Product and Process Improvement using TRIZ: A Case Study in Increasing Innovative Options.

Barry Winkless
AMT Ireland, University College Cork, Ireland
Tel: 00 353 (0) 87 9720544 Email: winkfull@hotmail.com

Darrell Mann
Systematic Innovation, Bristol, UK
Tel: +44 1275 337500 Email: Darrell.Mann@systematic-innovation.com

Abstract

This paper focuses on the application of a range of TRIZ tools and techniques in a small European-based food equipment company. The company in question had just completed the development and initial productionisation of a patented food heating process and was in the process of launching the new system and its associated novel business model onto the market. The paper describes how TRIZ was used at a variety of levels and areas of the company from the perspective of both problem solving and improved opportunity exploitation.

Introduction

The paper describes a multi perspective programme of work to assist a small European-based food equipment company to improve and extend their product range, and to develop their business model.

The company in question has recently introduced a novel hot-air based machine for heating French fry and related products in a restaurant, bar, or remotely situated food outlet where conventional 'cooking' is prevented either due to lack of space or amenities. In many senses, the hot-air heating method represents a disruption to the conventional deep fat frying method used in most establishments. The company's business model assumes that the time for the disruptive introduction of a fat-less heating concept is right due to increasing environmental consumer safety awareness. Essentially, the new heating concept allows users to eliminate the need for large amounts of oil which – regulations dictate – must be changed on a regular basis, and must be disposed of in an environmentally sensitive (and therefore expensive) manner.

The first hot-air-based machine (Figure 1) has been developed over a 2-year period, and production deliveries began during 2001. Early in-service experience with the machine showed that although the quality of the fries produced by the machine was excellent, there were a number of undesirable side effects that required attention in order to ensure long-term business success. Thus, a TRIZ-based analysis programme was instigated at the request of the company. The programme comprised three principle areas of activity; the first associated with improvement of the current version of the machine; the second associated with examining the bigger technical picture in order to identify threats and opportunities for new machine concepts; and the third associated with examining the prevailing business model in order to explore the possibility of enhancement in the future.

Figure 1: Overall View of French Fry Heating Machine

The specific details of the work conducted are commercially sensitive and will not be discussed. They are considered, in any event, to be irrelevant to the theme of this paper, which is to explore the application of TRIZ tools to the programme, and to then examine some of the implications as far as the method itself is concerned. Included in the discussion, therefore, are the following sections:

a) Application of Function and Attribute Analysis tools and subsequent resolution of limiting contradictions identified during this process for a near-term problem associated with the initial production run of the food equipment. Of particular relevance from a TRIZ methodology perspective in this discussion is the manner in which the considerable constraints on the problem were incorporated into the problem definition and solution generation process.

b) Application of an evolved series of technology evolution trends to the novel product in order to identify its future evolution potential and hence near term future development strategy.

c) Application of the same trends from a broader perspective to identify potential threats to the novel food heating product, and then, using this information in conjunction with novel patent search strategies, the use of TRIZ tools to help develop product evolution strategies aimed at countering the potential threats from competitor innovations.

d) Application of TRIZ-based business trends to identify threats and opportunities for evolving and improving the company's novel business model to ensure long-term competitiveness. Of particular interest in this part of the work was the incorporation of strategies for maximising use of existing resources and for identifying the timing for the introduction of the various business concept innovation steps identified.

The paper concludes with a short section highlighting the strengths, weaknesses and opportunities for evolution of TRIZ based on its application in the real world of small and medium sized enterprises operating in rapidly changing market conditions, with limited technical and financial resources.

A) Function Analysis of Current Machine

The current production version of the machine is relatively simple in its form. Essentially, pre-cooked and frozen frites are loaded into the machine in pre-determined portion sizes into a heating vessel (the machine contains features which prohibit users from using anything other than the authorised products, but these features will not be discussed here as they were independent of the

problem-causing features). The machine is then turned on, and air is circulated through the vessel via a fan. The air is heated to around 200degC through a simple, thermostatically-controlled heating element. The velocity of the hot air through the heating zone has been designed such that the frites become airborne – thus ensuring even heating on all sides of all of the frites.

The observed problems with the system were that a) it required regular cleaning and each time was difficult to clean, b) because the frites were in constant motion within the heating zone, they tended to shed small fragments during impacts with either each other or the walls of the container, and these fragments then gradually blocked up a filter that also had to be cleaned, and c) because the frites contained moisture which evaporated during heating and as a consequence then increased the pressure inside the machine, there was a problem with air leakage. While the air and water vapour leakage was in itself not a problem, the presence of small amounts of oil meant that there was a potential odour problem when the machine is situated in confined spaces.

In order to investigate means of eliminating these problems and improving the design of the machine, a series of function analysis diagrams were constructed. As described in Reference 1, it was necessary to construct a series of function analysis diagrams in order to adequately describe how the functioning of the system altered with time. As shown in Figures 2 to 4 respectively, the three principle times in the process were:-

1) the machine operating at the start of the heating cycle
2) the machine operating at the end of the heating cycle – when the water in the frites has begun to evaporate and the pressure in the machine has increased,
3) the machine during the cleaning activity.

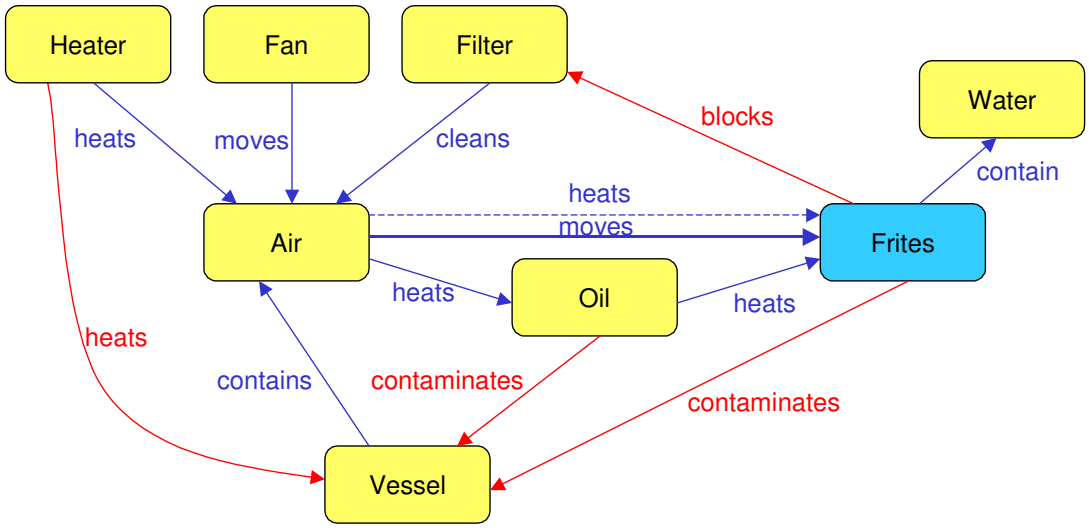

Figure 2: Function Analysis of Machine – Start of Operation Cycle

The function analysis model in this and all of the following cases was constructed using the sequence recommended in Reference [2] – i.e. 1) identify the components, 2) identify the useful function relationships, 3) identify the negative, insufficient and excessive functional relationships. This sequence is important when trying to maximise the match between task and the different modes of operation of the human brain.

Figure 3 illustrates the equivalent function analysis model of the machine towards the end of the heating cycle. The main point to note when comparing this model with the one in Figure 2 is that the water contained in the frites has become a problem – being attracted to the oil, and then both being released into the atmosphere to create the odour.

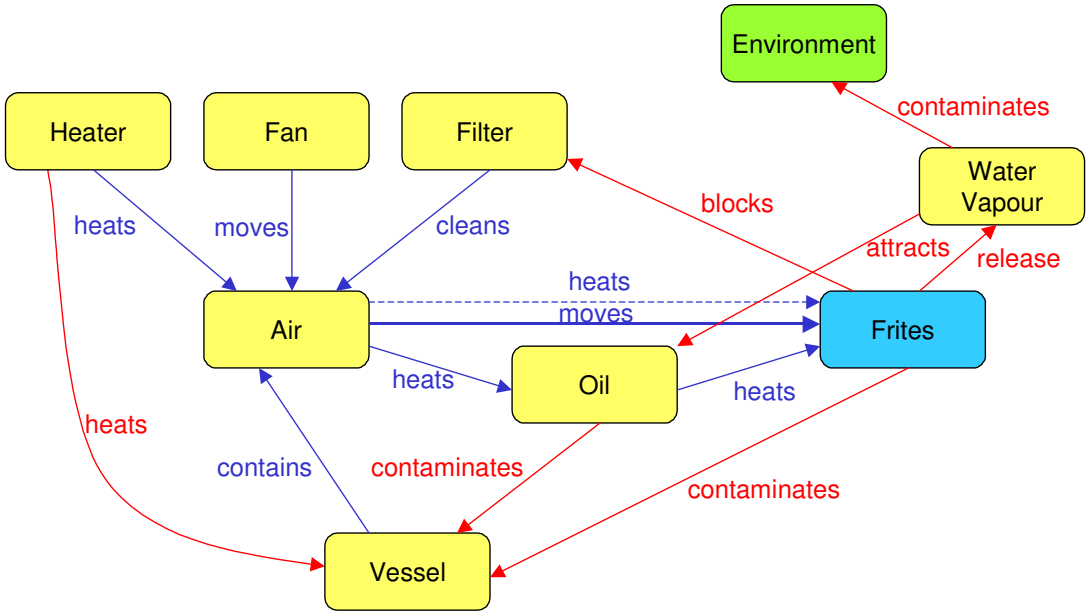

Figure 3: Function Analysis of Machine – End of Operation Cycle

In Figure 4, the focus of the function analysis shifts to the vessel that the frites were heated in, and specifically the problem of cleaning the oil that cools onto its surface.

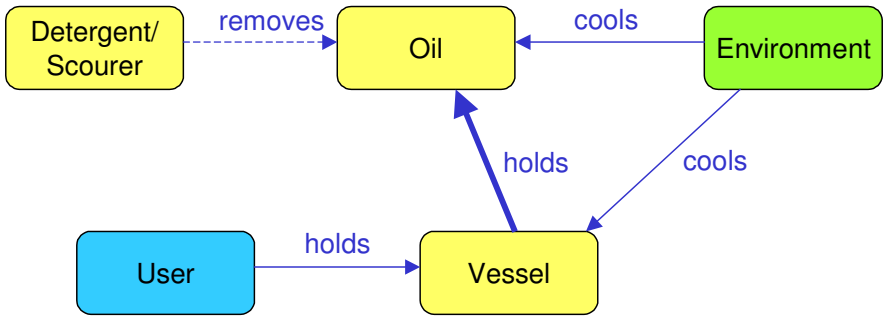

Figure 4: Function Analysis of Machine – Cleaning Cycle

What the function analysis models make clear is that the hot, moving air within the system carries out both harmful and useful functions. Examination of the useful functions highlights the presence of 1) heating of the oil by the air, 2) heating of the frites, and 3) agitation of the frites in order to improve heat transfer and cooking properties. It also incurs harmful functions- predominantly the spraying of oil from the frites onto machine walls and the over agitation of chips (shown as an 'excessive' action in Figure 2) causing more widespread distribution of oil and potato crumb debris, which in turn increases the difficulty of cleaning the machine after use.

The temperature within the system obviously has the useful function of heating and cooking the fries, however there is also the harmful function of causing the oil to liquefy and again cause deposition of oil onto machine surfaces. The oil itself carries out the useful function of improving heat transfer and mouth-feel of the chip but incurs the harmful function of being the major cause of dirt in the machine.

From a system analysis perspective, the functional analysis diagram can be used not only highlight the problems contained within the system, but also categorise them into different types in order to

facilitate the selection of the most appropriate TRIZ (or other) tool to help tackle that problem. In this particular case, for example, the model highlights the existence of a number of contradictions in the system. As previously mentioned, the description of problems as contradictions is a powerful tool in TRIZ as it enables the engineer to extract powerful contradiction-breaking solutions from the most successful inventive solutions of others who have successfully overcome similar problems. The contradictions and suggested solutions for the fry-heating machine were identified as follows:

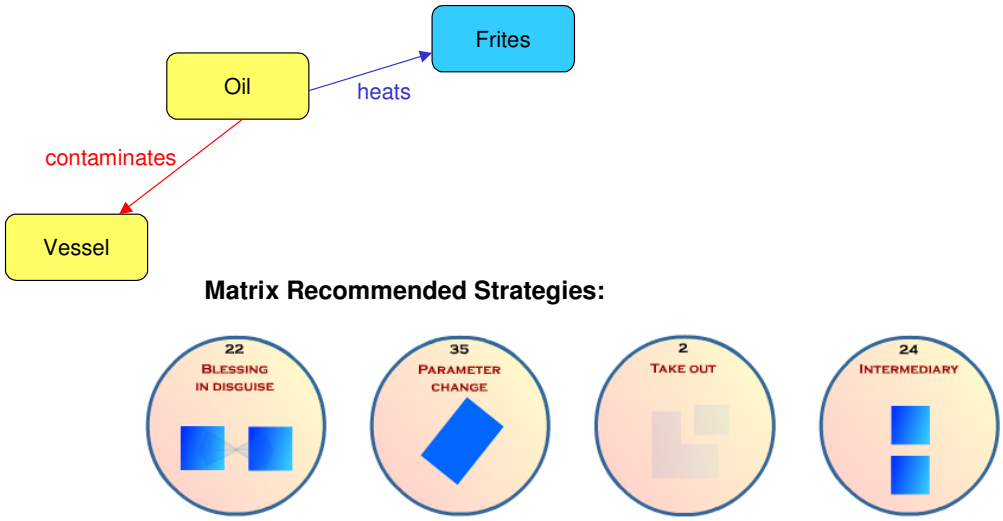

Figure 5: Exploration of Heats versus Contaminates Contradiction

More subtle than the heats versus contaminates contradiction is the one present in the relationship between the frites and the air used to heat them – Figure 6.

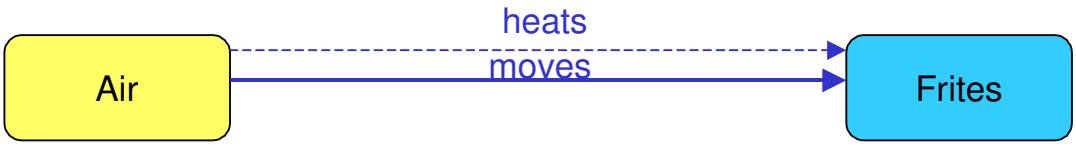

Figure 6: Exploration of Temperature versus Pressure Contradiction

In this situation, the problem was mapped onto the Contradiction Matrix as a temperature versus stress/pressure problem. The recommendations for solving this conflict pair were Principle 35, Parameter Changes, Principle 2, Taking Out, Principle 39 Inert Atmosphere and Principle 19 Periodic Action. The repeat of Principles 35 and 2 from the other main contradiction identified suggested that both were clearly relevant to achieving a good solution to the problem. In the event, the best solution was derived from Principle 19, Periodic Action; where the previously continuous motion of hot air was transformed into a pulsed flow which served to gently 'bounce' rather than blast the frites continuously. This solution in fact also helped to solve the contamination and filter blockage problems – another solid example of how solving a contradiction can also help to solve problems other than the ones being focused on. See also reference 3 for more examples of food related applications of the Inventive Principles.

As it happens, Principles 35 and 2 were used to generate concepts that helped with the cleaning process – 35 to incorporate easy-to-clean Teflon coatings, and 2 to recognise the possibility of separating the agitation and heating functions of the moving air, and to generate a longer term solution that managed the movement of the moisture within the frites in a more effective way.

B) Trends and Evolutionary Potential Analysis of Current Machine

In parallel with the function analysis, the current system was also analysed from the perspective of its state of evolutionary potential (Reference 4). The resulting analysis is reproduced in Figure 7.

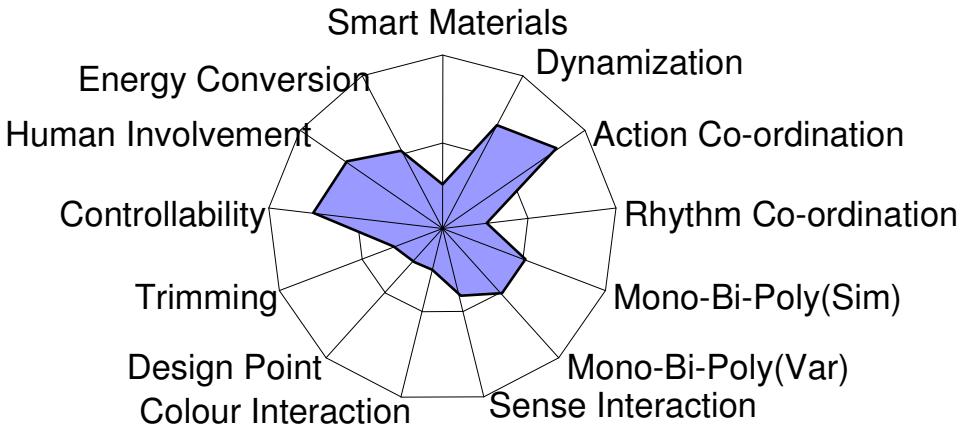

Figure 7: Evolutionary Potential Plot For Original Machine

What the analysis showed was that, relative to the global trends, the system contained significant untapped potential. This unused potential was then examined in the context of how it might be utilised to help solve some of the problems associated with the system. In particular, the delivery of the function 'air heats frites' (which had been classified as an insufficient action in the function analysis model) was used as a focus for correlating trend jumps to means of improving the performance.

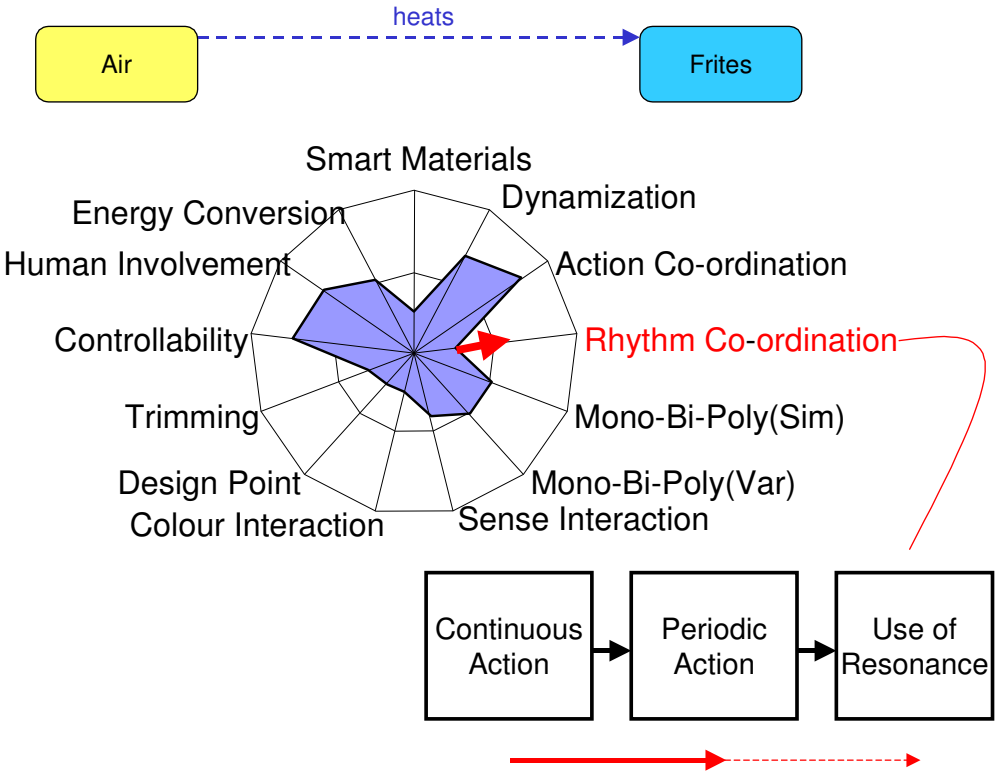

Figure 8: Plot Suggest Evolution Along Rhythm Co-ordination Trend

As illustrated in Figure 8, the rhythm co-ordination trend appeared to offer the simplest of the untapped trends to utilise. This perception came at least in part from the emergence of Inventive Principle 19, Periodic Action from the earlier contradiction analysis – an example of how different parts of TRIZ can often lead to the same sort of solution directions. What the trend analysis showed over and above the contradiction assessment was that the introduction of some form of pulsation could also be used to enhance the heat transfer rate of the frites – and thus enable a welcome reduction in the overall heating cycle time.

Taking the trend a stage further by introducing the 'resonance' stage generated the idea of using ultrasound as a means of achieving further increases in heat transfer rate and also – referring back to the contradiction solution suggestion Principle 2, Taking Out – potentially providing an alternative means of agitating the frites.

C) Super-System Perspective of Machine

Although the use of pulsation and resonance provided a reasonably good opportunity for a technologically improved system, the trend towards increased use of fields identified in the evolutionary potential analysis suggests a limited life of air based heating systems. In fact some French fry products, commercially available, already utilise field technology - i.e. microwaveable frites.

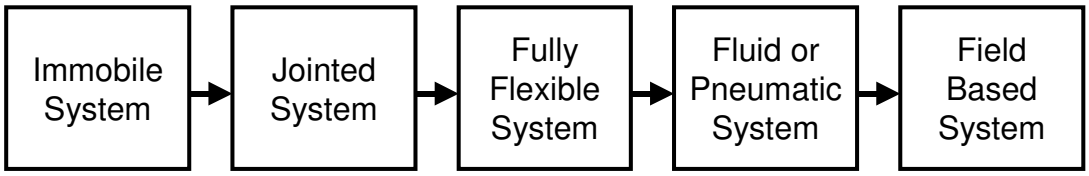

Figure 9: Dynamization Trend Suggests Limited Life of Air Heating Method

Microwaveable fries, such as McCains Micro Chips and Green Isle Micro Fries, could be seen from this analysis to pose a huge potential threat to the company's future profitability – fields inevitably solving, for example, many of the problems being exhibited by the current machine. The inevitable evolution from air to field based systems, however, also provide significant opportunities. Examination of McCain and Green Isle products using Evolutionary Potential Graphs, show that both are only a small way along many of the technology trend paths – Figure 10:

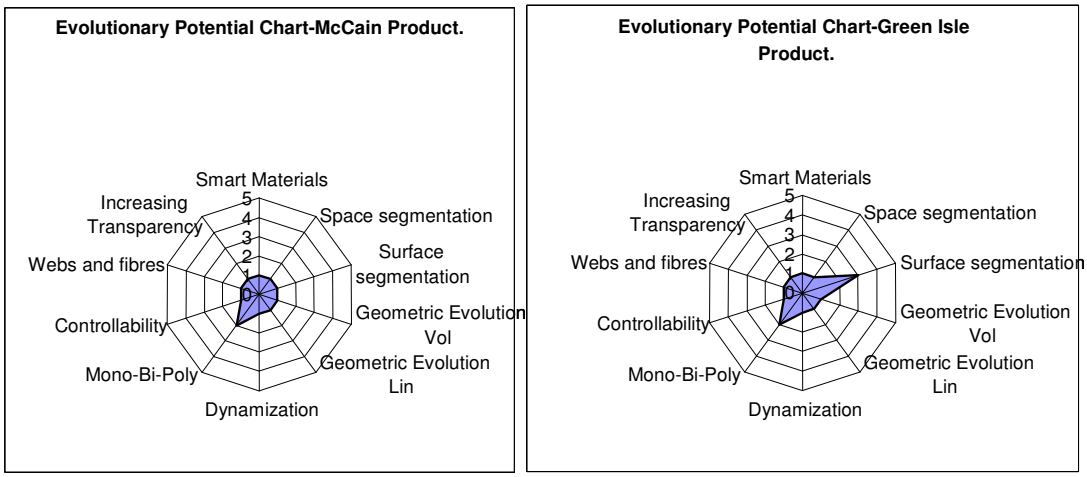

Figure 10: Evolutionary Potential Plots for Current Microwave Frites Packaging

These products can be seen as part of the sub-system of 'microwaveable frites' and 'microwaveable french-fry containers'. However these subsystems are only a small part of the larger system of 'microwaveable containers'. At this point a large study was carried out focusing on all microwaveable container patents contained within the US, Japanese, and European patent databases. This study was carried out for a number of reasons:

1) To ascertain the evolutionary stage of each microwave packaging patent.
2) To gain an overall picture of microwaveable packaging development over the past twenty years.
3) To gain an insight into potential development 'gap-paths' for the company to follow in order to produce a superior microwaveable French fry product to those currently available on the market.

The results of this large study will be published in future articles. However for the purposes of this paper, it suffices to say that many of the packages in the study are still at the early stages of their evolutionary development curves. One of the major trend paths along which the majority of packages have not been significantly developed along is the surface segmentation trend. Only a handful of the packages researched utilised this trend to any degree. This is surprising as roughened surfaces using geometric properties provide a large number of advantages, most importantly in this case, improved heat transfer properties. The cost of development utilising such features is also relatively inexpensive.

It was decided at this point by the company that the development of an improved microwaveable package should be pursued focusing predominantly on the use of geometric protrusions. Focus then shifted from concept development to prototype development. This involved statistical experimentation using susceptor materials configured in different geometric patterns. Some examples of the configurations used are shown in Figure 11 below.

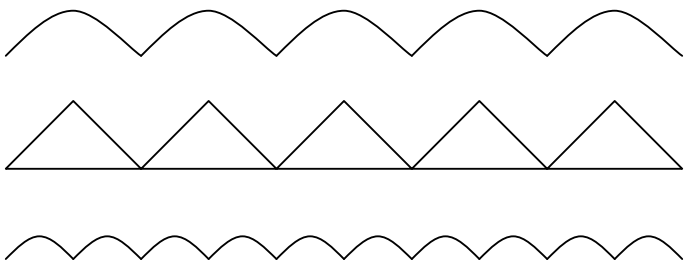

Figure 11: Alternative Susceptor Geometries

Design of experiments was used in the optimisation of the geometric feature, focusing on the frequency of the crests, the height of the crests, and the shape of the crest. Work is still continuing on this part of the project, however initial results suggest that the use of such features improve the crunchiness (texture) and overall taste of the frites significantly compared with other commercially available microwave French fry products. Appropriate patent applications have already been filed.

Furthermore, development costs have been extremely low, thanks mostly to the use of TRIZ and Patent analysis, and outsourced experimentation and prototype development work.

D) Business Model Innovation

Commercial considerations prevent us from discussing too many of the details of the work done to evaluate and enhance the business model of the company in question. Nevertheless, it is appropriate

to report that an evolutionary potential assessment of the business model currently operated by the company highlighted the presence of significant amounts of untapped potential – Figure 12.

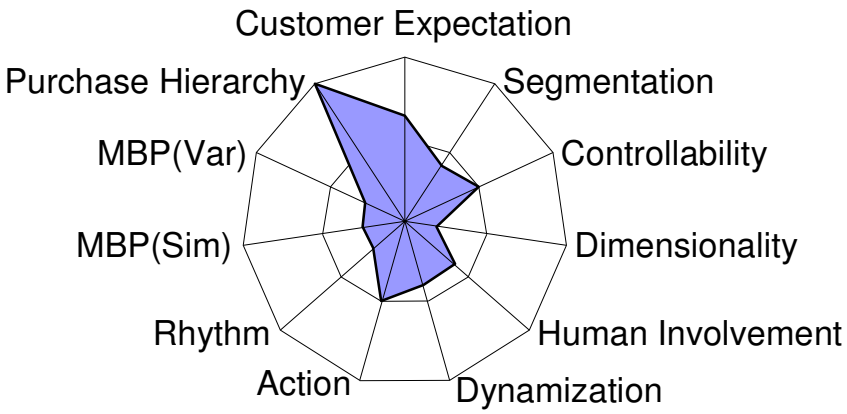

Figure 12: Evolutionary Potential Radar Plot of Business Model Operated by Company

Examination of this evolutionary potential plot highlighted a number of previously untapped opportunities that may in future serve to strengthen and extend the reach and durability of the current business model. These have so far included:

a) consideration of co-opetition (Reference 5) with previously unidentified organisations offering complementary products and services – for example branded sauce and other condiment suppliers (after the Mono-Bi-Poly(Various) trend).
b) Broadening of the product range and menu of options for potential customers by integrating different condiment offerings into the frites product (after the Mono-Bi-Poly(Similar) trend)
c) Consideration of more effective means of interacting and gaining feedback from intermediary suppliers and end-users through creation of a simple to use, virtual community (after the controllability and dimensionality trends).
d) Transformation of the 'service' provided to end users into something more akin to an 'experience' (after the customer expectation trend)

In actual fact, like a growing proportion of applications in other fields, it was observed that there was as much if not more business growth potential to be accrued through innovation of the business model as there was through technical innovation of the product offering.

Conclusions

The study has demonstrated the capabilities of TRIZ to successfully examine a range of issues associated with the machine under evaluation – from near term, fine detail problems, through to longer-term technology direction and high-level business strategy issues. A range of different tools was used when tackling each situation.

The French fry machine is a commercial success. The suggested evolution to increased use of fields, and the resultant emergence of microwave-based heating concepts has resulted in a patentable invention that may be expected to broaden the range, life and capability of the company concerned.

TRIZ is believed to offer huge potential for food product developers who want to develop innovative products at low cost. It is important, however, to follow a systematic route when using

TRIZ in this way- the development of a more systematic step-by-step 'warts and all' approach to technological and product development using TRIZ is important if TRIZ is to be utilised more fully by industry in the future. Some work is currently being carried out in this area by one of the authors of this paper.

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