4 IDEJE

Ko poznamo specifikacije novega produkta, potrebujemo konkretne ideje za nov produkt (za njegovo delovanje, izdelavo...). V resnici potrebujemo samo eno pravo idejo. Pravo idejo pa najdemo tako, da izbiramo med številnimi idejami. Le tako smo lahko prepričani, da je izbrana ideja najboljša. Več kot je idej, boljša je prava ideja.

Vir idej so lahko posamezniki (uporabniki, konkurenca, svetovalci, člani projektnega team-a za načrtovanje novega produkta). Pri iskanju idej smo kreativni. Sprašujemo se: "Kaj če?". Včasih ideje posameznikov niso dovolj in si je potrebno pomagati še z drugimi viri idej, kot so naravni produkti, naključna sinteza molekul s pomočjo plazme ali kombinatorna kemija.

Navadno v tej fazi načrtovanja produkta izbiramo okoli 5 najboljših idej med 100 idejami. Izbiramo v dveh korakih. V prvem koraku izločimo neprimerne ideje, ki so lahko nerealne, v nasprotju s strategijo podjetja, ali pa jih nismo sposobni uresničiti iz različnih razlogov (znanje, kadri, oprema...). V drugem koraku izbiramo med okoli 20 idejami (80 smo jih izločili v prvem koraku). Ocenjujemo splošne lastnosti posameznih idej iz strokovnega vidika. Preostane okoli 5 idej, ki so dobre, praktične in bi morale delovati.

4.1 ČLOVEŠKI VIRI IDEJ

Potrebujemo veliko število idej za en uspešen produkt. Du Pont pravi, da jih potrebuje 300, 3M 10, Zeneca in Pfizer 100. Da lahko pridobimo veliko število idej, je potrebno poiskati in motivirati ljudi ali skupine ljudi, ki bodo generirali ideje.

Pomembni človeški viri idej so:

- Projektni team za načrtovanje novega produkta: Člani projektnega team-a so strokovnjaki na področju, ki so sposobni hitro oceniti prednosti in slabosti idej. Njihova motivacija je visoka, saj je njihova profesionalna kariera odvisna od uspeha projekta.
- Potencialni uporabniki novega produkta, še zlasti vodilni uporabniki: Slednji imajo veliko izkušenj in znanja. Velikokrat sami poskušajo izboljšati obstoječi produkt.
- Konkurenca: Konkurenca ima podobne cilje kot mi. S skrbnim opazovanjem njenih aktivnosti na trgu, lahko pridemo do pomembnih informacij in idej.
- Strokovna in znanstvena literatura ter patenti: S skrbnim prebiranjem literature in povezovanjem informacij lahko dobimo dobre ideje. Na osnovi objav v mednarodno priznanih znanstvenih revijah lahko sklepamo, kaj na področju razvijajo raziskovalci, ki sodelujejo s konkurenco. Seveda so koristni znanstveni članki in patenti načrtno napisani tako, da to še zdaleč ni enostavno.
- Produktni eksperti, samostojni raziskovalci in inovatorji, svetovalci: Svetovalci v večini primerov ponujajo obstoječe lastne rešitve, redko tvorijo nove ideje.

Načina iskanja idej

Poznamo dva načina reševanja problemov (za posameznike, za stroke in tudi za korporacije): inovativen način in način prilagajanja. Oba sta kreativna!
Način prilagajanja: Za reševanje novega problema (za iskanje idej za nov produkt) se uporablja obstoječa ali sorodna tehnologija za podobne rešitve.
Inovativen način: Za reševanje problema se uporablja novosti in navidezno nepovezane informacije.
Pri načrtovanju novih produktov sta koristna oba pristopa.

Zbiranje idej

Najbolj direkten in učinkovit način je, da ljudje (člani projektnega team-a, uporabniki, eksperti) svoje ideje zapišejo in predstavijo. Če se ideje zapišejo, je objektivnost in angažiranost posameznikov večja, ideje so zato boljše, bolje razdelane. Zapišejo se procesne sheme, sintezne poti, reakcijski mehanizmi... Na takšen način se pridobi pomembne ideje, ki pa jih ni veliko.

Zato, da bo idej več, se v okviru projektnega team-a ustanovijo delovne skupine (recimo 3 skupine s 5-8 člani), ki imajo nalogo iskanja idej. Vsaka skupina ima vodjo. Pri takšnem "brainstorming"-u je koristno upoštevati nekaj pravil:

- Vse skupine naj ideje za isto stvar razdelajo v enakem obsegu.
- Svoboda pri tvorjenju idej mora biti velika.
- Ni pomembno čigava je ideja. Izogibati se je potrebno poudarjanju avtorstva idej.
- Ekscentričnost se načrtno vzpodbuja.

Med efektivnim delom skupin, ki traja okoli dve uri, se ideje zapisujejo (navadno na liste papirja velikega formata, ki so razobešene po prostoru).
Iz prakse vemo, da navadno produktivnost skupine po približno uri dela pade, saj se vse očitne ideje izčrpajo. Se pa zato poveča kreativnost pri predlaganju novih idej. Ko vnema delovni skupini pada, so lahko dodatna stimulacija:

- Spodbujanje kritike idej drugih: Včasih, ko nekdo nekaj označi za neumnost, lahko poda tudi rešitev: "To je bedarija. Če želiš, da bo delovalo, mora biti stranska veriga alifatska..."
- Naštevanje predpostavk v specifikacijah produkta ter razmišljanje o njih: Pri tem lahko nekatere zavržemo. Ugotovimo, da bi šlo tudi drugače: "Saj sploh ne rabimo topila..."
- Uporaba analogij: Na primer prenos toplote in prenos snovi sta opisana z isto matematiko... Na hitrost reakcije ne vpliva samo temperatura, ampak vpliva tudi pH vrednost...
- Uporaba nasprotij: "Kaj če bi uporabili sol-selektivno membrano namesto vodo-selektivne membrane?"

Na tak način lahko skupina začne razmišljati v novi smeri in nastajajo nove ideje.

Rezultat zbiranja idej je dolg seznam »surovih« in neurejenih idej.

Primeri »surovih« in neurejenih idej

V spodnjih tabelah so prikazani trije primeri neurejenih idej (Vir: E. L. Cussler in G. D. Moggridge, Chemical Product Design, Cambridge University Press, Cambridge, 2001.)

TABLE 3.1–1 Ideas for New Laundry Detergents Causing Less Pollution

1. Wash without soap.
2. Throw the clothes away.
3. Use less soap and less water.
4. Use a more effective soap.
5. Add enzymes to detergents.
6. Add dead cells to detergents.
7. Add live cells to detergents.
8. Mop up dirt with particles.
9. Use specific chemical interactions.
10. Improve the washing machine.
11. Recycle the soap.
12. Filter bigger detergent particles.
13. Make larger micelles.
14. Make emulsions out of the soap.
15. Grow microbes on dirty clothes.
16. Attach soap to particles, facilitating recycle.
17. Imitate dry cleaner agents.
18. Use a fine adsorbent.
19. Cook clothes under N_2.
20. Air out clothes as washing substitute.
21. Prevent soiling with antistatic coatings.
22. Wash until semiclean.
23. Remove odor without removing dirt.
24. Wash with base, converting sweat compounds into soap.
25. Split objectives of clean, color-fast, and odor.
26. Ultrafilter dirty water.
27. Imitate dry cleaning.
28. Get a new dry cleaning solvent.
29. Make a home dry cleaner that is sealed.
30. Use supercritical CO_2 for dry cleaning.
31. Use another supercritical solvent.
32. Wash with Fuller's Earth.
33. Dry clean with chlorine-free solvents.
34. Grind the clothes up and remake them.
35. Recycle the surfactant by using a pH change.
36. Recycle the surfactant by exploiting its cloud point.
37. Make a detergent that precipitates on command.
38. A detergent that forms many phases.
39. Wash clothes with dry shampoo.
40. Clean ultrasonically.
41. Shine with a UV light (to sterilize?).
42. Use pressure waves.
43. Cook clothes in high-pressure water.
44. Freeze clothes; shake off dirt.
45. Calcine dry shampoo to make it pure.
46. Use Fuller's Earth.
47. Use ultrafiltration.
48. Dry cleaning recycle is distillation.
49. Flocculant aid for detergent.
50. Adsorb detergent in clay.

Note: These speculations will be used in Section 3.3 to illustrate the sorting of ideas.

TABLE 3.1–2 Ideas for a New Lithographic Ink with Reduced Solvent Emissions

1. Don't use a solvent.
2. Switch solvents.
3. Clean the press with robots.
4. Change the press.
5. Use an electrostatic ink.
6. Use a laser printer instead of the current design.
7. Change ink chemistry.
8. Recycle all of the solvent.
9. Clean the press with a high-pressure spray.
10. Extract the solvent from the rags used to clean the press.
11. Do the whole process in a clean room.
12. Isolate all equipment.
13. Clean the press less often.
14. Clean the press in a fume hood.
15. Print more checks at a time.
16. Mix the current solvent methylene chloride with other solvents.
17. Have each worker wear a self-contained breathing apparatus.
18. Use a solvent mixture.
19. Use a solvent that dissolves the ink.
20. The solvent in the ink should differ from the cleaning solvent.
21. Use a nonvolatile solvent.
22. Use partial cleaning of specific components of the press.
23. Steam clean the press.
24. Clean the press with air.
25. Put the press in a car wash.
26. Clean the press by brushing.
27. Clean the press by burning.
28. Make the lithography more like a jet printer.
29. Don't use checks.
30. Use a disposable press.
31. Use oil to trap the solvent.
32. Make checks by photocopying.

Note: More chemical details of the current ink are given in Example 3.3–2.

TABLE 3.1–3 Ideas for Treating High Level, Water Soluble Radioactive Waste

1. Store waste in bedrock.
2. Separate cesium with irreversible sodium titanate ion exchange.
3. Cesium extraction out of caustic solution.
4. Better process control for cesium tetraphenylborate precipitation.
5. Zeolite ion exchange.
6. Stabilize cesium tetraphenylborate precipitate with palladium catalyst poison.
7. Electrochemical separation of sodium.
8. Fractional crystallization to remove solvent.
9. Make a ceramic of waste.
10. Precipitate as cesium tetraphenylborate and vitrify quickly.
11. Electrochemical membrane support.
12. Potassium precipitation before cesium precipitation.
13. Cesium ion exchange with acid regeneration.
14. Build more storage tanks to hold waste.
15. Stabilize cesium tetraphenylborate precipitation.
16. Hollow-fiber extraction of cesium.
17. Dewater salt tanks for more storage capacity.
18. Precipitation at reduced temperature and storage as cesium tetraphenylborate.
19. Ion exchange on glass; vitrification.
20. Concrete formation of total waste (grout).
21. Simulated moving bed adsorption to separate cesium.
22. Inject in ground; vitrify *in situ* with nuclear explosives.
23. Concentrate cesium in microorganisms.
24. Adsorption in sodium titanate.
25. Regenerable ion exchange.
26. Cesium extraction in acidic solution.
27. Magnetic particles that adsorb cesium.
28. Electrochemical nitrate destruction.
29. Fluidized bed ion exchange.
30. Cesium separation and concrete formation (grout).
31. Cesium absorption in $MnFe(CN)_6$.
32. Flocculate tetraphenylborate precipitate.
33. Salt washing plus fractional crystallization.
34. Electrically regenerated ion exchange.
35. Reversible adsorption by using crown ethers on inert substrate.
36. Reduce explosion risk for cesium tetraphenylborate precipitate.
37. Use smaller size of cesium ion for separation.
38. Total vitrification of waste.
39. Make storage tanks safer.
40. Separate interstitial liquid, evaporate to dryness, and vitrify.
41. Buy additional benzene release permits.
42. Precipitate potassium before cesium.
43. Selective crystallization.
44. Properly designed ion exchange processes.
45. Properly designed precipitation processes.
46. Alternate precipitation chemistry.
47. Countercurrent exchange with sodium titanate.
48. Electrodialysis.
49. Salt dehydration and vitrification.

Note: This partial list of submitted ideas is used in Section 3.4 to demonstrate the concept-screening matrix.

4.2 KEMIJSKI VIRI IDEJ

V nekaterih primerih samo človeški viri idej niso dovolj. Včasih ne vemo, katero kemijsko spojino (specialna kemikalija) potrebujemo oziroma želimo narediti. To je značilno za farmacevtsko industrijo. Takrat se poslužujemo pregleda naravnih produktov, naključne sinteze spojin s pomočjo plazme in kombinatorne kemije.

Pregled naravnih produktov

V naravi je prisotnih ogromno različnih materialov in kemijskih spojin, ki imajo izražene določene lastnosti in aktivnosti. Rastline, živali, glive, lišaji, morski organizmi in mikroorganizmi so bogat vir "novih" materialov in kemijskih spojin s specifičnimi funkcijami, ki lahko ustrezajo našim potrebam.
Posebej farmacevtska industrija to s pridom izkorišča. Veliko učinkovin, ki se danes sintetično proizvajajo, izvira iz narave: aspirin, opij, kinin, kofein, kodein... Celo material za neprebojne jopiče je analog naravnega produkta - pajkove mreže.

Naravni produkti se za proizvodnjo aktivnih kemijskih spojin uporabljajo na tri načine:

- Z direktno izolacijo spojin iz narave (Primer: Vincristin - zdravilo za otroško levkemijo se izolira iz madagaskarskega zimzelena (*Catharanthus*).
- Iz narave se izolira prekurzor, ki se uporabi v sintezi bolj kompleksne molekule (Primer: Iz korenine *Dioscorea villosa* se ekstrahirajo prekurzorji za sintezo progesterona in kortizona).
- Aktivna spojina se identificira v naravi, potem pa se sintetizira v laboratoriju oziroma na industrijski liniji. (Primer: Reserpin, učinkovina proti povišanemu krvnemu tlaku, je bil najprej izoliran iz *Rauwolfia Serpentina*. Danes se reserpin proizvaja iz osnovnih kemikalij.).

Prvi način je najpogostejša praksa, tretji pa je velik izziv sodobnih raziskav - še zlasti z uporabo mikroorganizmov (naravnih in gensko modificiranih).

Testiranih je bilo manj kot 0,1 % bakterij in gliv, ki živijo v tleh, in okoli 1 % cvetočih rastlin.

Pri iskanju zdravilnih učinkovin ne smemo pozabiti na tradicionalno medicino in zdravilce v odročnih krajih sveta.

Naključna sinteza spojin s pomočjo plazme

Naključna sinteza poteka tako, da v plazmi (ioniziran plin) med seboj reagirajo fragmenti molekul in nastanejo nove spojine, ki imajo lahko uporabno funkcijo.
Pri uporabi te metode poznamo vrsto molekule, ki jo želimo narediti, ne poznamo pa njene natančne kemijske strukture (Primer: modifikacija obstoječe farmacevtske učinkovine). Zato nabor izhodiščnih spojin, ki jih pri delu uporabljamo, ni prevelik. Raztopino izhodiščnih spojin injeciramo v plazmo, kjer poteče veliko število radikalskih reakcij. Produkt je temna viskozna smola, ki jo testiramo na želeno delovanje. Če ugotovimo, da je v smoli spojina, ki deluje oziroma ki jo želimo, sledijo separacija smole (s tekočinsko kromatografijo), izolacija in analiza (določitev kemijske strukture z masno in NMR spektroskopijo) uporabne spojine ter razvoj postopka za njeno sintezo.
Torej, v plazmi nastale kemijske spojine so skoraj naključno odkrite kemijske ideje.

Kombinatorna kemija

Avtomatizirana sinteza in analiza omogoča sintezo in analizo ogromnega števila spojin ali njihovih zmesi, ki so lahko želen produkt. Uporabna je takrat, ko iščemo spojino ali zmes spojin za rešitev konkretnega problema (farmacevtsko učinkovino, katalizator, strup za mikrobe). Metoda temelji na identifikaciji potencialne aktivne sestavine ali njenih fragmentov. Vse potencialne aktivne sestavine ali fragmente testiramo v vseh mogočih kombinacijah in koncentracijah ter pri različnih pogojih (temperatura, tlak, pH vrednost). Zato mora biti postopek avtomatiziran. Metoda je zelo uporabna v biokemiji, farmaciji, katalizi.

Tri vrste kemijskih virov idej (Vir: E. L. Cussler in G. D. Moggridge, Chemical Product Design, Cambridge University Press, Cambridge, 2001.)

TABLE 3.2–1 Three Routes to Chemical Ideas

Parameter	Natural Product Screening	Random Assembly	Combinational Chemistry	Remarks
Typical Starting Information	Potions from folk medicine	Similar chemicals of known structure	Similar chemicals of known structure	Note that we must have some chemical knowledge to begin
Chemical Synthesis	None	Random assembly of known fragments	Planned assembly of known fragments	We may not know what we have made
Trials for Efficacy	Use entire potion	Use entire product mixture	Use each known product	We will discard most of the chemical species present
Chemical Analysis	Identify active ingredients	Identify active ingredients	None	We know what we have made only in the third case

Note: Natural product screening is well developed and combinatorial chemistry is evolving rapidly. Random assembly is less often used.

Primer (Vir: E. L. Cussler in G. D. Moggridge, Chemical Product Design, Cambridge University Press, Cambridge, 2001.)

EXAMPLE 3.2–1 FUEL CELL CATALYSIS

An elegant example of combinatorial methods used in catalytic chemistry is given by Milhawk and co-workers. The problem is to optimize the composition of a catalyst for methanol fuel cells. High surface area Pt-Ru catalysts are the current technology, but waste about 25% of the fuel's energy. By chemical analogy, we want to consider the other platinum group metals Os, Ir, and Rh, as additives. The problem is to test efficiently many catalysts of different composition and with different combinations of elements.

How can this be done?

SOLUTION

To make these tests, Milhawk and co-workers built a modified ink jet printer to spray dots of mixed metal salts. They produced a 645-member electrode array, including the five pure elements, eighty combinations of two elements, 280 ternaries and 280 quaternaries. The dots were dried and reduced to the metals. To test each combination, Milhawk and co-workers used a fluorescent molecule that luminesces in acid but not base. (H^+ is produced as part of the fuel cell's catalytic cycle.) On testing, the most effective catalyst simply lit up the brightest.

The results are fascinating. A quaternary alloy, Pt(44)/Rh(41)/Os,(10)/Ir(5), was found to be the most efficient catalyst. It was significantly more efficient than the commercial binary, although the surface area was only about half. Other alternative catalysts were identified in different regions of both ternary and quaternary space. The most efficient ternary, Pt(62)/Rh(25)/Os(13), lies in a ternary region bounded by inefficient binaries, Pt-Os and Pt-Rh. We would not intuitively expect high activity from this ternary composition. These results could never have been achieved by conventional catalytic testing: the amount of work required would be just too great and the results show that a rational or intuitive approach would have failed.

4.3 UREJANJE IDEJ

V dveh korakih izbiramo okoli 5 najboljših idej med 100 nepopolnimi idejami.

Najprej skrčimo število zapisanih idej, saj se nekatere ponavljajo. Do ponavljanja navadno prihaja, ker so nekatere ideje zapisane bolj splošno, druge pa bolj specifično (Primer: "Odstrani dišavo iz pare." in "Uporabi selektivno membrano za koncentriranje dišave iz pare.").

Izločimo nore in napačne ideje. Nekatere ideje so lahko zdijo nesmiselne, ker so bile slabo zapisane. Druge, čeprav so napačne ali nore, so lahko inovativne. Teh ne želimo izgubiti, zato jih zbiramo na kupu "naključnih misli", ki ga od časa do časa pregledamo.

Po izločanju imamo navadno še 70 idej v obravnavi.

Naslednja stopnja je razvrščanje in združevanje idej (necelovitih, parcialnih idej) po skupinah. Slednje je potrebno naprej določiti (na osnovi idej, ki jih razvrščamo). Določanje skupin je na tem mestu najbolj težavno delo. Glavnih skupin, ki morajo biti okvirno enako pomembne, naj bo okoli 5. Podskupine idej (največ 4 na skupino) so specifični primeri, ki spadajo v isto skupino.
Razvrščanje in združevanje idej po skupinah zmanjša število zapisanih parcialnih idej in nam daje boljši pregled idej.

Nato izločimo skupine ali podskupine idej ali posamezne ideje, ki so v nasprotju s strategijo podjetja, ali pa jih nismo sposobni uresničiti iz različnih razlogov (znanje, kadri, oprema...). Tako nam ostane okoli 20 idej.

Primeri (Vir: E. L. Cussler in G. D. Moggridge, Chemical Product Design, Cambridge University Press, Cambridge, 2001.)

EXAMPLE 3.3–1 ADHESIVES FOR WET METAL

A product development team wants to produce a new group of adhesives that will stick to wet metal surfaces. Such an adhesive would have value in the automotive industry. The team has produced the ideas shown in Table 3.3–1.

Sort these ideas into a coherent organization.

TABLE 3.3–1 Ideas for an Adhesive for Wet Metal

1. Wipe the metal surface with a cloth (F)	32. Invent coupling chemistry (V)
2. Change the metal's composition	33. Adapt dental adhesives (V)
3. Change to a new adhesive (V)	34. Try a polymer with a protective layer and heat to use
4. Make the adhesive water absorbing	35. Use heat catalyzed polymer (V)
5. Use a plant that sticks to a ship (V)	36. Coat the surface before applying the adhesive (V)
6. Use a natural rubber	37. Invent an adhesive that reacts with metal
7. Electrostatically charge the metal	38. Welding with a laser (F)
8. Put a magnet in the current adhesive (R-7)	39. Replace the metal (F)
9. Use a super glue (i.e., a cyano acrylate) (V)	40. Solder (F)
10. Use a different resin (V)	41. Use a sugar solution (V)
11. Make a resin with a hydrophilic part	42. Use a reversible glue (F)
12. Treat the surface with zeolite	43. Apply a vacuum adhesive (V)
13. Use a zinc coating primer	44. Use an adhesive developed for the bathroom (V)
14. Spray on a silicone coating	45. Use candle wax (F)
15. Use neoprenephenolic as the adhesive (R-59)	46. Try water based adhesives (R-11)
16. Invent an adhesive that reacts with water	47. Use natural rubber (R-6)
17. Use a silica gel for surface treatment (F)	48. Use spider web (F)
18. Choose a van der Waals bonding material	49. Use asphalt
19. Try ionic bonding (F)	50. Eliminate metal from cars (F)
20. Use a water scavenger in the adhesive base	51. Use rope to tie up the metals
21. Treat the surface with alkali	52. Use bubble gum (F)
22. Use corn starch (F)	53. Make plastic or fiberglass cars (F)
23. Use an adhesive with a functional group that reacts with water	54. Don't use cars (F)
24. Use an isocynate with a water reactive part (R-23)	55. Use flower tapes (F)
25. Inject acidic salt in the metal (F)	56. Blow dry the surface
26. Use more adhesive (F)	57. Use toluene as the base solvent (R-4)
27. Use a concrete cement	58. Get water resistance by using nitrocellulose/polyisobutylene
28. Choose a water catalyzed polymer	59. Use a phenolic group
29. Choose an adherent with a water reactive part (R-23)	60. Use a zipper (F)
30. Use a water scavenging adhesive (R-20)	
31. Add a catalyst to speed up the reaction	

SOLUTION

To begin to sort these ideas, the team considered which seemed folly, vague, or redundant. These are labeled as F, V, or R in Table 3.3–1. The remaining ideas were grouped under the five rough headings shown in Table 3.3–2. These include improving existing adhesives and treating the metal surfaces. Note the final heading, a collection of ideas that the team felt had merit, but that are hard to imagine in practice.

Interestingly, in this case, the team felt that it found no competitive advantage for a new product. This product development was abandoned.

TABLE 3.3–2 Sorted Ideas for Wet Metal Adhesives

I. Improvements in Existing Adhesives
   A. Choose a van der Waals bonding material (18).
   B. Use an adhesive + a functional group that reacts with water (23).
   C. Add catalyst to speed up the reaction (31).
   D. Coupling chemistry (32).
   E. Apply a vacuum adhesive (43).

II. Water-Absorbing Adhesives
   A. Make the adhesive water absorbing (4).
   B. Make a resin with a hydrophilic part (11).
   C. Invent an adhesive that reacts with water (16).
   D. Use a water scavenger in the adhesive base (20).
   E. Choose a water catalyzed polymer (28).

III. Surface Treatments
   A. Treat surface with zeolite (12).
   B. Use zinc coating primer (13).
   C. Spray on a silicone coating (14).
   D. Treat the surface with alkali (21).
   E. Try a polymer with a protective layer and heat to use (34).
   F. Blow dry the surface (56).

IV. New Innovations
   A. Change the metal's composition (2).
   B. Use a natural rubber (6).
   C. Electrostatically charge the metal (7).
   D. Invent an adhesive that reacts with metal (37).
   E. Get water resistance with nitric cellulose/polyisobutylene (58).
   F. Use a phenolic group (59).

V. Curiosities
   A. Use a concrete cement (27).
   B. Use asphalt (49).
   C. Use rope to tie up the metals (51).

Note: The numbers in parentheses refer to Table 3.3–1. The ideas in boldface are felt to be the most promising.

EXAMPLE 3.3–2 REUSABLE LAUNDRY DETERGENTS

Our start-up company has raised considerable resources to seek pollution preventing, environmentally benign chemical technologies. Without many specifics, the company's prospectus promises "reusable detergents." These should be more attractive ecologically than many existing "environmentally friendly" detergents, some of which have high sodium hydroxide concentrations. A few consumer surveys generated product ideas like those shown in Table 3.1–1.

Sort these ideas so that we can begin to choose those that are most promising for development.

SOLUTION

The ideas in the earlier table break into the four groups shown in Table 3.3–3. The numbers shown in parentheses refer to the particular ideas in Table 3.1–1. These four groups represent different regions on the intellectual triangle in Figure 1.2–1. For example, those under heading "I. New Soap" is close to the "chemistry" corner of the triangle. "I.A. Chemistry" is nearest this corner. "1.B. Easier to Recycle" also depends to some extent on chemical engineering. The heading "II. New Washer Design" is going to be dominated by mechanics, and be relatively independent of chemistry.

This organization of ideas shows immediately that our new company needs to choose between several, very different strategies. The first heading implies making a new soap, and so makes sense for a company like Proctor & Gamble, who already make conventional detergents. It would be a major new initiative for a company like Whirlpool, whose current business centers on making washing machines. Whirlpool has already explored the topics under "II. New Washer Design." Interestingly, the washing machines available in Europe are dramatically more expensive and slower than those available in North America. However, European machines use both less water and less detergent, and hence cause less environmental intrusion.

TABLE 3.3–3 Sorting Ideas for Reuseable Laundry Detergents

- I. New Soap (4, 9, 11, 37)
  - A. Chemistry
    - 1. Base (24)
    - 2. Powders (8, 17, 18, 32, 39, 46, 50)
    - 3. Biochemical (5, 6, 7, 15)
    - 4. Emulsions (14)
  - B. Easier to recycle (48)
    - 1. Size (12, 13, 14, 16, 26, 47)
    - 2. Temperature (14, 36, 38, 45)
    - 3. pH (35)
    - 4. Other chemistry (49)
- II. New Washer Design (3, 10)
  - A. More mechanical energy
    - Ultrasonic and pressure waves (40, 42)
  - B. Thermal energy
    - 1. Cooking (43)
    - 2. Freezing (44)
  - C. Light (41)
- III. Improved Dry Cleaning (1, 27, 28, 48)
  - A. Altered equipment
    - 1. Sealed (29)
    - 2. Supercritical (30, 31)
  - B. New solvents (33)
    - 1. Gases (19, 20)
    - 2. Liquids (30)
- IV. New Directions
  - A. Disposable clothing (2, 34)
  - B. Soil resistant clothing (21)
  - C. Altered mores (22, 23, 25)

Note: The numbers in parentheses refer to the ideas given in Table 3.1–1.

EXAMPLE 3.3–3 A POLLUTION PREVENTING INK

A printing company prints personal checks with a lithographic ink containing the carcinogenic solvent methylene chloride (CH_2Cl_2). Workers at this company also clean the presses by wetting a shop rag with the same solvent, and scrubbing down the press. This procedure works well. The trouble is that much of the methylene chloride evaporates and so risks workers' health and censure from the environmental authorities. Also, the soiled rags have recently been reclassified as a hazardous waste, so that the cost of their disposal almost equals the cost of buying the solvent in the first place.

The company clearly needs to use a different ink, one that has less negative environmental impact. Some ideas for this ink are shown in Table 3.1–2. Sort these ideas to identify those most worth pursuing.

SOLUTION

The ideas easily break into four groups, as shown in Table 3.3–4. Again, the numbers in parentheses refer to the original sequence of ideas, which in this case are in Table 3.1–2. The first group in Table 3.3–4 involves changes in the printing presses. Because the company does not want to make the enormous capital investment involved in changing the presses, this group is deferred until other alternatives have been explored.

The second group of ideas involves either containing the solvent or using a different solvent. These ideas are the easiest to implement, and hence the most tempting for further development. The third group of ideas implies the invention of a new ink, a more major effort than the substitution of a new solvent. We will explain this option more in Section 4.1.

The final idea, "Don't Use Checks," may initially seem foolish; but consider the explosion in electronic money transfers. The company may decide that electronic data processing, which replaces handwritten checks, is like the automobile which replaced the horse-drawn buggy. If so, then printing checks may be like making buggy whips. Thus this fourth idea should be carefully considered in the idea screening process that is to follow.

TABLE 3.3–4 Sorting Ideas for a Pollution Preventing Ink

- I. Improve Current Printing
  - A. Change press (4)
    - 1. Isolate press (3, 11, 12, 14, 17)
    - 2. Use laser printer (6)
    - 3. Use photocopying (32)
  - B. Change cleaning
    - 1. Less often (13, 15)
    - 2. Other solvents (9, 23, 24, 25, 27)
- II. Use a New Solvent
  - A. Change CH_2Cl_2 operation
    - 1. Recycle (8)
      - a. Extract (10)
      - b. Spin dry (new)
    - 2. Burn (27)
    - 3. Freeze (new)
  - B. Replacement of CH_2Cl_2 (2, 20)
    - 1. Nonvolatile solvent (21)
    - 2. Oil as solvent (31)
    - 3. Solvent mixtures (16, 18)
- III. Solvent-Free Ink Chemistry (1, 7)
  - A. Electrostatic ink (5)
  - B. "Solvent that dissolves ink" (19)
- IV. Don't Use Checks (29)

Note: The numbers in parentheses refer to the ideas suggested in Table 3.1–2.

4.4 PREGLED IDEJ ("SCREENING")

Pri načrtovanju preprostih produktov lahko po razvrščanju idej ostane v igri samo še ena ali mogoče dve ideji. Takrat fazo pregleda idej preskočimo.
Pri načrtovanju bolj zahtevnih produktov pa je potreben dodaten pregled idej, ki vključuje ugotavljanje prednosti in slabosti idej, primerjavo idej med seboj ter izbor najboljših idej (do 5 izmed cca 20), ki se uvrstijo v naslednjo fazo - izbor idej. Pri tem uporabljamo kvantitativne izračune, kvalitativne ocene in različne objektivne (Na primer odločimo se tako, da bo produkt imel boljšo tehnično specifikacijo ali da bo produkt cenejši...) in subjektivne (Na primer odločimo se za bolj varen produkt, čeprav ni najcenejši...) kriterije. Odločitve pogosto predstavljajo kompromise med različnimi kriteriji.

Strategija za pregled idej

Strategij je več. Ena izmed bolj učinkovitih je izbor najpomembnejših kriterijev, na osnovi katerih ocenjujemo produkte. Ti kriteriji pogosto vključujejo:

- zrelost znanosti in tehnologije,
- enostavnost izdelave produkta,
- minimalno tveganje,
- nizka cena,
- varnost,
- vpliv na okolje.

Pomembni so tudi bolj subjektivni kriteriji (Primeri: "Produkt mora delovati tiho.", "Produkt mora biti udoben."...)

Izberemo do pet kriterijev, po katerih ocenjujemo ideje za produkt. Njihov izbor mora biti dosežen s konsenzom projektnega team-a.

Izbranim kriterijem pripišemo pomembnost z utežnimi faktorji, ki so normirani. Pomeni, da je vsota vrednosti vseh utežnih faktorjev 1. Navadno pripisovanje utežnih faktorjev posameznim kriterijem poteka bistveno hitreje kot sam izbor kriterijev.

Ko so kriteriji in njihovi utežni faktorji določeni, projektni team ocenjuje ideje z ocenjevanjem posameznih kriterijev. Uporablja se lestvica (navadno od 1 do 10). Za referenčni produkt je navadno ocena vseh kriterijev 5. Končna ocena posamezne ideje je vsota produktov ocene kriterija in njegovega utežnega faktorja.

Ker se samo ideje z največjim številom točk uvrstijo v naslednjo fazo projekta, v kateri se izbere prava ideja, je smiselno, da se smiselnost dobljenih rezultatov še enkrat preveri oziroma se pregled idej še enkrat preigra in, če je to potrebno, izboljša. Nekaj možnosti:

- Preverimo ali je bil referenčni vzorec (obstoječi produkt, konkurenčni produkt na tržišču, nov produkt, ki ga konkurenca lahko naredi...) smiselno izbran. Da se o tem prepričamo, lahko izberemo drug referenčni produkt in ponovimo ocenjevanje.
- Poiščemo še drugo mnenje. Primerjamo rezultate ocenjevanja projektnega team-a z rezultati ocenjevanja drugih ekspertov (predstavniki managementa, ki niso člani projektnega team-a, vodilni uporabniki). Pri tem se je potrebno zavedati, da so neinformirani ljudje navadno konzervativni.
- Naredimo analizo občutljivosti utežnih faktorjev. Utežne faktorje spreminjamo v smiselnih mejah in preverjamo ali se vrstni red idej pri tem pomembno spremeni. Če se, je potrebno še enkrat premisliti ali so kriteriji in njihovi utežni faktorji pravilno izbrani.

Opisana strategija je manj primerna, če se ideje za produkte med seboj zelo razlikujejo. Linearno ocenjevanje in linearna utežitev kriterijev ni primerna, ko:

- je kriterij binaren. (Na primer: Produkt je glasen ali tih, nič vmes.)

- obstaja možnost, da produkt ne bo deloval. (Na primer, ko je najbolje ocenjen produkt osnovan na inovaciji, ki lahko ne bo mogoča.)
- bo produkt spremenil tržišče. Pomeni, da mora biti inovacija tako dobra, da so vsi ostali kriteriji nepomembni.

Primer, ko produkt spremeni tržišče: Tiskarski stroj (Vir: E. L. Cussler in G. D. Moggridge, Chemical Product Design, Cambridge University Press, Cambridge, 2001.)

The truly innovative products, those that change the market, are the real concern. Even the vocabulary used to describe these products is different. They are "show stoppers," "game changers," or "step-out technologies." They are "out of the box," that is, conceived beyond current thinking. They are hard to find and hard to recognize.

As one vivid example, imagine that you are William Caxton in 1476. You are trying to decide whether it makes sense to print Chaucer's "Canterbury Tales,"

TABLE 3.4–1 Concept-Screening Matrix for Printing Chaucer's Canterbury Tales

Selection Criteria	Weighting Factor	Illuminated Manuscript	Printed Chaucer
Quality	0.4	5	1
Cost	0.4	5	6
Quantity	0.2	5	8
Total Score		5	4.4

Note: This matrix could be one developed by William Caxton, in 1476.

or continue to produce illuminated manuscripts. You might develop the concept-scoring matrix shown in Table 3.4–1. Your three scoring criteria are the quality of the finished product, its cost to produce, and the quantity that you can make. The illuminated manuscript is the benchmark and so gets a score of 5 for each criterion. The illuminated manuscript is of much higher quality than a smudged and crooked printed version of Chaucer, so the printed edition gets a low score for quality. The cost of the printed Chaucer is less, but that is not a big advantage: the monks, those postgraduate students of the Middle Ages, work for nothing. What would they do if they were not copying manuscripts? Finally, you can make more printed Chaucers. But the market is limited to the literate, mostly the monks. Thus the quantity you can make is not important. Thus, as Table 3.4–1 shows, it does not make sense to print books.

With historical hindsight, we know this conclusion is wrong: it does make sense to print books. The use of moveable type in printing was an enormous technical innovation. However, we should admit that recognizing such advances at the time will always be hard. In this sense, we should remember that when he first printed Chaucer, William Caxton was not a printer. He was a wool merchant: perhaps, he was looking for an outlet for excess sheepskins, which are of course the feedstock for parchment. He may have begun printing Chaucer to use up extra sheepskins. With this cautionary example in mind, we turn to a harder, technical example.

Primeri (Vir: E. L. Cussler in G. D. Moggridge, Chemical Product Design, Cambridge University Press, Cambridge, 2001.)

EXAMPLE 3.4–1 HOME OXYGEN SUPPLY

Those with lung disorders, including emphysema, can sometimes benefit from breathing air enriched with oxygen. This oxygen is presently supplied as cylinders of nearly pure oxygen, regularly delivered, just as those who live in remote areas may have regular deliveries of propane for use in cooking. Oxygen delivered in cylinders works well, but can be expensive. Shifting the cylinders around in the house can be difficult, especially if the user is older.

We want to find an alternative to gas cylinders to provide home oxygen. Our idea generation and sorting has led to two reasonable alternatives: membrane separation and pressure swing adsorption (PSA). The membrane separation uses selective hollow fibers in a module like a shell and tube heat exchanger, except with tubes less than 1 mm in diameter. It requires a pump to compress room air and force it across the fibers. This permeate air will contain perhaps 30% oxygen.

The PSA unit uses an adsorbant, which can be either oxygen or nitrogen selective. The adsorbant is often a zeolite. If the adsorbant is oxygen selective, then air at high pressure is forced through until the adsorbant is saturated. Then the flow is stopped and the pressure is released. The air coming out of the bed is enriched with oxygen. This system also requires a pump, as well as some valving.

Choose key factors and evaluate which of these ideas is better.

SOLUTION

In this simple case, the core team decided that there are three key factors: convenience, noise, and cost. The three factors are of roughly equal importance, with convenience marginally the more important. Noise may be unimportant to a geriatric patient who is deaf but it may be important to anyone who lives with the patient. Cost could be important if the patient pays for the system himself. However, the core team could decide that these costs will largely be borne by insurance or by health maintenance organizations, and that cost differences are not so important.

On this basis, we can prepare a concept-screening matrix like that shown in Table 3.4–2. This matrix shows the three selection criteria on the left-hand side of the table. The weighting factors for these criteria are shown in the second column, with convenience given a slightly greater importance than either noise or cost. The remaining three columns in the table give the scores of the three alternatives. Note that because it is the benchmark, the gas cylinder is always given the arbitrary score of 5. Note also that the hollow fiber membranes have the top score, followed by the PSA. However, we may find it harder to make a membrane with the desired properties than to locate an effective zeolite adsorbent.

TABLE 3.4–2 Concept-Screening Matrix for Home Oxygen Supply

Selection Criteria	Weighting Factor	Gas Cylinders	Hollow-Fiber Membranes	PSA
Convenience	0.4	5	8	8
Noise	0.3	5	4	2
Cost	0.3	5	7	7
Total Score		5	6.5	5.9

Note: Both membranes and PSA score better than cylinders delivered containing oxygen. However, no single process stands out compellingly.

EXAMPLE 3.4–2 HIGH-LEVEL RADIOACTIVE WASTE

This complex example is unusual in that the product is actually a chemical plant. The manufacturer of the product will be one of a handful of aerospace companies; the customers will be the US Department of Energy, British Nuclear Fuels Limited, and other similar agencies. The example is included because it dramatically illustrates how the ideas of product design tend to precede those of process design, as discussed in Section 1.4.

The technical problem is as follows. In the manufacture of atomic weapons, a significant number of by-products are made. Many of these by-products are dangerously radioactive isotopes; most of these are actinides which precipitate in basic solution. These precipitated isotopes are then separated and vitrified, that is, made into glass. The glass is sufficiently radioactive that it can boil water. It must be safely stored for thousands of years.

However, one highly radioactive isotope of cesium, ^{137}Cs, is not precipitated in base but remains dissolved in aqueous solutions. Millions of gallons of this aqueous solution are stored in aging tanks in the locations where the atomic weapons were manufactured. If the tanks leak because of aging or earthquakes, the escaping cesium would spell disaster.

Not surprisingly, there has been a recent major effort to develop a means to make the ^{137}Cs less dangerous. Some of the 180 serious ideas suggested for this are shown in Table 3.1–3. These ideas are sorted as shown in Table 3.4–3. The organization has an unsurprising form: the first heading (I) deals with improvements to the existing process; the next four (II to V) are essentially separation processes organized as unit operations; and the last heading (VI) centers on innovations. The innovations include technically feasible ideas that are certainly politically unacceptable. In particular, idea 23 suggests setting off nuclear weapons inside the existing storage tanks to use the heat to vitrify the entire contents of the tank *in situ*. It could work, and it would be inexpensive because the nuclear weapons are in inventory; but it is not politically feasible or morally justified.

Develop a concept-screening matrix which can choose among the ideas in Table 3.4–3 to find a small number for further development.

SOLUTION

Because this problem is so complex, we will offer only a partial solution here. Details of the decision are only partially available publicly, and the final choice of a treatment has not yet been made (in 2001). Still, the problem is a superb example of the power of the methods suggested in this section.

We begin by describing our benchmark, the existing process, and by choosing the screening criteria. The existing process hinges on the precipitation of the cesium cation with the tetraphenylborate anion:

$$Cs^+ + B(C_6H_5)_4^- \rightarrow CsB(C_6H_5)_4.$$

This anion also precipitates potassium ions, present in nonradioactive form at much higher concentrations than cesium. However, the sodium ion, which is the chief cation present, does not precipitate. Thus we can precipitate the radioactive cesium by adding saturated solutions of sodium tetraphenylborate. The resulting process separates and concentrates the cesium about 20,000 times.

In the existing precipitation process, the cesium precipitate is made in large quantities and then stored. It has to be slowly added to the other radioactive precipitates, and eventually vitrified into glass. Unfortunately, the cesium precipi-

TABLE 3.4–3 An Outline of Ideas for High-Level Waste

I. Improve Current Process
   A. Increase storage capacity (14, 17)
   B. Stabilize precipitate (4, 6, 36, 39)
   C. Legalize – more benzene release (41)
   D. Vitrify without separation (38, 49)
II. Separate by Precipitation (45)
   A. Process alternatives
      a. Make fast (10)
      b. Flocculate (32)
   B. Stabilize current precipitate (15)
      a. With catalyst poison (6)
      b. By chilling tanks (18)
   C. New selective precipitate (12, 42, 46)
III. Separate by Adsorption (44)
   A. Process alternatives
      a. Simulated moving bed (21)
      b. Fluidized bed (29, 47)
   B. Regenerable ion exchange (13, 25)
      a. Crown ethers (35)
      b. $MnFe(CN)_6$ (31)
      c. Electrically switched ion exchange (27, 34)
   C. Nonregenerable ion exchange
      a. On glass
      b. On crystalline silicon titanate (2, 24)
IV. Separate by Extraction
   A. Process – hollow-fiber membranes (16)
   B. New chemistry
      a. Caustic with zeolite or crown ether (3, 5)
      b. Acidic (26)
V. Less Conventional Separations
   A. Fractional crystallization (8, 33, 43)
   B. Decantation (40)
   C. Electrochemical methods (7, 11, 37, 48)
   D. Microbes (23)
VI. Stabilize Without Separation
   A. Into bedrock (1, 22)
   B. As concrete grout (9, 20, 30)

Note: The numbers refer to the specific ideas listed in Table 3.1–3.

tate is not stable: it decomposes to produce soluble cesium and benzene. Because benzene is volatile, the tanks where the precipitate is stored can have inflammable benzene vapor collecting in the headspace above the precipitate. As a result, this headspace is continually flushed with nitrogen. Although storing the unstable precipitate may look foolish now, the precipitate was not expected to be unstable. It is unstable because the waste contains parts per billion of palladium, which catalyzes this decomposition. The active role of this palladium was unexpected.

The screening criteria for this waste treatment center on finding a process that works now. This means that the two most important criteria are known science and reliable engineering. Each of these was given a weighting factor of 0.4. Two other important criteria are safety and the public response, each of which was given a weighting factor of 0.1. Note that cost does not appear in these criteria, an implicit recognition that all of these choices will be expensive. Note also the relatively low weighting factor for public response. This does not imply that public response is unimportant, or that the public may not veto any one of the choices. At this point, however, those involved – the core team – felt that choosing a process that was scientifically and technically reliable was paramount.

Each of the processes in Table 3.4–3 is then scored by using these criteria. Typical scores for four of these processes are shown in Table 3.4–4. These four are all reasonable alternatives: each could work well.

The processes in Table 3.4–4 merit more detailed discussion. "Precipitation and fast treatment" is closest to the existing process. It begins by precipitating the cesium tetraphenylborate, but under more controlled conditions than those used at present. Once the precipitate is formed, it is separated and forwarded to vitrification before significant decomposition can occur. For this option, the science and engineering are in good shape, and the safety and public response should be similar to that for the existing process.

The second and third options both replace the tetraphenylborate precipitation with the new chemistry of macrocyclic ethers, exemplified by the compound dibenzo-18-crown-6:

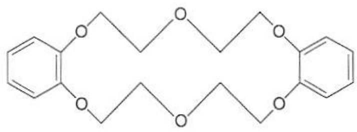


TABLE 3.4–4 Sample Scores for Four of the Processes for Treating Radioactive Waste Containing ^{137}Cs

Selection Criterion	Weighting Factor	Precipitation and Storage Benchmark	Precipitation and Treatment (II.A.a)	Crown Ether Ion Exchange (III.B.a)	Crown Ether Extraction (IV.B.a)	Concrete Formation (VI.B)
Mature science	0.4	5	9	3	2	6
Reliable engineering	0.4	5	7	6	9	8
Safety	0.1	5	5	4	8	10
Public response	0.1	5	5	5	5	1
Total score		5	7.4	4.5	5.7	6.7

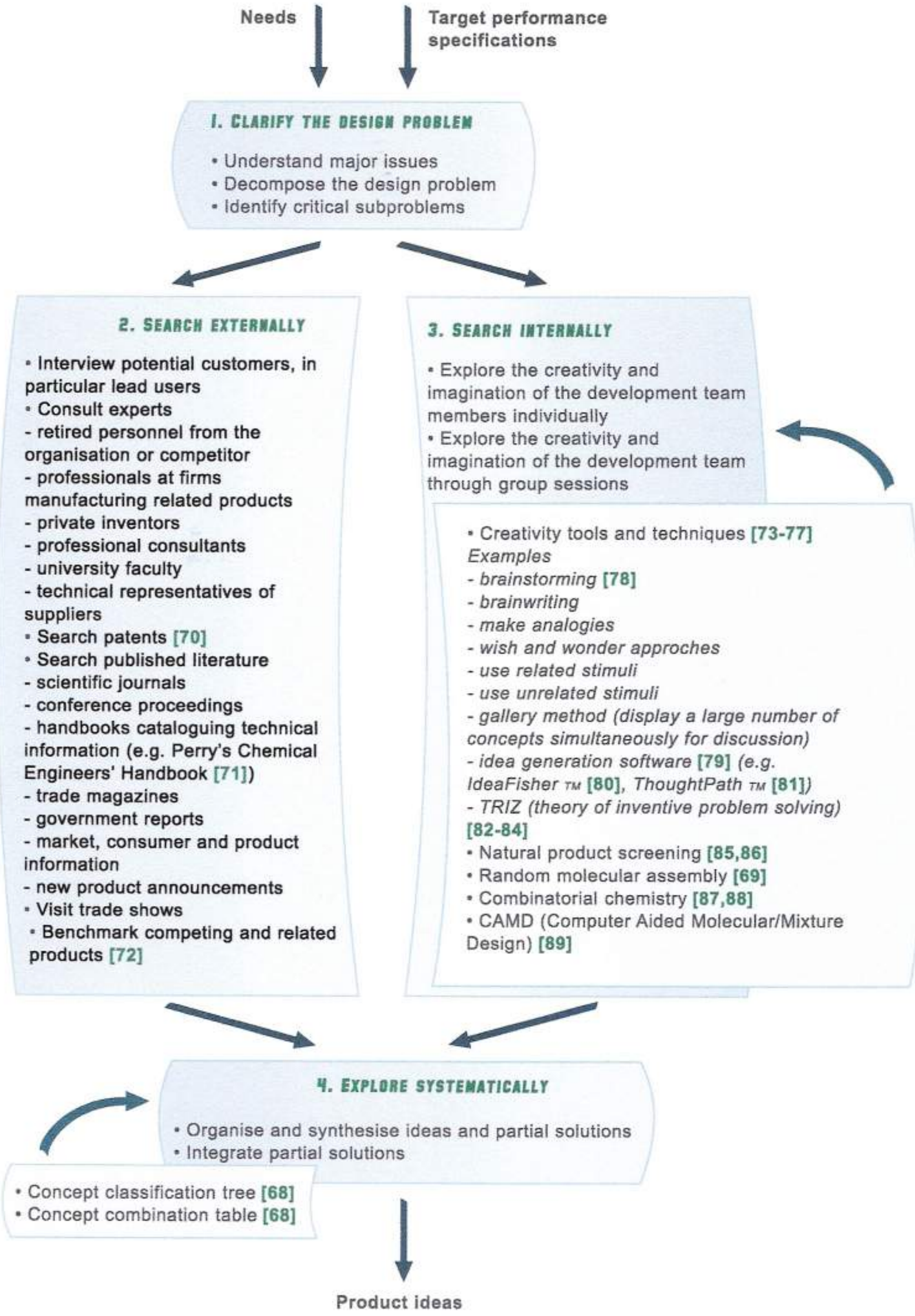
Note: The screening procedure described and the scores are a simplification of the actual method used.

Compounds like this species can selectively complex specific cations like cesium. Some specific materials suitable for both ion exchange and liquid-liquid extraction are known. However, only small amounts (perhaps 100 g) have been made. Commercial suppliers are either nonexistent or underfunded academic spin-offs. This means that both these options have low scores on scientific maturity. Nonetheless, an alternative like this was attractively developed by a laboratory at one of the sites where atomic weapons had been produced.

The final "concrete formation" option is the most risky. In this option, we would not try to separate the cesium at all, but simply turn the entire contents of the storage tank into a concrete-like solid, called "grout." While the science for such a high-salt grout needs a little work, the engineering is straightforward. The process is safe: because we do not concentrate the cesium, the waste remains in the less dangerous "low-level" form.

The risk is the public's response. Instead of concentrating the waste and shipping it to some distant desert storage, the waste is simply immobilized and left where it is. Local citizens and their elected officials will not like that, even though they have been happy to have the jobs that making atomic weapons has supplied. Although making grout is legal within the letter of existing laws, the public's response may engender so much litigation that the solution of the problem of radioactive waste is delayed and the danger of accidental release is increased. Still, this alternative is a strong contender. In more general terms, you can now see why we wanted such a complex example: it really does show how different alternatives must be carefully weighed.

Shematski prikaz generacije idej za produkt:
Vir: http://www.engsc.ac.uk/an/mini_projects/cpd/index.html (6.9.2011)



Systematic approach to idea generation.

Primer generacij idej za nov produkt: Pijača z mehurčki:
Vir: http://www.engsc.ac.uk/an/mini_projects/cpd/index.html (6.9.2011)

Po fazi "Ideje" jedro projektnega team-a pripravi drugo fazno pisno poročilo in drugo fazno ustno predstavitev aktivnosti in rezultatov projekta. Na predstavitvi sodelujejo tudi vodilni iz managementa organizacije. Po predstavitvi mora pasti odločitev ali se delo na projektu nadaljuje.