Changing The Game: Systematic Innovation in Food Engineering Using TRIZ and Function Simulation Tools

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"Worryingly…a significant number of Irish food companies are not actively developing any new food products, while many of that are engaged in new product development do not explicitly involve consumers in their research" (DeBurca and Ledwith 2000: 30).

ABSTRACT

The paper describes a novel approach to innovation in food engineering. The approach begins from function and attribute simulation of systems, and uses this as the basis for defining better ways of delivering both product and manufacture processes.

We take our definition of 'better' from the Theory of Inventive Problem Solving, TRIZ. Built on over 1500 person years of research, TRIZ has shown that the most effective problem solutions are ones where the problem solver:

a) has observed that, when systems hit a fundamental limit of optimization, the only way to further improve that system is to identify and eliminate a design contradiction.
b) has recognised that technical systems follow distinctly predictable technology evolution paths, and that the paths already trodden in one industry can be carried across to another.
c) has turned elements of an existing system thought to be harmful into useful resources.

We show how starting from a functional simulation it is possible to generate a description of an existing product or system that systematically enables engineers to identify and exploit the innovation strategies uncovered by TRIZ.

The paper provides a detailed description of the novel functional simulation process, and how it links to the systematic innovation principles and strategies contained within TRIZ.

We also demonstrate the relevance of the developed simulation approaches through two case study examples; the first examining the use of systematic innovation strategies to help develop a novel food product concept, and the second demonstrating how the approach has been used to fundamentally improve a manufacturing process previously believed to have been at the limits of its optimization potential.

The Russian initiated Theory of Inventive Problem Solving, TRIZ, is a series of tools, methods and strategies developed through over 1500 person years of research and the study of over two million of the world's most successful patents.

The key findings of TRIZ research are:-

- that all innovations emerge from the application of a very small number of inventive principles and strategies
- that technology evolution trends are highly predictable
- that the strongest solutions transform the unwanted or harmful elements of a system into useful resources.
- that the strongest solutions also actively seek out and destroy the conflicts and trade-offs most design practices assume to be fundamental.

TRIZ offers users access to the knowledge and experiences of the world's finest inventive minds. It is intended to complement and add structure to our natural creativity rather than replace it.

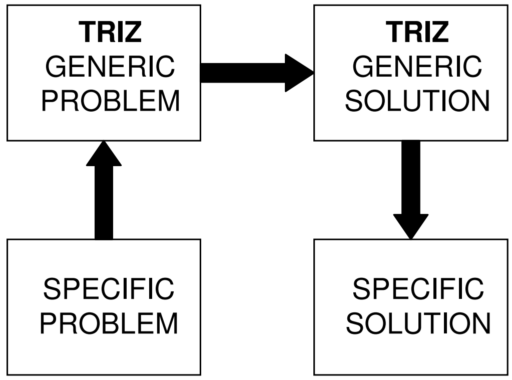
TRIZ can be used in a number of different ways. An overall process enables users to systematically define and then solve any given problem or opportunity situation. Some users will rigorously apply this process. Others are happier extracting individual elements from the overall structure and using those. The CreaTRIZ software implementation allows users significant flexibility in how to use TRIZ, offering both an over-riding structure and access to individual problem definition and solving tools. Although TRIZ is easily the most exhaustive creativity aid ever assembled, it does contain some gaps and holes. In keeping with TRIZ philosophy, CreaTRIZ has looked outside TRIZ at the best of creativity practice from all disciplines and integrated them together into a seamless whole. The overall aim of CreaTRIZ has been to construct a problem definition and solving process that works for any situation users may care to throw at it – whether that be technical or non-technical, simple or complex, highly constrained or clean-sheet, step change innovation or incremental improvement, or focused on products, processes or services. TRIZ effectively strips away all boundaries between different scientific, engineering and creative discipline and its effectiveness has been proved across a broad spectrum of fields and problem types.

TRIZ is both simple and complex. To learn and gather a working knowledge of the whole structure will probably take six months. Some people are prepared to make this investment, and others are not. Those that are not usually take great comfort from the fact that they will be able to learn and realise significant benefit from just a short exposure to individual elements of the overall structure. In many instances these benefits are enough. We've tried to design CreaTRIZ to suit every individual requirement. The basic version of the software contains the most useful of the individual tools and strategies. A collection of add-on tools allows the software to grow with evolving user skills and requirements.

TRIZ is different to most other creativity aids, and quite appear a little unnatural at first. Here are some of the things that may help how you think about TRIZ and the way you will use it:

TRIZ BASICS

TRIZ is about providing means for problem solvers to access the good solutions obtained by the world's finest inventive minds. The basic process by which this occurs is illustrated below. Essentially, TRIZ researchers have encapsulated the principles of good inventive practice and set them into a generic problem-solving framework. The task of problem definers and problem solvers using the large majority of the TRIZ tools thus becomes one in which they have to map their specific problems and solutions to and from this generic framework.



THE FOUR (PLUS ONE) PILLARS OF TRIZ

1500 person years of TRIZ research have produced a significant number of innovation tools and methods.. This section offers a brief summary of the four main elements that make the method distinct from other innovation and problem solving strategies.

Contradictions
TRIZ researchers have identified the fact that the world's strongest inventions have emerged from situations in which the inventor has successfully sought to avoid the conventional trade-offs that most designers take for granted. More importantly they have offered systematic tools through which problem solvers can tap into and use the strategies employed by such inventors. The most commonly applied tool in this regard is the Contradiction Matrix – a39x39 matrix containing the three or four most likely strategies for solving design problems involving the 1482 most common contradiction types. Probably the most important philosophical aspect of the contradiction part of TRIZ is that, given there are ways of 'eliminating' contradictions', designers should actively look for them during the design process.

Ideality
While studying the patent database, TRIZ founder Genrich Altshuller identified a trend in which systems always evolve towards increasing 'ideality' and that this evolution process takes place through a series of evolutionary S-curve characteristics. A key finding of TRIZ is that the steps denoting a shift from one S-curve to the next are predictable. A number of underlying technology evolution trends consistent with the ideality concept have been identified during the course of research on the global patent database. Used as a problem definition tool, the ideality part of TRIZ encourages problem solvers to break out of the traditional 'start from the current situation' type of thinking, and start instead from what is described as the Ideal Final Result (IFR). The simple definition of IFR is that the solution contains all of the benefits and none of the costs or 'harms' (environmental impact, adverse side-effects, etc). Although there are many instances where systems have been seen to evolve all the way to their Ideal Final Result, many have not. The method gets users to think about

these situations by working back from the IFR to something which is practicably realisable. Generally speaking these solutions incorporate the concept of systems solving problems 'by themselves'. The key word is 'self'; things that achieve functions by themselves – self-cleaning, self-balancing, self-heating, self-aerating, etc – all represent, when incorporated in a true TRIZ fashion, very powerful and resource-efficient solutions.

Functionality

Although the functionality aspects of TRIZ owe a significant debt to the pioneering work on Value Engineering, the method of defining and using functionality data is markedly different; sufficient at the very least to merit discussion as a distinct paradigm shift in thinking relative to traditional occidental thought processes. Three aspects are worthy of particular note:-

1) The idea that a system possesses a Main Useful Function (MUF) and that any system component which does not contribute towards the achievement of this function is ultimately harmful. In a heat exchanger, for example, the MUF is to transfer heat to the working medium; everything else in the system is there solely because we don't yet know how to achieve the MUF without the support of the ancillary components. (Systems may of course perform several additional useful functions according to the requirements of the customer.)
2) In traditional function mapping, the emphasis is very much on the establishment of positive functional relationships between components. TRIZ places considerable emphasis on plotting both the positive and the negative relationships contained in a system, and, more importantly, on using the function analysis as a means of identifying the contradictions, in-effective, excessive and harmful relationships in and around a system. Function and attribute analysis thus becomes a very powerful problem definition tool.
3) Functionality is the common thread by which it becomes possible to share knowledge between widely differing industries. A motor car is a specific solution to the generic function 'move people', just as a washing powder is a specific solution to the generic function 'remove solid object'. By classifying and arranging knowledge by function, it becomes possible for manufacturers of washing powder to examine how other industries have achieved the same basic 'remove solid object' function. '*Solutions change, functions stay the same*' is a message forming a central thread in the TRIZ methodology: People want a hole not a drill.

Use Of Resources

The Resources part of TRIZ relates to the unprecedented emphasis placed on the maximisation of use of everything contained within a system. In TRIZ terms, a resource is *anything in the system which is not being used to its maximum potential*. TRIZ demands an aggressive and seemingly relentless pursuit of things in (and around) a system which are not being used to their absolute maximum potential. Discovery of such resources then reveals opportunities through which the design of a system may be improved. In addition to this relentless pursuit of resources, TRIZ demands that the search for resources also take due account of negative as well as the traditionally positive resources in a system. Thus the pressures and forces we typically attempt to fight when we are designing systems, are actually resources. By way of an example of this 'turning lemons into lemonade' concept, TRIZ users often think of resonance as a resource. This is in direct contradiction to most Western practice, where resonance is commonly viewed as something to be avoided at all costs. TRIZ says that somewhere, somehow, resonance in a system can be used to beneficial effect. In effect, resonance is a potent force lever capable of amplifying small inputs into large outputs. Resonance is currently being used to generate beneficial effects in a number of new product developments from vacuum cleaners, paint stripping systems on ships (firing a pulsed jet of water – existing resource! – at the local resonant frequency of the hull), and in helping to empty trucks carrying powder-based substances more quickly.

Thinking in SPACE and TIME

While not strictly speaking a TRIZ development, TRIZ researchers have also recognized the enormous importance of thinking about situations from all angles. TRIZ users are continuously changing their perspective on problems – zooming in to look at the fine details, zooming out to see the bigger picture, and thinking about how the situation is affected by changing time – whether that be nano-seconds or decades – in both the past and future. This is not a natural process for most people – our brains aren't wired that way – and so CreaTRIZ contains tools to help in the process of thinking in TIME and SPACE.

Function and Attribute Analysis

Several attempts have been made by TRIZ researchers and suppliers to integrate function analysis/value engineering techniques into TRIZ software-based problem definition processes. To date, these attempts have largely failed to deliver much by way of user benefit over non-software based methods. This has largely been due to the fact that software has been written to do little more than mimic the manual methods. In effect, the potentially enormous leverage to be gained by harnessing the power of the computer has remained largely untapped. Problem solvers have seen the consequences of this failure in three main areas:-

1) an inability to take adequate account of the **attributes** (for example, weight, volume, surface finish, corrosion resistance, etc) of a system component. The consequence of this is that main often key functional relationships are not identified in models.
2) an inability to take due account of the **time** issues surrounding a problem. The essential consequence of this is that the user does not have any value-adding means of defining how a functional model changes with time-based elements of the problem, and thus receives no guidance on how time-based problem solving strategies can be applied.
3) a total failure of the software to **direct** a user from the function analysis model to the appropriate TRIZ solving tools.

The paper describes the novel function analysis/value engineering modelling technique to be found in the CreaTRIZ™ problem management software. The new model is shown to overcome each of the above problems and to offer users powerful new ways of managing problems. Several real life problem case studies are used to demonstrate the new capability in action.

State Of The Art

On of the key tenets of the TRIZ philosophy is that ‘someone, somewhere has solved your problem’. In the case of function modelling, TRIZ has imported significantly from the work of Miles (1) and successors (for example, Reference 2) on function analysis and value engineering. As in many other things, the TRIZ perspective on such tools has transformed a method that is ‘useful’ to one that provides users with a potent problem definition tool. The simple yet profound twist on ‘traditional’ function modelling is the ability to describe negative as well as positive functional relationships. Such function analysis tools (3, 4 for example) have been seen to offer a systematically useful problem definition capability for a range of different problem situations.

All of the available models – including manual (i.e. non software based) ones – may be seen, however, to still be relatively immature in terms of their full evolutionary development potential (5): All, for example, are predominantly two-dimensional in nature, fail to combine both time and space considerations, and provide users with little feedback on how to proceed once the model has been completed.

We now examine how evolution along some of the lines suggested by this evolutionary potential has resulted in a markedly improved performance capability.

Attribute Modelling

Traditional function analysis modelling techniques allow users to describe the functional relationships between components, but do not take into account the fact that all components feature attributes (size, weight, smoothness, aesthetic appeal, etc), and that it is often the case that the functional relationships occur between component and attribute rather than component and component.

To take the simple example of the system around a piston in an internal combustion engine, a traditional function analysis model would allow the user to describe a functional relationship between piston and oil like ‘piston breaks down oil’ or one between the oil and an additive ‘additive improves oil’. Neither of these descriptions, however, is very useful from a problem definition perspective, nor are they strictly speaking accurate. Far more accurate would be some means of ascribing the functional relationship description to attributes of the relevant components. Thus ‘temperature of piston harms oil’ and ‘sulphur improves lubricity of oil’ may be seen as more useful descriptions. Both actually relate attributes to problems.

The CreaTRIZ software has been designed to allow users to describe such attribute related relationships more readily. In simple terms this capability has been introduced by making the function analysis tool more three-dimensional. Traditional tools are little more than 2D drafting tools; adding the third dimension allows the user to obtain significantly increased operability and functionality – in this case in the form of a double click action on a component in order to access the attributes of that component. Figure 1 provides an example of the capability as it appears in the software.

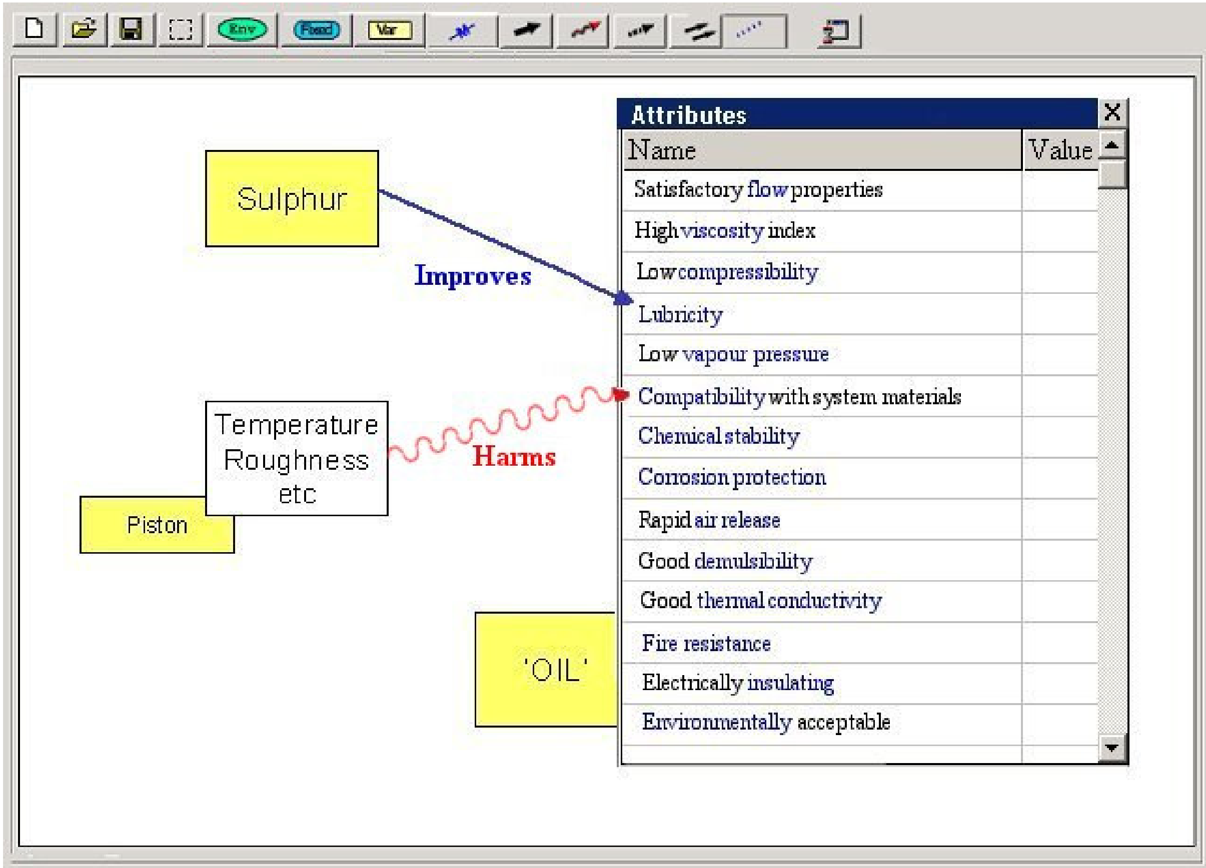


Figure 1: Use of Attribute Capability in FAA Modelling Tool

The user is able to connect functional relationships either from or to any combination of components and attributes. As such, it is intended to not only provide more flexibility of operation, but also to allow fundamentally better access to problem root causes.

In order to facilitate easy use, the software offers the user a comprehensive list of standard attributes and functional relationships. Although the user is also free to use their own words, the standard list has been designed with specific focus on what happens to the function and attribute diagrams once they have been completed. This topic will be explored in more detail in a later section.

Time and Space –Based Function Modelling

Effective application of TRIZ tools requires a sound appreciation of both space and time issues. The system operator or '9-Windows' tool is one explicit means of achieving this kind of thinking in a systematically reproducible way. Traditional function analysis modelling strategies allow users effective means of describing space-based relationships – not only how the 'system' is formed from sub-system components, but also how that system in turn interacts with the bigger picture 'super-system'. On the other hand, time-based problems are not well served by current models. This problem is frequently manifested as a single function analysis model in which several different time images are uncomfortably merged into a single image, often to the confusion of the problem defining team.

The CreaTRIZ software implementation has sought to overcome such problems by enabling the user to more adequately describe the function analysis model in terms of how it is affected by changes in time. As a default, the model assumes the user may wish to describe the functional model situation in the 'past', 'present' and 'future' time slices contained within the system operator. Like the system operator, this structure encourages the user to think about the precise meanings of the past, present and future definitions in the context of the specific problem – i.e. to think about the 'when's of the problem and to establish what the situation before and after the problem has occurred look like.

In many instances, the 9-Windows idea has been seen to be somewhat crude. This is especially the case for process-based problems where there may be a whole cluster of time-based changes in the problem situation. Previous work (Reference 6) has indicated the user of many more 'windows' – such as 'distant past', 'mid-past', 'near-term past', etc – can often be useful. The reference further suggests that a more continuous examination of time-change effects – in the form of 'running a movie' of the situation – can further elicit useful situation understanding and problem definition information. The software handles this situation by enabling the user to select as many different time-slices as are required to model the problem situation above and beyond the three default time-windows. In the interests of efficient use of time, the user is encouraged to think specifically about 'when' problems occur in order to enable function models immediately before, during and after the problem to be drawn rather than possibly drawing a potentially much higher number of models. In order to minimise user effort further, for each new time slice selected, the software re-draws the previous function model in order to provide a foundation for the new model. The basic capability is illustrated in Figure 2.

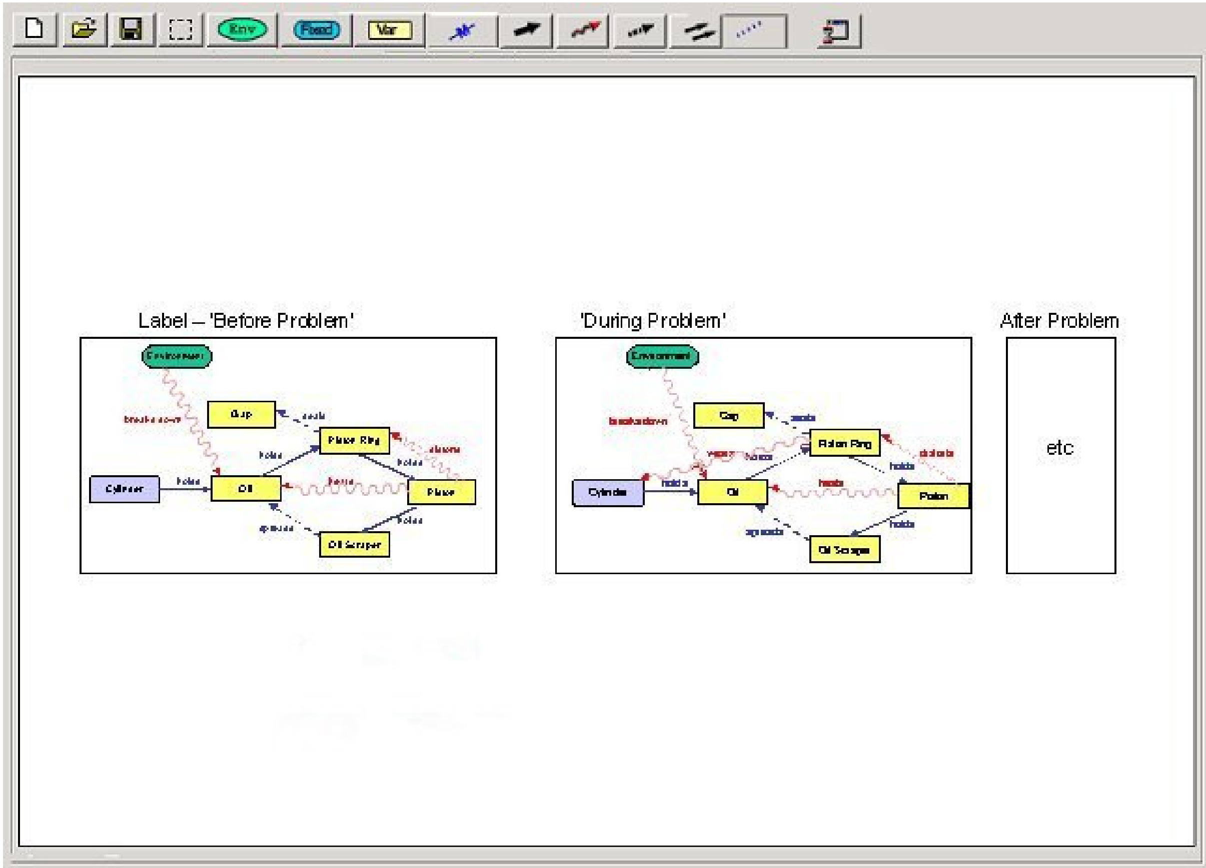


Figure 2: Time Modelling Capability of FAA Modelling Tool

As we will see later, the software will use the differences that occur between different function analysis models as a means of both defining what problems the user should seek to tackle, but also what strategies would be most appropriate to help resolve each defined problem.

Linking Function Analysis To Problem Solving Tool

One of the biggest frustrations of many users of traditional function analysis modelling methods is knowing what to do with the models after they have been completed. The TRIZ problem solving toolkit contains a wide variety of different solving strategies, but it has thus far not been possible to configure suitable algorithms to enable the process of connecting different problem situations to the most appropriate solving tool to be in any way automated.

This task has now been accomplished in the CreaTRIZ software implementation. Selecting a problem formulator button following the completion of a function and attribute analysis model (and possibly also the 'problem explorer' that forms another important part of CreaTRIZ beyond the scope of this programme) provides the user with a ranked list of identified problems – as shown in Figure 4.

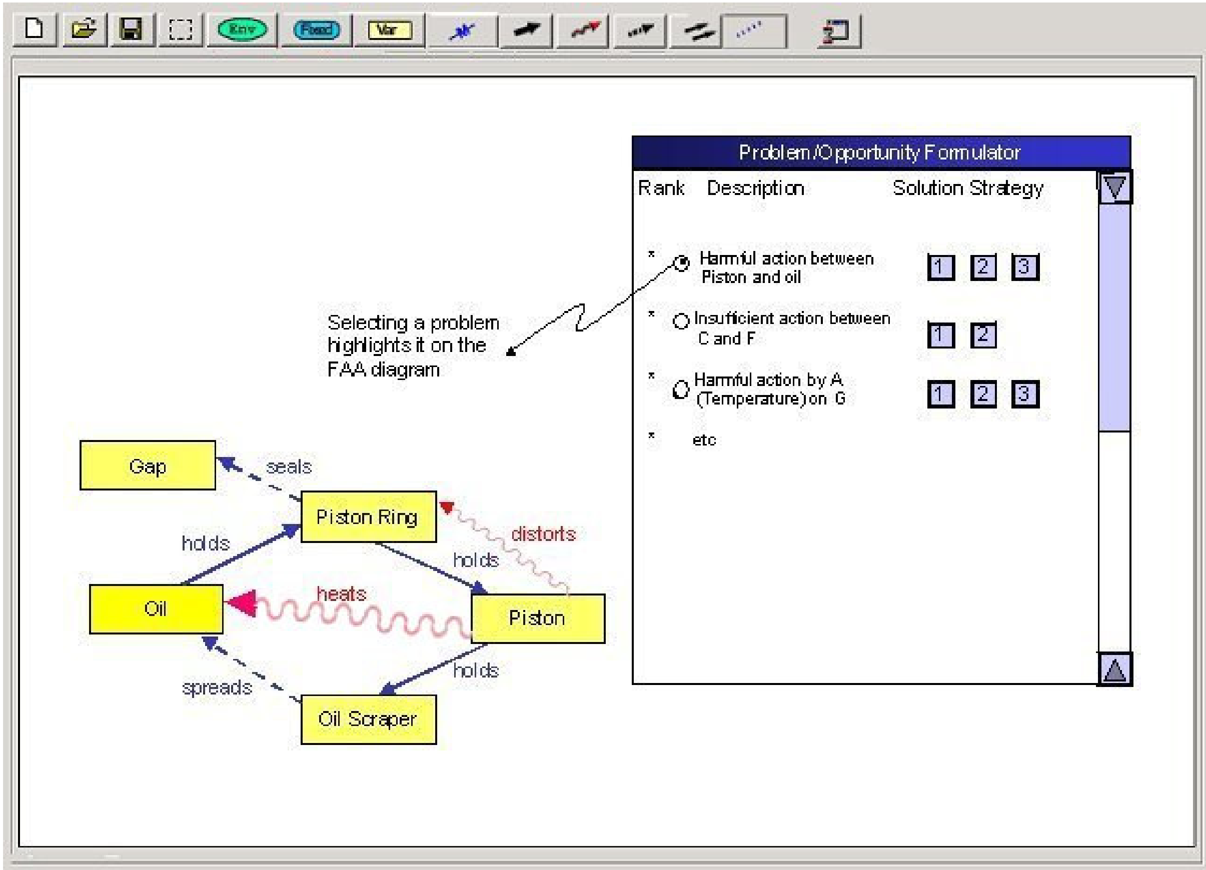


Figure 4: Sample Problem Formulator Output

Many of the algorithms contained in the software remain proprietary, but one or two examples here should serve to illustrate the capability of the software.

One of the more obvious occurs with respect to the Contradictions part of the method. One of the most commonly used and most effective parts of TRIZ, Contradictions have thus far been badly served by function analysis modelling tools. This is perhaps a little surprising given that technical contradictions within a system are relatively easy to spot – as may be seen in Figure 5. The same idea can be used to identify physical contradictions either separated in space or time (using FAA models drawn for different problem times).

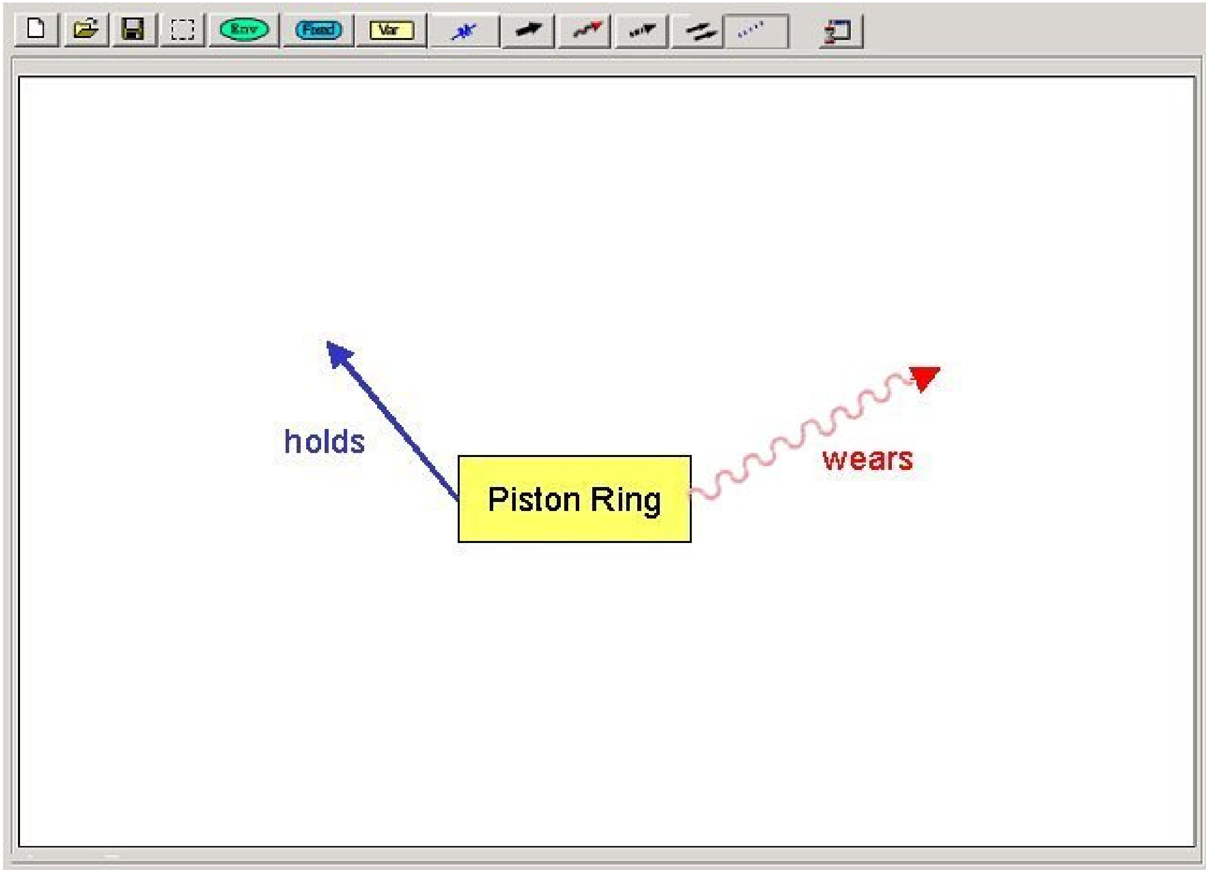


Figure 5: Identifying Contradictions From FAA Models

Presence of insufficient or excessive actions can similarly be used to direct users towards the use of knowledge, trends or S-Field parts of the method. (The precise sequence of which tool to use in which circumstance being of course requiring an additional layer of algorithm complexity depending on, among other things, any attributes supplied by the user).

There are also certain situations in which users are unable to identify problems within a system. In these situations, the user is pointed towards the Ideality part of TRIZ (a tool not found in other models) or a series of trimming algorithms.

All in all, the CreaTRIZ software has been designed to remove much of the uncertainty often experienced by users in trying to bridge the gap between the FAA model and the most relevant tools to help relieve the problem. In such times as the number of users able to use all of the TRIZ tools to a high degree of likelihood of success is still relatively low, the software further permits users the ability to chose between a number of different solution routes. Contradictions can often be solved using either S-Fields or Trends parts of TRIZ for example; albeit some of the tools will require a greater degree of lateral thinking to connect generic solution triggers to good specific answers. TRIZ, in other words, contains a fair degree of overlap between the different tools it contains, and this overlap has been incorporated into the software.

Conclusions

Traditional TRIZ-based function analysis methods are at the beginning of their evolution path and present TRIZ researchers and developers with significant potential for development and improvement of the capability they offer problem and opportunity owners.

The CreaTRIZ function and attribute analysis software is believed to offer users a significantly improved and evolved version of the original methods. The method is believed to offer improved modelling of component attributes and time-based problems, improved access to multiple users and better connection between problem definition and problem solution; specifically offering users an automated means of connecting problems to the most appropriate TRIZ solution tools, for both technical and non-technical problems.

No method of course, can ever rightly claim to be complete. This applies both to TRIZ and the CreaTRIZ software implementation. In the case of both, however, there is an ongoing development activity to integrate further definition and solution tools into the TRIZ armoury. Users might expect to see some of the fruits of this activity in future versions of the software containing handling of QFD, Design for Manufacture and Assembly, Theory of Constraints (containing even stronger root cause analysis modelling techniques), Axiomatic Design, NLP and several other emerging and established techniques.

References

1) Miles, L., ‘
2) ‘Value Engineering’, CRC Press.
3) Invention Machine, TechOptimizer Professional Edition
4) Ideation, Innovation Workbench
5) Mann, D.L., ‘Evolutionary Potential in Complex Technical Systems’, paper to be presented at CIRP2002, Hong Kong, April 2002.
6) Mann, D.L., ‘System Operator Tutorial 2) Between The Boxes’, TRIZ Journal, November 2001.