A PROPOSAL TO INTEGRATE TRIZ INTO THE PRODUCT DESIGN PROCESS

Dr. Noel León-Rovira
Instituto Tecnológico y de Estudios Superiores de Monterrey, México.
email: nleon@campus.mty.itesm.mx

ABSTRACT

Research work is being undertaken at the Center for Innovation and Product Design at the Monterrey Institute of Technology (Mexico), looking for the integration of different design tools and methodologies to increase product design effectiveness and productivity. This paper describes the integration of TRIZ and "Classical" Design Methodologies as Morphological Matrix during the design process at the conceptual and at the embodiment design stage. As TRIZ is not originally a tool that belongs to the "classical" product design methodologies, its place in the product design process has to be identified in order to increase its effectiveness. The proposed approach has been tested and improved during several years at the course Product Analysis and Design (M99-235) of the Master Program in Manufacturing Engineering at ITESM Campus Monterrey. The course is based on the strategy of Project Oriented Learning, focused on enhancing creativity and inventive skills of the students and its ability to create virtual 3D-Parametric CAD models of the products being designed. Students work in teams solving real world product design projects from Mexican manufacturing enterprises on a contractual basis. This allows the evaluation of the used approach from the point of view of its usefulness for solving real world product design problems as also from the point of view of its friendliness for learning and use.

1. INTRODUCTION

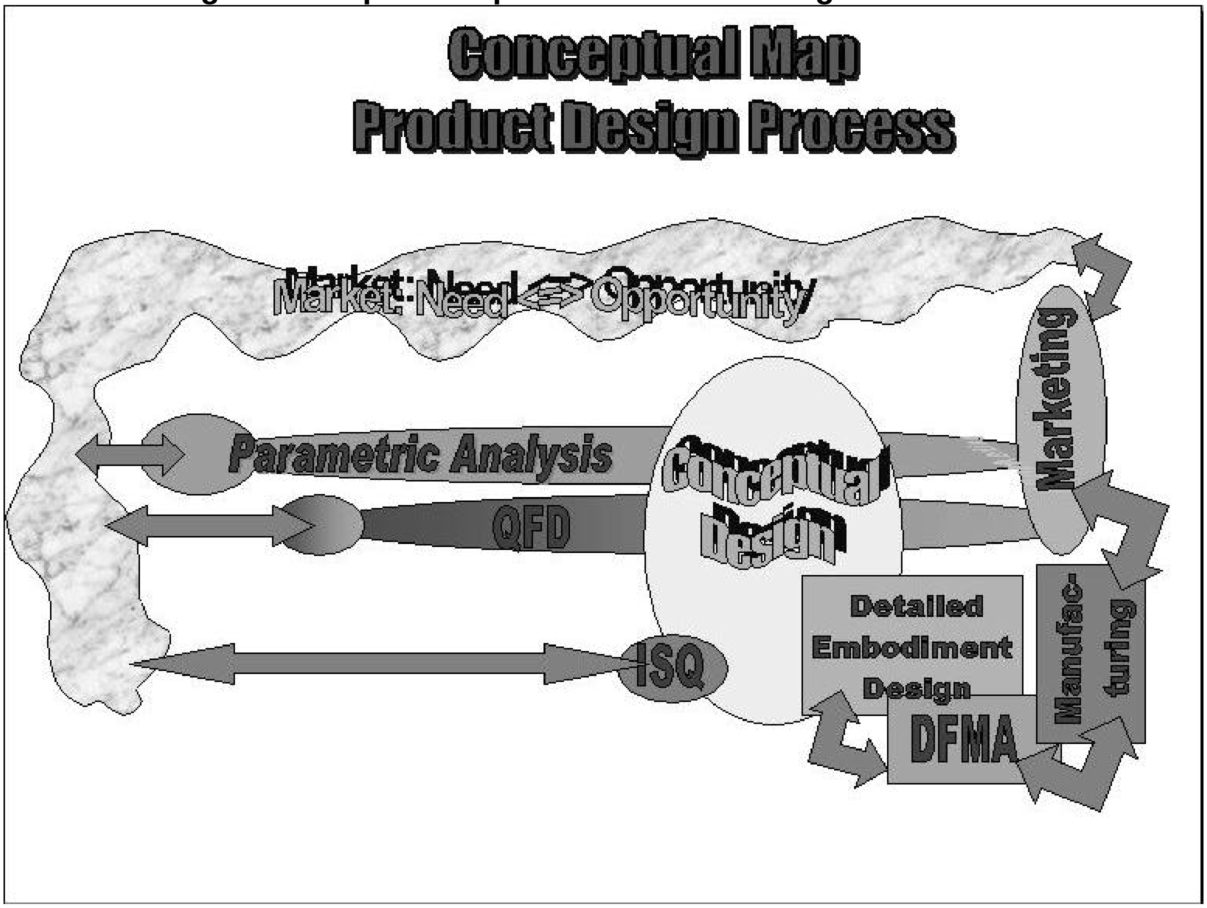
The product development process may be defined as the complex system of activities that produces the information required for bringing products to manufacture that is derived from market opportunities. Further more it is known that the design process is an information generating process, which starts with an abstract and often uncertain and confuse description of a new or enhanced product performance and ends with the documentation for manufacturing the desired product. Efficiently and effectively supporting the design process with computational tools and methods is limited due to its lack of integration.
Research work is being undertaken at the Center for Innovation and Product Design at the Monterrey Institute of Technology (Mexico), looking for the integration of different design tools and methodologies to increase design effectiveness and productivity.
First results about our approach of an integrated model of the Conceptual Design Process were presented at the QFD Symposium [1] and TRIZCON'99 [2]. In both papers the integration of QFD and TRIZ in the product design process was presented based on case

studies. Further theoretic reflections about the integration of TRIZ and CAD were presented at TRIZCON'2001 [3].
This approach is intended to contribute to a reduction in product development time and to an improvement in quality and performance by creating the groundwork for integrating product development tools and methods.
Furthermore it is intended to have an approach of the design process that may be easily learned due to its logical structure and to the enhanced capability of students/designers for achieving better solutions for challenging design projects.

2. M-99-235 AND THE QTC APPROACH

The present approach is based on the integration of parametric analysis [4] and Quality Function Deployment (QFD) during the specification/planning stage; the Theory of Inventive Problem Solving (TRIZ) [5] and "Classical" Design Methodologies as Morphological Matrix at the conceptual design stage [6], [7] and 3D-parametric computer aided design tools at the embodiment design stage. The approach is named **QTC**, because of the integrated use of **Q**FD, **T**RIZ and **C**AD.
QTC has been tested and improved during several years at the course Product Analysis and Design (M99-235) of the Master Program in Manufacturing Engineering. The course is based on the strategy of Project Oriented Learning and is focused on enhancing creativity and inventive skills of the students and their ability to create virtual 3D-Parametric CAD models of the products. Students work in teams solving real world product design projects from Mexican manufacturing enterprises on a contractual basis. The enterprises assign experienced representatives to follow up the projects and to provide the students with the needed background and existing information.
One of the requisites for choosing a project for the course is that it should contain a reasonable challenge and it should be estimated as possible to fulfill during an academic semester. In cases when the challenge or volume of work may be too big, it is possible to divide the content in two or more students' teams.
Actually it is not possible to rigorously evaluate the results from the point of view of its designed performance, as it is not feasible to have the same products designed through alternative or classical approaches. However the achieved solutions can be evaluated from the point of view of the acceptance of the enterprise representatives. Furthermore the approach is evaluated from the point of view of its acceptance and ease for being learned by the students.
Students learn and apply the referred tools in their design projects in four modules: specification/planning, conceptual design, embodiment design and design for manufacturing.
In Fig. 1 a diagram of the conceptual map that supports this approach is shown.
Following is a briefly description of the activities accomplished during the first two course modules and its relationships to the conceptual map.

Fig. 1 Conceptual Map of the Product Design Process



2.1. Specification/planning

During the first module Parametric Analysis followed by QFD are applied as main tools of the specification/planning stage. Although both tools are applied mainly during the first module, students are encouraged to extend its use through the whole recurrent product development process, as shown in Fig 1, pursuing the objective to further improve their insight into the products being developed. This appeal is based on the judgment that due to the huge amount of time and work needed to execute a parametric product analysis and the QFD process, both tools may not be accomplished as a simple stage of the project schedule of a product design but rather have to be continuously performed as part of the enterprises' culture in order to gain a competitive advantage in the market.

However, executed as an academic exercise during the first module of the course, the combination of both tools allows students to gain a deep insight into the products being developed.

Students are encouraged to use the INTERNET with advanced search engines to gather information of similar products that may be considered competitors. Commonly students perform this assignment in 2 weeks, during which they gather parametric and graphic information that is then resumed in tables and graphics showing the correlations of important product parameters or indicators.

In table 1 an example is shown of gathered information about can vending machines.

Table 1: Parametric Analysis Vending Machines (extract)

Parametric Analysys Vending Machines	Height (in)	Wide (in)	Depth (in)	Columns # of	# of cans (12 oz)	Weight (lb)	Selections # of
Avanti UV510	72.0	39.000	30.000	10	510	670	10
Avanti UV600	79.0	39.000	30.000	10	600	735	10
Cavalier C6-276	72.0	29.500	29.500	ND	276	ND	8
Cavalier C7-392	72.0	39.500	29.500	ND	392	820	9
Cavalier C7-564	72.0	39.500	32.500	ND	564	653	13
Dixie-Narco DMV-72Na	72.0	28.000	32.000	ND	400	680	10
Dixie-Narco DMV-72W	72.0	37.000	32.000	ND	500	750	10
Dixie-Narco DMV-79W	79.0	37.000	32.000	ND	620	880	10
Metalfrio VM-6	79.5	37.000	29.500	ND	448	735	9
Metalfrio VM-7	72.0	37.000	33.000	ND	552	536	13
Metalfrio VM-8	79.5	37.000	33.500	ND	802	594	8
Rock-ola C8-00G	72.0	36.500	25.500	ND	470	714	9
Royal Vendors GIII RVC660-7	72.0	37.000	33.500	ND	660	580	9
Royal Vendors GIII RVCC550	72.0	30.800	34.000	10	550	640	9
Royal Vendors GIII RVCC660	72.0	37.000	34.000	12	660	599	13
Sanden UniVendor-2-511	72.0	39.000	33.000	10	511	ND	10
Sanden UniVendor-2-601	79.0	39.000	33.500	10	601	ND	10
USI Can Mart II	72.0	26.625	36.250	ND	300	510	6
USI CD10	72.0	42.000	36.000	ND	478	ND	9
USI CD8	68.0	32.000	35.000	ND	346	640	7
Vendo 280	66.0	32.000	30.000	6	280	525	6

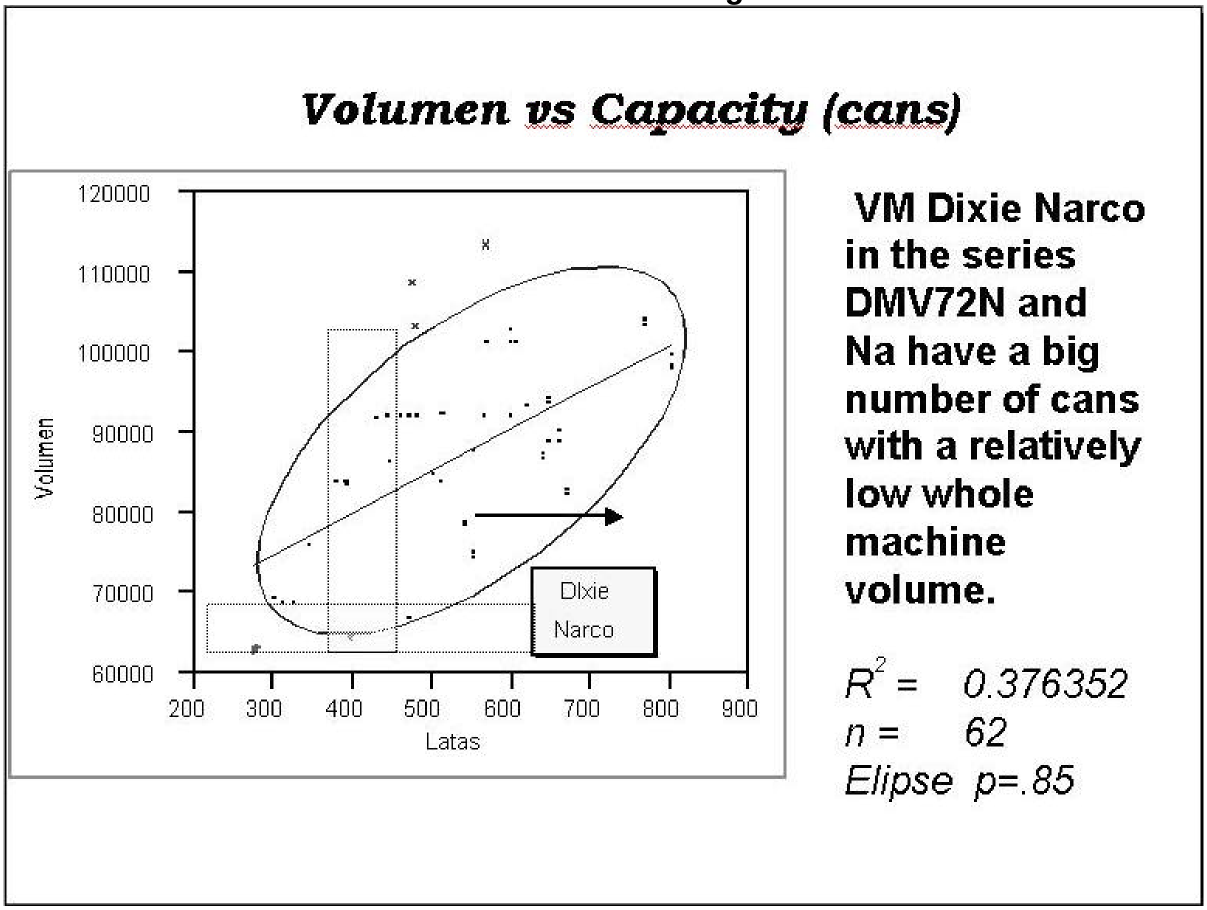
In Fig. 2 is shown a parametric correlation of two selected parameters of vending machines. The selected parameters are the whole machine volume and its capacity, measured as the total number of cans that the machine is able to contain.

Each point in this graphic represents one of the vending machines encountered. The parametric analysis performed was to find the ellipse's axis ratio that includes the most representative of the 62 machines registered (in this case p= 0.85) and the regression coefficient of the line that better follows the pattern of points (in this case R^2= 0.376).

In each case students/designers have to choice and decide which parameters should be graphically represented in order to recognize trends and important relationships among the product parameters.

Based on these graphics, specification/planning decisions may be supported. One recommended exercise is to draw a line that connects the parameter values of the existing product with the recommended values for the new product being developed and to compare this line with the general pattern identified for the bunch of products analyzed. The notion of innovation and technical contradiction of TRIZ may be perceived at this point if the proposed relative change of the parameters for the new product follows the identified pattern or not.

Fig. 2 Parametric relationship:
Volume vs. # of cans in vending machines



The primary purpose of QFD was described in [1] and [2] as to identify the most important issues and parameters of the products and to link priorities and target values back to the customer **before** the new product design process is started.
After that one of the features of the HOQ diagram requires to define the directions in which product parameters has to change, or which parameters should remain unchanged for a better customer satisfaction. Identifying relationships among the parameters at the roof of the HOQ helps in identifying technical contradictions and innovations requirements stated. The use of TRIZ at the conceptual design stage may then focus on **how** to achieve these changes to gain bigger market shares.
This combined use of parametric analysis and QFD allows gaining a better understanding of the market and customer needs and of its relationships to the existing product structure and parameters.

2.2. Conceptual Design

Morphology is the science of relationships between ideas and actions, founded and developed by Swiss (American) astrophysicist Fritz Zwicky [7]. The resulting technique of creativity aims to replace subconscious mind driven and therefore arbitrary, random production of ideas by a conscious, systematic approach.

Functional decomposition is the analysis of the activity of a system as the product of a set of subordinate functions performed by independent subsystems, each with its own characteristic domain of application. It assumes that there are a variety of functionally independent units, with intrinsically determined functions, that are minimally interactive.
Students start the conceptual design module from the now as "classical" recognized method of Zwicky's morphological matrix [8] as proposed in several Engineering Design Books [6] and [7]; combined with the functional decomposition of the design object. The functional decomposition helps in gaining a better understanding of the product.
The generation of ideas for the different items of a design object through the combined use of Functional Decomposition and Morphological Matrix is a proved useful method in product design as it stimulates creativity and helps to find new unexpected solutions through new combinations of solutions at the lower functional levels.
This method may be considered a kind of "structured" brainstorming, as the ideas generation for the different functions occurs more or less spontaneously. Not always the ideas generated during a Morphological Matrix session are able to solve the technical contradictions inherently in the problems.
Synectic is a method commonly used in Germany to improve the ideas generation after a morphological matrix session. Author of the method Synectic is William J. J. Gordon [9]. He developed this method in 1944 on the basis of intense studies about mental and problem solution processes. This heuristic principle is based on the reorganization of different knowledge to new patterns.
The synectic method is based on the principle of the systematic confrontation by analogies. The method acknowledges that original ideas often appear not from a conscious problem treatment, but as a reaction to the confrontation with elements strange to the problem (events, structures, etc). So, e.g., Newton should become clear of the gravitation principle while observing falling an apple. This natural creative process is tried to be imitated with the methods of the creative confrontation.
Although the synectic method has also proved to be useful to enhance the results obtained after a morphological matrix session, its use is difficult and it not always provides innovative results. Therefore the use of TRIZ combined with the morphological matrix is tried as an alternative method.
TRIZ has proved to be a very strong tool in helping to solve difficult technical problems that requires inventive thinking; that means problems where one or more technical contradictions are involved and which do not have known ways or means of solution [10], [11]. However the use of TRIZ in the product design process has yet to be better identified and established.
Students are introduced to TRIZ during the second course module and are asked to use it combined with the morphological matrix to enhance its results. Although commonly acceptable solutions appear since the first trial with the morphological matrix, students are asked to not stop at that level of solutions and to go further with TRIZ to increase their capability of developing more creative and innovative solutions.
The concept of Ideal Final Result has shown to be a universal and robust way to lead to better solutions, as psychological inertia and creativity inhibitions are eliminated.
Students are asked to first clarify the concept of Ideal Final Result in relation to their projects and then use the Altshuller's Contradiction Matrix applying it to the strong conflicts (#) identified at the roof of the House of Quality. This task is aimed to help them

gaining a better understanding of the concept of technical contradictions. As the probability of obtaining a suitable inventive principle through the use of the Contradiction Matrix is rather low, students are encouraged to scan the 40 inventive principles looking for those more likely to be applied to their specific problems. They are also asked to work on converting the technical contradictions in physical contradictions and to try to solve the problems based on this conversion.

Students are also introduced to the use of TRIZ software as IWB and TechOptimizer [12] and are encouraged to apply these tools to search for better innovative solutions.

As a measure of the improvements obtained, students are asked to make a comparative presentation of results obtained before and after applying TRIZ tools and methods.

Commonly students recognize important improvements achieved which increase the quality and technical level of the solutions obtained.

Students are also asked to identify how comfortable they feel using this approach. Their response is generally enthusiastic or at least positive.

At the end of the conceptual design stage Pugh concept selection is applied to choice solutions among the variants developed with the Morphological Matrix and enhanced with TRIZ. One handicap related to the Morphologic Matrix approach, lies in not having yet certain ways for identifying possible incompatibilities among the different combinations of the partial functions; as also in not possessing confident enough evaluation methods for selecting the best solutions among the huge numbers of possible combinations that may be obtained. In Table 2 (see attachment) an example is shown of the morphological matrix for the development of a fuel-water separating device. The additional ideas generated with TRIZ tools are in gray shaded cells with bold letters.

3. CONCLUSIONS

Students and research assistants participating in these projects agree that the combined and systematic use of these tools facilitated their design tasks and helped them in finding better solutions.

Prevalently students show enthusiasm in applying TRIZ tools and methods combined with the morphological matrix and declare to feel comfortable in using both methods in a combined way.

When asked which characteristic they perceive better in this approach they generally declare that the morphological matrix helps them to organize the conceptual design tasks while TRIZ methods and tools help to gain a deeper insight in the problematic and to gain confidence in the proposed solutions which are generally more innovative and technically better.

More than 50 case studies have been developed in the last 5 years, which ranges from consumer products as home appliances up to subassemblies of industrial machines. The acceptance of the results by the enterprise representatives is prevalently enthusiastic although it depends of the degree of involvement that they perform during the project.

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Table 2: Morphologic Matrix for fuel-water separating device
(Enhanced solutions to partial functions generated with TRIZ tools in gray shaded cells)

	Variants							
Functions	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Connect with pipe	Threaded coupling	Fast coupling	Embracer	With metallic belt	**Welded**	**Soldered**		
Sealing	With cardboard	With neoprene	With cork	With lead seals	**R.T.V**	**With SILICON**	**Ribbon**	**Vulcanized**
Warming	With electric resistance	With motor's cooling water	With escape gases	With flame	**Impeller**	**Laser**	**Infrared radiation**	**Eddy currents**
Separate free water	Decanting	Centrifugation	With a sheet	With filter	With a mesh	**Thermal shock**	**Ultra shall**	**Vibration**
Separate emulsified water	Coalescing	Centrifugation	**Ultra shall**	**Vibration**				
Extract contaminants	Butterfly valve	Pressure valve	1/4 round	**Pressure valve**				
Dispose contaminants	Throw away	Dispose	Evaporate					
Store contaminants	Steel sheet	Plastic container	Aluminum container	Glass Container	**Titanium container**			
Store fuel	Steel sheet	Plastic container	Aluminum container	Glass container				
Filter	Cardboard	Wire mesh	Paper	Thread	**Stone**	**Carbon**		