and acts as a blueprint for aligning design and engineering with customer value. ifm.eng.cam.ac.uk+1

🧩 Explanation & Process

- Left side (Customer complaints/needs – "Whats"): This captures what the user/customer complains about or desires — in mechanical engineering: "Excessive noise in gearbox", "High maintenance on pump bearings", "Component weighs too much for handling", "Poor thermal performance".
- Top (Technical/engineering requirements – "Hows"): List the measurable design or process parameters that can address those Whats: e.g., "Gear tooth surface finish Ra < 0.8 µm", "Bearing material hardness ≥ HRC 60", "Weight of assembly ≤ 12 kg", "Cooling fin area ≥ 0.5 m^2".
- Body – Relationship Matrix: Each cell where a row meets a column indicates how strongly the engineering spec affects that customer need. Use symbols or numbers: strong (●/9), moderate (○/3), weak (△/1), none (blank). ConceptDraw+1
- Roof – Correlation among engineering specs: This part shows how the engineering specs interact with each other: positive correlation (one spec helps another), negative correlation (trade-off), or none. For example, reducing weight may conflict with increasing stiffness or increasing bearing hardness may increase cost/harder machining. This part is crucial in mechanical design because many specs interplay (mass vs stiffness vs cost). ifm.eng.cam.ac.uk
- Importance weights & priorities: On the left margin of the rows you put the importance rating of each customer need (e.g., 1–5 or %); on the bottom you derive priority ratings for engineering specs after multiplying by relationship strength. The highest priority specs become focus for design/manufacturing changes.

- Benchmarking and target values: Some HOQs include competitor values and target values for each spec to set design direction. EdrawMax

🧩 Example (Mechanical Engineering)

Let's take an example of an industrial compressor unit with customer complaints:

- Whats:
  - "High noise under full load" (importance 5)
  - "Frequent bearing replacement" (importance 4)
  - "Heavy handling during installation" (importance 3)
- Hows:
  - "Shaft surface roughness Ra ≤ 0.4 µm"
  - "Use of vibration damping mounts (isolation efficiency ≥ 90%)"
  - "Bearing material hardness HRC ≥ 62"
  - "Total mass of unit ≤ 150 kg"
- Relationship matrix:
  - "High noise" strongly relates to "vibration damping mounts" (9), moderately to "shaft surface roughness" (3), weak to "mass ≤ 150 kg" (1)
  - "Frequent bearing replacement" strongly relates to "bearing material hardness HRC ≥ 62" (9), moderately to "shaft surface roughness" (3)
  - "Heavy handling" strongly relates to "mass ≤ 150 kg" (9)
- Roof: Example: "Mass ≤ 150 kg" may negatively correlate with "bearing material hardness HRC ≥ 62" (because harder bearing may increase mass/cost) → show negative sign.
- After calculating: "Use of vibration damping mounts" and "bearing material hardness HRC ≥ 62" may have highest priority scores → mechanical design team focuses there first.

✅ Benefits

- Directly links customer complaints/needs to engineering specs and manufacturing decisions.

- Helps prioritise mechanical design changes in complex product systems with many interacting specs.
- Improves cross-functional alignment (design, manufacturing, maintenance) especially in mechanical engineering where many disciplines (materials, manufacturing, assembly, service) overlap.
- Makes trade-offs transparent: you can see conflict between specs via roof and make informed design decisions.

❌ Limitations

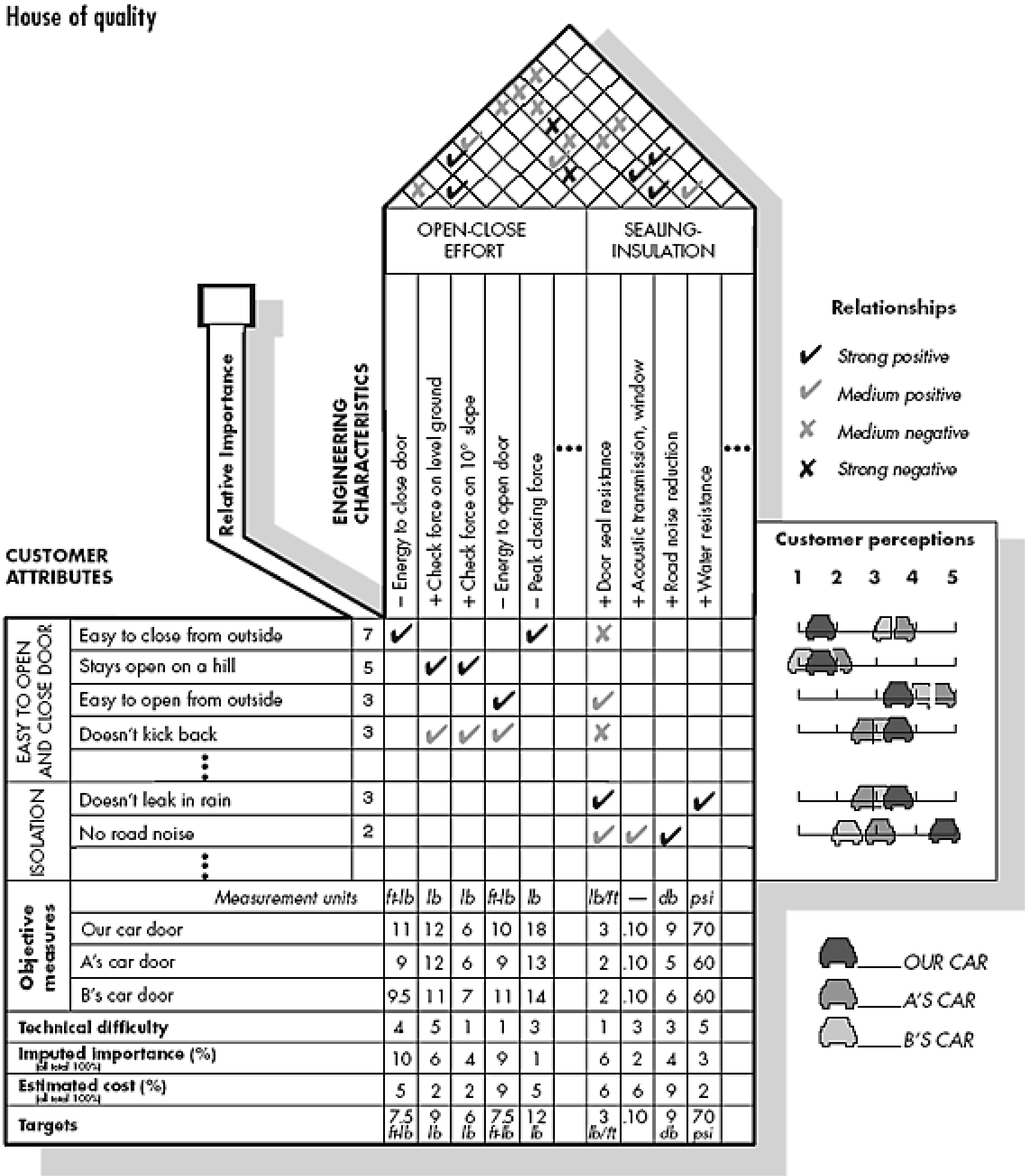
- Building HOQ is time and resource-intensive (especially for large mechanical systems with many specs).
- Requires good quality data (customer complaints and accurate engineering spec relationships); otherwise matrix may mislead.
- Relationship scoring may be subjective and depends on team expertise.
- For very dynamic markets or extremely novel mechanical designs with unknown parameters, HOQ may be less effective or may need iteration.

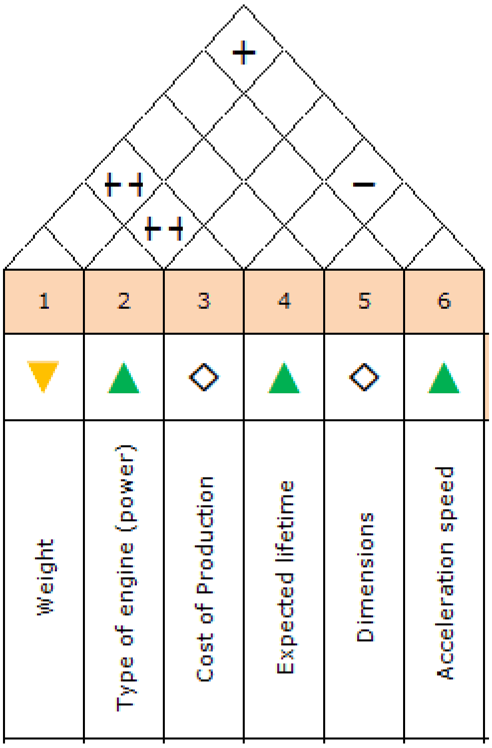
🗣 Summary (Hinglish)

House of Quality ek powerful tool hai mechanical design me — jahan user complaints ya maintenance issues (Whats) se hum engineering specs (Hows) ko map karte hain, relationship matrix bharke priority nikalte hain, aur roof ke through trade-offs samjhate hain. Isse design team sahi jagah pe effort lagata hai.

EXHIBIT X

House of quality





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