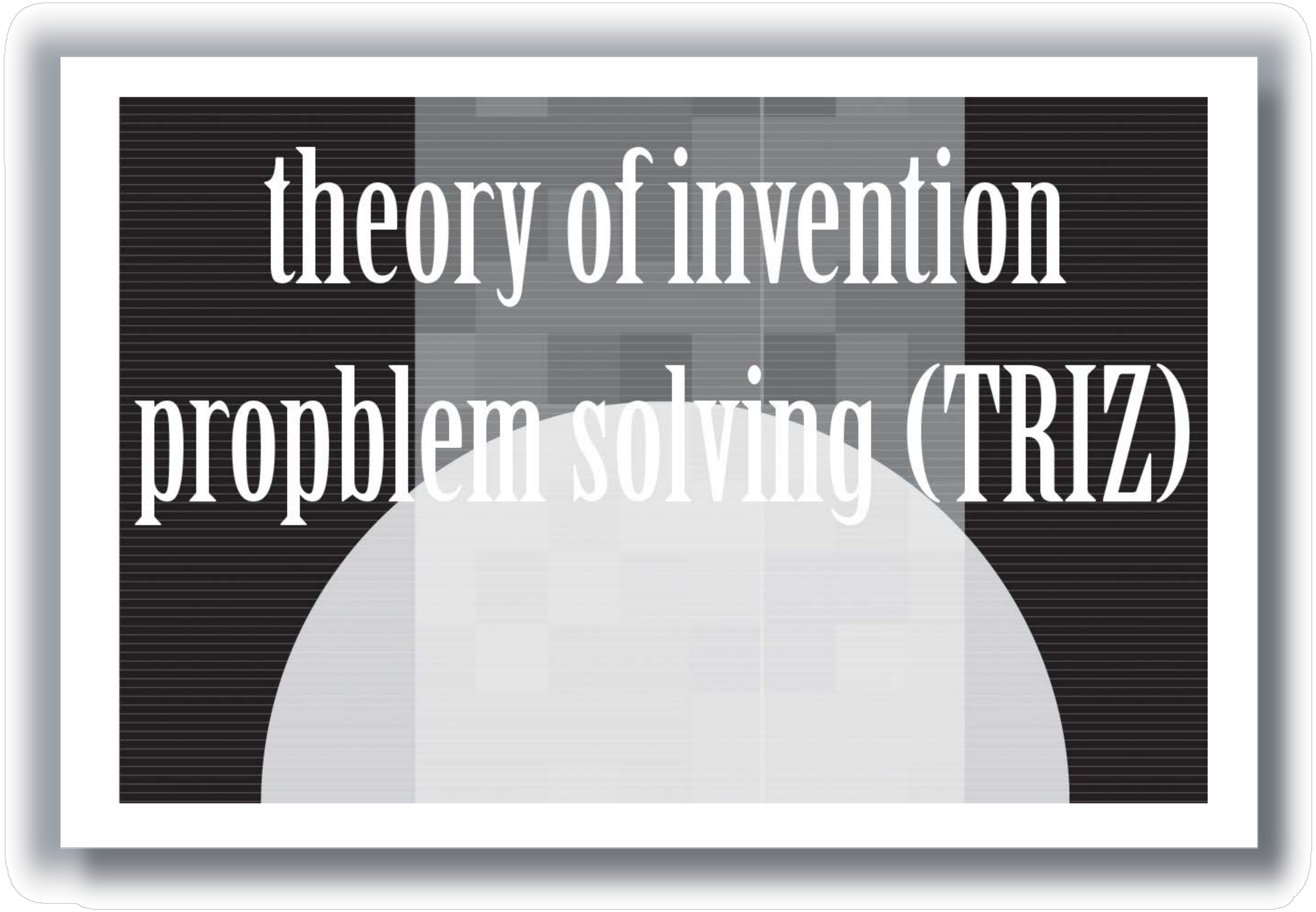


Instructor’s
Title & Name

Course Title….

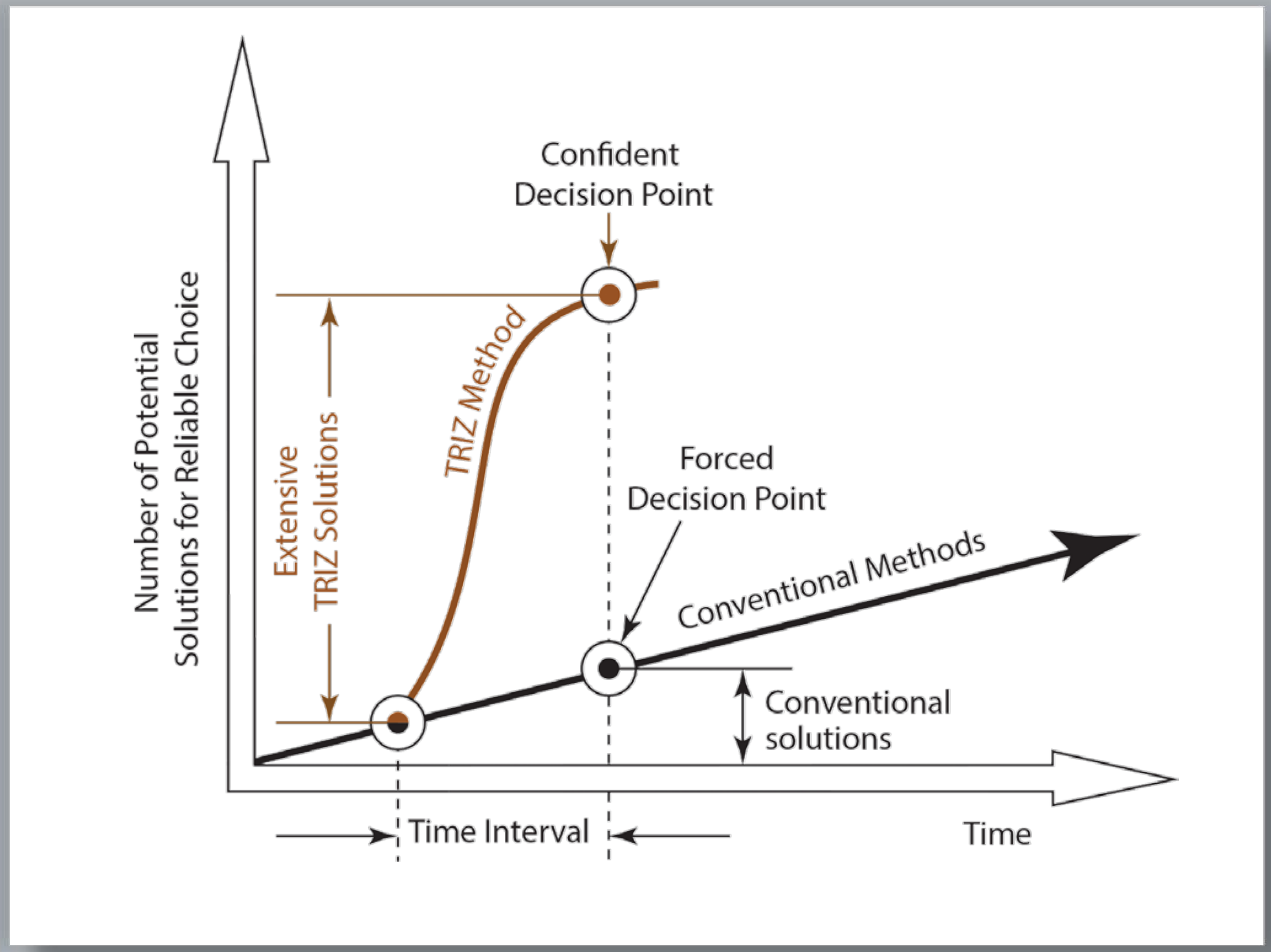
Theory of Invention Problem Solving (TRIZ)

“**TRIZ**” is the Russian acronym for the “theory of inventive problem solving” developed by G.S. Altshuller and his colleagues in Russia between 1946 and 1985.

More than 3 million patents have been analyzed to discover the patterns that predict innovative solutions to problems. These problems which have been solved by someone before, have been collected and organized within TRIZ.

Impact of TRIZ on an Organization

Figure 3.1: Impact of TRIZ on an organization (adapted from reference 7).



QFD-TRIZ Integration

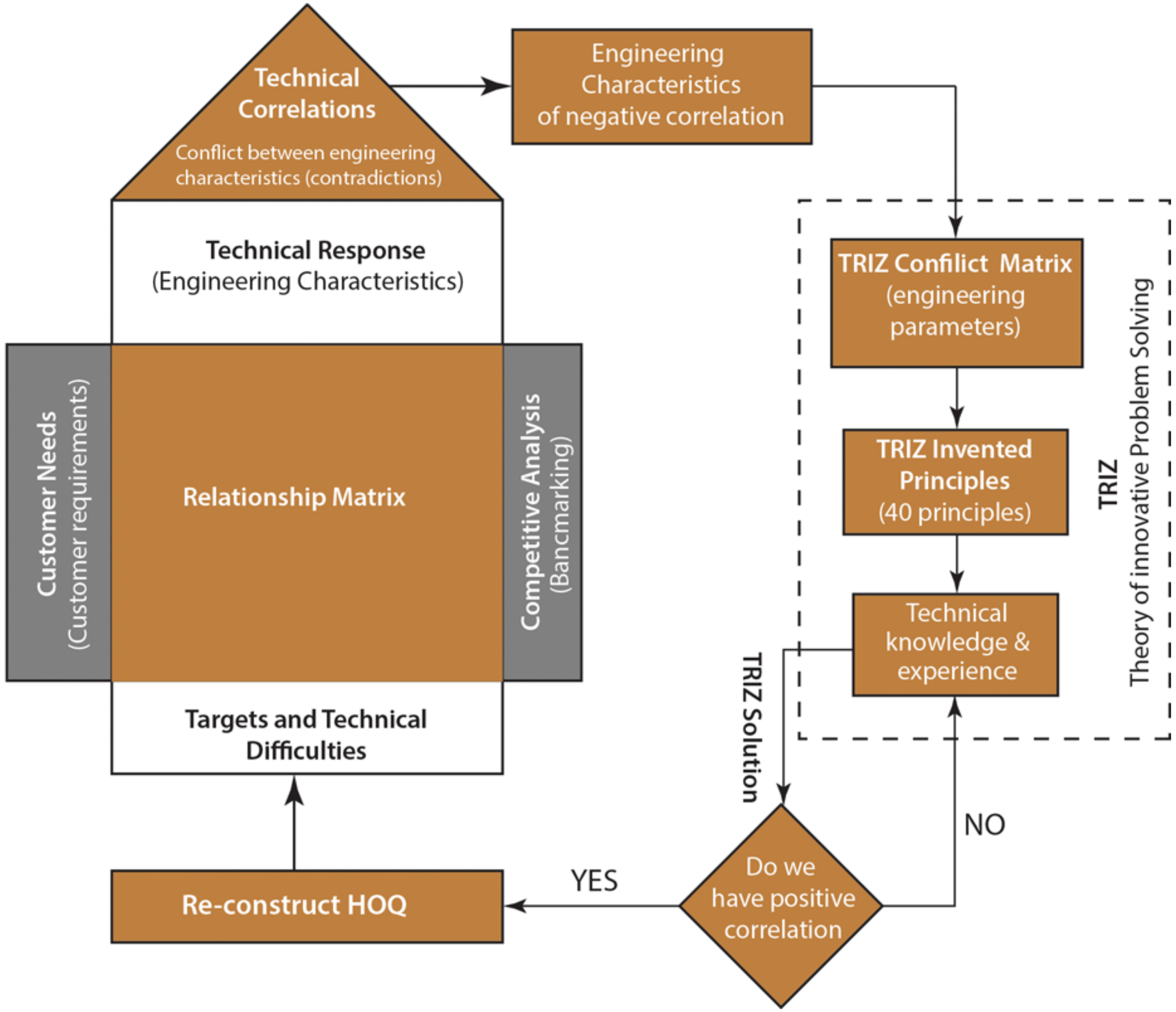


Figure 3.2: *QFD-TRIZ Integration* Flow chart.

TRIZ Problem Solving Process

1. Identify the conflicting engineering characteristics (EC) with negative correlation in the HOQ correlation matrix.
2. Identify the EC's type, which one is improving and which one is worsening characteristics.
3. Replace the ECs with corresponding parameters from TRIZ 39 contradiction matrix (Tables 3.1 through 3.6).
4. Using the contradiction matrix tables, identify which of the 40 inventive principles is applicable for your problem to resolve the contradiction (see Table 3.8 for 40 inventive principles).
5. After brainstorming, adapt the appropriate solution from 40 inventive principles to resolve the conflict among the ECs in the HOQ correlation matrix.
6. Re-construct the HOQ with the new ECs.

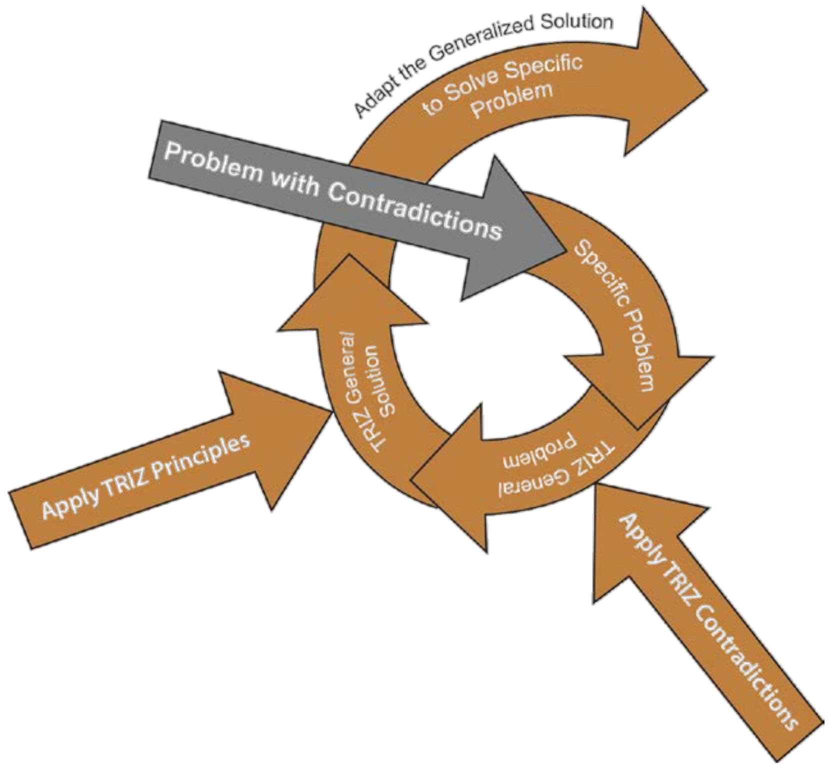


Figure 3.3: TRIZ problem solving process (adapted from reference 7).

Contradictions

A contradiction is a situation of two parameters in opposition to one another. There is three kinds of contradictions in TRIZ: **administrative**, **technical**, and **physical** contradictions.

Administrative contradiction: It is temporary, has no heuristic value, and stays at the surface of the problem.

Technical Contradiction: *Technical contradictions* are the typical engineering “trade-offs.” When something gets better, something else is affected and gets worse.

Example: The part products get stronger (good) but the weight increases (bad).

Physical Contradiction: Technical contradictions occurs between two parameters whereas a *physical contradiction* occurs when there is a conflict within a parameter itself.

For example, if we use a long regular magnetic tool to pick up several objects as shown in Figure 3.4(a), it may not be handy to carry. If we use a shorter magnetic tool for the same reason it may not be long enough to reach. In this case, the length of the tool is a parameter that creates a contradiction within a parameter (length) itself.

There are several ways of solving this contradiction. For example, if we use a telescopic magnetic tool to pick up various objects as shown in Figure 3.4(b), it is short enough to carry easily and if we extend it will be long enough to reach.

Figure 3.4: Magnetic pickup tool: (a) regular, (b) telescopic.

EXAMPLE

New material for aircraft structural parts needed. The design of an aircraft takes into consideration a variety of factors, one of the most important ones is the strength to weight ratio of the aircraft structural parts. The strength/weight conflict plays an important role in the design of aircraft structural parts. Use TRIZ analysis to resolve the conflict that will improve the strength/weight ratio.

ANALYSIS OF STATEMENT

Aircraft structural parts should be strong, but not heavy.

STEP 1:

Identify the contradiction(s) -- Strength (improves) versus Weight (worsens)

STEP 2:

Check Tables 3.1 through Table 3.6 and identify the improving and worsening features -- Strength – #14 and Weight – #2 (see Table 3.1)

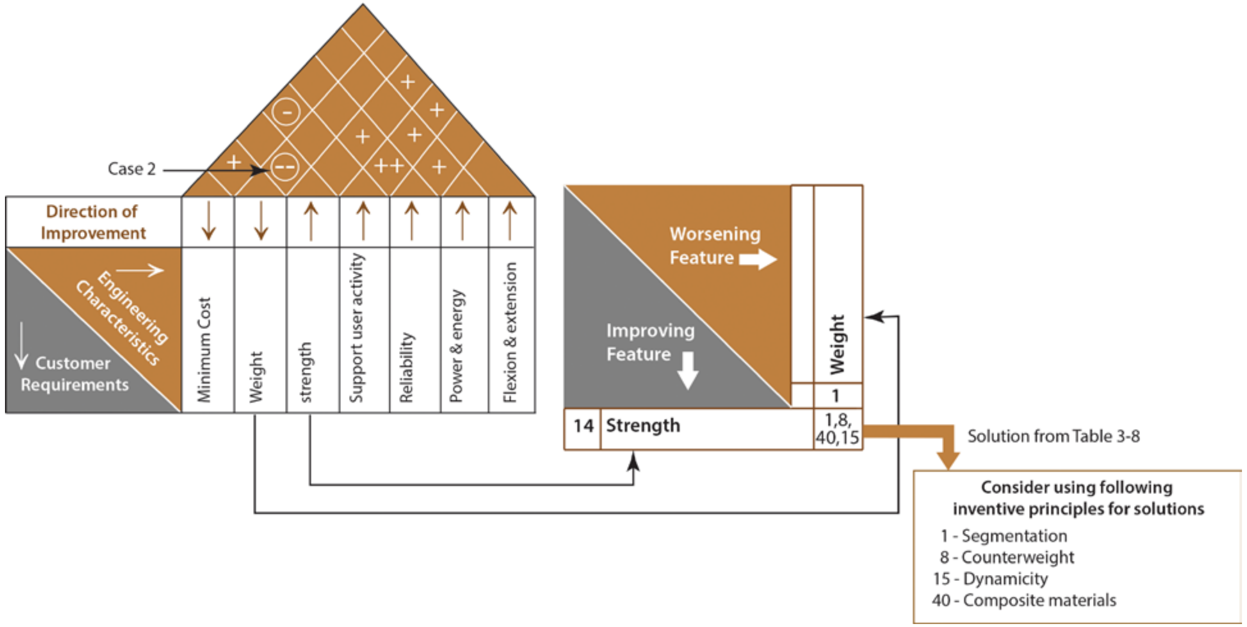
EXAMPLE (Continued)

Table 3.1: TRIZ Contradiction Matrix (Engineering Characteristics).

Weight (worsening) #1

Strength (improving) #14

Improving Feature ↓ / Worsening Feature →		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 Speed	10 Force	11 Tension or Pressure	12 Shape	13 Stability of object
1	Weight of moving object			15,8 29,34		29,17 38,34		29,2 40,28		2,8 15,38	8,10 18,37	10,36 37, 40	10, 14 35, 40	1,35 19, 39
2	Weight of stationary object				10,1 29,35		35,30 13,2		5,35 14,2		8,10 19,35	13, 29 10,18	13, 10 29,14	26,39 1,40
3	Length of moving object	8,15 29,34				15,17 4		7,17 4,35		13,4 8	17,10 4	1,8 35	1,8 10,29	1,8 15,34
4	Length of stationary object		35,28 40,29				17,7 10,40		35,8 2,14		28,10	1,14 35	13,14 15,7	39,37 35
5	Area of moving object	2,17 29,4		14,15 18,4				7,14 17,4		29,30 4,34	19,30 35,2	10,15 36, 28	5,34 29,4	11,2 13,39
6	Area of stationary object		30,2 14,18		26,7 9,39						1,18 35,36	10,15 36,37		2,38
7	Volume of moving object	2,26 29,40		1,7 4,35		1,7 4,17				29,4 38,34	15,35 36,37	6,35 36,37	1,15 28, 4	28,10 1,39
8	Volume of stationary object		35,10 19,14	19,14	35,8 2,14						2,18 37	24, 35	7,2 35	34,28 35,40
9	Speed	2,28 13,38		13,14 8		29,30 34		7,29 34			13,28 15,19	6,18 38,40	35,15 18,34	28,33 1,18
10	Force	8,1 37,18	18,13 1,28	17,19 9,36	28,10	19,10 15	1,18 36,37	15,9 12,37	2,36 18,37	13,28 15,12		18,21 11	10,35 40,34	35,10 21
11	Tension or Pressure	10,36 37,40	13,29 10,18	35,10 36	35,1 14,16	10,15 36,28	10,15 36,37	6,35 10	35,24	6,35 36	36,35 21		35,4 15,10	35,33 2,40
12	Shape	8,10 29,40	15,10 26,3	29,34 5,4	13,14 10,7	5,34 4,10		14,4 15,22	7,2 35	35,15 34,18	35,10 37,40	34,15 10,14		35,40 24,31
13	Stability of object	21,35 2,39	26,39 1,40	13,15 1,28	37	2,11 13	39	28,10 19,39	34,28 35,40	33,15 28,18	10,35 21,16	2,35 40	22,1 18,4	
14	Strength	1,8 40,15	40,31 2,1	1,15 8,35	15,14 28,26	3,34 40,29	9,40 28	10,15 14,7	9,14 17,15	8,13 26,14	10,18 3,14	10,3 18,40	10,30 35,40	13,17 35
15	Duration of moving object	19,5 34,31		2,19 9		3,17 19		10,2 19,30		3,35 5	19,2 16	19,3 27	14,26 28,25	13,3 35



STEP 3:

Identify which principles can be used for this problem (see Figure 3.5).

Table 3.8: Altshuller's TRIZ – 40 Principles.

Principles	Principles
1. Segmentation	21. Rushing through
2. Extraction (taking out)	22. Convert harm into benefit
3. Local Quality	23. Feedback
4. Asymmetry	24. Mediator (intermediary)
5. Combination (merging)	25. Self-service
6. Universality	26. Copying
7. Nesting	27. Inexpensive short life
8. Counterweight (anti-weight)	28. Replacement of a mechanical system
9. Prior Counteraction	29. Use pneumatic or hydraulic systems
10. Prior Action	30. Flexible film or thin membranes
11. Cushion in Advance	31. Use of porous materials
12. Equipotentiality	32. Changing the colour
13. Inversion (the other way round)	33. Homogeneity
14. Spheroidality- Curvature	34. Rejecting and regenerating parts
15. Dynamicity	35. Parameter Change
16. Partial, overdone or excessive action	36. Phase transition
17. Moving to a new dimension	37. Thermal expansion
18. Mechanical vibration	38. Use strong oxidisers
19. Periodic action	39. Inert environment
20. Continuity of useful action	40. Composite materials

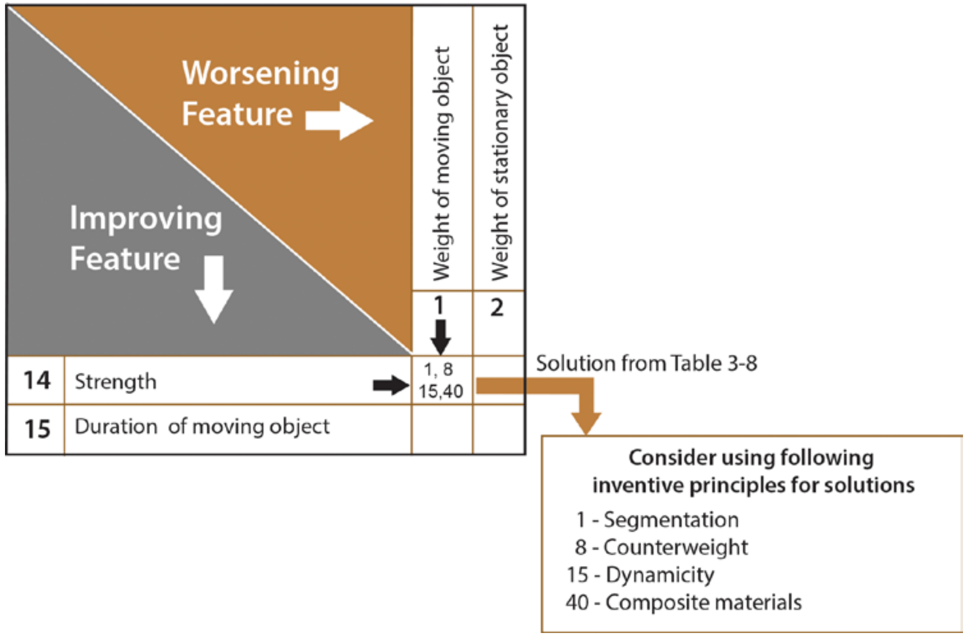


Figure 3.5: Identifying improving and worsening features.

STEP 4: Next step is to think about which principle is useful to solve our problem. Principle 40 (composite material) is the most useful solution for this problem.

TRIZ Separation of Principles

There is four separations of principles to resolve physical contradiction:

1. Separation in time
2. Separation in space
3. The Separation between the parts (components) and the whole (system)
4. Separation upon condition

1. Separation of Conflicting Properties in Time

Changing a property, response, and behavior vs. time. For example, by changing the cargo ship propeller blades to the optimal pitch in time, higher efficiency can be obtained, thus saving fuel (see Figure 3.6).

Applying separation in time results in an inventive solution of controllable pitch propellers. Changing the pitch of the propeller in time will run the ship in forwarding and astern directions both, without the change of engine rotational direction.

From Table 3.8, TRIZ principles most applicable to “separation in time” are: 9, 10, 11, 12, 15, 16, 18, 19, 20, 21, 35, 36, 37, 38, and 39.

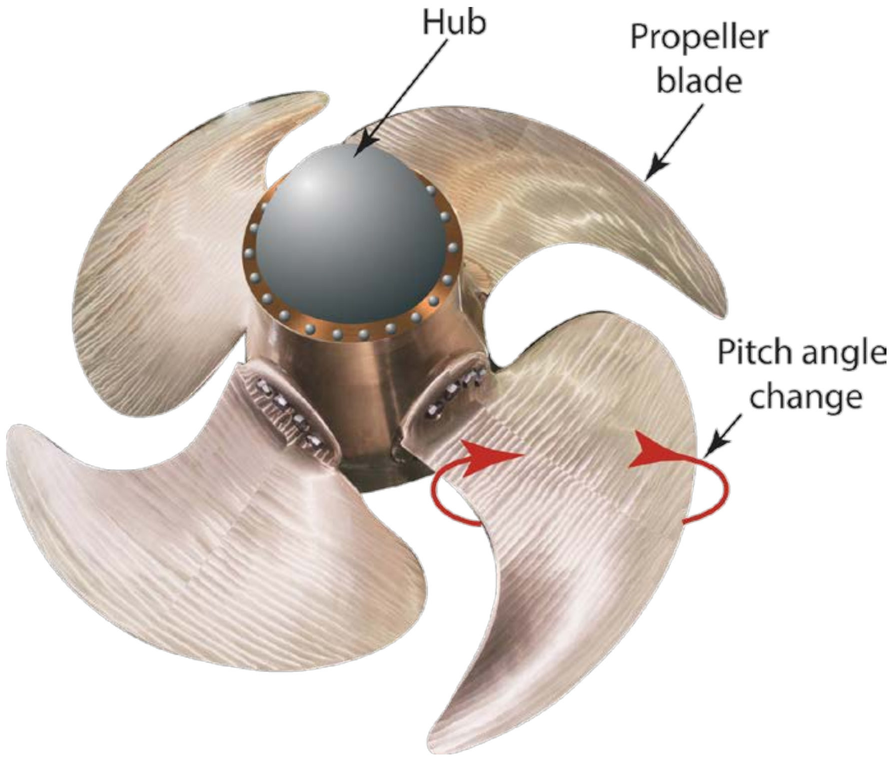


Figure 3.6: Controllable pitch propeller.

2. Separation in Space

Changing a property, response, behavior based on a special location. From Table 3.8, TRIZ principles most applicable to “separation in space” are: 1, 3, 4, 5, 7, 8, 13, 14, 15, 16, 17, 26, 27, 30, 31, and 32.

Example: A knee brace is used after a knee injury to provide support while the knee injury is healing. They are designed to limit movement of the knee while it is healing after an injury or surgery. However, **certain conditions will cause the kneecap to track improperly, causing pain in other locations**. The pain is present in one place (around the knee joint) and absent in another place. The solution is having a small hole as shown in Figure 3.7 to support the kneecap.

Figure 3.7: Knee brace.

3. Separation between the Parts and the Whole

Changing a property, response, and behavior to make it different at the component or system level. In other words, exists at the system level but not exist at the component level (or vice versa).

For example plastic body fillers and hardeners shown in Figure 3.8 are liquids, but when you mixed them combination became solid.

Table 3.8, TRIZ principles most applicable to “between parts and the whole” are 2, 3, 6, 7, 24, 26, 27, 33, 34, and 40.

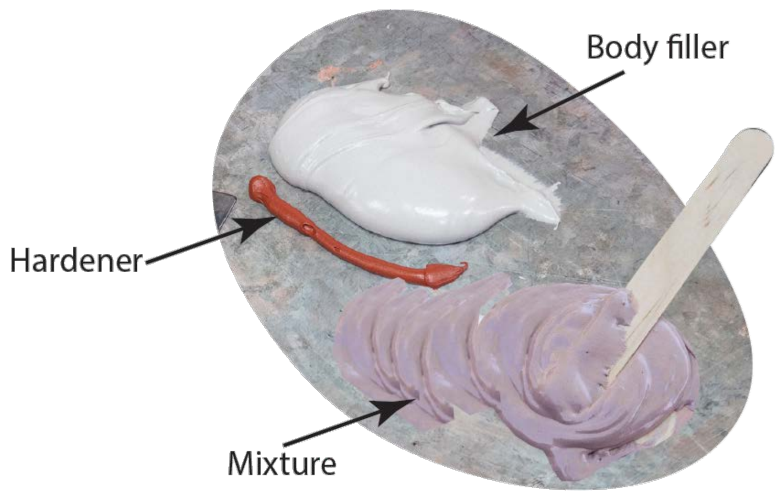


Figure 3.8: Mixing body filler and hardener.

4. Separation upon Condition

Changing the property, response, or behavior on condition. Properties can be high under one condition and low under another condition.

A good example of this case is transitions lenses with a light-sensitive photochromic coating as shown in Figure 3.9. The lenses are light or dark changing on the conditions of UV radiation present.

From Table 3.8, TRIZ principles most applicable to “separation of conditions” are 6, 15, 16, 18, 19, 22, 28, 29, and 32.

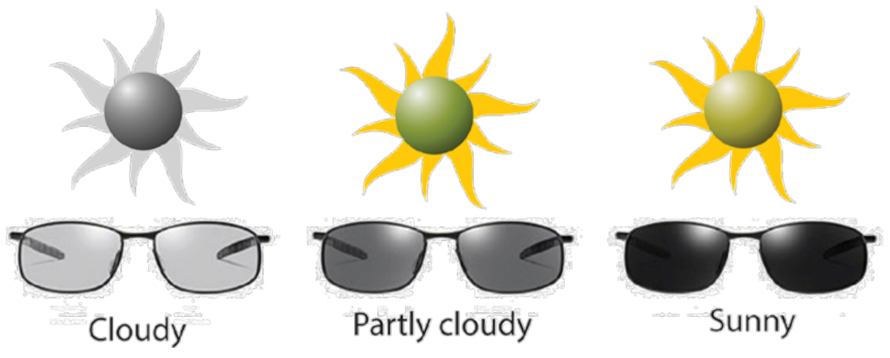


Figure 3.9: Light-sensitive photochromic coating lenses.

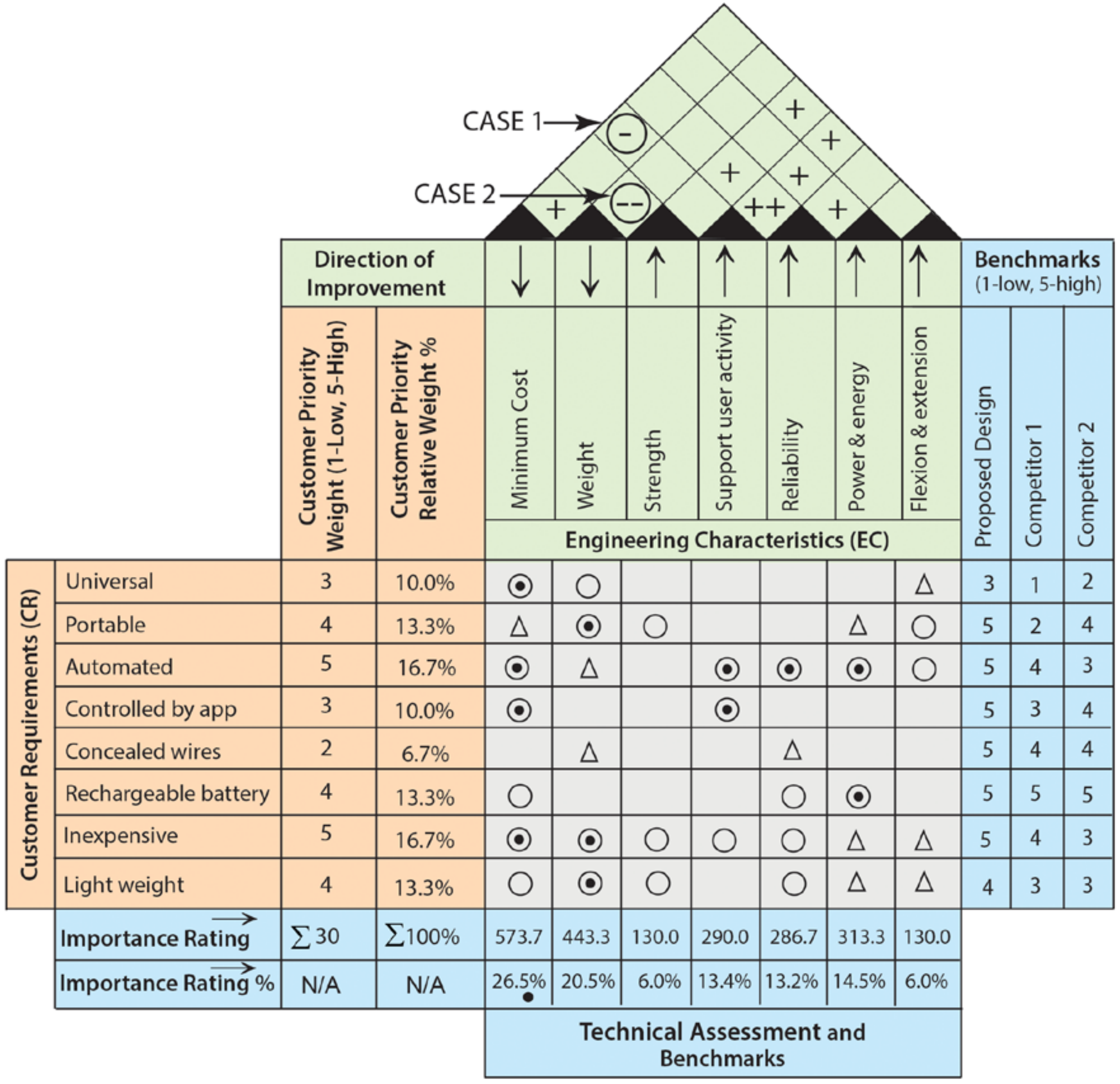
CASE STUDY

Using the TRIZ inventive principles resolve the conflicts among the ECs shown in Figure 3.10.

Two negative correlations occur:

CASE 1: *Cost* (worsening characteristic) and *Support user activity* (improving characteristics)

Case 2: *Weight* (worsening characteristic) and *Strength* (improving characteristics)



Customer Requirements (CR)	Customer Priority Weight (1-Low, 5-High)	Customer Priority Relative Weight %	Minimum Cost	Weight	Strength	Support user activity	Reliability	Power & energy	Flexion & extension	Proposed Design	Competitor 1	Competitor 2
Direction of Improvement			↓	↓	↑	↑	↑	↑	↑			
Universal	3	10.0%	⊙	○					△	3	1	2
Portable	4	13.3%	△	⊙	○			△	○	5	2	4
Automated	5	16.7%	⊙	△		⊙	⊙	⊙	○	5	4	3
Controlled by app	3	10.0%	⊙			⊙				5	3	4
Concealed wires	2	6.7%		△			△			5	4	4
Rechargeable battery	4	13.3%	○				○	⊙		5	5	5
Inexpensive	5	16.7%	⊙	⊙	○	○	○	△	△	5	4	3
Light weight	4	13.3%	○	⊙	○		○	△	△	4	3	3
Importance Rating	Σ30	Σ100%	573.7	443.3	130.0	290.0	286.7	313.3	130.0			
Importance Rating %	N/A	N/A	26.5%	20.5%	6.0%	13.4%	13.2%	14.5%	6.0%			

Figure 3.10: HOQ.

CASE STUDY (continued)

Case 1: The improvement of the “support user activity” causes an increase of production “cost”.

Cost reduction is a widespread topic throughout the industry. However, many techniques of TRIZ do not deal with cost explicitly.

CASE STUDY (continued)

Darrell Mann (2004) included some of the same parameters used in the TRIZ matrix that cause costs to increase.

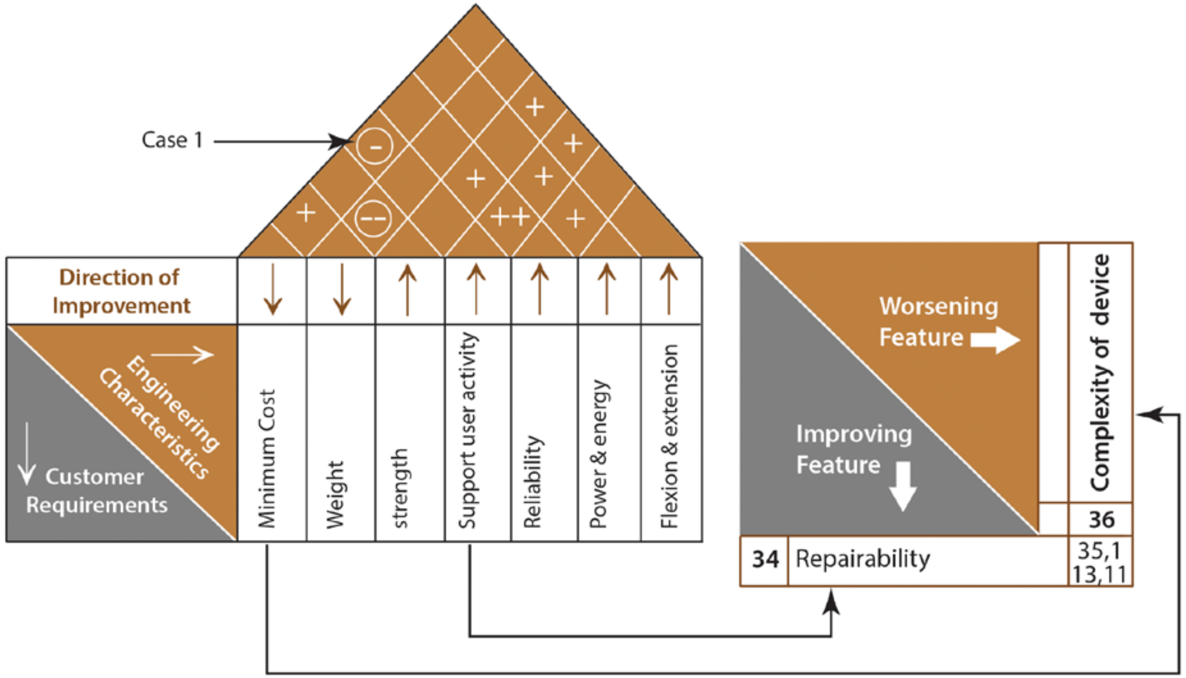
- Complexity of the system/device
- Complexity of control
- System-generated harmful factors
- Time and risk issues for the R&D, Production, Supply, and Support
- Speed of a process
- Duration of action
- Loss of energy, loss of material, loss of information, loss of time
- Reliability
- System-generated harmful factors
- Ease of operation, ease of production, ease of repair
- System complexity
- Extent of automation
- Productivity

For Case 1, we adopt "**complexity of device**" (worsening characteristic) for "*cost of production*" and "**ease repair (repairability)**" (improving characteristic) for "*support user activity*".

CASE STUDY (continued)

Table 3.6: TRIZ Contradiction Matrix (Engineering Characteristics).

Improving Feature ↓ / Worsening Feature →		Reliability 27	Accuracy of measurement 28	Accuracy of manufacturing 29	Harmful factor acting on object 30	Harmful side-effects 31	Manufacturibility 32	Convenience of use 33	Repairability 34	Adaptability 35	Complexity of device 36	Complexity of control 37	Level of automation 38	Productivity 39
34	Repairability	11,10 1,16	10,2 13	25,10	35,10 2,16		1,35 11,10	1,12 26,15		7,1 4,16	35,1 13,11		34,35 7,13	1,32 10
35	Adaptability	35,13 8,24	35,5 1,10		35,11 32,31		1,13 31	15,34 1,16	1,16 7,4		15,29 37,28	1	27,34 35	35,28 6,37
36	Complexity of device	13,35 1	2,26 10,34	26,24 32	22,19 29,40	19,1	27,26 1,13	27,9 26,24	1,13	29,15 28,37		15,10 37,28	15,1 24	12,17 28
37	Complexity of control	27,40 28,8	26,24 32,38		22,19 29,28	2,21	5,28 11,29	2,5	12,26	1,15	15,10 37,28		34,21	35,18
38	Level of automation	11,27 32	28,26 10,34	28,26 18,23	2,33	2	1,26 13	1,12 34,3	1,35 13	27,4 1,35	15,24 10	34,27 25		5,12 35,26
39	Productivity	1,35 10,38	1,10 34,28	18,10 32,1	22,35 13,24	35,22 18,39	35,28 2,24	1,28 7,10	1,32 10,25	1,35 28,37	12,17 28,24	35,18 27,2	5,12 27,2	



SOLUTIONS ARE: 35, 1, 13, 11

CASE STUDY (continued)

Solutions from Table 3.8 are: **35, 1, 13and 11.**

35-Parameter change – change an object’s physical state (e.g. to a gas, liquid, or solid).

1-Segmentation – divide an object into independent parts.

- Replace mainframe computers with personal computers
- Replace a large truck with a truck and trailer
- Use a **W**ork **B**reakdown **S**tructure (WBS) for a large project.

13-Invertion *(the other way around)* – invert the action(s) used to solve the problem (e.g. instead of cooling an object, heat it).

11- Cushion in Advance - Prepare emergency means beforehand to compensate for the relatively low reliability of an object.

Table 3.8: Altshuller’s TRIZ – 40 Principles.

Principles	Principles
1. Segmentation	21. Rushing through
2. Extraction (taking out)	22. Convert harm into benefit
3. Local Quality	23. Feedback
4. Asymmetry	24. Mediator (intermediary)
5. Combination (merging)	25. Self-service
6. Universality	26. Copying
7. Nesting	27. Inexpensive short life
8. Counterweight (anti-weight)	28. Replacement of a mechanical system
9. Prior Counteraction	29. Use pneumatic or hydraulic systems
10. Prior Action	30. Flexible film or thin membranes
11. Cushion in Advance	31. Use of porous materials
12. Equipotentiality	32. Changing the colour
13. Inversion (the other way round)	33. Homogeneity
14. Spheroidality- Curvature	34. Rejecting and regenerating parts
15. Dynamicity	35. Parameter Change
16. Partial, overdone or excessive action	36. Phase transition
17. Moving to a new dimension	37. Thermal expansion
18. Mechanical vibration	38. Use strong oxidisers
19. Periodic action	39. Inert environment
20. Continuity of useful action	40. Composite materials

CASE STUDY (continued)

Solution Decision

After thorough analysis, the principle 1- segmentation of “use a Work Breakdown Structure (WBS) for a large project,” will be implemented. A WBS helps to make a large project more manageable. Breaking it down into smaller pieces work can be done simultaneously by different team members, leading to better team productivity. This will save a lot time and effort, ultimately, saves money and reduces the production cost.

CASE STUDY (continued)

CASE-2: The improvement of the“ **strength**” causes an increase of “**weight**”, thus resulting in a strong negative correlation in the correlation matrix.

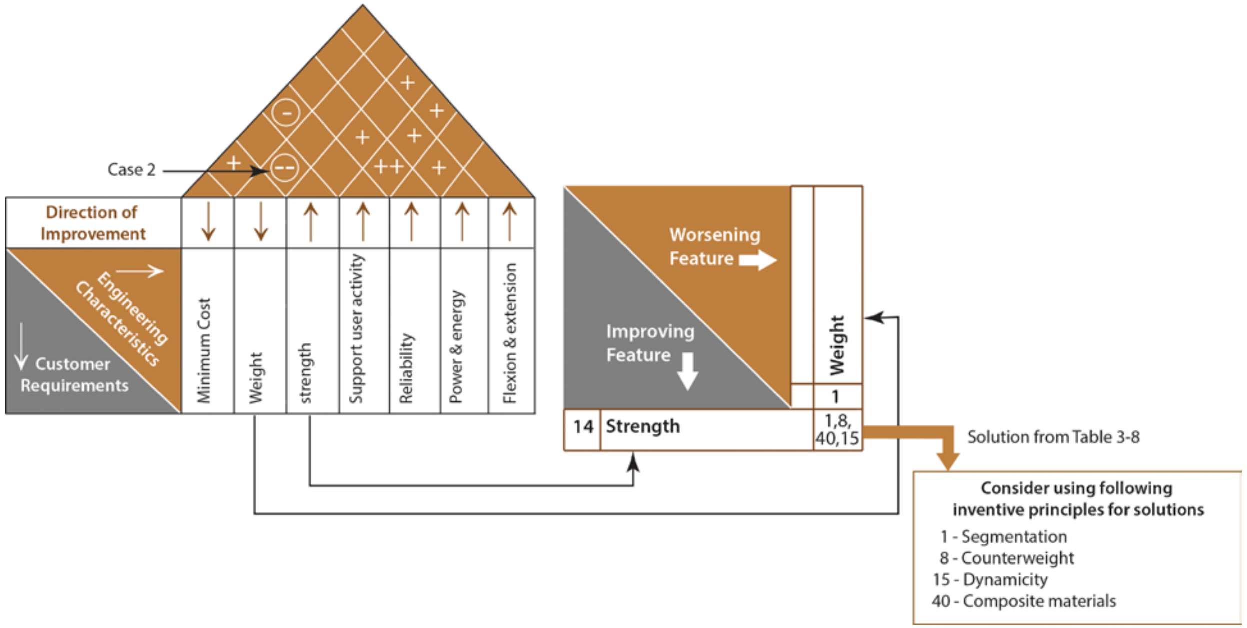
In this case,
Strength is the improving characteristic
Weight is a worsening characteristic.

Weight (worsening)
#1

Strength (improving)
#14

Table 3.1: TRIZ Contradiction Matrix (Engineering Characteristics).

Worsening Feature → / Improving Feature ↓		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 Speed	10 Force	11 Tension or Pressure	12 Shape	13 Stability of object
1	Weight of moving object			15,8 29,34		29,17 38,34		29,2 40,28		2,8 15,38	8,10 18,37	10,36 37, 40	10, 14 35, 40	1,35 19, 39
2	Weight of stationary object				10,1 29,35		35,30 13,2		5,35 14,2		8,10 19,35	13, 29 10,18	13, 10 29,14	26,39 1,40
3	Length of moving object	8,15 29,34				15,17 4		7,17 4,35		13,4 8	17,10 4	1,8 35	1,8 10,29	1,8 15,34
4	Length of stationary object		35,28 40,29				17,7 10,40		35,8 2,14		28,10	1,14 35	13,14 15,7	39,37 35
5	Area of moving object	2,17 29,4		14,15 18,4				7,14 17,4		29,30 4,34	19,30 35,2	10,15 36, 28	5,34 29,4	11,2 13,39
6	Area of stationary object		30,2 14,18		26,7 9,39						1,18 35,36	10,15 36,37		2,38
7	Volume of moving object	2,26 29,40		1,7 4,35		1,7 4,17				29,4 38,34	15,35 36,37	6,35 36,37	1,15 28, 4	28,10 1,39
8	Volume of stationary object		35,10 19,14	19,14	35,8 2,14						2,18 37	24, 35	7,2 35	34,28 35,40
9	Speed	2,28 13,38		13,14 8		29,30 34		7,29 34			13,28 15,19	6,18 38,40	35,15 18,34	28,33 1,18
10	Force	8,1 37,18	18,13 1,28	17,19 9,36	28,10	19,10 15	1,18 36,37	15,9 12,37	2,36 18,37	13,28 15,12		18,21 11	10,35 40,34	35,10 21
11	Tension or Pressure	10,36 37,40	13,29 10,18	35,10 36	35,1 14,16	10,15 36,28	10,15 36,37	6,35 10	35,24	6,35 36	36,35 21		35,4 15,10	35,33 2,40
12	Shape	8,10 29,40	15,10 26,3	29,34 5,4	13,14 10,7	5,34 4,10		14,4 15,22	7,2 35	35,15 34,18	35,10 37,40	34,15 10,14		35,40 24,31
13	Stability of object	21,35 2,39	26,39 1,40	13,15 1,28	37	2,11 13	39	28,10 19,39	34,28 35,40	33,15 28,18	10,35 21,16	2,35 40	22,1 18,4	
14	Strength	1,8 40,15	40,31 2,1	1,15 8,35	15,14 28,26	3,34 40,29	9,40 28	10,15 14,7	9,14 17,15	8,13 26,14	10,18 3,14	10,3 18,40	10,30 35,40	13,17 35
15	Duration of moving object	19,5 34,31		2,19 9		3,17 19		10,2 19,30		3,35 5	19,2 16	19,3 27	14,26 28,25	13,3 35



SOLUTIONS ARE: 1, 8, 15, 40

From TRIZ Tool we have

(1) *Segmentation* – divide an object into independent parts.

(8) *Counterweight* – to compensate for the weight of an object, merge it with other objects that provide lift.

(15) *Dynamicity* – allow (or design) the characteristics of an object, external environment, or process to change to be optimal or to find an optimal operating condition.

(40) *Composite material* – change from uniform to composite (multiple) materials.

- Composite epoxy resin/carbon fiber golf club shafts are lighter, stronger, and more flexible than metal. Same for airplane parts.
- Fiberglass surfboards are lighter and more controllable and easier to form into a variety of shapes than wooden ones.

SOLUTION

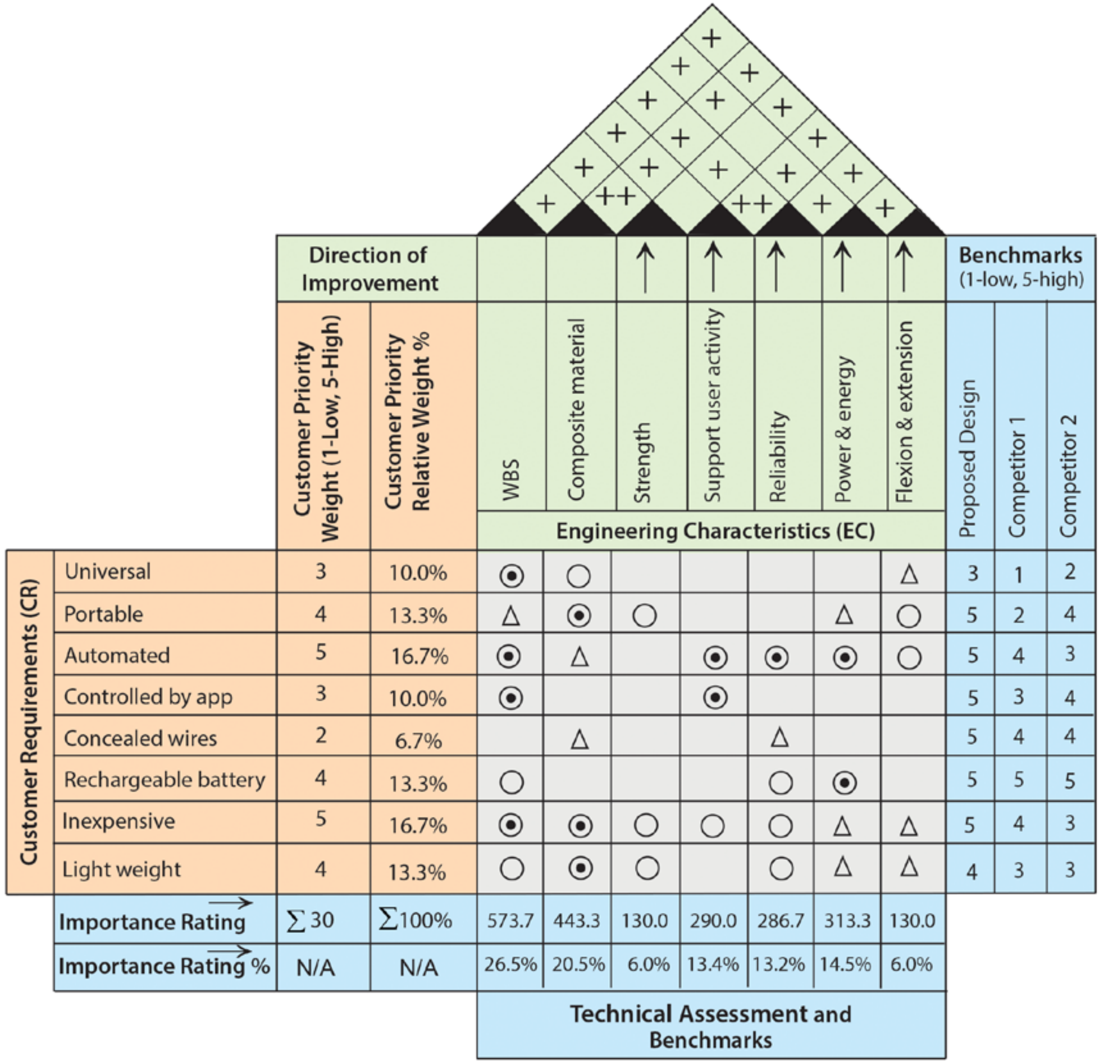
For this case, among the other suggested solutions, composite material (40) will lead to a solution. This solution will eliminate the contradiction between weight and strength.

U.S. Department of Energy defines WBS as “A WBS is the cornerstone of effective project planning, execution, controlling, statusing, and reporting. All the work contained within the WBS is to be identified, estimated, scheduled, and budgeted. The WBS is the structure and code that integrates and relates all project work (scope, schedule, and cost).” Therefore, the relationships of the engineering characteristics with this new characteristic (WBS) should be carefully reconsidered to re-build the HOQ. A similar argument is justifiable for the replacement of “composite material” in the HOQ.

A negative correlation between ECs, mainly “cost of production” and “weight (material)”, certainly affects the performance of product design. Thus, these ECs, which have negative correlations are replaced in the HOQ as shown in Figure 7.8.

RE-BUILDING HOQ

Make sure that you re-evaluate the correlations among the engineering characteristics for the new HOQ.



Customer Requirements (CR)	Customer Priority Weight (1-Low, 5-High)	Customer Priority Relative Weight %	WBS	Composite material	Strength	Support user activity	Reliability	Power & energy	Flexion & extension	Proposed Design	Competitor 1	Competitor 2
Direction of Improvement					↑	↑	↑	↑	↑			
Universal	3	10.0%	◉	○					△	3	1	2
Portable	4	13.3%	△	◉	○			△	○	5	2	4
Automated	5	16.7%	◉	△		◉	◉	◉	○	5	4	3
Controlled by app	3	10.0%	◉			◉				5	3	4
Concealed wires	2	6.7%		△			△			5	4	4
Rechargeable battery	4	13.3%	○				○	◉		5	5	5
Inexpensive	5	16.7%	◉	◉	○	○	○	△	△	5	4	3
Light weight	4	13.3%	○	◉	○		○	△	△	4	3	3
Importance Rating	∑30	∑100%	573.7	443.3	130.0	290.0	286.7	313.3	130.0			
Importance Rating %	N/A	N/A	26.5%	20.5%	6.0%	13.4%	13.2%	14.5%	6.0%			

Figure 7.8: New re-build HOQ.

Transforming QFD results to ISM