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COST · VAVE · TARGET COST · BOM OPTIMISATION · REFERENCE DOCUMENT · PUBLIC

Cost engineering and VA/VE

Reference for value analysis / value engineering (VA/VE), target costing, BoM optimisation, and the systematic methods to reduce unit cost without sacrificing function or quality.

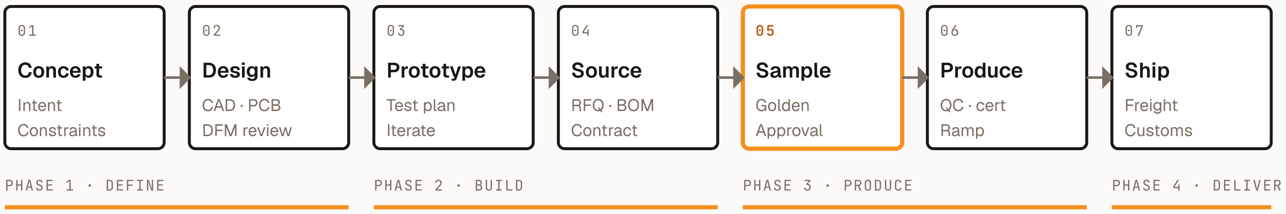
REVISION	ISSUED	OWNER	COMPANION
1.0	May 2026	Ideambox engineering	PDF reference

ABSTRACT

Cost engineering is the discipline of deliberately managing product cost. Value Analysis (VA) examines an existing product for cost reduction; Value Engineering (VE) builds the cost discipline into new designs. Both use a systematic approach: identify function, eliminate non-functional cost, substitute equivalent lower-cost components, simplify assembly.

Section 1 covers target costing fundamentals. Section 2 covers cost structure analysis. Section 3 covers VA/VE methodology. Section 4 covers BoM optimisation techniques. Section 5 covers design-for-cost (DFC) rules. Section 6 covers cost-reduction examples.

HARDWARE PRODUCT DEVELOPMENT — 7-STAGE PIPELINE



COST ENGINEERING RUNS ACROSS THE LIFECYCLE — MOST COST IS LOCKED IN DURING PHASE 2 (BUILD) AT DESIGN FREEZE. LATE CHANGES ARE 10-100× MORE EXPENSIVE THAN EARLY ONES.

CONTENTS

1. Target costing fundamentals

Target costing is "design to a price" — set the unit cost target at concept and design backwards from there.

1.1 The target cost equation

``` Target unit cost = Target retail price ÷ Channel markup multiplier − Variable cost premium (warranty, returns) − Selling, general, and admin (SG&A) − Marketing reserve − Profit target

Example: Target retail price: $100 (premium DTC product) Channel multiplier: 2× (DTC) Target unit revenue: $50 Less SG&A: $5 Less marketing: $10 Less warranty reserve: $3 Less profit (20%): $10

= Target unit cost (COGS): $22 ```

## 1.2 Channel multipliers (recap)

| CHANNEL | MULTIPLIER | NOTES |
|---|---:|---|
| **Direct-to-consumer** | 2.0-2.5× | Lowest channel cost |
| **Amazon marketplace** | 2.5-3× | Add fulfilment fees |
| **Specialty retail** | 3-4× | Distributor + retailer margin |
| **Mass retail** | 4-5× | Walmart, Target |
| **Premium / luxury** | 5-10× | Channel + brand premium |

## 1.3 Working backwards from price

| RETAIL PRICE | MASS RETAIL | SPECIALTY | DTC | TARGET COGS (DTC) |
|---:|---:|---:|---:|---:|
| **$50** | $10 | $13 | $20 | $7 |
| **$100** | $20 | $25 | $40 | $18 |
| **$200** | $40 | $50 | $80 | $40 |
| **$500** | $100 | $125 | $200 | $90 |
| **$1 000** | $200 | $250 | $400 | $180 |

## 1.4 Cost lock-in timing

Cost is largely set by the time mechanical CAD is complete:

- **Concept stage**
  Process selection, material choice, complexity. ~90 % of cost.
- **Detailed design**
  Specific components, tolerances. ~95 % of cost locked in.
- **Pre-production**
  Final supplier negotiations. ~98 % cost locked.
- **Mass production**
  Volume + experience curve reduces cost by 5-15 % over time.

Wait until design freeze to think about cost = "redesigning" the product. Front-load.
```

2. Cost structure analysis

Before reducing cost, understand where it is. Break down the BoM and process to identify opportunities.

2.1 Cost breakdown framework

For a typical consumer electronic product (~$30 COGS):

CATEGORY	% OF COGS	EXAMPLES
Electronics (PCBA)	35-45 %	MCU, sensors, ICs, passives, PCB
Mechanical (enclosure)	20-30 %	Plastic parts, fasteners, mechanical
Battery	10-15 %	Cells, BMS, protection
Display / screen	0-15 %	If applicable
Cables + connectors	5-10 %	USB, internal cables
Packaging	3-7 %	Color box, inner trays
Labels / printing	1-3 %	Stickers, manual
Assembly labor	8-15 %	Per-unit labor
Test + QA	2-5 %	Functional test, sampling
Logistics / overhead	5-10 %	Factory overhead, freight to dock

2.2 Pareto analysis on BoM

Apply 80/20 rule to BoM:

- **Top 5-10 line items typically = 60-80 % of BoM cost.**
- **These are your A-parts; focus cost reduction here.**
- **B and C parts have less leverage; don't waste effort below the threshold.**

2.3 Cost driver analysis

For each major cost category, identify the driver:

COST DRIVER	EXAMPLE	LEVER TO REDUCE
Component count	More parts = more assembly + inventory	Combine features
Tolerance class	Tighter = higher cost	Loosen non-critical
Material grade	Premium polymer = +20-50 % vs. commodity	Material substitution
Surface finish	SPI A1 vs. SPI B3	Lower finish where invisible
Tooling complexity	More slides, undercuts, multi-cavity	Simpler geometry
Process choice	Injection mold vs. CNC	Volume-matched process
Custom vs. standard part	Custom = NRE + lead time	Standard alternative
Single-source	No negotiation leverage	Dual-source

3. VA / VE methodology

Value Analysis (VA) is applied to existing products. Value Engineering (VE) is applied to new designs. Both use the same 5-step methodology.

3.1 The 5-step VA/VE process

1. **Information phase** — Gather full BoM, drawings, specs, supplier costs, function tree. 2. **Function analysis phase** — For each component, ask: "What does it DO?" Express each function in 2 words (verb + noun). 3. **Creative phase** — Brainstorm alternatives to provide the same function. No critique yet. 4. **Evaluation phase** — Score alternatives on: function preservation, cost, quality, feasibility, time. 5. **Implementation phase** — Engineering changes (ECNs), supplier negotiations, ramp.

3.2 Function analysis (FAST diagram)

For each component, ask: "What does this DO?" and "How is it done?" Build a tree:

`` ` `` `Provide light ← Primary function (why the product exists) ↓ Emit visible photons ← Basic function ↓ Convert electrical to light ← Required function ↓ LED ← Current solution ↓ Phosphor + driver + heatsink ← Sub-functions` `` ` ``

For each level, ask: is this function necessary? Is there a cheaper way?

3.3 VA/VE substitution checklist

- **Different material**
  Same function, lower cost (PC → PC+ABS, brass → zinc).
- **Different component**
  Same function, different MPN (premium → generic equivalent).
- **Standard vs. custom**
  Off-the-shelf vs. custom; standard usually wins below 50k volume.
- **Multi-function consolidation**
  One part doing two jobs (overmold replaces two parts).
- **Process change**
  CNC → casting → injection mold per volume.
- **Outsourcing decision**
  In-house vs. supplier specialisation.

4. BoM optimisation techniques

Specific tactics to reduce BoM cost.

4.1 Component consolidation

- **One regulator instead of two**
  If acceptable voltage drop, use single regulator with branched output.
- **Shared decoupling caps**
  One 10 μF + multiple 100 nFs serves the whole board (per power-rail bank).
- **Standard resistor values**
  Reduce variant count; supplier discount on volume.
- **Common connector types**
  One USB-C, one barrel, eliminate proprietary.

4.2 Material substitution

- **PC + ABS instead of pure PC**
  Slightly lower clarity + slightly lower cost.
- **Glass-filled vs. unfilled polymer**
  Higher strength + slight cost increase, often net reduction in part wall.
- **Generic equivalent ICs**
  Microchip vs. ATmega; second-source as direct substitute.
- **Recycled plastic where cosmetic + structural allow**
  10-30 % savings + sustainability story.

4.3 Tolerance relaxation

- **Critical features tight (±0.05 mm)**
  Tolerance budget on critical mating.
- **Non-critical features loose (±0.3 mm)**
  Process-capable tolerance.
- **Cumulative tolerance budget**
  Set per assembly stack-up.

4.4 Process change examples

FROM	TO	SAVINGS	VOLUME CROSSOVER
CNC (5-axis)	Injection molded plastic	50-90 %	1k-5k units
Injection mold (4-cavity)	Family mold + multi-cavity	30-50 %	50k-200k units
Sheet metal stamping (single die)	Progressive die	40-70 %	50k+ units
Hand assembly	Semi-automated	30-60 % labor	10k+ units per month
Manual SMT (selective solder)	Reflow oven	60-80 %	1k+ units per shift

4.5 Geometric optimisation

- **Reduce wall thickness where not structurally required (saves material + cooling time).**
- **Reduce part count through snap-fits, living hinges, overmolds.**
- **Standardise screws**
  One size, one drive type per assembly.

- **Reduce cable harness complexity**
  Internal PCB connections vs. cables.

5. Design-for-cost rules

Tactical rules engineers apply during design to keep cost down.

5.1 Mechanical DFC rules

- **Plan for high-volume process at design time**
  Don't design for 5-axis CNC if volume justifies injection molding.
- **Single material per part**
  Multi-material parts require multi-shot molding or assembly.
- **Snap-fits over screws**
  Each screw = 3-8 s assembly time + screw cost.
- **Self-aligning features**
  Asymmetric mating prevents misorientation = faster assembly.
- **Standard fastener sizes**
  M2.5, M3 for most consumer hardware.
- **Minimum draft angles**
  1-2° (smooth), 3-5° (textured).
- **Minimum wall thickness**
  1.5-3 mm for most polymers.

5.2 Electronics DFC rules

- **Use largest acceptable component package**
  0603 over 0402 except where space-constrained.
- **Standard 2-layer or 4-layer FR-4**
  Avoid 6+ layer or HDI when possible.
- **Lower copper weight**
  1 oz (35 μm) over 2 oz (70 μm) for non-power layers.
- **Minimise via count**
  Each via adds drill cost.
- **Avoid blind/buried vias**
  Add 2-5× cost vs. through-holes.
- **Standardise component packages**
  Few package variants; supplier discount on volume.

5.3 Assembly DFC rules

- **Fewer parts = less assembly time**
  Each part needs picking, placing, joining.
- **Visual orientation cues**
  Operator doesn't need to verify orientation = less time.
- **Linear assembly**
  Top-down or one-direction stacking; minimal flipping.
- **Fewer tools per station**
  One screwdriver type, one connector type.

6. Cost reduction examples

Real examples of cost reduction in consumer hardware.

6.1 Example 1: Bluetooth speaker

Original BoM cost: $14.50 After VAVE (Year 1):

CHANGE	SAVING
Combined display + button PCB (was 2 boards)	$1.20
Single 8 Ω driver instead of dual (same SPL)	$0.85
Snap-fit instead of 6 screws	$0.30
Standard barrel jack instead of USB-C (DC-only model)	$0.70
Reduced packaging (litho sleeve instead of color box)	$0.45
Total saving	**$3.50 (24%)**
New cost	**$11.00**

6.2 Example 2: Soil moisture sensor

Original BoM cost: $8.80 After VAVE (Year 2):

CHANGE	SAVING
Generic equivalent MCU (different vendor)	$1.10
Removed RTC IC (firmware uses MCU's internal clock)	$0.40
Eliminated LDO (direct-drive MCU from battery)	$0.30
Reduced battery from 2 000 mAh → 1 000 mAh (firmware optimised)	$0.90
Simpler housing (eliminated snap-fit detail)	$0.50
Total saving	**$3.20 (36%)**
New cost	**$5.60**

6.3 Example 3: Smart watch

Original BoM cost: $42.00 After VAVE (Year 1.5):

CHANGE	SAVING
Lower-grade OLED (same resolution, cheaper supplier)	$5.50
Battery cell substitution (different chemistry, similar capacity)	$2.20
Combined accelerometer + gyro (single 6-DoF IMU instead of two)	$1.80
Simplified strap connector (proprietary → standard)	$1.20
Reduced premium PVD coating to anodise	$1.50
Total saving	**$12.20 (29%)**
New cost	**$29.80**

6.4 When NOT to reduce cost

- **Safety-critical components**
  Battery protection, ESD diodes, fuses.
- **Brand-essential features**
  The thing that makes customers buy.
- **Compliance-critical**
  Substance restrictions, certifications.
- **Single-source long-lead**
  Where supply security trumps cost.
- **Cosmetic where the user touches**
  Premium materials on contact surfaces matter.

> **FINAL NOTE.** cost engineering is engineering. The same discipline that delivers a high-quality product also delivers a cost-target product. Both must be in scope from day one. A 30 % cost reduction discovered at year 2 means a year of unprofitable shipping; the same reduction designed in from the start means a viable product at launch.