Editor's note: Gennady Retseptor is the author of very popular articles on examples of the 40 principles in microelectronics and quality management. This article starts to collect examples from sales, marketing, advertising and negotiation—the editors have added a few more examples to Gennady Retseptor's list, and readers are invited to add more, and share them!

40 Inventive Principles

in Marketing, Sales and Advertising

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Continuing to search for various non-technical applications of 40 Inventive Principles, which have been received favorably in spheres related to quality management [9], the author presents his collection of marketing, sales and advertising examples.

Principle 1. Segmentation

A. Divide an object or system into independent parts.

- ***Market segmentation: clustering prospective buyers into groups that have common needs.***
- ***Sales splitting between customers.***
- ***Autonomous sales region centers.***
- ***Division and sorting advertisements by categories.***

B. Make an object or system easy to disassemble.

- *Separate a sale into permanent and replacement part, requiring constant new purchase. S.C. Johnson's business strategy, for aroma products especially, and famous as the Gillete strategy—sell the razor cheaply, or give it away, then sell the blades.*

C. Increase the degree of fragmentation or segmentation.

- ***Mass customization: each customer is a market. Publix supermarkets in FL prints out instantly, as you shop, coupons on the back of your receipts from competitors of what you bought!***
- ***Stratified sampling for heterogeneous customer population.***
- ***Product advertisement mini-kits.***

D. Transition to micro-level.

- ***Description of product function in advertisement on micro-level (e.g. food, drugs advertised based on molecular properties).***

Principle 2. Taking Out

A. Separate an interfering part or property from an object or system, or single out the only necessary part or property of an object or system.

- ***Separating from competitors by emphasizing product differences in advertisement.***

- ***Outsourcing: subcontracting marketing, sales and advertising activities.***

- ***Cluster analysis: distilling qualitative customer feedback into quantitative data.***

- ***Impersonal anonymous questionnaire and telephone interview to preserve confidentiality at survey.***

- ***Separate shelves for discounted goods. Shelf space is also determined by promotion fees from suppliers.***

Principle 3. Local Quality

A. Change an object or system structure from uniform to non-uniform, change an external environment (or external influence) from uniform to non-uniform.

B. Make each part of an object or system function in conditions most suitable for its operation. *Regional variability in gasoline octane, volatility, emissions done all the time.*

C. Make each part of an object or system fulfill a different and useful function.

- ***Regional marketing. Stores, including restaurants, have local menus. McDonald's has a different menu Florida that has Hispanic items, in India with mutton and vegetarian items, not beef, etc.***

- ***Locating distribution centers near customers.***

- ***Choosing trade location at heavily popular areas.***

- ***Hiring local people to acquire cultural knowledge of local customers.***

- ***Selecting market segments on which organization will focus.***

- ***Differential strategy development approach for each market segment.***

- ***Addressed advertising by the use of customer perceived needs (image, prestige) for each customer stereotype.***

- ***Emphasizing product or service advantages in advertisement.***

- ***Targeting sales for purchase occasion (routine use, present, season, weather, vacation, etc).***

- ***Benefits, bonuses, extra service for the most valuable customers.***

- ***Customized marking, packaging, labeling.***

- ***Focus groups for customer preferences study.***

- ***Forced allocation survey type: quantifying customer preferences for product or service features.***

- ***Smoothing technique for conflict resolution: emphasizing areas of agreement, de-emphasizing areas of disagreement, seeking a joint problem solving opportunity.***

Principle 3 (inverted). Global Quality

- ***Mass marketing: market with no segmentation.***
- ***'Carpet bombing' advertisement.***
- ***Census instead of sampling survey.***

Principle 4. Asymmetry

A. Change the shape of an object or system from symmetrical to asymmetrical.

B. If an object or system is asymmetrical, change its degree of asymmetry.

- ***Market of buyer vs market of seller.***
- ***Male and female product or service orientation.***
- ***Left and right side handling products.***
- ***'Customer is always right' approach at all disputable issues.***

Principle 5. Merging

A. Bring closer together (or merge) identical or similar objects or systems; assemble identical or similar parts to perform parallel operations.

B. Make operations contiguous or parallel; bring them together in time.

- ***Business synergism: partnership, merger, alliance.***
- ***Network of sales intermediaries.***
- ***Selling sets, discount packages (e.g. 1+1 for price of 1). More commonly known as cross-selling, a well known marketing concept.***
- ***Coupons of neighborhood shops and services.***
- ***Serial labels (e.g. film heroes, sport teams).***
- ***Bounty for labels collection.***

Principle 6. Universality

A. Make an object or system perform multiple functions; eliminate the need for other parts.

- ***Greater diversity of products or services offering due to increased level of customer expectations.***
- ***Marketing of products with multiple functions.***
- ***Combining non-traditional with traditional service (e.g. money exchange in post office).***
- ***Marketing agency with integrated sales and advertising functions.***

B. Use standardized features.

- ***International quality standards.***
- ***Standardized forms for record of key customer information.***

Multiple function products (Eveready new flashlight can use any size battery).

Principle 7. Nesting

A. Place one object or system inside another; place each object or system, in turn, inside the other.

- ***Product niches inside market segments.***
- ***Niches inside niches.***
- ***Plant or store shops.***
- ***Including information about other similar or related products or services into advertisement.***

B. Make one part pass through a cavity in the other.

- ***Surprise selling benefits (e.g. extra-service incorporation into flight package).***

Principle 8. Anti-Weight

A. To compensate for the weight (downward tendency) of an object or system, merge it with other object or system that provides lift.

B. To compensate for the weight (downward tendency) of an object or system, make it interact with the environment (e.g. use global lift forces).

- ***Using business driving forces and global events for marketing, sales and advertisement promotion.***
- ***Cooperation with brand name bodies.***
- ***Advertisement by media, movies, video, stories, concerts, sport games.***
- ***Using bazaars, fairs, festivals for marketing, sales and advertisement.***
- ***Benchmarking on industry leaders.***
- ***'Champion customer always buys our product' –use endorsements by high-profile celebrities in advertising.***

Principle 9. Preliminary Anti-Action

A. If it will be necessary to do an action with both harmful and useful effects, this action should be replaced with anti-actions to control harmful effects.

- ***Get intelligence on competitors' products or services to anticpate their actions.***
- ***Use patents, licenses, copyrights, etc., for proprietary rights protection.***
- ***Do customer perception surveys to anticipate harm to your reputation.***
- ***Use statistics of past behavior to reveal situations for potential customer defection (switch to competitor).***
- ***Beforehand negation of negative client stereotype.***

B. Create beforehand stresses in an object or system that will oppose known undesirable working stresses later on.

- ***Customer trials, pilot sales of high-risk new products or services.***

- ***Stretching internal vs external specification requirements (safety margins).***
- ***Starting from tough offer, higher price during sales negotiations.***
- ***Mistake-proofing (poke-yoke) product or service design.***

Principle 10. Preliminary Action

A. Perform, before it is needed, the required change of an object or system (either fully or partially).

- ***Preliminary market research, before the product/service is designed.***
- ***Preliminary advertising at the stage of product or service development.***
- ***Selling of semi-fabricated products.***
- ***Pre-paying.***
- ***Red-line position prior to sales negotiation.***
- ***Introductory questions for customer priming at survey interview.***

B. Pre-arrange an object or system such that they can come into action from the most convenient place and without losing time for their delivery.

- ***Building stock profile and placing pre-orders for cycle time reduction.***
- ***Pre-arranged documents for sale (price list, payment bills, etc).***

Principle 10 (inverted). Afterwards Action

- ***Post-paying.***
- ***After-sales service.***
- ***Bounty for purchase, service or labels collection.***
- ***Rebate coupon for next purchase or service.***
- ***Lottery with partial price reimbursement.***
- ***Keepsake - token for memory.***

Principle 11. Beforehand Cushioning

A. Prepare emergency means beforehand to compensate for the relatively low reliability of an object or system.

- ***Sales splitting between customers to prevent drop in sales due to unexpected decrease in demand from one major customer.***
- ***Contingency clauses in contracts.***
- ***Mistake-proofing product or service design.***
- ***Excess inventory.***
- ***Emergency telephone (fax, e-mail), web technical support, troubleshooting guide, help file, frequently asked questions.***

- ***Recovery system for response to customer complaint and conflict resolution.***

- ***Back-ups (communication channels, computer data, etc).***

Principle 12. Equipotentiality

A. In a potential field, limit position changes (e.g. change operating conditions to eliminate the need to raise or lower objects in a gravity field).

- ***Off-shore trading zones.***

- ***Marketing, sales and advertisement promotion conduits.***

- ***Leveling of relationships with customer (language, terminology, analogies, etc).***

- ***Advertisement and technical literature translation to local language.***

- ***Smooth transfer of free temporary product or service use (e.g. web program) to permanent.***

- ***Free customer service telephone numbers.***

Principle 12 (inverted). Potentiality Gap

- ***Building entrance barrier for competitors.***

Principle 13. Inverse

A. Invert the action(s) used to solve the problem (e.g. instead of cooling an object, heat it).

B. Make movable parts (or the external environment) fixed, and fixed parts movable.

C. Turn an object, process, or system 'upside down'.

- ***'Push' instead of 'pull' marketing approach in order to direct customer needs and lead them to new products.***

- ***Manufacturing to customer order instead of manufacturing to stock.***

- ***Making designers 'to be the customers'.***

- ***Making marketing people to be (temporarily) purchasing agents and vice versa.***

- ***Managing complaints handling system, which proactively encourages customers to complain.***

- ***Survey and analyze lost customers instead of current customers***

- ***Getting customer to determine price by himself.***

- ***Reception of competitor coupons.***

Principle 14. Spheroidality (Use of curves, increasing curvature)

A. Instead of using rectilinear parts, surfaces, or forms, use curvilinear ones; move from flat surfaces to spherical ones; from parts shaped as a cube (parallelepiped) to ball-shaped structures.

B. Use rollers, balls, spirals, domes.

C. Go from linear to rotary motion, use centrifugal forces.

- ***Having rounded personalities to provide customer service.***
- ***Corner smoothing during negotiations.***
- ***Customer survey questionnaires circulation.***
- ***Rolling forecast of customers purchase requirements.***
- ***Rounded price figures.***

Principle 15. Dynamics

A. Allow (or design) the characteristics of an object, process, system, or external environment to change to be optimal or to find an optimal operating condition.

- ***Adapting to highly competitive business environment with dynamic customer needs and steadily increasing expectations.***
- ***Design for specific market niches.***
- ***Mass customization.***
- ***Flexible policy for price vs quantity.***
- ***Season prices.***

B. Divide an object or system into parts capable of movement relative to each other.

C. If an object, process, or system is rigid or inflexible, make it movable or adaptive.

- ***Mobile retail.***
- ***Electronic trade with mobile purchase delivery to client home.***
- ***Moving picture advertisement.***

Principle 16. Partial or Excessive Action

A. If 100 percent of an objective is hard to achieve using a given solution method then, by using 'slightly less' or 'slightly more' of the same method, the problem may be considerably easier to solve.

- ***Under-promising and over-delivery approach to achieve customer satisfaction.***
- ***‘Saturation’ advertising by all media for nurturing customer needs.***
- ***Compromising at conflict resolution.***
- ***Quoting more to allow reduction during price negotiations.***
- ***9, 99, 999 price figures.***
- ***Bargains. Discounts.***
- ***Embellishment of product features by advertisement.***
- ***Extra-weight, extra-service as a bounty.***

Principle 16 (inverted). All or Nothing

- ***Zero price for overdue delivery (Pizza Hot).***

Principle 17. Another Dimension

A. Move an object or system in two- or three-dimensional space.

- ***Multiple sources of information at marketing research.***
- ***Multi-dimensional customer surveys. Matrix tabulation of survey results.***
- ***Multi-dimensional factor and cluster analyses.***
- ***House of quality matrices (QFD).***

B. Use a multi-story arrangement of objects or systems instead of a single-story arrangement.

- ***Multi-level marketing.***
- ***Multi-level sales network.***

C. Tilt or re-orient an object or system, lay it on its side.

D. Use 'another side' of a given area.

- ***Interviewing both won and lost customers.***
- ***Printing bounty coupon on another side of purchase check.***

Principle 18. Mechanical Vibration

A. Cause an object or system to oscillate or vibrate.

B. Increase its frequency (even up to the ultrasonic).

- ***Frequently communicating with customer in multiple modes.***
- ***Making a fuss over customers, which have experienced a problem with product or service, in order to re-enforce their positive feeling to a level greater than that where no problem had occurred.***
- ***Creating buyer hesitation by inkling on alternative proffers during price negotiations.***

C. Use an object's or system’s resonant frequency.

- ***Probing for exact buyer boundaries during price negotiations.***

D. Use piezoelectric vibrators instead of mechanical ones.

E. Use combined ultrasonic and electromagnetic field oscillations. (Use external elements to create oscillation/vibration).

Principle 19. Periodic Action

A. Instead of continuous action, use periodic or pulsating actions.

- ***Periodical reminding advertisement for stable business image support.***

B. If an action is already periodic, change the periodic magnitude or frequency.

- ***Batch manufacture: small customized series.***

- ***Mass customization: totally individual production.***

C. Use pauses between impulses to perform a different action.

- ***Filling pauses during negotiations.***
- ***Using pauses and breaks in TV and radio translations for advertisement.***

Principle 20. Continuity of Useful Action

A. Carry on work continuously; make all parts of an object or system work at full load, all the time.

- ***Long-term business and marketing alliances.***
- ***Building customer retention.***
- ***Nurturing customer loyalty.***
- ***Satisfaction of customer needs as never ending challenge.***
- ***Using customer stereotype.***
- ***Building customer standards based on tradition.***
- ***Preserving company brand image.***
- ***Re-marketing, supporting marketing for steady demand.***

B. Eliminate all idle or intermittent actions or work.

- ***Synchro-marketing for periodical or season demand.***

Principle 21. Skipping

A. Conduct a process, or certain stages (e.g. destructive, harmful or hazardous operations) at high speed.

- ***Getting through money losing processes (e.g. discounts, sell-offs) quickly.***
- ***'Strike while the iron is hot'. Prompt decision making during negotiations. Fast anchoring of negotiation agreement by contract.***

Principle 21 (inverted). Lagging

- ***Awareness of lagged consumer reaction to advertisement.***

Principle 22. "Blessing in Disguise"

A. Use harmful factors (particularly, harmful effects of the environment or surroundings) to achieve a positive effect.

- ***Using customer complaints as opportunities for improvement.***
- ***Customers whose complaints are handled properly are more loyal than customers who never had a complaint.***
- ***The most loyal customer is a dissatisfied customer who later has all of his needs met.***

B. Eliminate the primary harmful action by adding it to another harmful action to resolve the problem.

- ***Eliminating fear of change by introducing fear of competition.***

C. Amplify a harmful factor to such a degree that it is no longer harmful.

- ***Restricting supply of product or service to create scarcity value.***

Principle 22 (inverted). "Cursing in Disguise"

- ***Lack of customer complaints could indicate a lack of customer candor and unwillingness to share information.***
- ***Advertisement saturation (e.g. web 'spam').***

Principle 23. Feedback

A. Introduce feedback (referring back, cross-checking) to improve a process or action.

- ***Marketing review.***
- ***Listening 'the voice of the customer' (survey, visit, report, focus group, interview, mail, feedback form, customer satisfaction checklist).***
- ***Customer response team.***
- ***Customer complaints and suggestions system.***
- ***Product or service guarantees: provide feedback data to organization on how products or services fail to meet customer needs.***
- ***Enlisting customers into design process.***

B. If feedback is already used, change its magnitude or influence.

- ***'Measuring customer skin temperature every day'.***
- ***Exposing designers as well as marketing people to customers.***
- ***Toll-free telephone numbers for consumer communication.***
- ***Website attendees counting.***
- ***Feedback buttons on website.***
- ***Bar-codes system in supermarkets: gathers information to assist future marketing decisions.***

Principle 23 (inverted). Feedforward

- ***Expert system for marketing research.***
- ***Marketing forecasting.***
- ***Anticipating customer future needs - the ideal basis for customer loyalty.***

Principle 24. Intermediary

A. Use an intermediary carrier article or intermediary process.

- ***Region sales offices.***
- ***Wholesalers.***
- ***Retailers.***
- ***Export/import agents.***
- ***Distribution systems (e.g. FedEx, UPS).***
- ***Third-party external certification bodies.***

B. Merge one object or system temporarily with another (which can be easily removed).

- ***Hiring consultant.***
- ***Using of neutral third party (arbitrator) during difficult negotiation.***

Principle 24 (inverted). Intermediary Removal

- ***On-line Internet marketing and sales.***
- ***Barter transactions.***
- ***Interview without interviewer (mail, telephone, e-mail, website).***

Principle 25. Self-Service

A. Make an object or system serve itself by performing auxiliary helpful functions.

- ***Self-benchmarking.***
- ***Self-competing.***
- ***Getting customers to advertise the organization's products or services.***

B. Use waste (or lost) resources, energy, or substances.

Principle 26. Copying

A. Instead of an unavailable, expensive, fragile object or system, use simpler and inexpensive copies.

- ***Measuring customer satisfaction as a measure of organization business wellbeing.***
- ***Imitation method of marketing research.***

B. Replace an object, process, or system with optical copies.

- ***Numerical simulation.***
- ***Virtual modeling.***
- ***Video-conferencing.***
- ***Trade mark, logo.***
- ***Franchising - trade mark license.***

C. If optical copies are used, move to IR or UV (Use an appropriate out of the ordinary illumination and viewing situation).

- ***Evaluating customer satisfaction using multiple techniques.***
- ***Getting customers to benchmark the organization.***
- ***Responding to perceived customer needs.***

Principle 26 (inverted). Anti-Copying

- ***Avoiding negative associations in advertisement.***

Principle 27. Cheap Short-Living Objects

A. Replace an expensive object or system with a multiple of inexpensive objects or systems, compromising certain qualities (such as service life, for instance).

- ***Inference statistics methods at survey: sampling instead of census.***
- ***Low paid, temporary staff (students, etc.) for telemarketing and telephone survey.***
- ***Voucher, coupon for sales promotion.***
- ***Sales of second-hand goods (cheaper than new goods)***

Principle 28. Mechanics Substitution

A. Replace a mechanical means with a sensory (optical, acoustic, taste or smell) means.

B. Use electric, magnetic and electromagnetic fields to interact with the object or system.

- ***Electronic communication.***
- ***Electronic trade.***
- ***Electronic auction.***
- ***Electronic tagging.***
- ***Electronic cards for demographic data collection at market testing.***
- ***Telemarketing.***
- ***Computerized interview.***
- ***Website attendees counting.***

C. Change from static to movable fields, from unstructured fields to those having structure.

D. Use fields in conjunction with field-activated (e.g. ferromagnetic) particles.

Principle 29. Pneumatics and Hydraulics

A. Use gas and liquid parts of an object instead of solid parts (e.g. inflatable, filled with liquids, air cushion, hydrostatic, hydro-reactive).

- ***Introducing ‘breathing spaces’ into contracts.***
- ***Sampling expansion during survey.***

Principle 30. Flexible Shells and Thin Films

A. Use flexible shells and thin films instead of three-dimensional structures.

- ***Customer service employee as a 'flexible shell' of the organization.***

B. Isolate the object or system from the external environment using flexible shells and thin films.

- ***Using 'trade secret' methods to separate organization's proprietary knowledge from general knowledge.***

- ***'Pacing on thin ice' during difficult negotiations.***

Principle 31. Porous Materials

A. Make an object or system porous or add porous elements (inserts, coatings, etc.).

- ***Customer-facing layer as a porous membrane, which filters information flow both into and out of the organization.***

B. If an object or system is already porous, use the pores to introduce a useful substance or function.

- ***Empowering customer-facing layer employees.***

Principle 32. Color Changes

A. Change the color of an object, system, or external environment.

- ***Creating a strong brand image through use of 'corporate colors'.***

- ***Different colors in mistake-proofing (Poka-Yoke) to prevent unintended use.***

B. Change the transparency of an object, system, or external environment.

- ***Smoke-screen misinformation to disguise confidential (e.g. R&D) activities.***
- ***Make packaging transparent to enable product self-advertising.***

- ***Convert position from transparent (encouraging trust) to opaque (keeping secrets) and vise versa during negotiations.***

Principle 33. Homogeneity

A. Make objects interact with a given object of the same material (or material with identical properties).

- ***Product families (brands).***

- ***Homogeneous customer sectors (clusters).***

- ***Homogeneous focus groups.***

Principle 34. Discarding and Recovering

A. Make portions of an object or system that have fulfilled their functions go away (discard by dissolving, evaporating, etc.) or modify them directly during operation.

- ***Subcontracting marketing, sales, or advertisement agencies.***

B. Conversely, restore consumable parts of an object or system directly in operation.

- ***Warranty: manufacturer commitment to repair or replace any part that fails during the life of product.***

Principle 35. Parameter Changes

A. Change an object's or system's physical state (e.g. to a gas, liquid, or solid).

- ***Virtual shopping (e.g. Amazon.com).***

B. Change the concentration or consistency.

- ***'Special offers' for sales promotions.***

C. Change the degree of flexibility.

- ***Introducing intelligence into on-line catalogues (search engines, expert systems, etc.).***
- ***Switching marketing of product or service to non-traditional customers.***

D. Change the temperature.

- ***Getting customers excited about the product or service by giving them sense of advantage over their competitors.***

E. Change other parameters.

- ***Selling non-material attributes (sense, image, function, etc).***

Principle 36. Phase Transitions

A. Use phenomena occurring during phase transitions.

- ***Awareness of S-curve for marketing and sales evolution - different product or service life stages: 'problematic child', 'star', 'milky cow', 'outsider'.***

Principle 37. Thermal Expansion

A. Use thermal expansion (or contraction) of materials.

B. If thermal expansion is being used, use multiple materials with different coefficients of thermal expansion.

- ***Expanding or contracting marketing efforts depending on the product 'hotness' - rate of sales and profitability.***

Principle 38. Boosted Interactions

A. Replace common air with oxygen-enriched air (enriched atmosphere).

B. Replace enriched air with pure oxygen (highly enriched atmosphere).

C. Expose air or oxygen to ionizing radiation, D. Use ionized oxygen, E. Replace ozonized (or ionized) oxygen with ozone (atmosphere enriched by 'unstable' elements).

- ***Using post-crisis enthusiasm for marketing and sales promotion.***
- ***Making sense of emergency for marketing and sales promotion.***
- ***Hiring highly creative individuals who understand 'the voice of the customer'.***

- ***Overcoming reluctance of dissatisfied customers to complain.***

Principle 39. Inert Atmosphere

A. Replace a normal environment with an inert one.

- ***Anonymous survey or interview.***
- ***Neutral, indifferent tonality of questions at survey and interview.***
- ***Awareness of employee indifference as a major reason for customer detection.***

B. Add neutral parts, or inert additives to an object or system.

- ***Using neutral third party during difficult negotiations.***

Principle 40. Composite Structures

A. Change from uniform to composite (multiple) structures.

- ***Multi-disciplinary marketing and sales teams, including different employee personality types.***
- ***Hard person/soft person negotiating team.***
- ***Combined high risk/low risk marketing strategy.***

References

1. Tate, K., Domb, E. “40 Inventive Principles with Examples”. The TRIZ Journal, July 1997.

2. Mann, D., Domb, E. “40 Inventive (Business) Principles with Examples”. The TRIZ Journal, September 1999.

3. Terninko, J. “40 Inventive Principles with Social Examples”. The TRIZ Journal, June 2001.

4. Mann, D., Ó Catháin, C. “40 Inventive (Architecture) Principles with Examples”. The TRIZ Journal, July 2001.

5. Mann, D., Winkless, B. “40 Inventive (Food) Principles with Examples”. The TRIZ Journal, October 2001.

6. Rea, K., C. “TRIZ and Software - 40 Principles Analogies”. The TRIZ Journal, September and November 2001.

7. Retseptor, G. “40 Inventive Principles in Microelectronics”. The TRIZ Journal, August 2002.

8. Mann, D. “Disruptive Advertising: TRIZ and the Advertisement”. The TRIZ Journal, October 2002.

9. Retseptor, G. “40 Inventive Principles in Quality Management”. The TRIZ Journal, March 2003.

10. Belski, I., Kaplan, L., Shapiro, V., Vaner, L., Wong Peng Wai. “SARS and 40 Principles for Eliminating Technical Contradictions: Creative Singapore”. The TRIZ Journal, June 2003.

11. Grierson, B., Fraser, I., Morrison, A., Niven, S., Chisholm, G. “40 Principles – Chemical Illustrations”. The TRIZ Journal, July 2003.

12. Hsiang-Tang Chang, Jahau Lewis Chen. “Eco-Innovative Examples for 40 TRIZ Inventive Principles”. The TRIZ Journal, August 2003.

13. Jun Zhang, Kah-Hin Chai, Kay-Chuan Tan. “40 Inventive Principles with Applications in Service Operations Management”. The TRIZ Journal, December 2003.

14. Marsh, D., Waters, F., Marsh, T. “40 Inventive Principles with Application in Education”. The TRIZ Journal, April 2004.

15. Dourson, S. “The 40 Inventive Principles of TRIZ Applied to Finance”. The TRIZ Journal, October 2004.

Working with Innovative Principles of Science, Engineering, Business and Everyday Life: Expanding on Altshuller's 40 Principles

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Genrich Altshuller developed one of the primary sources of innovative principles between 1946 and 1973. Genrich's 40 principles were developed as a result of his research of patents and the history of technology. From Genrich's point of view these principles were foundational and today they have been expanded well beyond his original work to encompass all areas of science, engineering, business and even everyday life.

When conducting any type of creative or innovative work with the underlying principles from any field it is important to look beyond the words to more fully understand the intent of the author. In the case of Altshuller's work or any work developed in a language different than your own the challenge is compounded by translations. The early translations, although well intended, are often simplifications of the author's work. Frequently, the first translations are crude and gradually become refined by people who are the early adopters of the methods or principles. This process of refinement transitions the definitions of the principles for more practical use.

The following analysis of one of Altshuller's 40 principles (an extraction from ***40 Principles: Extended Edition*** by Genrich Altshuller with commentary by Dana W. Clarke, Sr. and published by the Technical Innovation Center) demonstrates the transition from an early translation of the principle to its interpretation for practical application.

Altshuller was very talented at selecting Russian words that could be easily visualized and were memorable. Principle #3 of Altshuller's 40 Principles, "принцип местного качества" has more meaning in Russian than Lev Shulyak's first English translation for this principle, "Local Quality". This principle like many innovative principles has more than one part, for example Principle #3, Local Quality, as translated by Lev includes: a) transition from homogeneous to heterogeneous structure of an object or outside environment (action); b) different parts of an object should carry out different functions; and c) each part of an object should be placed in conditions that are most favorable for its operation.

Fully accepting Lev's translation and moving to the next level of interpretation for practical application, the understanding can be simplified with the following description:

> *Change the characteristic of something (gas, liquid, solid or system) in a specific area (locally) in order to gain a required functionality. Note: The word "system" is an addition that allows this principle to be easily expanded to cover human and organizational situations.*

Beyond this we can begin to identify more information that will support how the principle can be used, for example:

The Principle may more appropriately be called "Optimal Resource", which came from a discussion with Len Kaplan, because when using this principle, the features are made non-uniform or optimal for each particular location and/or moment in time. Even this definition leaves room for improvement but for individuals who are actively involved in TRIZ this definition should have some value as an option to "Local Quality".

Generally, it is assumed that system characteristics are similar everywhere and all of the time. Although the assumption is simple and easy to imagine, it does not reflect reality. By applying the "Local Quality" principle, we consider improving or degrading the conditions of a characteristic in order to provide optimal function ability. For example, we have a large steel part that is subject to wear in a specific area. In order to reduce wear we could heat treat a specific area. Alternately, in order to machine a specific area – such as drilling a hole in the hard material – we could anneal (soften) the area of interest.

Thus we can achieve optimum functionality by varying conditions in different places, at different moments, for different features.

To apply the Local Quality principle to a given system, identify a specific area that requires different characteristics for optimal performance. Suggestions for altering conditions may include using different forms of energy, such as:

- Mechanical (burnishing, cold working)
- Thermal (heat treating, cryogenic treatment)
- Chemical (oxidizing)
- Electrical (electrostatic charge)
- Magnetic (selective magnetization)
- Electromagnetic (radiation treatment such as chemotherapy)

Next we need examples to reinforce the definitions. Altshuller's work outwardly appeared to be focused on science and technology but there was much more behind it. When reading the definitions you need to look beyond the specific terminology and technical examples to discover that there is value in applying these principles in any area of life. The following examples demonstrate the flexibility of this principle.

Example of Principle #3, Local Quality

- A polished surface reduces friction. Texturing a surface increases friction.
- A polished surface reflects light. A textured surface changes the coefficient of light refraction.
- Apply psychology locally – a pleasant and helpful receptionist in the lobby of a company creates a positive first impression of the company (at a particular location). Each time the client returns the receptionist reinforces that image (in time).

- A business may release a press release to focus attention on a very successful aspect of the business and away from a more problematic aspect. This same press release may be intended to shift pressure on a competitor in the larger marketplace. This principle may be applied to whatever scales the system demands.
- Repeatedly applying a load to the tricep muscles that is out of proportion to the biceps allows for stronger punches in a martial artist. Appling repeated loads to the biceps out of proportion to the triceps develops sensational beach muscles – looks good, but not as useful for fighting.
- The formation of ice on a pond in winter is a natural event that allows a person to stand or ice skate on a locally hardened area – the surface.

References:
You can learn more about how to apply Altshuller's 40 Principles from the new ***40 Principles: Extended Edition*** by Genrich Altshuller with commentary by Dana W. Clarke, Sr., published by the Technical Innovation Center (make sure you get the Extended Edition available from the Altshuller Institute at www.aitriz.org.)
You can also get a monthly dose of Dana's writings on many more innovative principles for business, science and engineering by subscribing to his Innovation Magic newsletter at www.aia-consulting.com.

About the author: Today, Dana is President/CEO of Applied Innovation Alliance, which is involved in the development of innovation strategies for business leaders. In March of 2001, Dana W. Clarke, Sr. became the first natural-born U.S. citizen to be certified by the International Association of TRIZ. Dana is a student of and had the unique opportunity of working with TRIZ Masters Boris Zlotin (who originally certified him as a TRIZ Specialist in 1995), Alla Zusman, Victor Fey, Vladimir Gerasimov and Kiril Sklobovski. Beyond this he has worked with TRIZ Specialists – Len Kaplan, Peter Ulan, Sergy Malkin, Vladimir Proseanic, Svetlana Visnepolschi, Valeriy Prushinskiy, Gafur Zainiev, and Inlika Zainieva. Between 1997 and 2001, under the direction of Boris Zlotin and Alla Zusman, Dana was responsible for the training of 38 TRIZ Specialists from around the world and was responsible for training hundreds of individuals in the principles of TRIZ. Dana is the author of "***TRIZ through the Eyes of an American TRIZ Specialist***" and has authored new materials to complement Genrich Altshuller's' book "***40 Principles: Extended Edition***", which is being released in April 2005.

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A Case Study of Substance Field Analysis and Resource Analysis; Development of New Mosquito Traps

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Abstract

New mosquito traps were developed by substance-field analysis and resource analysis. At the concept development the useful and harmful relationship between mosquito and human was modeled by substance field model and resolved by one standard. The resource analysis and technology forecasting stimulated to generate the new mosquito traps by using the photo catalysis, TiO_2 (titanium dioxide). The new traps implemented catch over 10 thousands a one night near cattle shed in Korea, in summer.

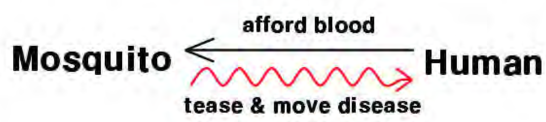
Key words: TRIZ, Su-Field Analysis, Resource Analysis, Mosquito Trap, Photo catalysis, Ideality

1. Finding the problem related to mosquito

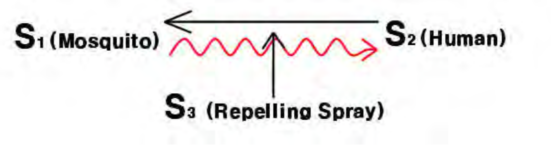
Summer in Korea is hot and humid like Italy. There are so many mosquitoes. Specially, the summer in 1998 was so hot with high humidity. At that time I with our undergraduate students at Korea Polytechnic University thought that who invents the method to protect mosquitoes from human may make big money.

2. Su-field modeling for mosquito problems and the conventional remedies

The fall in 1998, we tried to model the problem related to mosquito by using Su-field modeling in TRIZ. For the conventional methods to protect mosquitoes biting human, we drew the Su-field diagrams. Specially, for repelling spray ("DEET") the Su-field modeling was as follows;



The repelling spray on human body is not sufficiently effective and harmful to human body a little. It is one extra substance S_3 between mosquito S_1 and Human S_2 in Su-field model as follows;



In the problem above, all kinds of methods against mosquito are complete yet.

By using one standard solution in TRIZ, the S_3 (the third substance) is recommended by the substance modified from S_1 and S_2.

The S_3 may be imaged as substance modified from S_1 (mosquito) or from S_2 (human).

The idea on system like artificial human (S_3) seducing more mosquitoes than real human, might be generated easily from that the S_3 is the substance modified from the S_2 (human).

So the system would be the mosquito trap. The S_3, mosquito trap protects mosquitoes against going to human.

At that time we got the initial conceptual idea for mosquito trap as an artificial human to seducing the mosquitoes more than real human.

The ideality of the mosquito trap may be written down as follows;

$$\text{Ideality} = \frac{\text{Functionality}}{\text{Cost + Harmful}} = \frac{\text{Capability to seduce mosquitoes more}}{\text{Cost of System + Other Harmful functions}}$$

On capability to seduce mosquitoes more, we get the advise from some experts related to mosquitoes at Korea NIH.

3. New mosquito trap with photo catalysis TiO_2 based on the ideality concept

Most mosquitoes like the CO_2 (Carbon dioxide) gas very much. To generate CO_2 gas cost effectively is very difficult besides CO_2 or propane gas bottles with high pressure.

We investigated the many methods to get the CO_2 cost effectively with other good functionality and low cost with little harmful function based on the ideality concept.

We found the mosquito trap using ultra violet light lamp with suction motor fan for catching some mosquitoes. Through the directional search for methods to generate the CO_2, we knew that the photo catalysis material, TiO_2 (Titanium dioxide) generates CO_2 after purifying airs by OH- (Hydrogen oxide radical) generated by ultra violet lamp as the source of the photo catalysis.

The process to generate the CO_2 is as follows;

1) The UV light as the source of photo catalysis, onto the TiO_2 surface generates much OH-.
2) The much OH- purifies the dirty air with smell and organics including carbon.
3) The by-products from the purifying are $CO_2 + H_2O$ (water vapor).
4) Both CO_2 and H_2O are some attractants for mosquitoes.

So we modified the initial idea with mosquito trap by the new traps using photo catalysis TiO_2 with ultra violet lamp.

The ideality was increased as follows:

$$\text{Ideality of new trap} = \frac{\text{higher capability to seduce mosquitoes + air purification}}{\text{A little cost up (for } TiO_2 \text{ coating) + no harmful function}}$$

The structure of the new mosquito traps is below schematically and was pended as the patent internationally (the number of patent is PCT/KR/01-00427). The prototype was made and evaluated as an invention with bronze medal in one of German international invention completion, IENA 2000 in Nurnberg, Germany. The new traps implemented catch over 10 thousands a one night near cattle shed in Korea, in summer. The prototype was commercialized and the products are being exported to the world such as U.S.A and Europe including Italy.

Figure for principle of new mosquito trap

Product

4. Development of recent new mosquito trap through resource analysis and ideality concept

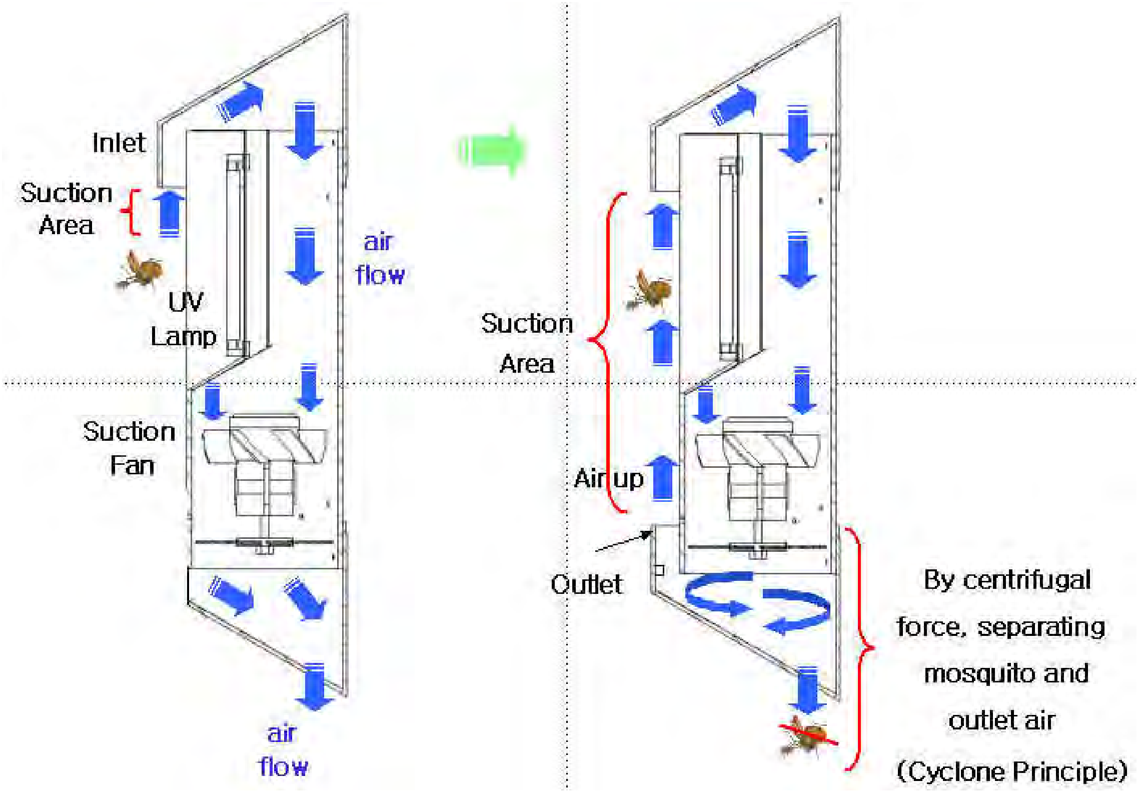
Meantime, some customers of the new mosquito trap complained the burden to clean up the cylindrical capture-net with numerous mosquitoes captured every morning and the suction power is not powerful.

We designed the recent new mosquito traps as shown in the figure below through resource analysis.

The power suctioning the inlet air is too low and the burden to clean up the numerous mosquitoes captured over night, may be eliminated for some customers to manage the traps everyday.

Through the resource analysis of the new designed mosquito trap, the outlet air from the trap was not used and discarded. We decided to guide the outlet air up to inlet for empowering the suctioning power.

In addition, for the automatic cleaning up, we devised the cyclon principle with centrifugal force generated by rotating motor and fan. That is, the centrifugal force separates the mosquitoes captured and outlet air. The outlet air is guided up for empowering the suctioning power at inlet and the mosquitoes fall down automatically by gravitational force as shown in figure.



$$\text{Increased Ideality} = \frac{\text{more higher capability for mosquitoes + air purification + automatic clean up}}{\text{a little cost up (for } TiO_2 \text{ coating + extra simple structure) + no harmful function}}$$

Hence the concept and products on the hand-free and clean-up free excellent mosquito traps were generated and implemented.

Prototype of recent new mosquito trap and the figure attached pole of street lamp

5. Conclusions

The new and recent hand-free mosquito trap and the products were invented using the Su-field analysis and resource analysis based on the ideality concept. Also, we can conform that every (technical) system has evolved to the new system based on higher ideality. Through the products and its development process, TRIZ was conformed as a powerful tool to generate new innovative ideas. We hope that our concepts and products would be one excellent remedy to eliminate mosquitoes efficiently, specially, environment friendly.

6. Acknowledgement

This paper is a modified one which was presented before at ETRIA 2004, Florence in Italy, “Development of New Mosquito Traps by Using Substance Field and Resource Analysis.

Author with his students and employees really appreciate the financial support of Korea Small and Medium Business Association and Korea Ministry of Commerce, Industry and Energy to implement those ideas as real products.

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Reference

1. Andrew Spielman Sc.D and Michael D'Antonio, 2001, "Mosquito", Hyperion.
2. Salamatov, Y, 1999, "Right solution at right time", Insytec.
3. Victor Fey and Eugene. Rivin, 1997, "The science of innovation", trizgroup.
4. G. Altshuller, 1999, "The innovation Algorithm",Technical Innovation Center
5. Masao Kaneko and Ichiro Okura, "Photocatalysis", Springer-Verlag Telos
6. Hong Suk, Lee and Kyeong-Won, Lee, 2003, "Practical Case Study of Resolving the Physical Contradiction in TRIZ; Super Water-Saving Toilet System Using Flexible Tube", in triz-journal.com, Nov. 2003

Innovation management methods and tools for sustainable product service systems (With a Case Study)

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Abstract
Sustainability guarantees the continuous availability of resources for the well being of man and society through preserving the environment and concurrently raising the living standards. To this end, Product Service Systems (PSS) play major role in shifting the economy to be more sustainable with more added value.

Carrying sustainability to future systems, products and services requires the availability of sustainability awareness starting from the design and development phases. This paper provides an example of implementing this concept through presenting a PSS development strategy through the development of a “Simulation Product Service of Material and Energy Flow in Production Facilities”. The strategy is more directed to implement innovation management (IM) methods and tools with TRIZ (Russian acronym for inventive problem solving) at its core. Providing a systematic methodology that can be used for improving and/or designing new PSSs and uncovers the strengths and applicability of the TRIZ methodology in fulfilling the concept of PSSs.

Keywords: PSS, problem identification, problem solution, mapping characteristics, TRIZ, resource utilization.

Introduction

This work is emanating from the INNOPSE project (INNOvation studio and exemplary Product Service Engineering, an EU funded project under the fifth framework 'Competitive and Sustainable Growth' programme). In brief, the project is split into three interdependent strands: the first strand conducted research and a survey to identify the general obstacles that hinder innovation, especially for SMEs for the purpose of identifying ways and means to overcome these obstacles. The second strand, the innovation studio, houses infrastructure in terms of hardware and software designed to provide innovation management (IM) with the state of the art methods and tools for idea generation and problem solving. The methods and tools in the innovation studio (with TRIZ being at the core) are implemented in order to facilitate the production of the third strand (the exemplary development of four Product Service Systems "PSS").

The strategy developed in the innovation studio for the design and development of PSSs is implemented here and explained through the design and development of a new PSS namely "Simulation Product Service of Material and Energy Flow in Production Facilities"
PSSs concept deals with products (which needs traditionally known means of management, production process, customer requirements, skills, technology…etc.) and services (which are the intangible part and require the identification of the market, means of delivery, value added, strategy and vision…etc.), the innovation studio PSS development strategy leaves this untouched and presents a simplified methodology of developing new and/or improving existing PSSs. It is, as Jelsma suggested [3], based on fostering sustainability through starting from the environmental needs (general characteristics of PSSs) and then mapping the consumer wants (specific characteristic of PSS under design) to be in harmony with those needs. This strategy is simplified because it presents the concepts and the implementation of methods and tools to analyse the situation for problem identification and to generate solution ideas and concepts. These ideas and concepts are then inputted to the different traditional stages of product and service development and delivery (beyond the responsibility of the innovation studio).

PSS quick review

The concept of product service systems is an imperative milestone to achieve sustainability, economical developments and environmental awareness. PSSs are the tools by which societies can reach environmentally sound economical developments, enhanced quality of life, introducing new businesses and utilizing existing resources to guarantee sustainable developments. They create values for both the customers, through adding quality and comfort or by providing customized solutions, and for the providers through introducing new business fields and functions, reducing the investment capital by utilizing the resources, and enhance the quality of information collected from customers through the continuous contacts.
There are three major categories of characteristics that define a PSS [4], [6], these are:

1. Reduction and optimisation of use of resources
2. Adding value for customers (quality, comfort, reduced costs, time) through the delivery of the product's function in a form of service
3. Sustainable, economic and environmental friendly

For a successful development of PSSs that provide satisfying functions to the customers want, it is imperative, in general, to identify certain factors that play roles in the development of a PSS that delivers satisfaction to the customers. Knowledge about these factors can be achieved and strengthened by conducting an early phase study about the situation. These factors can be summarized as:

1. Knowledge about the customers requirements: the introduction of a new PSS or the replacement of an existing product with its function requires the availability of knowledge about the requirements of the customers, their work environments, resources…etc.
2. Technical knowledge about their products and quality improvement.
3. Means of delivery: i.e. transportation means, involved materials, personnel, marketing…etc. there is also the need to identify any required support products/services for the main PSS.

Development strategy

The following sections will present the development strategy in more detailed explanation through the development of the simulation product service of material and energy flow in production facilities. Nevertheless, the strategy is, as shown in Figure **1**, manifested in the following points:

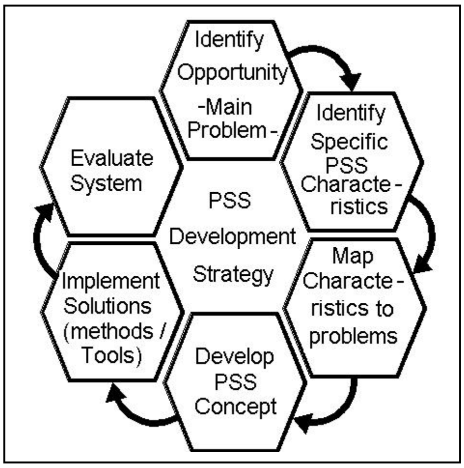


Figure 1: PSS development strategy

1. Identify the opportunity: either by picking up a product and brainstorming additional functions, or by identifying an existing problem or need across a certain sector in the society, industry and or businesses. The outcome of this stage, similar to the problem definition stage in the TRIZ methodology, is a clear definition of the problem/s to be tackled.
2. Map the specific features and characteristics of the proposed PSS to that of the general characteristics of PSS in general (resource optimisation; value added; sustainable, economic and environmental). These mapped characteristics hint for new ideas and provide directions for applications.
3. Develop the PSS concept: at this stage the developer must have a clear idea to what the PSS shall provide and what problems to solve.
4. Implement TRIZ: based on the nature of the problem, choose between the different TRIZ tools to look for solution concepts. Use the ARIZ methodology of tackling problems to solve the previously identified problem/s and conduct a scan for the TRIZ tools looking for new ideas and directions for solutions.
5. Evaluate the results especially by checking the solution against the patterns of evolution and especially the law of increased ideality.

Developing an example

1. The opportunity: Situation background

Coolant is a major ingredient in most manufacturing processes, especially when it comes to machining and tooling. Early techniques in manufacturing used extra and uncontrolled coolant that polluted the environment and lead to health hazards and unsafe work environments.

Coolant usage for lubrication and cooling of machines and tools is necessary, but the inefficient use of coolant and the excessive amounts used is a problem that causes extra costs and constitute a key hazardous pollutant and safety factor. SMEs, who are resource restricted, are the most suffering from this problem. The diversity of factors (i.e. machine design, process, work piece, mist extraction process) playing roles in this problem makes it even harder for them to pursue viable solutions.

Existing remedies are scattered and vary according to the service provider (i.e. Minimum Quantity Lubrication technology, Filter technology, pumps variety … etc.). Still this does not provide an optimal solution because, for example, a filter solution technology provider will not recommend any other solution that does not include his products.

In general, the following points are common to most machining installation:
1- Coolant is the most used cooling material in the manufacturing industry.
2- The coolant is being pumped over the surface of the tool and the work piece (workspace).
3- Mist extractor handles the evaporated coolant and mist generated from the machining process.
4- Finished and coolant-wet work pieces transported on conveyor belt spreading coolant.
5- Poor designs of machines and transportation systems cause the spreading of coolant.
6- Inefficient use of coolant results in:
   a. Extra costs
   b. Pollution to the environment
   c. Unsafe work environments
   d. Health hazards.

The proposed PSS
The idea behind the proposed PSS is to give the SMEs in the sector of machining the opportunity to look into solutions for the coolant flow and excess usage problems in a short time and without incurring extra costs and/or efforts i.e. buying new equipment, machinery handling activities during the process (assembly, disassembly of machines for testing).

In other words, the PSS will enable the SMEs to prioritise their solution options by identifying the critical point causing the most of the damage and/or according to their financial and economic priorities (i.e. return on investment (ROI) calculations). This is seen in developing a simulation software that can model the existing setup of the manufacturing process in order to identify the stages where the problem exist most, and provide solution options based on the simulation of alternative components for those identified weak points.

Defining the problems
Reviewing the situation background, it is clear that what is causing the problems identified in point 6 (from a to d) is the uncontrolled (excessive) and inefficient application of coolant. The process of coolant flow stretches across the whole production line (from pumping the coolant to the machining workspace to transportation to cleaning and the mist extraction process). The whole process can be divided into sub-processes, as indicated, each of them is contributing to the problem with varied degrees of seriousness. An identification of the most contributors with the most severe consequences can lead to the identification of solution options that vary according to technology, cost, speed of implementation and viability. It is here where most SMEs fall short of achieving because they lack the specialized knowledge (and personnel resources) to analyse their production mechanism in order to identify the weak

points causing the inefficient optimisation of coolant flow and control together with the unavailability of affordable tools to help guide them do so.

To further define the problem/s, it is imperative to list all possible causes that lead to number 6 above (points a to d). Table 1 provides a list of these problems:

Table 1: problems, causes and sub-causes

Problem	Cause/s (sub-problem)	Sub-cause/s (sub-sub-problem/s)
Extra costs	Loss of coolant	Amount of pumped coolant
		Coolant sticks to the workpieces
		Coolant is lost in transporting workpieces
	Heat (requires more coolant)	Material used (tools and workpieces)
		Speed of machining and feed rate
Pollution to the environment; Unsafe work environments; and Health hazards.	Transportation (spread of coolant)	Coolant sticks to the workpieces
		Type and speed of Conveyor belt
		Speed of the whole process
	Forming of coolant mist	Heat
		Speed of machining

From the above table, it is evident that the borders between the problems, causes and sub-causes are fuzzy. For example, extra cost can also be a result of pollution (governments oblige SMEs to adhere to the environmental laws) or any health hazard is going to cost the SME in terms of time and money. Similarly, the higher the speed of machining the more heat and the more mist and the more coolant used. Nevertheless, there has to be some kind of separation in order to simplify the solution process.

The problems that SMEs face in trying to overcome the previously identified problems are:

1. Lack of knowledge to analyse the system
2. Lack of resources (personnel, financial, time and equipment)
3. Unavailability of tools that help analyse the system (i.e. simulation software)
4. Physical analysis means interruption of production (more losses)
5. Lack of information about the alternatives (imagine an SME replacing its transportation system for example and then realizing that it is not the optimal solution)

The proposed PSS is meant to override these problems and presents solutions to the problems in Table 1. In short, the PSS will help SMEs identify the weak point/s in the coolant flow process and identify the alternative options (starting from the ideal case) with observed advantages.

2. Mapping characteristics

The purpose of mapping the specific characteristics of the given PSS from the general characteristic of PSSs is to form a strong link of coherency between the specific (wants of the customers) and the general characteristics (needs of nature) of the PSS.

The second point from this mapping process is to identify possible solution options (or sub problems) for the originally identified problem/s simplifying the solution process by tackling more miniature problems in order to lead to provide a solution to the major problem (or to the one that is one level higher). In other words, the mapping process identifies the offerings of the new PSS and solves the problems within the PSS characteristics. Table 2 shows the mapping results.

Table 2: mapping the proposed PSS characteristics to the general PSS characteristics

PSS general Characteristics	Simulation Product Service of Material and Energy Flow in Production Facilities	Problem/s to overcome
Reduction and optimisation of use of resources	Automated process (less labor and time)	• Costs • Spreading of coolant • Heat, Amounts of pumped coolant • Coolant sticking to the workpieces
	Resource efficient (less coolant)	
	Better optimization (Use of databases about different machines and equipments used))	
Adding value for customers (SMEs)	Save time and money	• Costs • Unclean technology • Lack of knowledge, viability • Amount of coolant • Production interruptions
	Stay competitive	
	Reduce risks and hazards	
	Reduce need to treat coolant	
	Simulation	
	Optimizing use of tools	
Sustainable, economic and environmental	Eliminate mist	• Pollution, health hazards and safety • Mist extraction • Lack of information about alternatives • Spread, loss, and amount of coolant used.
	Software (less paper/ink…etc.)	
	Safer	
	Increase efficiency (optimizing the use of tools)	
	Calculating costs from the simulation	
	Simulation for least energy consumption	
	Meet environmental laws	

The mapping process helps in understanding the situation and hints for new ideas based on the general characteristics (i.e. the simulation for energy consumption is an added feature, reduce need to treat waste “coolant” is an added value…etc.). This process also identifies certain solution directions for the problems at hand i.e. production interruptions can be solved by introducing a simulation service, or “pollution, health hazards and safety” can be solved (or reduced) by “eliminating mist”…etc.

3. PSS concept

To provide a service means that:

- The solution is repeatable to similar or quite similar situations using the same resources
- The service provider must provide different options for solutions (starting from the ideal case) to a given situation to match the needs of the customers (i.e. based on a service to costs ratio)

Coming from an engineering background, to analyse a given situation it is imperative to represent that situation in a graphical representation. Failing to do so, correctly, means that there is a missing chunk of knowledge. Taken from the ARIZ (the TRIZ tools for inventive problem solving) problem analysis procedures [1], drawing a graphical model means that one must understand the functional relationship between the different objects in the system. From this point of view, Figure 2 represents the concept of the proposed PSS; the shadowed boxes represent the PSS components.

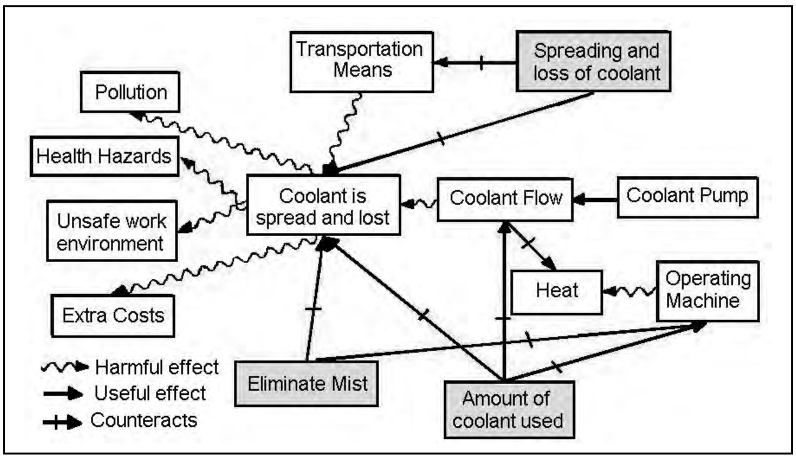


Figure 2: PSS concept

The PSS concept, derived from the previous analysis, can be stated as:
To provide a simulation services for metal machining SMEs facilities (production plans) in order to identify the weak points that are causing the most coolant related problems.
The general setup of the production plans in the sector of machining covers the following stages (most relevant to the coolant related problems):

1. Machining stages (with different types and designs of machines)
2. Transportation stages (wet finished workpieces are transported using containers and conveyor belts)
3. Mist extraction stage (including the different filtering systems)

The PSS is to provide solution options for the different stages identified as shown in Figure 2. To achieve this the simulation software shall include databases about the used machines and equipment, industry wide, describing their parameters (i.e. feed rate, speed, design, energy consumption…etc.)

4. Implementing TRIZ

Resource identification

TRIZ focuses on the use of "existing" resources and elimination of contradictions. This concept is at the core of sustainability and can be further strengthened by reducing the amounts of used resources and avoiding the introduction of new resources as much as possible. For these reasons TRIZ emphasizes the identification of resources available for the system at hand. Generally, a resource fits one or a combination of the following elements [2]:

1. Any substance, including waste, available in the system or its environment.
2. Has the functional and technological ability to jointly perform additional functions
3. Constitutes an energy reserve, free time, unoccupied space, information, etc.

Following this definition, Table 3 lists the usually available resources in a given machining industry.

Table 3: typical resources in a given manufacturing facility

General resources	Time resource	Space resources:	Field Resources
Coolant	Time during operations	Dimensions of the workspace	Electric Energy
Machines (different brands, types and technologies), with their parameters databases	Time during replacement of the finished work piece	Dimensions surrounding the tooling machine	Mechanical energy
Tools, with parameters	Time while cleaning the work piece.	Dimensions of transportation means	Temperature
Conveyor belts (types and parameters)	Time after the machine is turned off	Dimensions of collection means	Gravity
Pumps, With parameters	Time to replace the tool.	Dimensions of workpiece	
Production plan	Time during transporting the work piece.	Dimension of the production plan	
PCs	Time to sharpen the tool.		
Information about the system (layout, amount of coolant			

purchased, used, cleaning costs, disposal costs, Health costs)			
Labor			
Cleaning materials (rags, soaps, detergents…)			
Containers (for work pieces and chips)			
Work pieces,			
Chip extractors,			
Mist extractors,			
Filter systems			
Water			
Air			
Weather			

Ideas generation

In TRIZ, the solution ideas are generated, usually, by identifying the Ideal Final Result (IFR) and finding a contradiction in the system and implementing other TRIZ tools to solve the contradiction, utilizing existing resources, implementing a field and field sensitive substances, implementing patterns of evolution and the innovative principles in order to achieve that IFR. In case of failure TRIZ says to step back from the IFR and do the same trials until a solution is reached [1], [5].

Ideality is defined as the quotient of the sum of the system's useful effects, Ui, divided by the sum of its harmful effects, Hj:

$$Ideality = \frac{\sum U_i}{\sum H_j} \qquad (1)$$

The IFR in the "Simulation Product Service of Material and Energy Flow in Production Facilities" can be stated, according to equation (1), as "to perform machining (useful effect) without the use of coolant (harmful effect)"! When this is not possible, a shift one step backward is taken to simulate with minimum quantity lubrication. When that is not possible a simulation is taken to look for weak points to reduce the use of coolant and minimize the other consequences (environmental, health, safety and economic). In order to achieve these options, a solution has to be found for the previously identified problems.
The TRIZ knowledge base is the place where solution ideas can be generated. With no prejudice, a scan to the available tools in TRIZ is performed on the bases of the specific characteristics of the PSS and the problems identified, with the presence of the IFR and the backward steps in mind.
The following table summarizes the results from TRIZ tools scan looking for further solutions ideas for the development of the PSS:

Table 4: TRIZ tools scan for solutions

PSS characteristic / situation problem	Relevant TRIZ Tool	Ideas generated (PSS context)	Idea No.
Simulation Strategy in identifying the weak points	Principle 1: segmentation	Divide the production plan into segments and check each segment for optimal implementation (machining, transportation, mist extraction, storage…etc.) and increase segmentation by addressing coolant pump, coolant concentration, flow, cleaning…etc.	1

	Principle 10: Prior action	Use simulation before execution	2
Amount of coolant flow for lubrication and cooling	Principle 16: Partial or excessive action (slightly less or slightly more)	Adjustable pump power	3
	Patterns of evolution (law of ideality) Principle 2: Separation Use of resources	Dry machining Cooling without the coolant, take out coolant) Use of free existing air for cooling	4
	Patterns of evolution (law of ideality)	Use minimized quantity lubrication	5
	Patterns of evolution (law of ideality)	Better tools can provide higher cutting power and withstand higher temperatures.	6
	Utilize resources	Use existing free resources “Gravity” to replace pumps for coolant flow	7
	TRIZ 76 standard solutions: (Phase transition changing phase) Principle “9” or10: Prior “counter” action Principle 22: convert harm into benefit	Change the phase state of the coolant Cool the coolant before using it. Use the cold environment to cool the coolant (most fit for countries of long and cold winters)	8
	Principle 10: Prior action	Adjust speed, feed rate and other technology parameters for optimal setting before operating	9
	Use of resources / principle 34: Parameter change (change concentration)	Adjust the water to coolant concentration ratio	10
Spreading and Loss of coolant	Separation principles (time)	Make the workpieces wait to drain and collect the coolant back	11
	Principle 17: Dimension Change	Change type and or adjust speed and or angle of inclination of the transportation systems (conveyor belts)	12
	Principle 18: vibration	Introduce adjustable shaking frequencies to the container of the chips.	13
	Principle 24: intermediary	Use of fans (with adjustable speeds) to speed cleaning the coolant off the workpieces after machining (in container).	14
	Principle 24: intermediary	Humans using cleaning materials to clean coolant	15
	Principle 24: intermediary	Use centrifugal force	16
Eliminate mist	Separation principles (space)	Surround work space with falling coolant so that the mist is recollected with the falling coolant	17
	Principle 2: Separation	Strong sucking fans to take out the mist Suck the mist from the tool touching point in the workspace (changing the position of the sucking fan relative to the tool)	18
	Principle 10: prior action / Separation principles (space)	Introduce housing to the workspace (if doesn’t exist add it; if it is partial complete it)	19
	Principle 26: copying	Use multi fans (in multi positions)	20

Both ideas 1 and 2 are concerned with the approach and development of the PSS; the remaining ideas are to be prioritised for further concept development for solution options.

Ideas prioritization

The evaluation of solution ideas in TRIZ is conducted by seeing whether the new solution gets the system closer towards ideality or the IFR. If all ideas do not get the system to IFR a step back from the IFR is taken and the ideas are evaluated based on the (reduced) IFR. This process is being repeated until a satisfactory solution idea is identified. This is the ideal (and most favoured) case when the target is to solve an identified problem.
When it comes to PSS, the customers are varied according to the nature of their problems, capabilities, and choices. In this case, all solutions are to be kept as possible options starting from the most ideal IFR and ending to the least ideal IFR. The choice then is allocated to the

customer who might base his choice on economic or technological factors. This is viable through simulation services like the one under development.

To achieve this pool of solutions, it is imperative to prioritise the solutions according to their degree of meeting the success factors that, when achieved, constitute the level of the most ideal IFR (in the PSS example, as shown in the table below, it is idea number 4 "dry machining; cooling without coolant"). The identified success factors constitute the criteria for selecting the solution ideas.

Tables 5, 6 and 7 below show the success factors and the prioritisation grading of each idea presented in the Table 4 above against their capabilities of achieving the identified success factors.

According to the problems identified above, there are three categories of problems (amount of coolant used, spread and loss of coolant and mist extraction) each of these has a number of ideas. They are prioritised in the following tables. The grading is based on the following scales: not related (0), weak (1 to 3), intermediate (4 to 7) strong (8 to 10).

Table 5: ideas prioritisation for the reduction of "amount of coolant for lubrication and cooling".

		Ideas							
		Idea 3	Idea 4	Idea 5	Idea 6	Idea 7	Idea 8	Idea 9	Idea 10
Success Factors	Does it help reduce costs?	6	10	8	4	5	5	5	6
	Less coolant	7	10	9	8	5	7	5	5
	Eliminate Mist	4	10	8	7	4	5	5	1
	Less labor	0	7	5	0	0	0	0	0
	Implementation time	10	7	6	10	5	2	10	9
	Less pollution	4	10	9	8	4	3	4	2
	Reducing health hazards	3	10	8	8	3	3	7	5
	Safer work environment	4	10	9	8	4	4	7	4
	Investment capital	10	7	6	4	5	1	10	10
Total		**48**	**81**	**68**	**57**	**35**	**30**	**53**	**42**

Table 6: ideas prioritisation for the mitigation of " spreading and loss of coolant"

		Ideas					
		Idea 11	Idea 12	Idea 13	Idea 14	Idea 15	Idea 16
Success Factors	Does it help reduce costs?	8	8	5	5	1	5
	Less coolant	0	0	0	0	0	0
	Eliminate Mist	0	0	0	0	0	0
	Less labor	0	0	0	0	0	0
	Implementation time	8	5	4	6	8	4
	Less pollution	6	6	5	3	1	6
	Reducing health hazards	4	7	5	3	3	6
	Safer work environment	8	8	6	3	6	6
	Investment capital	10	6	3	6	4	5
Total		**44**	**40**	**28**	**26**	**23**	**32**

Table 7: ideas prioritisation to "eliminate mist"

		Ideas			
		Idea 17	Idea 18	Idea 19	Idea 20
S uc ce	Does it help reduce costs?	1	3	7	3
	Less coolant	3	3	3	3

	Eliminate Mist	8	8	8	8
	Less labor	0	0	0	0
	Implementation time	2	5	4	4
	Less pollution	6	6	7	7
	Reducing health hazards	7	8	9	8
	Safer work environment	7	7	8	7
	Investment capital	1	7	5	6
Total		**35**	**47**	**51**	**46**

From the previous evaluation, the IFR can be simulated for any given SME according to the following ideas:

1. To control the amount of coolant used: idea number 4 (scoring 81 points), based on the TRIZ law of ideality (patterns of evolution) and the use of existing resources (air): "Dry machining; Cooling without the coolant, take out coolant; Use of free existing air for cooling"
2. To reduce the spreading and loss of coolant: idea number 11(scoring 44), based on TRIZ separation principles (separation in time): "Make the work pieces wait to drain and collect the coolant back"
3. To eliminate mist: idea number 19 (scoring 51), based on TRIZ inventive principle 10 "prior action and the separation principles (separation in space): "Introduce housing to the workspace (if doesn't exist add it; if it is partial complete it)"

Solutions options can be implemented from the prioritized tables above according the steps back from the IFR (based on the customers requirements) until they are manifested in the least ideal options resembled in the following ideas:

1. To control the amount of coolant used: idea number 8 (scoring 30 points), based on TRIZ 76 standard solutions: (Phase transition changing phase); Principle "9" or10: Prior "counter" action: "Change the phase state of the coolant; Cool the coolant before using it; Use the cold environment to cool the coolant (most fit for countries of long and cold winters)
2. To reduce the spreading and loss of coolant: idea number 14 (scoring 26), based on TRIZ inventive principle 24 (intermediary): "Use of fans (with adjustable speeds) to speed cleaning the coolant off the workpieces after machining (in container)."
3. To eliminate mist: idea number 17 (scoring 35), based on TRIZ separation principles (separation in space): "Surround workspace (around the tools and the workpieces) with falling coolant so that the mist is recollected with the falling coolant"

Similarly, together with these two options, the service provider can offer a combination of ideas for options concerning each of the three problem categories for an optimal solution i.e. using separation in time principle and moving to a new dimension for the transportation means to reduce the spreading and loss of coolant category.
Relating the figures of the different simulation runs to that of the existing system would bring solid knowledge and trust to the SME. Thus the first step in providing the service is to build a model of the existing system to provide trusted figures about the simulation performance (which shall be similar to what the SME is experiencing in reality). Further simulations shall start from the IFR and then subsequent runs corresponding to steps back IFR (one step at a time) according to the wishes of the customer.

5. Evaluation of the system

An excellent tool in TRIZ that offers valuable evaluations, especially to PSSs, is the patterns of evolution. In this regard, a check of the awareness that the PSS holds about the evolution patterns is an indication of its robustness and validity.
The previous analysis and solution ideas have been implemented by WIUP ("Wrangell-Institut für Umweltgerechte Produktionsautomatisierung GbR" a partner in the INNOPSE project) for the development of their simulation software to provide simulation services as part of the project outputs. The evaluation in this section is based on the beta version developed so far.

Patterns of evolution checksum:

- **Non-Uniform Development of System Elements:** since the industrial installations are composed of different equipments and processes (machining, transportation, storage, mist extraction…etc), it is imperative for the simulation to identify which stage or process is holding the system back from its development (i.e. in terms of causing the most problems related to coolant). The simulation addresses all of the processes and components that deal with the coolant in the manufacturing premise (at the work space, at the transportation process, at the mist extraction process and at the cleaning process). Uneven evolution of parts or processes stages that lead to deviation from the Ideal Final Result is identified by the simulation (with alternative options)
- **Stages of Evolution of a Technological System:** the figures that result from the initial simulation (the model of the existing situation) gives a clear indication to where the system is in its S-Curve evolution (with the assumption that dry machining (the IFR case) is the most developed stage).
- **Evolution Toward Increased Ideality:** the Simulation shows the IFR solution i.e. the changes needed to reach the dry cutting or minimized coolant usage and the costs incurred. This gives a variety of options to the service recipient (SME). The process is based on enhancing the useful features (i.e. cutting without heat; transporting without coolant; 100% mist extraction efficiency) and decreasing harmful features (use of coolant; spilling and spreading of coolant; evaporating coolant)
- **Segmentation**: the simulation is able to segment the solution to different parts (i.e. fixing the coolant at the workspace or at the transportation stage or at the mist extraction stage). Thus the SME will not only be given a "take it or leave it" one package solution, but incremental developments (solutions) for the different parts are possible.
- **Evolution Towards Increased Dynamism and Controllability:**
  - –Transition to multi-functional performance: New service modules: Based on the collected information and data to achieve the previously identified problem categories (amount of coolant, spread and loss of coolant and eliminating mist), other simulation modules can be built to further add value for the bother the service provider (through utilizing his available resources, which is the simulation software and the collected data about the different machines, tools and equipment i.e. from manufacturing catalogues) and for the customers where they will have a better opportunity to have a full understanding about their industrial installation. The collected data can extend the service with the following modules, thus adding more functions to the system:
    1. Simulation for least energy consumption
    2. Increase efficiency of tooling and machining through optimising the use of tools (based on their life cycle, wear and type) thus reducing break down times.
    3. Calculating costs for the new changes showing the investment capital needed and the time to recover that capital.
  - –Increasing degree of freedom: the user can experiment with many options and parameters in designing the simulation model.
- **Increased Complexity followed by Simplification:**

The software in its development is complex (must includes databases “models of machine, transportation systems, mist extractors, filter system, work piece list…etc.”; computational functions to do mathematical computation; graph representation “bars, lines, …”.
Then this complexity is hidden behind a graphical user interface that enables the user to choose from different icons (machines, transportation systems, mist extractors, filter systems, containers, dialog boxes) and enables the user to use the left and right mouse buttons to choose the parameters and manipulate the models. The simulation results can be seen in a text format so that they can be further edited, printed and exported to other applications.
Further, the complexity of checking the viability of a certain solution is simplified through simulation.

- **Evolution Toward Decreased Human Involvement:** if the SME were to perform the changes without the simulation it would incur extra costs with a large margin of risk besides the involvement of many personnel. The simulation service saves the SME the costs (except for a pre-determined fee), labor and lots of efforts and mitigates the risk by testing before implementing. Similarly, only one person is needed to operate the simulation software.

Conclusion

In this case study, the development of PSS has been addressed from the problem definition and solution concepts generation aspects. Other critical issues of the PSS development, that are beyond the field of the used methods and tools, i.e. customer acceptability, organizational changes, skills and competencies have to be clarified.
The uniqueness of PSSs does not stem from its orientation towards mediating the needs of nature and the wants of customers only, rather it is formulated through the ability of a given PSS to provide a wide range of solutions and options to match the wants of the diversified situations that different customers experience in a customized form. These factors have to be taken into account at the design and development stage. Usually the wants of customers vary according to their capabilities, choice of technology and type of function they want to fulfill. This can be translated into TRIZ concept by introducing its IFR tool and stepping back from that “most ideal” IFR until reaching the “least ideal” IFR correlating these IFRs to the customers’ wants, as has been presented in the analysis.
Brainstorming sessions for the idea generation part of this case study have been conducted before introducing the TRIZ methodology; **30% more ideas have been generated when TRIZ has been introduced**. The nature of the TRIZ stimulated ideas are more fit to the concept of PSS in terms of optimization of resources, sustainability and environmental aspects (review ideas 7, 8, 13, 14, 17 and 18).
TRIZ also is found not only to extend the number of ideas produced for the solution concepts, rather it has provided a stimulating venue for extending the functionality of the new PSS especially through its resource utilization concept and the patterns of evolution (namely in this case study the “evolution towards increased dynamism and controllability”).
Finally, the scan of the TRIZ 40 inventive principles were fruitful in producing ideas for solution concepts. The most promising principles in this case study were principles numbered: 1 “segmentation”, 2 “Separation”, 10 “prior action”, 16 “partial or excessive action”, 17 “Dimension Change”, 18 “Vibrations”, 22 “convert harm to benefit”, 24 “Intermediary”, and 26 “Copying “

References:

[1] Ideation International Inc. (1999). Tools of Classical TRIZ. MI, USA.
[2] Ideation international Inc., (2001). I-TRIZ, Inventive Problem Solving and Innovation WorkBench. Software manual.

[3] Jelsma, J. (2000), Design of behaviour steering technology, Proceedings of the International Summer Academy on Technology Studies, Deutschlandsberg, July 9-15, 2000, pp. 121-132.
[4] Mont, O. (2001) Introducing and developing a Product-Service System (PSS) concept in Sweden. [Online] available: http://www.iiiee.lu.se/Publication.nsf/$webAll/71B8996A95A245B1C1256BE9003C2F62/$FILE/NUTEK.PDF [Accessed 7 April, 2004]
[5] Rantanen, K. and Domb, E. (2002). Simplified TRIZ: New Problem-Solving Applications for Engineers and Manufacturing Professionals. ST. Lucie Press, Washington, D.C.
[6] Tischner. U. and Martijn, V. (2002) Product Service Systems best practice document (Status: for review) [online] available: < http://www.suspronet.org/fs_reports.htm> [Accessed 5 April 2004].

*To April 1- **International Day of Laughter***
(Editor's note: Also called April Fools' Day)

Machine of Luck

By Gennady Kizevich@list.ru

Machines should work. People should think.
IBM Pollyanna Principle

When you try to prove to someone that a machine won't work, it will.
Willoughby's Law

Attempts to create the machine for instant moving through the space (or in the time) have failed, therefore I suggest to not waste time any more on similar silliness. I invite you to invent the *machine of luck!*

Tell me fairly quickly, what for to create other machines? What for you should move anywhere and to aspire to something greater, if Success already in your pocket?
So, the *Pocket Machine of Luck!* It seems it is that ideal product in which manufacture it is necessary to engage immediately.

But what market? Can you imagine how many people want to buy it? If you think someone will refuse, you are mistaken. I shall not torment you any longer by abstract reasoning. I suggest using the *method on contrary* immediately!

If there is no clear conception about exterior and structure of *machine of luck*, it is necessary to find the image of its **antipode**: *the machine of failure.* And then search for a way to get it to operate in reverse (if you think the reverse of failure is success!) Or (as a last resort) to find an effective way of canceling the effect of failure, or denying the failure the opportunity to happen.

From abstract formulation of problem we immediately pass to synthesis procedure. For the beginning we shall try to imagine an ideal of failure or (at the worst case) its symbol. For example, a black cat, numbers ***13*** or ***666.*** Here it is possible to add ten more names of the well-known losers, politicians, tyrants, and the name of geographical points or names to which well-known troubles are connected. For example: The *Bermuda Triangle* is perfectly included in a circle of troubles and can become a nucleus of a collection of the Misfortune Museum. All these objects are excellent "material" for designing of *failure machine*.
If to mean only numbers the stop watch counting up to 13 and then issuing despicable cry is the modest prototype. The new portion of time (13 seconds) and vicinities covers new groan of the loser!

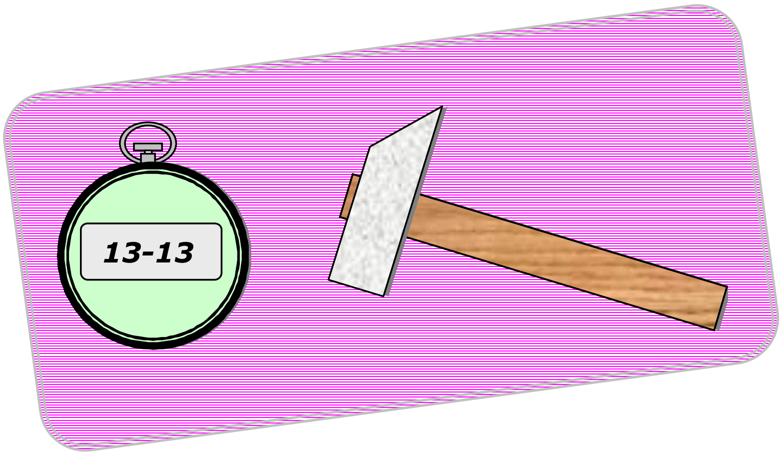
The following natural step is a resolute break from failure to Success. What exactly it is necessary and expedient to do?

To destroy failure and its symbols!

Now obvious: the *machine of failure* should be completed with a big hammer for its destruction! It is not a whim, but the fair requirement of a *principle of completeness.*
The *machine of failure* + *means for its destructions* simply and naturally forms a "harmonious" pair with adequate and intriguing name "*The Machine of luck"!*
Ignore the generally playful tone of this discussion—actually, the idea is quite serious. Talk

about a new product! It seems rather silly to buy such a machine yourself, but you might buy this as a tribute or commemoration of a birth date for a friend. The cost of such a gift will be not more than cost of a nice bouquet of flowers!

Let's recollect *Rubik's Cube*. For many people the cube became a source of irritation, and then turned to a symbol of failures, so the wooden hammer as additional equipment to crush a hated cube would be a good idea. The cube and a hammer were on sale separately. I see the essential omission of the talented inventor in it. He could sell the cube in the set with a hammer from the very beginning in fact, assuming and taking additional profit.
We shall act wisely if will sell the *completed system*! You should agree: It is difficult to struggle against temptation to possess the *machine of luck* in kind completed and quite ready to use!



Don't be confused with the strange combination of the squealing stopwatch and a hammer. In fact we do not always aspire to sovereignty of reason. Sometimes we all need immediate and effective satisfaction of a sincere impulse. Therefore the machine of luck has chance to become a funny souvenir or the means of emotional discharge.

What can you invent for April Fools' Day or the International Day of Laughter?

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EMS Models: Adaptation Of Engineering Design Black-Box Models For Use In TRIZ

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Abstract
The Theory of Inventive Problem Solving (TRIZ) has been widely recognized as a powerful systematic innovation technique that can be applied to a wide arrange of disciplines. This paper focuses on engineering design and illustrates how modeling methods already familiar to engineering designers can be adapted for use in TRIZ. Specifically, the 'black-box' modeling technique, common in problem formulation and clarification in engineering design, is modified for use in TRIZ. The new technique, referred to as Energy, Material, System modeling, can not only serve as a substitute for substance-field modeling, but as it builds on existing knowledge in the engineering design community, removes one of the barriers to wider TRIZ adoption by not requiring designers to learn new and radically different modeling techniques. The efficacy of the technique is illustrated via several examples.
Keywords: Problem formulation, problem clarification, TRIZ standard solutions.

1. Introduction

TRIZ has been touted as a method that can be applied across numerous disciplines due to the generality of its collection of principles and tools. In trying to generate a wider audience, most TRIZ texts use the general modeling methods and terminology developed over the years by the TRIZ community. The presentations, however, may also present a barrier to wider implementation due to the difficulty in relating TRIZ concepts typically discussed in the context of TRIZ modeling techniques to one's specific discipline.

Despite the power of TRIZ, it has not seen wide usage in the engineering design community, both in industry and in academe. This article explores ways to increase the implementation of TRIZ in the engineering design community by adapting and incorporating modeling techniques already familiar to engineering designers into TRIZ. This is achieved by adapting the black-box modeling technique, widely used in engineering design for problem clarification and decomposition, for use in TRIZ. The new technique, referred to as Energy-Material-Signal (EMS) modeling, can not only serve as a substitute for substance-field analysis, but also provide the following desirable features.

1. Builds on existing knowledge within the engineering design community, thereby removing one of the barriers to widespread TRIZ adoption.
2. Applicable to both physical and technical contradiction systems.
3. Inherently provides sequence of events within the modeled system.
4. Includes multiple scenarios in the same model.
5. Identifies the true problem to be solved, within the context of the overall system.
6. Includes all the resources available in the system that can be used to furnish a final solution. A separate resource list is therefore not required.

The development and use of the EMS model in the context of two examples follows in the rest of the paper. In addition, the standard solutions, most based on substance-field modeling, are modified to incorporate the new modeling method.

2. TRIZ

TRIZ, the Russian acronym for Theory of Inventive Problem Solving, was first developed in Russia by Genrich Altshuller and is now used across the world. It was originally based on analyses in the early sixties and seventies of thousands of Russian patents[1]. These original analyses articulated numerous solution patterns found across patents that can be successfully applied to solve new problems. These patterns have since been synthesized into numerous tools including (1) physical effects, (2) laws of evolution, (3) standard solutions, (4) technical contradictions and the contradiction matrix, and (5) physical contradictions and the separation principles.

TRIZ has been recognized as a concept generation process that can develop clever solutions to problems by using the condensed knowledge of thousands of past inventors. It provides steps that allow design teams to avoid the ``psychological inertia" that tends to draw them to common, comfortable solutions when better, non-traditional ones may exist. With reference to Figure 1, a design team using TRIZ converts their specific design problem to a general TRIZ design problem. The latter is based on the analysis and classification of a very large number of problems in diverse engineering fields. The general TRIZ design problem points to corresponding general TRIZ design solutions from which the design team can derive solutions for their specific design problem. The power of TRIZ, therefore, is its inherent ability to bring solutions from diverse and seemingly unrelated fields to bear on a particular design problem, yielding breakthrough solutions.

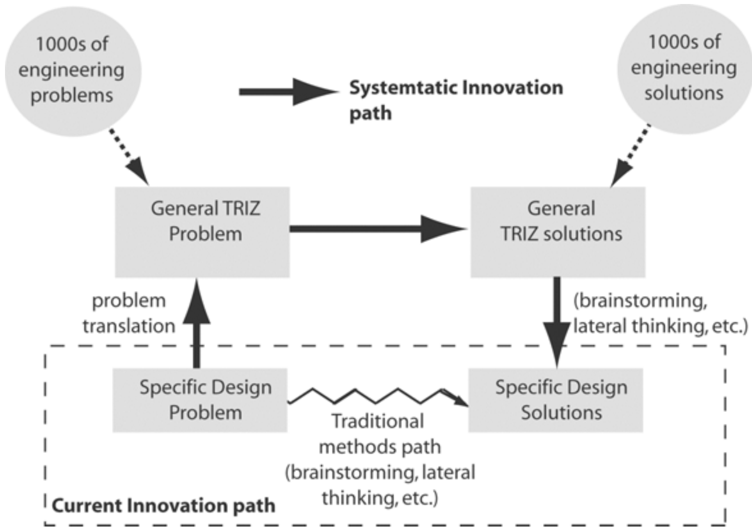


Figure 1. Generation of design solutions using TRIZ

3. Substance-Field Analysis and Variants

A key concept in TRIZ is the modeling of all material objects (visible or invisible) as *substances*, and sources of energy (mechanical, chemical, nuclear, thermal, acoustic, etc.) as *fields*. A *function* (also known as substance-field) can therefore be defined as a substance, S_1, acted upon by a field, F_1, created by a second substance, S_2. The substance-field for a complete system can be represented with the notation,

$$S_2 \xrightarrow{F_1} S_1 \qquad (1)$$

where the arrow shows S_2 having a positive or desired effect on S_1 through the field F_1. Note that in the TRIZ literature the graphical representation for the substance-fields varies greatly. Equation 1 merely presents a possible representation.

The parameters S_1 and S_2 are often referred to as *object* and *tool*, respectively, where the tool is acting on the object to create the desired effect. Models that do not have all three components (tool, object and field) are referred to as incomplete. By adding the missing element, a problem that may have been present in the system can be solved. Alternatively, if the tool has a harmful effect on the object, the straight field line would be wavy to indicate that harm is being done.

Royzen(1999) proposed the use of the Tool-Object-Product (TOP) analysis, a variant of SFA, as the next generation modeling approach. In TOP analysis a complete system has four elements: tool, object, field and product. The latter is defined either as a useful product (UP) or a harmful product (HP). The TOP analysis for a complete system can be represented with the notation

[1] Altshuller's work focused primarily on mechanically oriented patents. In recent years numerous researchers have begun to analyze worldwide patents in all fields and to update the TRIZ tools.

$$T \xrightarrow{F_1} O \quad UP \qquad (2)$$

Equation 2 states that the tool creates the desired effect on the object via a field to produce a useful product.

Despite the appeal of both the SFA and the TOP models, they both require engineering designers to learn new modeling techniques, conventions and nomenclature and may therefore present a barrier to adoption. The following section will introduce black-box modeling upon which the presented energy-material-signals (EMS) models are based.

4. Problem Clarification with Black-Box Modeling

The following discussion of Black-box modeling is based upon the work by Pahl and Beitz (1996). An analysis of engineering systems reveals that they essentially channel or convert energy, material or signals to achieve a desired outcome. *Energy* is manifested in various forms including, optical, nuclear, mechanical, electrical, etc. *Materials* represent matter. Signals represent the physical form in which information is channeled. For example data stored on a hard drive (information) would be conveyed to the computer's processor via an electrical signal.

An engineering system can therefore be initially modeled as a black-box (Figure 2) with energy, material and signal inputs and outputs from the system. In black box modeling, energy is represented by a thin line, material flows by a thick line, and signals by dotted lines as shown. The engineering system therefore provides the functional relationship between the inputs and the outputs.

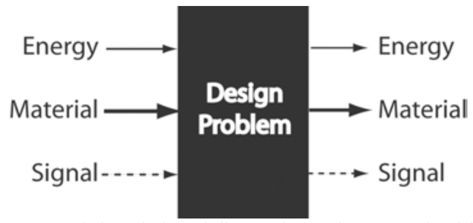


Figure 2. Energy, material and signal flows through a generic `black box' design

Problem clarification involves forming a clear understanding of the problem. The *overall problem* represented by the black-box can be decomposed into smaller *sub-problems.* Problem decomposition allows solutions to complex engineering design problems to be found by considering simpler sub-problems. Design teams can then focus on the sub-problems critical to the success of the project first, deferring others. Sub-problems are then mapped to sub-functions for which a design is created. Combination of all the designs that achieve each of the sub-functions results in the desired system solution that achieves the overall desired function. Note that the functional decompositions and the resulting black-box diagrams are generic and do not commit the design team to any particular technological working principle.

Black-box modeling of existing systems that are to be redesigned, on the other hand, decomposes the existing system into sub-systems as opposed to sub-functions. The sub-systems would then be translated to sub-functions from where the redesign proceeds.

4.1 Black-Box Modeling Examples

Throughout the paper two examples found in the TRIZ literature will be used. They are presented here to illustrate the use of black-box models.

4.1.1 Automobile Airbag

The automobile airbag, when used in conjunction with a seat belt, provides protection to occupants during front end collisions. Airbag systems deploy when crash sensors located on the front of the vehicle detect high-rate deceleration. The sensors trigger the inflator module that through a rapid chemical reaction (a mini-explosion) rapidly releases nitrigen gas that fills the airbag. Typically the air-bag will be fully deployed within 1/20 th of a second after impact detection (Kowalick, 1997). An initial black-box model of the airbag system is presented in Figure 3(a). The entire airbag system is represented as a black-box with a single input, the mechanical energy from the automobile impact. Figure 3(b) illustrates the decomposition of the black-box into sub-systems, with the corresponding the energy, material and signal flows.

The sequence of events, indicated by the arrows, starts with the detection of an impact, that signals the chemical reaction, rapidly releasing gas and mechanical energy into the airbag. The occupant then slams into the airbag, that in turn collides with the car interior. Note that the double arrows between the occupant and the airbag, and the airbag and the car interior are used to indicate that the mechanical forces are bi-directional.

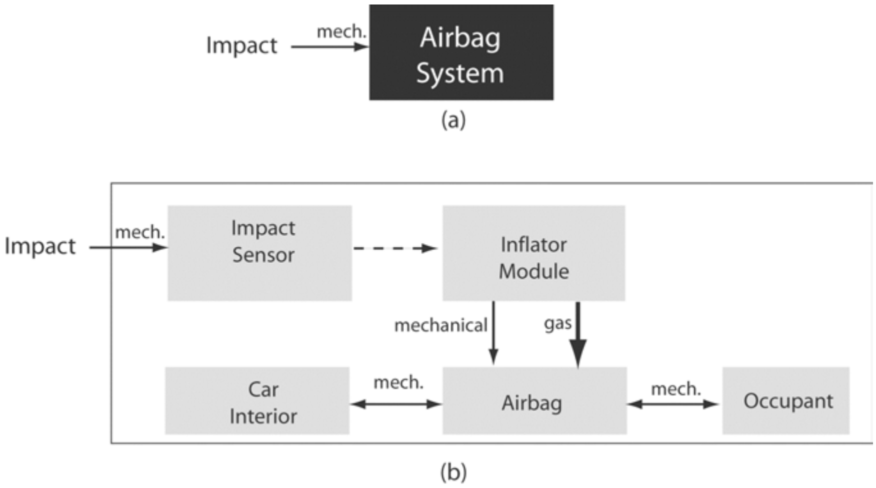


Figure 3. Black-box model of an airbag system

4.1.2 Computer Hard Drive

A computer hard drive is used to store and retrieve data (Figure 4). Within the hard drive, data is stored on a rotating magnetic disk, from which data is read using a read/write head. The head, situated at the end of a moveable actuator arm, can magnetize (write) or sense the magnetic field (read) on the disk. The head floats on the airflow generated by the disk rotation that maintains a very small gap between the two, preventing contact that may result in data loss. A black-box model of the hard drive in operation is shown in Figure 5.

Figure 4. Image of hard drive with cover removed to reveal magnetic disk, actuator arm and read/write head

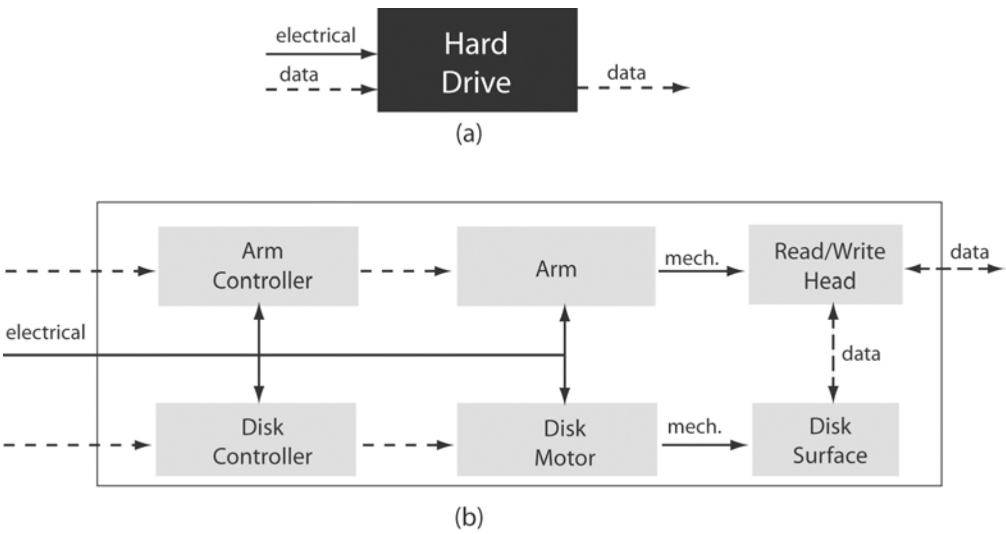


Figure 5. Black-box model of a computer hard drive

5. Energy-Material-Signal (EMS) Models in TRIZ

The EMS model extends the black-box model by incorporating symbols that indicate harmful and insufficient energy, material and signal flows with in the system. In addition, symbols are also included to allow the modeling of multiple scenarios and discrete time-separated events. Table 1 lists the new symbols with their corresponding description. The EMS model will be explained in the context of the previous two examples.

Despite the success of airbags at saving lives, they have also resulted in numerous deaths to smaller occupants due to their deployment force. An EMS model of the airbag system during a frontal impact is illustrated in Figure 6. A comparison of the black-box model and the EMS model shows that the main difference between the two is that in the EMS model, the generic occupant is now separated into a large and a small occupant, with the harmful effect of the mechanical energy on the small occupant shown. Within the context of the airbag system, one can clearly identify where the problem is that requires further attention. In addition, available system resources that could be used as part of the design solution are integrated into the problem clarification model. As such a separate list of resources is not required, as is traditionally the case if SFA or TOP analysis methods are used.

Table 1. EMS model symbols and description. System could mean an assembly, sub-assembly, function, user, and so on

S	The original system
S^c	A copy of the original system
S'	A modification of the original system
A	An additive can be material, energy, voids, systems, sub-systems or super-systems
E (dashed box)	The immediate system environment
- - - →	Signal flow
➡	Material flow
→	Energy flow
[I]	When placed next to an energy, material or signal flow signifies that flow as being *Insufficient* to perform its desired task adequately.
∧∧	A wavy line representing any of the three flows (energy, material, signal) indicates that flow to be harmful to the system receiving it
↓	Placed above a flow indicates a decrease in the flow level from the original problem
↑	Placed above a flow indicates an increase the flow level from the original problem
┤□┝┤□┝	Discrete sequential events
⊟	Each slot represents a different scenario and its effects on the EMS model

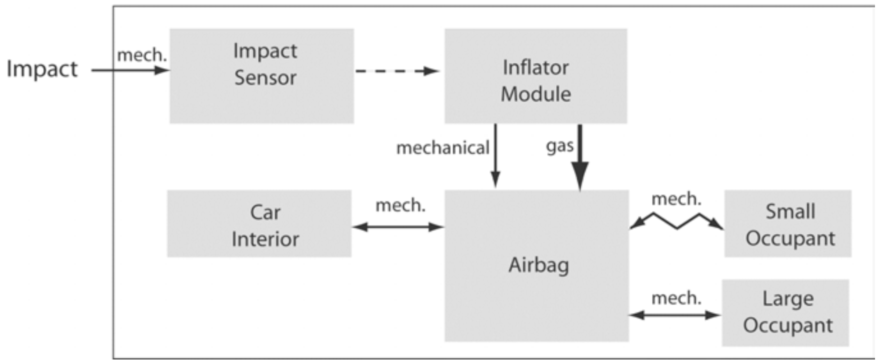


Figure 6. EMS model of an airbag system

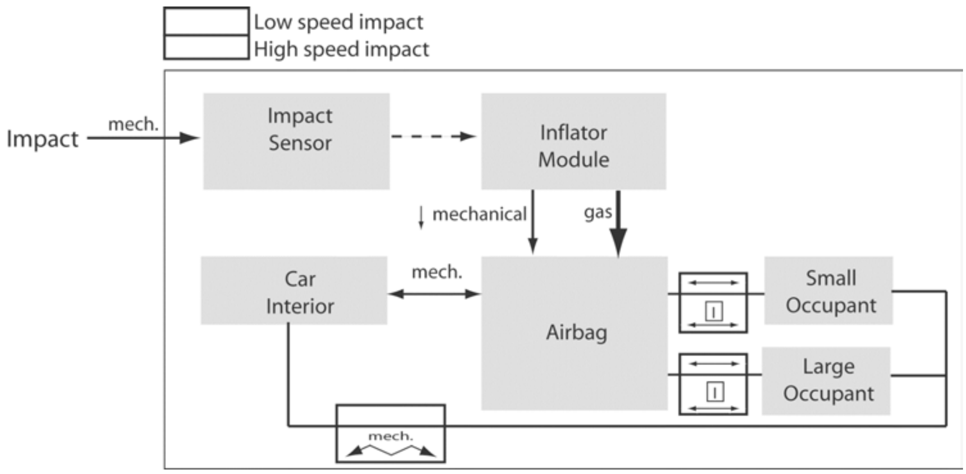


Figure 7. EMS model of proposed solution: De-powering of the airbag. This example illustrates the ability to model multiple scenarios in the same model

To reduce airbag caused fatalities, numerous automakers have installed de-powered airbags. The bags do not deploy as fast as the original ones and therefore do not cause harm to small occupants. The problem with de-powered air bags, however, is that they are less effective during high-speed crashes. This is because the time it takes to achieve full deployment for the de-powered airbag is not fast enough to prevent the occupants (both large and small) from hitting the interior of the vehicle. The two scenarios, low-speed and high-speed collisions, are illustrated in the EMS model in Figure 7. Using the multiple scenario symbol, the low speed impact scenario is represented by the top slots. In this scenario, the mechanical force from the airbag is sufficient to shield both types of occupants from colliding with the vehicle interior. In the second scenario, high-speed impact represented by the lower slots of the multiple scenario symbols, also results in airbag deployment. However, the mechanical force from the airbag is insufficient to prevent either occupant from colliding with the vehicle interior (harmful effect).

Turning to the hard drive example, an area of concern arises when the computer is off and receives a hard external knock. Without the hard drive disk spinning, the head can be knocked off its rest position and data on the disk destroyed. In the rest position, the head is typically held in place by a magnetic latch. When the computer is powered on again, the airflow from the disk motion raises the head, and a permanent magnet/electro-magnet system situated at the arm axes of rotation (the pin) generates enough force to release the arm from the magnetic latch and move the head to wherever data needs to be written or read (Royzen, 1999). An EMS model of this scenario is illustrated in Figure 8. In the model, one can track the sequence of events (the flow) from when the computer chassis receives a hard knock to the point where there is damage (harmful effect) to the disk surface by the read/write head. In the figure, the magnetic field is shown to be insufficient, and therefore an area that would be addressed.

A possible solution may be to use a stronger magnetic latch. This, however, may present its own problem by making it difficult for the arm to be released during start-up. The two scenarios are modeled in Figure 9, where the top slot in the multiple scenario symbols represents the hard knock scenario, and the lower slot the computer start-up. Note that by increasing the magnetic strength of the latch, a desirable effect is achieved in response to reduction of damage from external knocks, but it also produces an undesirable effect during system start up.

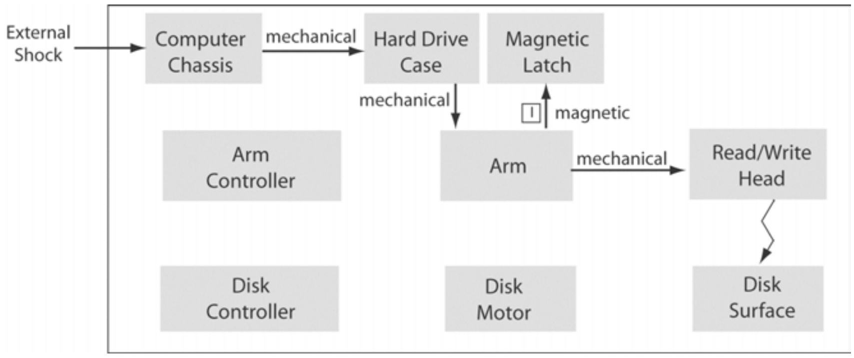


Figure 8. EMS model of hard drive when the computer is turned off. A hard knock on the computer dislodges the arm resulting in the head damaging the disk magnetic surface

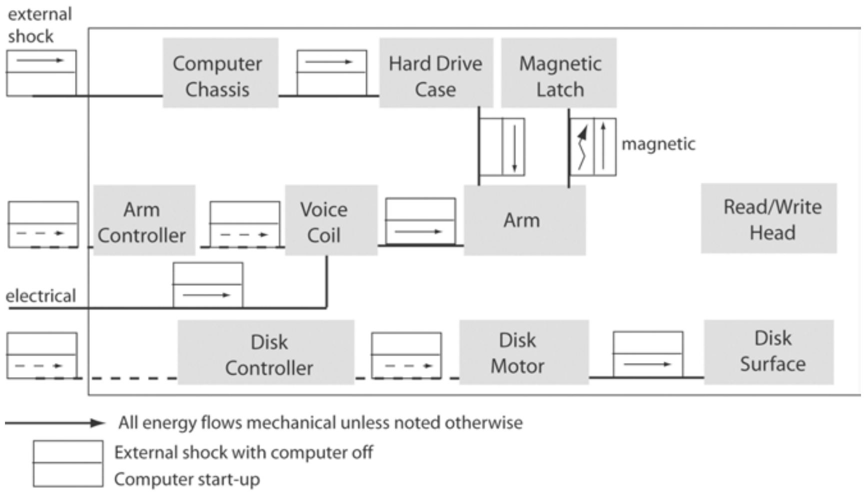


Figure 9. EMS model of hard drive with a stronger magnetic latch

The two examples presented have served to illustrate how EMS models can be developed to identify where harmful or insufficient effects occur in a system, focusing engineering designer's attention to those areas. In addition, the models present the problem area in the context of the overall system allowing engineers to see what resources are available that may be used as part of a solution. Further, unlike traditional black-box modeling, the EMS models allow the inclusion of multiple scenarios within the same model.

6. EMS Models and the 76 Standard Solutions

The 76 standard solutions are to a large extent, based on the substance-field modeling method. To effectively use the EMS models, therefore the solutions were modified and articulated in terms of EMS models. In addition, several authors have noted the significant degree of repetition amongst the standard solutions, developing their own reduced versions. Soderlin (2002) preferring to use `rules' as opposed to 'standards', reduced the number of solutions from 76 to 16 rules. Orloff (2003) renames the standard solutions as 'compact standards', and reduces the number to 35.

In this work, suggestions put forth by Soderlin (2002) and Orloff (2003) have been taken into account while generating a set of *Condensed Standards* composed of 27 solutions. In addition to reducing the number of solutions from 76, the Condensed Standards, (a) use the language and jargon typical in engineering design, and (b) replace the substance-field models found in the original 76 solutions with the EMS models. The classical 76 standard solutions fall into five classes:

1. Class I: Improving the system with little or no change
2. Class II: Improving the system by changing the solution
3. Class III: System transitions

4. Class IV: Detection and measurement
5. Class V: Strategies for simplification.

The Condensed Standards have reduced these five classes to three sets of standards:

1. Condensed Standards I: Improving the system with little or no change
2. Condensed Standards II: Improving the system by changing the solution
3. Condensed Standards III: Detection and measurement

The Condensed Standards incorporating the EMS models are presented in Tables 2 - 4 in the Appendix. Within the tables, the numbers in italics refer to the classic TRIZ standard solutions on which the condensed set are based. Where applicable, solution fragments based on the EMS model are included.

7. Concluding Remarks

TRIZ has been widely recognized as a powerful systematic concept generation technique that is applicable to a wide array of disciplines. This paper has described the development of a new modeling method, energy-material-signals (EMS) models based on the black-box models found in engineering design. By adapting a method already familiar to engineering designers it is hoped that one of the barriers to wider TRIZ implementation within the engineering design community will be removed.

References

Kowalick, J., (1997) " 'No-compromise' Design Solutions to the Air-Bag Fatalities Problem", Triz Journal, no. 7..
Orloff, M., (2003) *Inventive Thinking through TRIZ: A Practical Guide*, Springer, Berlin.
Pahl, G. and Beitz, (1996) *Engineering Design. A Systematic Approach*, 2nd Edition, Springer-Verlag, London.
Royzen, Z., (1999), "Tool, Object, Product (TOP) Function Analysis"", TRIZ Journal, no. 9.
Soderlin, P., (2002), "TRIZ The simple way", TRIZ Journal, no. 2.

Appendix: Condensed Standards

Table 2. Condensed Standards I (9 solutions): Improving the System with Little or no Change. This class looks at ways to modify a system in order to produce a desired outcome or eliminate an undesired one. An *additive* can be material, energy, voids, systems, sub-systems or super-systems.

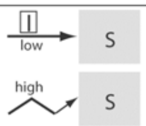
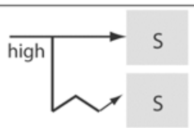
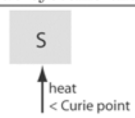
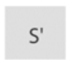
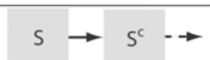
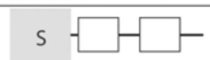
	Problem	Solution
1.1		Without changing the system, add a temporary or permanent, internal or external additive. The additive may or may not be present in the environment *(1.1.2-1.1.4, 1.2.1-1.2.2, 1.2.4, 5.1.1.1-5.1.1.3, 5.1.1.6, 5.1.4, 5.2.2,5.2.3)*
1.2		 Change the environment. *(1.1.5)*
1.3		 If a moderate energy is insufficient, but higher energy is damaging, apply higher energy to an additive that acts on the original system. *(1.1.7)*
1.4		 Both low and high energy levels are required. Use an additive to protect those sub-systems that require low energy. *(1.1.8, 1.2.3)*
1.5		 Heat a material above its Curie point to neutralize harmful magnetic effects. The Curie point is the temperature above which a ferromagnetic material loses its ferromagnetism. *(1.2.5)*
1.6		Use a small amount of a very active additive *(5.1.1.4)*.
1.7		Add additives to a copy or model of the object if it is not possible to add to the original *(5.1.1.7)*.
1.8		Desired additives can be obtained by decomposition of other materials *(5.5.1)*, such as hydrogen from water decomposition.
1.9		Desired additives can be obtained by combining other materials *(5.5.2)*.

Table 3. Condensed Standards II (11 solutions): Ways to improve the system by changing it. An additive can be material, energy, voids, systems, sub-systems or super-systems

	Solutions
2.1	Apply an additional energy source to the system *(2.1.1, 2.1.2)*. Example: Use of water and detergent (chemical energy) is not very effective for washing clothes. Agitating the system (mechanical energy) improves the cleaning.
2.2	Replace or add to energy existing in the system that is difficult to control with energy that is easier to control *(2.2.1)*. From the Laws of Evolution, in order of improved controllability: mechanical to thermal to chemical to electric to magnetic to electromagnetic energy.
2.3	Replace uncontrolled energy with energy that has predetermined patterns *(2.2.5)*.
2.4	Replace a uniform or uncontrolled system with a non-uniform system having a predetermined structure *(2.2.6)*.
2.5	If it is difficult to accurately control small quantities, use large quantities and remove the extra *(1.1.6)*.
2.6	Match or mismatch frequencies of elements within the system *(2.3.1,2.3.2)*. Example: *Noise canceling headphones* introduce a second signal with the same frequency but 180^o out of phase.
2.7	A pair of incompatible or independent actions can be accomplished by running one during the down time of the other *(2.3.3)*.
2.8	Add ferromagnetic materials (objects or liquids) and/or electric generated magnetic fields (dynamic, variable or self-adjusting) *(2.4.1-2.4.11)*. For example: *Maglev trains* use dynamic magnetic fields to levitate and propel trains at high speeds.
2.9	Transition to the super-system. Simplify, improve the links between or create bi- and poly-systems *(3.1.1-3.1.4)*. Example: *Modern traffic lights* have replaced the use of a single light bulb with a large array of light emitting diodes (LEDs). LEDs have a longer life and use significantly less energy than regular bulbs.
2.10	Transition to the micro-level by dividing the system into smaller and smaller units *(3.2,5.1.2)*.
2.11	Make use of a material's phase transitions *(5.3.1-5.3.5)*.

Table 4. Condensed Standards III (7 solutions): Detection and measurement. Mainly used for control. Often the best designs are those with automatic control that do not require detection or measurement, but utilize physical, chemical or geometrical effects within the system. An additive can be material, energy, voids, systems, sub-systems or super-systems.

	EMS Model	**Class III Problem**
		Current measurements in the system are insufficient
	EMS Model	**Solutions**
3.1		Modify the system to make detection and measurement unnecessary *(4.1.1)*
3.2		Measure a copy or image of the system. *(4.1.2)*.
3.3		Make two detections instead of continuous measurement *(4.1.3)*.
3.4		Introduce an additive (into the system or its environment) that reacts to changes in the system. Measure changes in the additive or changes in the energy from the additive. *(4.2.2-4.2.4)*. Example: *Wind tunnels:* Adding smoke particles (additive) into the air flow in wind tunnels (original system) makes it easy to observe (measurement) the flow of air around objects.
3.5		Determine the state of a system by measuring the changes in scientific effects known to occur in the system. This could include the system's natural frequency *(4.3.1-4.3.3)*.
3.6		Add ferromagnetic materials (objects, particles, liquids) to the system or its environment and measure changes to the magnetic field *(4.4.1-4.4.5)*.
3.7		Measure the first or second derivatives in time or space *(4.5.2)*. For example: *Ground-based radar systems* measure *changes in the frequency* (second derivative of displacement) to accurately determine position, velocity and acceleration of an aircraft.

Software Process Improvement –TRIZ and Six Sigma
(Using Contradiction Matrix and 40 Principles)

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ABSTRACT
This paper proposes an innovative application of Theory of Inventive Problem Solving (TRIZ) and Six Sigma for software process improvement. Use of contradiction matrix and 40 principles readily help in developing the solutions for the problems. This paper discusses out how to use TRIZ principles while carrying out six sigma projects using 3 cases where TRIZ application has directed the process improvement teams towards solutions.

Keywords: TRIZ, Software process improvement, Six Sigma

INTRODUCTION:

Six Sigma[1] is being used in software process improvement for quite some time now. Based on the rigorous methodology and statistical techniques, Six Sigma helps us in identifying the root causes for variation and low performance in the process. By eliminating these root causes we can realize dramatic improvements. However, many a times to eliminate this root causes one needs creativity in the Improve phase for developing solutions. Here, many creative tools like lateral thinking techniques are used to develop solutions. However, these tools while giving results, limit the usage due to their inability to directly drive towards solutions.

One of the simple, powerful yet easy tools is TRIZ for systematic process innovation. TRIZ directs towards solution and once the principles are identified the solutions are almost apparent. Also, the process can be improved using the solutions developed and can be refined until an optimum solution is obtained.

WHAT IS SIX SIGMA:

Six Sigma is a compelling method for breakthrough improvements for delivering world-class processes with a defect rate of less than 3.4 ppm (parts per million). Typically Six Sigma follows a five–step methodology known as DMAIC (Define, Measure, Analyze, Improve and Control).

Define phase focuses on developing business cases, defining the problems and the scope. It also helps understand the customer requirements to identify the process that delivers the same.

Measure phase measures the problem in quantifiable terms, which helps estimate the process capability that meets the needs of the customer.
Analyze phase identifies different causes for the failure of delivering the customer requirements. A variety of statistical and graphical techniques are used for prioritizing

different causes and identifying the root causes having high impact on customer requirements.

Improve phase is a creative phase, where one is aware of the problem and the cause. The cause needs to be eliminated through developing the solutions. However this is not very simple to remove the cause. We need to think creatively to develop the solution. These solutions will be piloted and then with confirmed results will go ahead for organization wide implementation.

To avoid fall back of improvement actions, there is a need to create lock-in effect and develop advanced warning system. *Control* phase takes care of these requirements.

FRAMEWORK FOR USE OF CONTRADICTION MATRIX:

Contradiction matrix helps us by directing towards right solution, is a perfect fit in the Improve phase of the methodology. Following framework is developed to use contradiction Matrix.
Step 1: Identify the root cause using Six Sigma Methodology
Step 2: Establish Contradiction and select principles
Step 3: Apply principles to develop the solution

CASE EXAMPLES

Case 1: CODING PRODUCTIVITY IMPROVEMENT
This case illustrates how the coding productivity in software maintenance process was improved. Customer is concerned with coding productivity, as the customer wants to improve the pace of maintenance. Coding Productivity is about 2.1 Size unit/day which is required to be increased to 3-size unit/day to meet the customer requirements.

Stage 1: Use of Six Sigma Methodology to find out the Root cause
A Six Sigma project was taken up for improving the coding productivity. In the define phase the problem statement was developed and project scoped. Productivity figures were collected and it was found that Mean of productivity was 2.1 and Standard Deviation was as high as 1. Different tools and techniques like cause and effect diagram, sub process mapping were used to list down the causes impacting the productivity variation. Through the prioritization techniques like ANOVA, it was understood that the amount of code used from earlier programmes by the programmers was the high impact cause.

To detail the scenario, the change requests being given by the customer could have used some of the code already written. However, each programmer kept his or her own word files to re-use the code. Additionally, the programmer does not have any access to the code written by others. Hence, every programmer only used the code, which they have written earlier.

Step 2: Establish Contradiction and select principles

Once the root cause was identified, it was understood that increasing the percentage usage of code already written is required to improve the productivity. The system features contradicting are 39. Productivity and 38. Automation.

Since the aim was to maximize the productivity while automating it was assumed that if we increase automation then productivity would reduces, which was the contradiction. The principles to be applied were then selected such that productivity increases while automation increases.

The principles from Contradiction Matrix are:

5. Merging
12. Equipotentiality
35. Parameter changes
26. Copying

Step 3: Apply principles to develop the solution
After brainstorming different principles, the following principles have driven the solution:

Principle: Merging

What it says: Bring together (or merge) the identical or similar objects; assemble identical or similar parts to perform parallel operations.

What was done: All the word files from different team members were collated under a common knowledge base, which was made accessible to everybody, thus enabling parallel operation. .

Principle: Copying

What it says: Instead of an unavailable, expensive, fragile object, use simpler and inexpensive copies.

What was done: Reusable code was divided into different design elements, which could be reused.

Summary
Coding productivity improved from 2.1-size unit/day to 3.2 size unit/day. This case example illustrates the effectiveness of applying TRIZ in Software maintenance process.

Case 2: TIME REDUCTION IN MIGRATION

Migration project was all about upgrading the development technology to the latest available. Technology of current project under discussion is VC++ 6.0, to be upgraded to VC++7.1. Process of migration typically includes selecting a project and building a project in higher version of software. Then, the software poses a number of errors. Correcting these errors such that we get 0 errors/warning makes the code migrated in to higher version of the software successful.

Step 1: Use of Six Sigma Methodology to find out the Root cause
Six Sigma project is taken up for reducing the migration time. There are several projects in a code base, which needs to be migrated. In the analysis phase of Six Sigma the root cause identified was - A lengthy build process.

Step 2: Establish Contradiction and select principles
The contradiction is established as Migration Time increases as the build time increases. Migration time vs. lengthy Build.

Migration time is the efforts spent by team members. For the process, effort is metaphorical to weight to a technical system. Lengthy build process is metaphorical to Length of a technical system.

From this established contradiction using the contradiction matrix the principles are selected. <u>Contradiction:</u> 2. Weight of Stationary object increases when 4. length of stationary object increases.

The principles from Contradiction Matrix are numbers
10 Preliminary Action
1 Segmentation
29 Pneumatics and hydraulics
35 Parameter Changes

Step 3: Apply principles to develop the solution
After brainstorming different principles, the following principles were used to develop the solution:

Principle: Preliminary Action
What it says: Perform, before it is needed, Pre-arrange objects such that they can come into action from the most convenient place.
What was done: Analyzed the code-base and grouped the dependant projects together. This preliminary action helps in arranging for batch builds.

Principle: Segmentation
What it says: Divide an object into independent parts, Make an object easy to disassemble, Increase the degree of fragmentation or segmentation.

What was done: Divided an object into independent parts, each group of batch builds is now independent from each other. Earlier all projects were having dependencies.

Summary
Migration time decreased from 2 hours/KLOC to 0.4 Hours/KLOC (KLOC is Kilo Lines of Code, a measure for software size). The results were amazing as 5 times improvement was seen in the process.

Case 3: Customer Report Preparation
This case illustrates how the customer report preparation time was reduced drastically using TRIZ and Six Sigma in Independent Testing projects. In the independent testing projects, Test Management Software is used for testing process management. However the reports are prepared using MS excel software, the process is manual and takes almost 30 % of the team effort for documenting and report preparation.

Stage 1: Use of Six Sigma Methodology to find out the Root cause
A Six Sigma project was taken up to reduce this report preparation time in all independent software testing projects. It was observed that manual process of taking out data from Test Management Software and copying in excel is the root cause for lot of time.

Step 2: Establish Contradiction and select principles
The team decided to go for automating the process and took the help of contradiction matrix since the team wanted to maximize the productivity while automating. It was assumed that if increase in automation would result in a decrease in productivity. The principles selected to be applied were such that productivity increases while automation increases.

The principles from Contradiction Matrix are numbers 1. Merging 2. Equipotentiality 3. Parameter changes 4. Copying

Step 3: Apply principles to develop the solution
Team used different principles in the following manner

- 5. Merging
- 12. Equipotentiality
- 35. Parameter changes
- 26. Copying

Principle: Merging
What it says: Bring closer together (or merge) identical or similar objects, assemble identical or similar parts to perform parallel operations.
What was done: A number of manual steps like copying pasting, counting, verifying etc. being done sequentially was combined. Downloading a detailed report, which Test Management Software develops in MS Word format, enables this

Principle: Parameter changes

What it says: Change an object's physical state (e.g. to a gas, liquid, or solid.)
What was done: Number of challenges came to fore while trying to do automation. They were

- Test Management Software supports detailed Report Generation of Test Cases in Word Format and not in other applications
- Customization of the Report Generation is not supported in Test Management Software.
- Summarized Report cannot be directly generated from Test Management Software.

Using the parameter change principle, the team creatively generated a report from Test Management Software to MS Word (Test Management Software can generate MS Word file) and then from MS Word it was converted to Excel file (MS Word and MS Excel are compatible).

Summary
Report preparation time has been reduced from 30% of total time to 10% of total time. The results are telling and definitely Contradiction Matrix/40 Principles gives a direction towards solution.

CONCLUSION
This paper proposes a new way of applying TRIZ with Six Sigma to the software process improvement. However the classical TRIZ orientation is very much towards the technical systems. More research is required towards bringing out database of solutions and principles application in software process improvement. This will help application of TRIZ maturing for process improvement. Also, This paper demonstrates use of Six Sigma along with TRIZ for better results.

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REFERENCES:

1. **http://**software**.isixsigma.com for Six Sigma in Software development**
2. www.triz-journal.com **for Contradiction Matrix and 40 principles**

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In his present role as Six Sigma Black belt, he has successfully implemented number of Six Sigma Projects in Software processes like Software development and Software Testing and support services like Marketing, helpdesk etc. He is also a certified Software Quality Analyst (CSQA).

A prolific trainer, he has logged more than 800 person hours training in Quality management and related fields, he is certified for Direct trainers skills and design of training by Govt. of India. He has also authored technical and research papers in Quality management.

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SPECIAL ISSUE – UPDATING THE THEORY OF INVENTIVE PROBLEM SOLVING
Guest Editor: Martin Möhrle

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Announcement of New Journal:
Journal of TRIZ in Engineering Design

http://www.togopressllc.com/trizined/

The Theory of Inventive Problem Solving has been widely recognized as a powerful systematic innovation technique that can be applied to a wide array of disciplines. The aim of the **Journal of TRIZ in Engineering Design** is to provide an avenue for scholarly exchange on the application of, and research on TRIZ in the context of engineering design. All papers submitted to the journal will be peer-reviewed to ensure the highest level of scholarly work, and to encourage from academia increased research and publishing on TRIZ in the context of engineering design.

Topic areas include but are not limited to:

(1) Research advances in TRIZ methodology.
(2) TRIZ-based research covering all aspects of engineering design, including its use with other engineering design methodologies.
(3) Strategies for the effective teaching of TRIZ, especially at the university level.
(4) Detailed case studies that show how the use of TRIZ has broken new ground in the design of products or processes.
(5) Review of TRIZ texts focused on engineering design, especially those appropriate for use at a college level (undergraduate or graduate) texts.

The journal is published quarterly (March, June, September and December) by Togo Press LLC (Pittsburgh, PA), **with the first issue expected in June 2005.**

The journal employs a double-blind peer review process for manuscripts in that both the reviewers and the authors remain anonymous to each other. This policy will reduce the influence of personal and other non-technical factors in the review process.

The Editorial Board (listed below) has chosen an **open access policy** for the journal. This means that all articles are universally and freely available online to everyone and their authors retain copyright. In addition, the journal's articles will be archived in internationally recognized free-access digital libraries, and indexed in the Compendex (Engineering Index).

Open access allows engineers from countries and institutions that may have limited funds to have access to the same materials as wealthier ones, thus providing a wider audience to the journal's authors. Such access is associated with increased readership and increased citation of an author's work.

We hope that the availability of an English language peer-reviewed journal will encourage more researchers, especially from academia, to use and further develop TRIZ by providing an avenue for them to publish and receive appropriate recognition for their work.

We strongly encourage you to submit papers for publication consideration using the journal’s online system at http://www.togopressllc.com/trizined/.

Finally, the journal is always looking for individuals who would like to serve as reviewers. To do so simply use the journal’s online system to create an account, complete the user profile section and we will be in touch.

Announcement: Opportunity to contribute to developing improved understanding of the use of TRIZ in software development

Recently growing interest in the application of TRIZ for software problems has prompted others to contribute to the original list of software analogies of the 40 inventive principles published back in 2001 by Kevin C. Rea. (Please see the archives)

In August 2004, Ron Fulbright published missing analogs completing an initial baseline of 40 principles for software.

Over the past three years, Kevin Rea has received additional analogies and examples for the initial set. As a result, it is evident that an up-to-date resource and subsequent process should be created to handle further contributions; a moderated ‘‘software pattern-type’’ database of the analogs would be ideal, however initially the process will produce a working document. Kevin C. Rea has volunteered to be moderator for this process and to revise the document as new analogs are accepted.

The process is simple: send an email to ‘‘soft40@triz-journal.com’ with your software analog(s) and/or example(s). After contributions have been accepted, an updated revision will be published at the TRIZ Journal replacing the existing version.

Contributor's information; a contributor should specify what info he/she doesn't want published ELSE it will be: name, date, email, location.

NOTE: Sometimes a contributor may need to get clearance with their respective employer before publishing – most of the time this is for proprietary information; therefore verify that you are not publishing anything proprietary.)