Contradictions: Air Bag Applications

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Introduction: A basic principle of TRIZ is that a technical problem is defined by contradictions. That is, if there are no contradictions, there are no problems. This radical-sounding statement forms the basis for the TRIZ problem solving methods that are fastest and easiest to learn. This session will combine a tutorial workshop on how to identify contradictions and use them to solve problems with examples drawn from the automotive industry, with particular emphasis on the air bag system, subsystems, and components. Appendix 1 to this paper is the Contradiction Matrix, which is used to determine which principles have the highest probability of solving a particular problem. Appendix 2 to this paper lists the 40 Principles for Problem Solving, with general examples and examples from the industry..

The benefit of analyzing a particular innovative problem to find the contradictions is that the TRIZ patent-based research directly links the type of contradiction to the most probable principles for solution of that problem. In other words, the general TRIZ model of Fig. 1. is particularly easy to apply for contradictions.

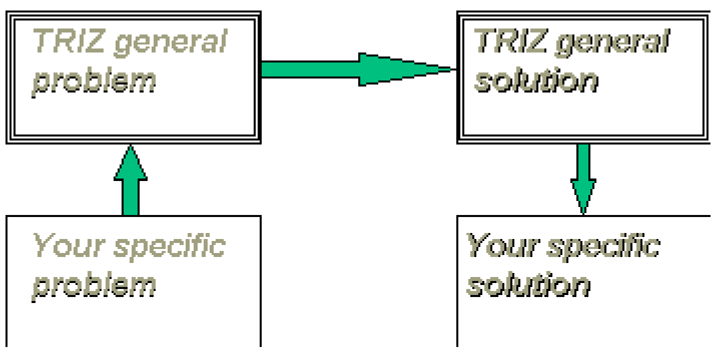

Figure 1. The General Model for Problem Solving with TRIZ

Contradictions:

TRIZ defines two kinds of contradictions, "Physical" and "Technical". These labels are artefacts of the early translations of TRIZ works, and should be thought of as reference labels-neither is more or less "physical" than the other!

Definitions:

Technical contradictions are the classical engineering "trade-offs." The desired state can't be reached because something else in the system prevents it. In other words, when something gets better, something else gets worse. Classical examples include

- The product gets stronger (good) but the weight increases (bad)
- The bandwidth increases (good) but requires more power (bad)

Automotive examples are easy to construct:

- The vehicle has higher horsepower, but uses more fuel
- The vehicle has high acceleration but uses more fuel
- The ride feels smoother, but the handling is difficult on high speed curves
- A pick-up truck has high load capacity (stiff rear suspension) but the ride is rough.
- Putting controls on stalks increases driver convenience, but makes assembly of the steering column more complex.
- Electric vehicles can go long distances between recharging, but the battery weight gets too high to move at all!

Air bag examples of technical contradictions are found in the technology and in the social problems that surround the entire passenger protection situation. Examples:

- If the threshold for deployment is set low, protecting belted occupants, more unbelted small people in the passenger seat are injured.
- If the threshold for deployment is set high, unbelted passengers are protected from air bag-caused injury, but belted passengers suffer more injury from the collision.
- High power ("aggressive") deployment saves lives of average-sized drivers, but increases injuries to unbelted or small passengers.
- Adding more sensors (and data processing) to customize the deployment to the circumstances, and thereby save lives of small and unbelted people, increases the complexity of the system.
- Adding more sensors (and data processing) to customize the deployment to the circumstances, and thereby save lives of small and unbelted people, decreases the reliability of the system.

Examples of technical contradictions can be constructed for every system, subsystem, and component of the automobile, the air bag, and the entire highway transportation system.

Physical Contradictions are situations where one object has contradictory, opposite requirements. Everyday examples abound:

- When pouring hot filling into chocolate candy shells, the filling should be hot to pour fast, but it should be cold to prevent melting the chocolate.
- Aircraft should be streamlined to fly fast, but they should have protrusions (landing gear) to maneuver on the ground.

- Aircraft should fly fast (to get to the destination) but should fly slowly (for minimum change in velocity on landing.)
- Surveillance aircraft should fly fast (to get to the destination) but should fly slowly to collect data directly over the target for long time periods.
- Software should be easy to use, but should have many complex features and options.

Automotive industry examples come from both design, production, and implementation:

- Highways should be wide for easy traffic flow but narrow for low impact on communities.
- Braking should be instantaneous to avoid road hazards but braking should be gradual for control.
- Refueling should be sealed but should be open.
- Upholstery should be luxurious but be easy to maintain.
- The frame should be heavy (for structural safety) but the frame should be light (for cost and ease of assembly.)
- Manufacturing should be done in small lots for flexibility but manufacturing should be done in large lots for low cost.

Air bag examples are found throughout the system and subsystems:

- The deployment threshold should be high and low.
- The air bag should be aggressive and de-powered.
- The air bag should protect everyone and harm no one.
- The gas should be generated quickly and slowly.
- The sensor should be complex and simple.
- The air bag should exist and should not exist.

As in the case of the air bag deployment threshold, many problems can be stated as both physical and technical contradictions. When using the TRIZ research findings, in general the most comprehensive solutions come from using the physical contradiction formulation, and the most prescriptive solutions come from using the technical contradiction. In terms of learning, people usually learn to solve technical contradictions first, since the method is very concrete, then learn to solve physical contradictions, then learn to use both methods interchangeably, depending on the problem.

Resolving Technical Contradictions:

The TRIZ patent research classified 39 features for technical contradictions. Once a contradiction is expressed in the *technical contradiction* form (the trade-off) the next step is locate the features in the Contradiction Matrix. See Appendix 1 for the complete matrix, and see Figure 2, below, for an extract.

	Worsening Feature → Improving Feature ↓	Volume of moving object	Speed	Force (Intensity)	Stress or pressure	Shape	Reliability	Object-generated harmful factors	Ease of operation	Ease of repair	Device complexity	Difficulty of detecting and measuring
		7	9	10	11	12	27	31	33	34	36	37
9	Speed	7, 29, 34	+	13, 28, 15, 19	6, 18, 38, 40	35, 15, 18, 34	11, 35, 27, 28	2, 24, 35, 21	32, 28, 13, 12	34, 2, 28, 27	10, 28, 4, 34	3, 34, 27, 16
10	Force (Intensity)	15, 9, 12, 37	13, 28, 15, 12	+	18, 21, 11	10, 35, 40, 34	3, 35, 13, 21	13, 3, 36, 24	1, 28, 3, 25	15, 1, 11	26, 35, 10, 18	36, 37, 10, 19
11	Stress or pressure	6, 35, 10	6, 35, 36	36, 35, 21	+	35, 4, 15, 10	10, 13, 19, 35	2, 33, 27, 18	11	2	19, 1, 35	2, 36, 37
12	Shape	14, 4, 15, 22	35, 15, 34, 18	35, 10, 37, 40	34, 15, 10, 14	+	10, 40, 16	35, 1	32, 15, 26	2, 13, 1	16, 29, 1, 28	15, 13, 39
15	Duration of action of moving object	10, 2, 19, 30	3, 35, 5	19, 2, 16	19, 3, 27	14, 26, 28, 25	11, 2, 13	21, 39, 16, 22	12, 27	29, 10, 27	10, 4, 29, 15	19, 29, 39, 35
33	Ease of operation	1, 16, 35, 15	18, 13, 34	28, 13 35	2, 32, 12	15, 34, 29, 28	17, 27, 8, 40		+	12, 26, 1, 32	32, 26, 12, 17	

Figure 2. Selected rows and columns from the Contradiction Matrix. The numbers in the cell refer to the principles that have the highest probability of resolving the contradiction. See Appendix 1 for the complete matrix. and Appendix 2 for the 40 principles The circled cell is discussed in the example in the text.

Find the row that most closely matches the feature or parameter you are improving in your "trade-off" and the column that most closely matches the feature or parameter that degrades. The cell at the intersection of that row and column will have several numbers. These are the identifying numbers for the Principles of Invention that are most likely, based on the TRIZ research, to solve the problem: that is, to lead to a ***breakthrough*** solution instead of a trade-off.

For example, consider the proposal to change the speed of inflation of the air bag, to reduce injuries to small occupants. The trade-off is that injuries in high speed accidents increase. Translating this into the TRIZ matrix terms, the parameter that improves is "Duration of action of a moving object" (Row 15) and the parameter that worsens is "Object-generated harmful effects" (Column 31). The cell at the intersection has the notation "21,39,16,22" which are the identifiers for four of the Principles of Invention. Figure 3. shows the same analysis, as presented by the Principles module of The Invention Machine Laboratory 2.11 software.

The 40 Principles of Invention are listed in Appendix 2, with examples of the application of each in various areas of every-day life, technology, and the automobile industry. Some TRIZ practitioners follow the guidance of the Contradiction Matrix to select which principles to apply to a specific problem. Others try each of the principles for every problem, rather than depend on the "most probable."

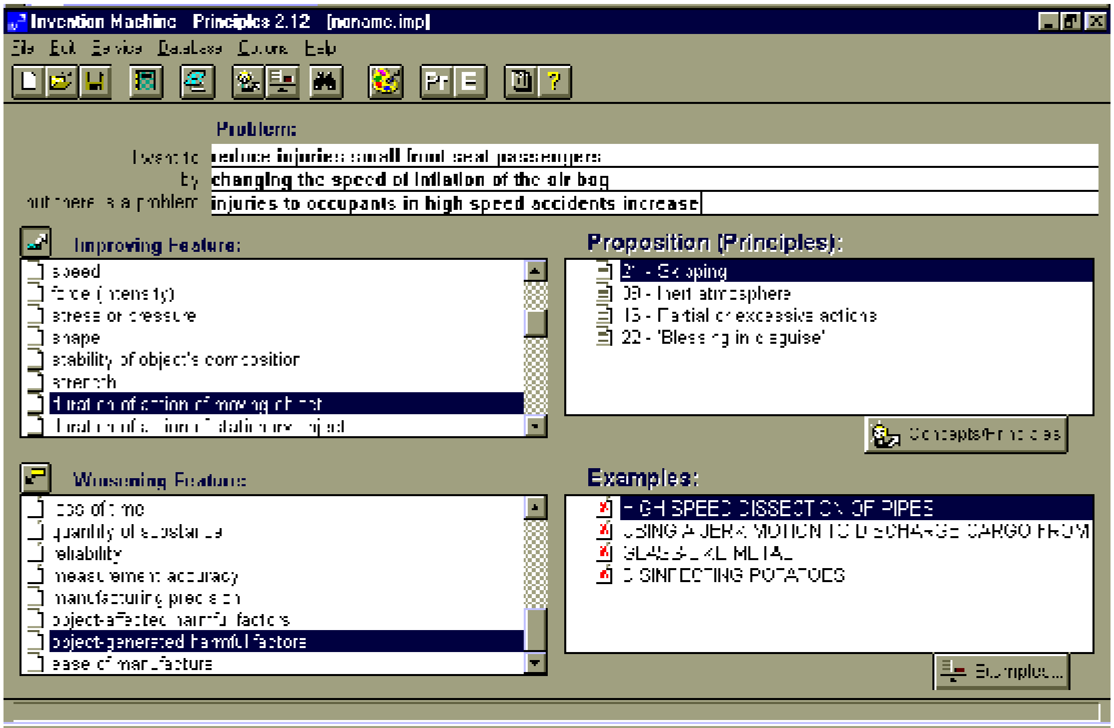

Figure 3. The opening page of the Principles module of the Invention Machine Laboratory 2.11 software, showing the identification of the inventive principles most likely to resolve the conflict between the improving feature and the worsening feature identified in the boxes on the left side of the screen.

To illustrate the use of the 40 Principles, consider the recommendation that Principles 21,39, 16, and 22 are good starting points for this situation. Starting with the 4 recommended principles, read each, consider the examples, construct analogies between the examples and your situation, then create solutions to your problem that build directly on the concept of the principle and the analogies to the examples. Air bag and automotive examples are marked ""

Principle 21. Skipping

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

- *Use a high speed dentist's drill to avoid heating tissue.*
- *Cut plastic faster than heat can propagate in the material, to avoid deforming the shape.*

Inflate the air bag faster than current practice, so that it is fully inflated when the small person impacts it.

Principle 39. Inert atmosphere

A. Replace a normal environment with an inert one.

- *Prevent degradation of a hot metal filament by using an argon atmosphere.*

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

- *Increase the volume of powdered detergent by adding inert ingredients. This makes it easier to measure with conventional tools.*

What does the damage is the encounter between the person and the air bag, before it is fully inflated. The bag acts "hard" because of its motion. So something that would "soften" the surface would be the equivalent of an "inert" material-it does not prevent the original purpose (inflate the bag and protect the person from hitting solid objects) but it cushions the blow from the bag itself. How can this be implemented? Change the structure of the bag-make it corrugated, or make it of filaments, or use multiple crushable layers. Change the "hardness" without changing the structure (this is the 2-stage inflation that has already been proposed.)

Principle 16. Partial or excessive actions

A. If 100 percent of an object 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.

- *Over spray when painting, then remove excess. (Or, use a stencil--this is an application of Principle 3, Local Quality and Principle 9, Preliminary anti-action).*
- *Fill up, then "top off" when filling a tank with fuel.*

The de-powered air bag has been proposed as a solution of this type. By using less power, the acceleration of the bag is less, and injuries will be reduced.

Conversely, smaller bags with higher power would reach full inflation sooner, so that the passenger would be protected from the accident and not injured by the air bag.

Principle 22. "Blessing in disguise" or "Turn Lemons into Lemonade"

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

- *Use waste heat to generate electric power.*
- *Recycle waste (scrap) material from one process as raw materials for another.*

Use the relative motion of the person and the vehicle as part of the protection. Design other parts of the system (seat, dash, side panels) to redirect the moving person to be properly placed for best air-bag protection.

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

- *Add a buffering material to a corrosive solution.*
- *Use a helium-oxygen mix for diving, to eliminate both nitrogen narcosis and oxygen poisoning from air and other nitrox mixes.*

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

- *Use a backfire to eliminate the fuel from a forest fire*

This again suggests inflating the air bag faster, so that it is no longer harmful by the time the person reaches it.

If the problem is better expressed as a ***physical contradiction*** (where one parameter has opposite requirements) rather than a technical contradiction then the Contradiction Matrix won't work-it has no entries on the diagonal, so you can't look for "X gets better but X gets worse."

TRIZ has 4 classical ways to resolve physical contradictions

1. Separation in time
2. Separation in space
3. Phase transition

Solid - liquid - gas - plasma

Paramagnetic -Ferromagnetic

Others-ferroelectric, superconducting, crystal structure, …

1. Move to the super-system or the sub-system

Examination of the 40 Principles shows extensive overlap with these 4 methods, since they are based on the same research on the same collection of innovative solutions to a wide variety of problems. For example, one dominant physical contraction for the air bag system is

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The deployment threshold should be high but it should be low

(For non-air bag industry readers: the deployment threshold is the speed of the car that is required for the air bag to fire. Many air bag injuries happen in low-speed accidents, where the people would not have been severely injured by the accident itself. The higher the threshold, the fewer times air bags will be used, so the less chance of injury from the air bag itself. But, the higher the threshold, the more damage is done by the accident, and the more useful the air bag is for protecting the people.)

Since this is a contradiction, the answer will not be a number-that would be the non-TRIZ way of doing a trade-off. Applying the 4 methods for resolving a physical contradiction will cause us to deal with the *cause* of the problem (air bags cause injuries) and not just with the short-term solution (changing the speed of deployment.)

Applying the first of the 4 ways to resolve the contradiction, *separate the requirements in space.* This leads to ideas like using a low deployment threshold for a belted, average sized or above driver, and a high deployment threshold for a small driver or unbelted passenger, addressing just the ways to resolve the deployment threshold problem. It introduces problems of sensor and logic complexity, so that the car "knows" where to set the threshold, so it is not a very good solution in terms of ideality. Addressing the more general problem, the popular solutions are already known: put children in the back seat (separate them in space from the air bag) and have drivers sit as far as possible from the steering column (using pedal extenders, special seats, etc.) But it could also lead us to look in detail at the *space* where the problem occurs. Could the shape of the airbag be changed so that it is fully deployed when the short person reaches it? And still protect the average and large person?

Separation in time suggests examining the sequence of events in an accident to see if different kinds of accidents require different deployments, rather than using the velocity at the time of impact as the triggering factor. This has considerable overlap with the idea of solving the problem at the super-system level, since it changes the problem from one of how to set the threshold, to examination of whether the threshold is the right parameter to use at all.

Phase transition appears unlikely to help in this case, but should not be rejected immediately. Consider the physical state of everything that does harm in the scenario.

For example, one form of injury is caused when short drivers sit close to the steering column. The bag is still accelerating when the person strikes it, instead of fully inflated as it would be for average height drivers. The acceleration of the bag has been blamed for face and neck injuries. Could the acceleration that harms people be moderated by using some other material? This leads us to challenge the entire problem-should it be a foam bag instead of an air bag? Or a liquid barrier? Or a magnetic field (much faster to deploy than a mechanical device, but will people wear a magnetic protection vest if they won't wear seat belts? At least it would protect belt-wearing short drivers)

Change the problem: use the super-system or the subsystem: The air bag industry has done a lot already with this approach. The 30% de-powered air bag concept attempts to mitigate the injuries by using lower power inflation, so that the acceleration of the air bag will be lower, causing less injury to the person who strikes it, while still inflating with enough power to protect the person from injury in the accident. The ultimate super-system approach is to prevent accidents and eliminate the need for the air bag.

There is a fifth way to resolve a physical contradiction: convert it to a technical contradiction. The conversion may be obvious or subtle: the most useful technique is to separate the element s of the contradiction and ask "WHY?"

For example, continuing with the high/low deployment threshold contradiction:

Why must it be high? To avoid deployment in low-speed accidents and prevent air bag-caused injuries

Why must it be low? To protect people in accidents at any speed

This leads us to the technical contradiction

As speed of the car increases, injuries to occupants become worse

This is not just circular logic: it focuses us on the root cause of the problem, protection of people in automobile accidents, and makes it very clear that changing the deployment threshold is only a "band-aid" solution the problem of harm done by air bags. This is why resolving the physical contradiction is regarded as a more general solution than resolving the technical contradiction. TRIZ does not generate breakthrough solutions by "better brainstorming" or by teaching people to "think creatively." In dealing with contradictions TRIZ generates breakthrough solutions by giving you the tools to find the problem behind the problem, and remove it.

TRIZ References

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