TABLE 10.6. PARTIAL MORPHOLOGICAL MATRIX—BATTER UP! APPLICATION

Functions	Solution Principles			
	Mechanical	Hydraulic	Electrical	Other
Adapt to Handedness	Gears, Pulleys, Wheels, Pegs, Pins	Water/Air pressure	Solenoid, Servo motor	
Accept Person	Walking, Rolling to product	Riding a water wave, Flying		
Accept Bat	Slot, Groove, Hole, Guide rail, Ridge	Fluid suction		Magnetic attraction
Position Bat	Pegs, Axis movement	Piston cylinder	Solenoid, Servo motor	Magnets
Secure Bat	Clamp, Vice, Belt, Brace, Latch	Fluid suction	Electrical charge (Static cling)	Velcro, Magnets, Adhesion
Initiate Bat Swing	Conveyor, Lift, Mechanical impulse, Catapult	Water jet, Piston cylinder	Electrical impulse	Magnetic propulsion
Guide Bat	Guide rails, Parallel plates, Friction, Loop in bat, String, Hole in bat	Jet Stream		Magnetic restriction/ Attraction
Channel Bat	Human input, Gravity, String	Air flow, Water pressure		Magnets, Explosion
Accept Ball	Mount, Cartridge, Hoop	Tube		
Adjust Ball Height	Jack, Pegs, Pulley system, Lever	Air pressure	Electric current	Magnets, Explosion
Maintain Ball Height	Clamp, Mount	Air pressure, Fluid suction		Magnets, Adhesion
Propel Ball	Loop, Impact	Air suction, Jet stream, Water pressure		Magnetic attraction, Explosion
Accept Energy	Lever, Four bar, Crankshaft, Rope	Tuber, Pipe, Fan, Windmill	Electrical inlets	Metal surfaces, Panels, Fuses
Store Energy	Translational/Rotational Spring, Material Deformation, Rubber band Pendulum, Bat movement	Fluid column, Compressed air (Balloon, Bladder)	Batteries, Capacitor	Magnetic field, Solar panels, Chemical
Transform Energy	Gears, Belt/Sprocket, Lever, Four bar, Cam, Rack and pinion, Universal joint	Piston cylinder	Motor, Generator	
Transmit Energy	Linkages, Bearings	Pipe, Volume deformation	Wires, Volt potential energy	Magnetic field

TABLE 10.7. GENERALIZED ENGINEERING PARAMETERS FOR DESCRIBING PRODUCT METRICS

1. Weight of moving object
2. Weight of stationary object
3. Length of moving object
4. Length of stationary object
5. Area of moving object
6. Area of stationary object
7. Volume of moving object
8. Volume of stationary object
9. Velocity
10. Force
11. Stress or pressure
12. Shape
13. Stability of object's composition
14. Strength
15. Duration of action generalized by moving object
16. Duration of action generalized by stationary object
17. Temperature
18. Brightness
19. Energy consumed by moving object
20. Energy consumed by stationary object
21. Power
22. Energy loss
23. Substance loss
24. Information loss
25. Waste of time
26. Quantity of a substance
27. Reliability
28. Accuracy of measurement
29. Manufacturing precision
30. Harmful actions affecting the design object
31. Harmful actions generated by the design object
32. Manufacturability
33. User friendliness
34. Repairability
35. Flexibility
36. Complexity of design object
37. Difficulty to control or measure
38. Level of automation
39. Productivity

TABLE 10.8. TIPS' DESIGN PRINCIPLES (1–20) TO SOLVE ENGINEERING CONFLICTS

1 Principle of segmentation.	Divide the object into independent parts that are easy to disassemble, increase the degree of segmentation as much as possible.
2 Principle of removal.	Remove either the disturbing part or the necessary part from the object.
3 Principle of local quality.	Change the object's or environment's structure from homogeneous to non-homogeneous. Let different parts of the object carry different functions.
4 Principle of asymmetry.	Make object asymmetrical, or increase asymmetry.
5 Principle of joining.	Merge homogeneous objects or those intended for contiguous operations.
6 Principle of universality.	Let one object perform several different functions. Remove redundant objects.
7 The nesting principle.	Place one object inside another, which in turn is placed in a third, etc., or, let an object pass through a cavity into another.
8 Principle of counterweight.	Attach an object with lifting power or use the interactions with the environment, e.g., aerodynamic lift.
9 Principle of preliminary counteraction.	Perform a counter-action to the desired action before the desired action is performed.
10 Principle of preliminary action.	Perform the required action before it is needed, or set up the objects such that they can perform their action immediately when required.
11 Principle of introducing protection in advance.	Compensate for the low reliability of an object by introducing protections against accidents before the action is performed.
12 Principle of equipotentiality.	Change the conditions such that the object does not need to be moved up or down in the potential field.
13 Principle of opposite solution.	Implement the opposite action of what is specified. Make a moving part fixed and the fixed part mobile. Turn the object upside down.
14 Principle of spheroidality.	Switch from linear to curvilinear paths, from flat to spherical surfaces, etc. Make use of rollers, ball bearings, spirals. Switch from direct to rotating motion. Use centrifugal force.
15 Principle of dynamism.	Make the object or environment able to change to become optimal at any stage of work. Make the object consist of parts that can move relative to each other. If the object is fixed, make it movable.
16 Principle of partial or excessive action.	If 100% is unobtainable, try for slightly less or slightly more.
17 Principle of moving into a new dimension.	Increase the object's degree of freedom. Use a multi-layered assembly instead of a single layer. Incline the object or turn it on its side. Use the other side of an area.
18 Use of mechanical vibrations.	Make the object vibrate. Increase the frequency of vibration. Use resonance, piezovibrations, ultrasonic, or electromagnetic vibrations.
19 Principle of periodic action.	Use periodic or pulsed actions, change periodicity. Use pauses between impulses to change the effect.
20 Principle of uninterrupted useful effect.	Keep all parts of the object constantly operating at full power. Remove test or set-up runs.

TABLE 10.9. TIPS' DESIGN PRINCIPLES (21–40) TO SOLVE ENGINEERING CONFLICTS

21 Principle of rushing through.	Carry out a process or individual stages of a process at high speed.
22 Principle of turning harm into good.	Use harmful factor to obtain a positive effect. Remove a harmful factor by combining it with other harmful factors. Strengthen a harmful factor to the extent where it ceases to be harmful.
23 The feedback principle.	Introduce feedback. If there already is feedback, change it.
24 The go between principle.	Use an intermediary object to transfer or transmit the action. Merge the object temporarily with another object that can be easily taken away.
25 The self service principle.	The object should service and repair itself. Use waste products from the object to produce the desired actions.
26 The copying principle.	Instead of unavailable, complicated or fragile objects, use a simplified cheap copy. Replace an object by its optical copy, make use of scale effects. If visible copies are used, switch to infra-red or ultra-violet copies.
27 Cheap short life instead of expensive longevity.	Replace an expensive object that has long life with many cheap objects having shorter life.
28 Replacement of a mechanical pattern.	Replace a mechanical pattern by an optical, acoustical or odor pattern. Use electrical, magnetic or electromagnetic fields to interact with the object. Switch from fixed to movable fields changing over time. Go from unstructured to structured fields.
29 Use of pneumatic or hydraulic solutions.	Use gaseous or liquid parts of an object instead of solid parts.
30 Using flexible membranes and fine membranes.	
31 Using porous materials.	Make the object porous or use porous elements, e.g., inserts, covers, etc. If the object is already porous, fill the pores in advance with some useful substance.
32 The principle of using color.	Change the color or translucency of an object or its surroundings. Use colored additives to observe certain objects or processes. If such additives are already used, employ luminescence traces.
33 The principle of homogeneity.	Interacting objects should be made of the same material, or material with identical properties.
34 The principle of discarding and regenerating parts.	Once a part has fulfilled its purpose and is no longer necessary, it should automatically be discarded or disappear, e.g., evaporate, or change its shape. Parts that become useful after a while should be automatically generated.
35 Changing the aggregate state of an object.	Change state, e.g., solid to liquid. Use pseudostates and intermediary states, e.g., elastic solid bodies.
36 The use of phase changes.	Use phenomena occurring in phase changes, e.g., use of volume changes, heat dissipation, etc.
37 Application of thermal expansion.	Use expansion or contraction of materials by heat. Use materials with different thermal expansion coefficients.
38 Using strong oxidation agents.	Replace air with enriched air or replace enriched air with oxygen. Treat the air or oxygen with ionizing radiation. Use ionized oxygen. Use ozone.
39 Using an inert atmosphere.	Replace the normal environment with an inert one or a vacuum.
40 Using composite materials.	Switch from homogeneous materials to composites.

TABLE 10.10. DESIGN PRINCIPLES APPLIED WITHIN PRODUCT EXAMPLES/ANALOGIES

Design principles	Examples
1	Papasan Chair; Sectional Garden Hose; Computer Components; Steering Column; Food Processor; Personal Computer
2	Journal Bearing; Mounted Bicycle Pump; Air Cushion Soccer Game; Hover Craft
3	Boeing Fuselage Skin; Bimetallic Skin; Composite Mongol Bow; Stapler
4	Bumble Ball. Eccentric weight on motor creates vibration; Water Buoy: Weight at one end creates orientation; Oval Race Car: Weight shifted to left side of car to aid turning
5	TV/VCR; Cassette Tape Heads; IC Chip
6	Fountain Pen Body; Door Knob; Fingernail Clipper
7	Antenna; Bike Seat Lock; Sleeping Bag Stuff Sack; Boy Scout Glass
8	Hot Air Balloon; Hydro foil; Life Preserver
9	Door Closer; Black-and-White Film
10	Color Coding of Parts; PVC Primer
11	Fuse; Electric Breaker; Shaft Couplers; Slip Clutch
12	Jiffy Lube Pit; Loading Dock; Airport Gate
13	Mill; Lathe; Rock Polisher; Mouse Ball
14	Computer Mouse; Door Jam; Soda Can Lids; Screw Lift
15	Camera Lense; Bicycle Drivetrain and Derailer
16	Rain Parka; Snowboards
17	Book: Open–pages exposed; closed–stored vertically; Computer Mouse: 2-D screen to horizontal mouse pad; Composite Wing: Loads in only one direction per layer
18	Quartz Clock; Reed Pipe; Building Natural Frequency Adjustment
19	Stepper Motor; Hammer Drill
20	Steam Turbine; Mechanical Watch
21	High Speed X-Ray Film; Inkjet Printer Ink; Metal Alloy Quenching
22	Crumble Points on an Automobile; Heat Lamp; Medical Defibrillator
23	Air Conditioning/Thermostat
24	Gear Trains; Bock and Tackle
25	Knife Sharpening Storage Devices
26	Rapid Prototyping; Sand Casting; Crash Test Dummy
27	Paper; Ballpoint Pen; Cardboard Box
28	CD; Microwave; Crane with Electromagnetic Plate
29	Air Shock; Power Steering
30	Astronaut Crew Escape Bubble; High Altitude Balloon; Dome Tent
31	Ivory Soap (floats instead of sinks); Running Shoe Soles; Air Filters
32	Clear Bandage; Roadway Signs; Prescription Sunglasses
33	Shaft and Bushing
34	Multistage Rockets
35	Pipe Freezing Sleeve; Light Stick; Heat Pack
36	Fire Extinguisher; Fuse with Filament
37	Thermometer; Bimetal
38	Metal Forming Ovens; Torch Cutting
39	Heliarc Welding; Aluminum Soda Can; Light Bulb; Goodyear Blimp (vs. Hindenberg)
40	Steel Belted Tires; High Performance Aircraft Wings

TABLE 10.11. A SUBSET OF TIPS' PHYSICAL EFFECTS FOR CERTAIN SYSTEM (PRODUCT) FUNCTIONS

Product function (required property)	Physical effects (solution principles)
Temperature:	
Lower Temperature	Phase transitions. Jowlie-Tomson effect. Rank effect. Thermoelectric.
Measure Temperature	Heat distribution and change in natural frequency of vibrations; changes in optical, electrical, and magnetic properties. Curie point. Hopkins and Barkhausen effects.
Raise Temperature	Electromagnetic induction, vortical currents, surface effects, dielectrical heating, electronic heating, absorption of radiation.
Stabilize Temperature	Phase transitions (including moving through a Curie point).
Objects:	
Change the Dimensions of Objects	Heat distribution, deformation, piezoelectrics, magnetic-electrostriction.
Control Location of Objects	Magnetic, ferromagnetic link, electrical field + charged object, mechanical oscillations, centrifugal forces, heat distribution, pressure.
Control Movement	Capillary action, Osmosis, Toms effect, Bernoulli effect, waves.
Destruct (Destroy) Object	Electrical discharge, resonance, ultrasonics, cavitation, radiation.
Indicate Position/Location of Objects	Marker substances, luminescent traces, reflection of light, Doppler.
Measure Dimensions of Object	Natural frequency of oscillation, apply/read magnetic/electrical markers.
Setup Interaction Mobile/Fixed Objects	Electromagnetic fields.
Stabilize Position of Object	Elec. & magnetic fields, liquids that harden in fields, hydroscopic effect.
Surfaces, Volume, & Structures:	
Check State & Properties of Surfaces	Electrical discharge, reflection of light, electronic emissions, Moire effect, radiation.
Measure Surface Properties	Friction, absorption, diffusion, Bauschinger effect, electrical discharge.
Inspect State & Properties of Volume	Marker substances, change electrical resistance, polarized light, etc.
Change Volume Properties of an Object	Change viscosity by fields, heat action, phase transition, ionization.
Create & stabilize Structure of object	Interference waves, standing waves, Moire effect, magnetic waves, phase transitions, mechanical/acoustical oscillations, cavitation.
Gases & Mixtures:	
Control Aerosol Flows (dust/fog/smoke)	Electrisation, electrical & magnetic fields, light pressure.
Form Mixtures	Ultrasonics, cavitation, diffusion, elec. fields, magnetic fields, and ferromagnetic substance, electrophoresis, solubilization.
Separate Mixtures	Electric and magnetic, change viscosity, centrifugal forces, diffusion.
Forces/Energy:	
Create & Control Forces/High Pressure	Magnetic field + ferromagnetic substance, phase change, centrifugal forces, heat distribution, change hydrostatic forces, conducting liquids.
Change Friction	Johnson-Rabeck effect, radiation, Kragelsky phenomenon, oscillation.
Accumulate Mechanical & Heat Energy	Elastic deformation, hydroscopic effect, phase transitions.
Transfer Energy	Deformations, oscillations, Alexandrov effect, wave movement (& shock waves), radiation, conductivity, convection, induced radiation.
Fields, Light, & Chemicals:	
Indicate Electrical & Magnetic Fields	Osmosis, discharges, Piezo & magneto effects, Hall effect, nuclear magnetic resonance, electronic emissions, gyromagnetic phenomenon.
Indicate/Detect Radiation	Optical acoustic effect, heat distribution, photo effect, luminescence.
Generate Electromagnetic Radiation	Josephson effect, induced radiation, Tunnel effect, Hann effect.
Control Electromagnetic Fields	Screening, increase/decrease electric conductivity, change surface form.
Control/Modulate Light	Refraction/reflection of light, photoelasticity, Kerr/Faraday effects.
Initiate/Intensify Chemical Changes	Ultrasonics, cavitation, ultraviolet, X-ray, shock waves, catalysis.

TABLE 12.1. CHECKLIST FOR EMBODYING A PRODUCT CONCEPT (AFTER PAHL AND BEITZ 1996)

Embodiment heading	Checklist issue (Partial list)
Function	Are the customer needs satisfied, as measured by the target values? Is the stipulated product architecture and function(s) fulfilled? What auxiliary or supporting functions are needed?
Working principles and form solutions	Do the chosen form solutions (architecture and components per function) produce the desired effects and advantages? What disturbing noise factors may be expected? What byproducts may be expected?
Layout, geometry, and materials	Do the chosen layout, component shapes, materials, and dimensions provide minimal performance variance to noise (robustness), adequate durability (strength), efficient material usage (strength-to-mass ratio), suitable life (fatigue), permissible deformation (stiffness), adequate force flows (interfaces and stress concentrations), adequate stability, impact resistance, freedom from resonance, unimpeded expansion and heat transfer, and acceptable corrosion and wear with the stipulated service life and loads?
Energy and kinematics	Do the chosen layout and components provide efficient transfer of energy (efficiency), adequate transient and steady state behavior (dynamics and control across energy domains), and appropriate motion, velocity, and acceleration profiles?
Safety	Have all of the factors affecting the safety of the user, components, functions, operation, and the environment been taken into account?
Ergonomics	Have the human-machine relationships been fully considered? Have unnecessary human stress or injurious factors been predicted and avoided? Has attention been paid to aesthetics and the intrinsic "feel" of the product?
Production	Has there been a technological and economic analysis of the production processes, capability, and suppliers?
Quality control	Have standard product tolerances been chosen (not too tight)? Have the necessary quality checks been chosen (type, measurements, and time)?
Assembly	Can all internal and external assembly operations be performed simply, repeatedly, and in the correct order (without ambiguity)? Can components be combined (minimize part count) without affecting modular architectures and functional independence of the product?
Transport	Have the internal and external transport conditions and risks been identified and solved? Have the required packaging and dunnage been designed?
Operation	Have all of the factors influencing the product's operation, such as noise, vibration, and handling been considered?
Life Cycle	Can the product, its components, its packaging be reused or recycled? Have the materials been chosen and clumped to aid recycling? Is the product easily disassembled?
Maintenance	Can maintenance, inspection, repair, and overhaul be easily performed and checked? What features have been added to the product to aid in maintenance?
Costs	Have the stipulated cost limits been observed? Will additional operational or subsidiary costs arise?
Schedules	Can the delivery dates be met, including tooling? What design modifications might reduce cycle time and improve delivery?