# Integration of DFMA and DFE for Development of a Product Concept: A Case Study

**Boppana V. Chowdary**[1]
[1]The University of the West Indies, St Augustine, Trinidad, chowdary@eng.uwi.tt

**Azizi Harris**[2]
[2]The University of the West Indies, St Augustine, Trinidad, margazi@yahoo.com

## ABSTRACT

Integrating DFMA and DFE methodologies can be beneficial to organisations involved in the design and development of products. Design decisions are responsible for up to 20% of the costs of a product (Boothroyd et al, 1994) and 80% of environmental damage (OHA, Wood, 2001). Thus it is important to include DFMA and DFE principles early in the design process. This paper presents the integration of DFMA and DFE with product design and development tools such as research analysis and Quality Function Deployment (QFD).The case study involved is a desktop organiser designed to increase workspace available on a desk. SolidWorks was used to generate CAD models which were further analysed using SimPro7 Demo software for DFE and Excel for DFMA principles.

**Keywords:** product design, integrated approach, design for environment, design for manufacture and assembly.

## INTRODUCTION

The current societal awareness of the environment has resulted in government regulations and mounting consumer pressure that companies must address in order to ensure future profitability. Design for Environment (DFE) aids in sustainable development which states that resources must be used in such a manner so as to ensure their availability for future generations (Fabio et al., 2006).

Design for Manufacture and Assembly (DFMA) assists DFE in its application, especially in the recycling and recovery stages of a product's life cycle. In addition to assisting DFE, DFMA reduces costs and product development time by minimising the number of design corrections at the manufacturing stage, via early application in the design process and simplification of the design (Boothroyd et al., 1994). The overall result is a better product which is environmentally friendly and is profitable to the organisation involved in its development.

The approach of the DFE in this case was to manufacture the desk organiser from recycled materials that can be repeatedly recycled, thus avoiding the use of virgin material. To assist in material selection the eco-indicator 99 methodology was used to help determine the recyclable materials with the least environmental impact.

## BACKGROUND

A desk organiser is a product which is used to store stationery. It is a tool for maintaining a tidy desk by convenient location and organisation of stationery making it easy to retrieve items as needed. Desk organisers have a wide range of types and are used by a significant portion of the population on a regular basis. They contribute to the productivity of their users. However, shortcomings in current desk organisers (storing only a few stationery items and occupying too much desk space) present a design opportunity to satisfy customer need more effectively.

**INTEGRATION OF DFMA AND DFE WITH PRODUCT DESIGN AND DEVELOPMENT TOOLS**

To meet the goal of the study, an integrated framework as shown in Figure 1 was developed.

Phase 1 The approach begins with Market Research, which was conducted by means of data collection using

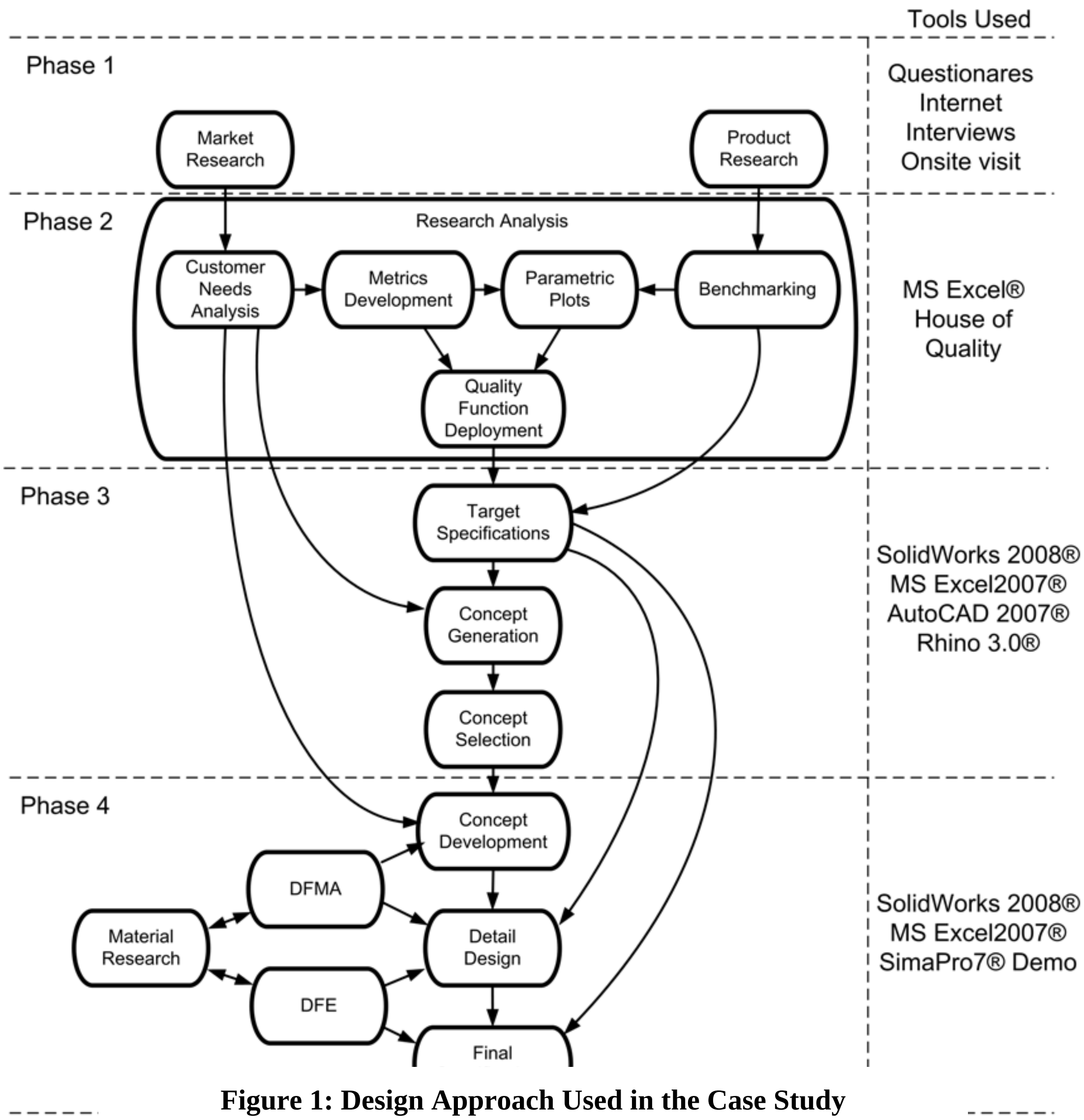


**Figure 1: Design Approach Used in the Case Study**

quick questionnaires and prompt questions. This was followed by a Product Research on current desk organisers to obtain product specifications such as dimensions, material and retail price.

Phase 2: Research Analysis involved the analysis of the market research into a hierarchy of customer needs and development of product metrics. Product research data was collected for benchmarking which was used for parametric plots (see Figure 2), which were developed to investigate relationships between metrics that were established from customer needs.

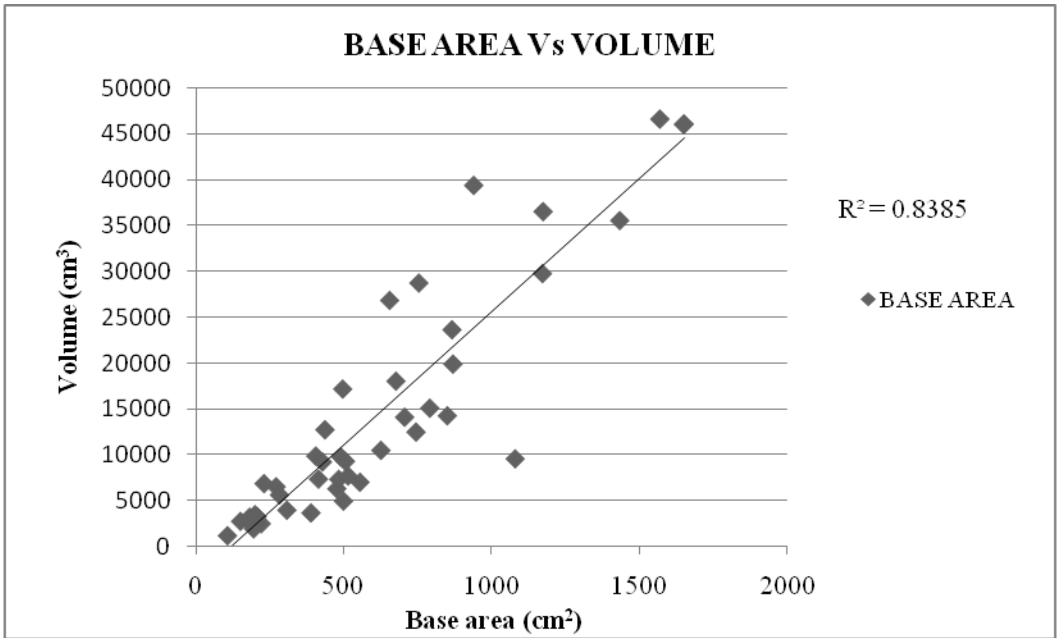


**Figure 2: Parametric Plot Showing the Relationship between Base Area and Volume.**

The customer needs, product metrics and parametric plots were used to develop the House of Quality (see Figure 3). The House of Quality (HOQ), a tool of Quality Function Deployment (QFD), helps to determine the limits of the design; shows the connection between the customer needs and the metrics used to satisfy them; and illustrates what the development team must focus on in order to produce a quality product.

Phase 3: The outcome of the Research Analysis was used to develop target specifications which in turn guided the concept generation and selection process. Preliminary Concepts from the project team were assembled and given an initial subjective assessment. This resulted in more concepts being generated based on the preliminary concepts. Six concepts from the large group of concepts were screened and scored using the concept screening and concept scoring matrix respectively. The weights used in concept selection were established from the HOQ.

Phase 4: Once a final concept was selected, two concept variants developed. The first variant was developed without the use of DFE and DFMA methodologies. The second variant was developed using DFE and DFMA methodologies.

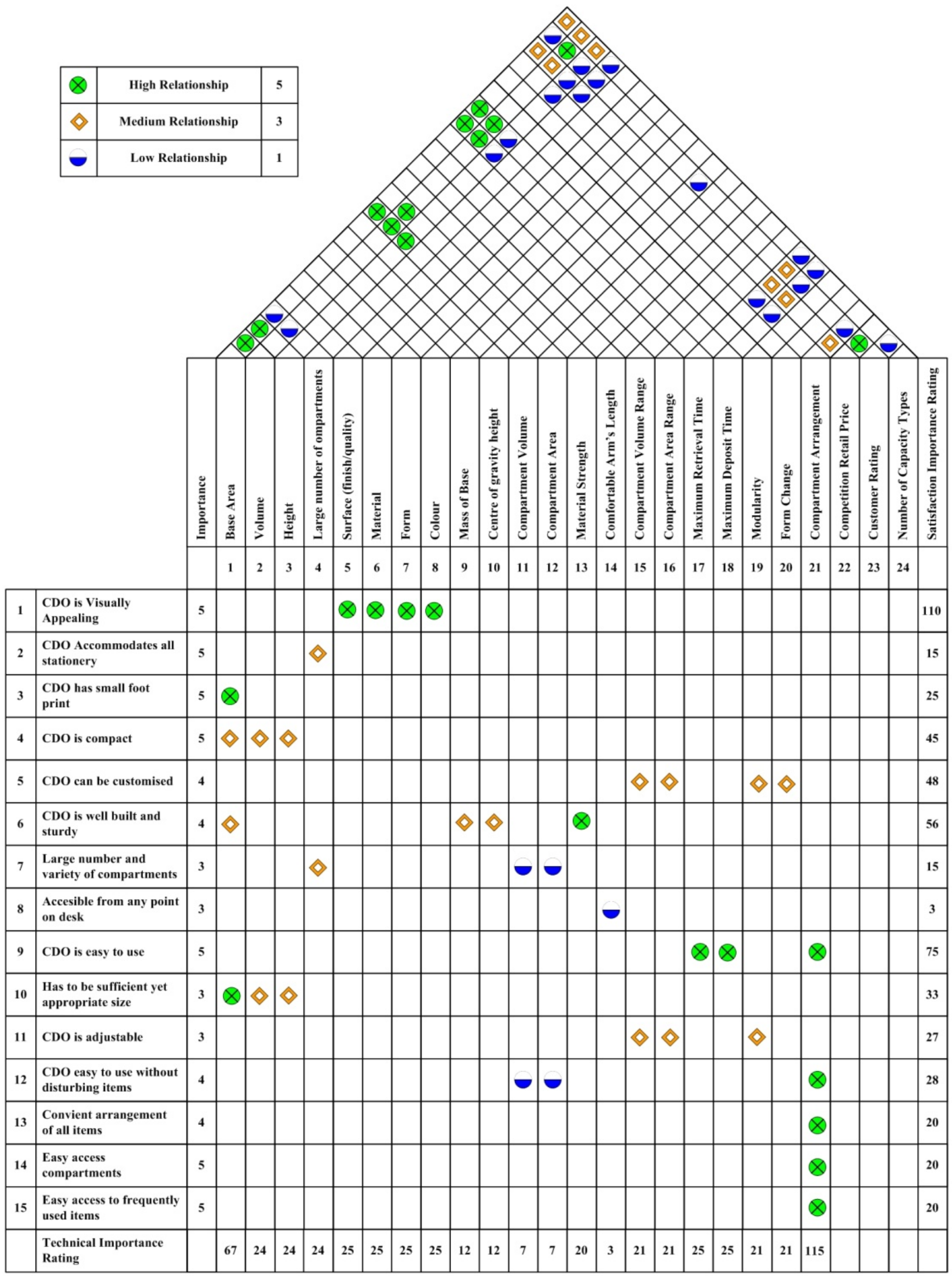


**Figure 3: House of Quality of the Case Study**

## ROLE OF DFE

The form of the design was influenced by DFE guidelines taken from Fiskel (1996). Noticeable guidelines include having multifunctional parts, use of the same material for neighbouring parts, and easily located high value parts ensuring the ability of the desk top organiser to be recyclable at the end of its life cycle.

Material selection focused on minimising the environmental impact in three areas: human health, ecosystem quality and resource depletion. The eco-indicator 99 system was used to select a set of promising materials (see

Figure 4) which would satisfy the low environmental impact requirement. The eco-indicator 99 system is an assessment system that takes into account the total environmental (Ministry of Housing, Spatial Planning and the Environment, 2000) impact made by a product during its entire life cycle, from material extraction, manufacturing, transport, energy consumption, material waste and product disposal. The three main categories of impact are: damage to resources; damage to ecosystems; and damage to human health. The eco-indicator 99 value allows different materials processes and designs to be compared in terms of overall impact. Lower values indicate lower environmental impact.

Initially, stainless steel, one of the lowest eco-indicator 99 materials was considered. However, because of cost considerations recycled aluminium was eventually chosen. In addition to a low eco-indicator 99 value, recycled materials were chosen to manufacture the desk organiser in order to stimulate the demand for use of recycled material.

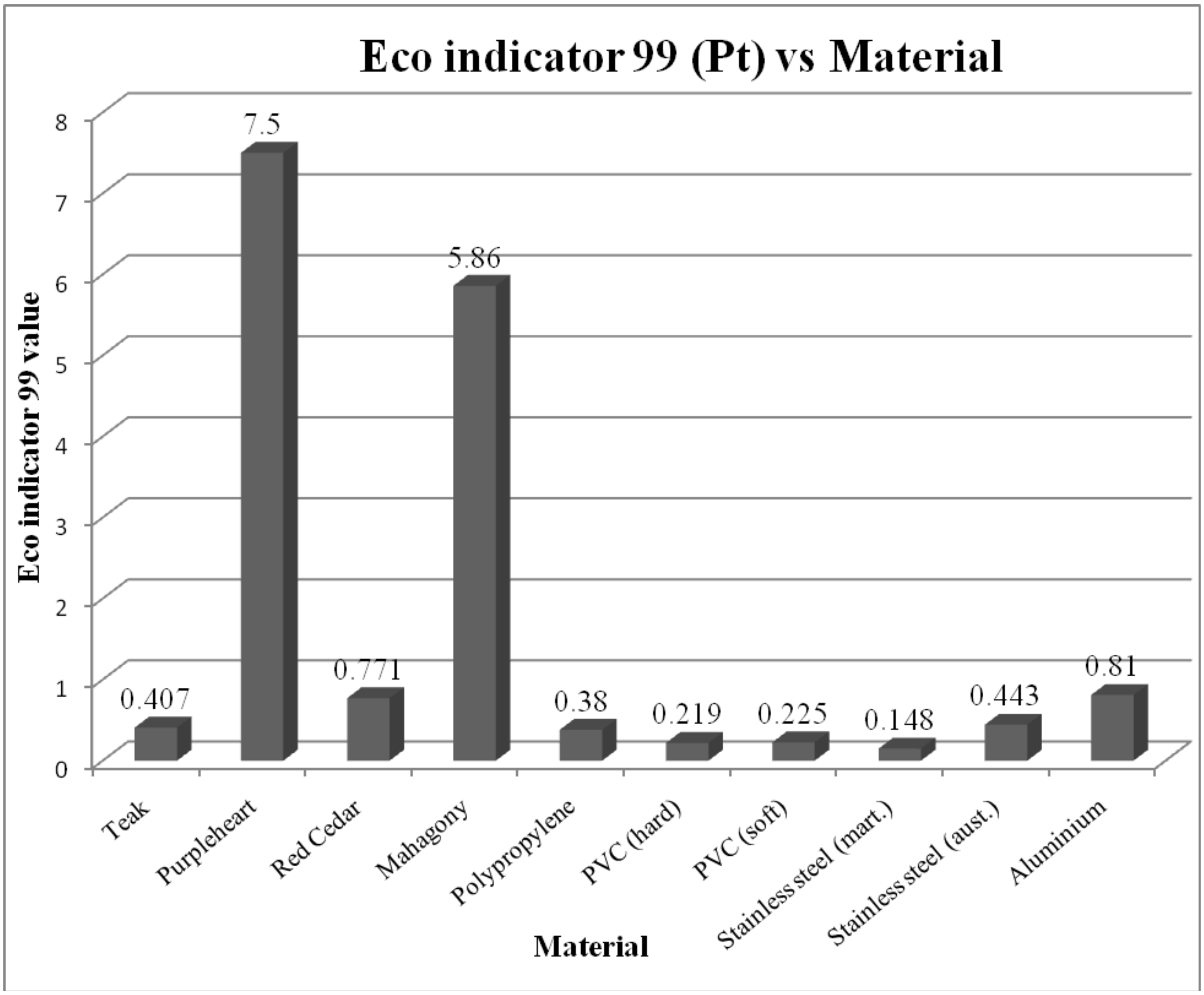


**Figure 4: Eco-indicator 99 Values for the Material Researched in the Case Study**

## ROLE OF DFMA

DFMA guidelines influenced the form of the design in the following areas: part minimisation, multifunctional parts and fastener reduction (Boothroyd et al., 1994). Parts were designed to ensure ease of alignment and insertion. This resulted in reduced assembly times and material reduction, which in turn resulted in reduced overall costs.

### COMPARISON BETWEEN THE DESIGN VARIANTS

Two variants of the final design were assessed with the aid of SolidWorks 2008 and SimaPro7 Demo. The results are shown in Table 1. As shown in Figure 5, the variants have a similar form although differences are evident in the exploded views shown in Figure 6.

**Table 1: Results of Concept Variant Assessment**

| Criteria | Design Variant | | Percentage Reduction |
|---|---|---|---|
| | Conventional | DFE/DFMA Applied | |
| Mass (g) | 1722.24 | 1351.05 | 22% |
| Cost (TTD) | 41.93 | 33.23 | 21% |
| Number of Parts | 45 | 11 | 76% |
| Eco 99 indicator (Pt) | 1.2 | 0.212 | 82% |
| Assembly Time (s) | 295 | 113 | 62% |

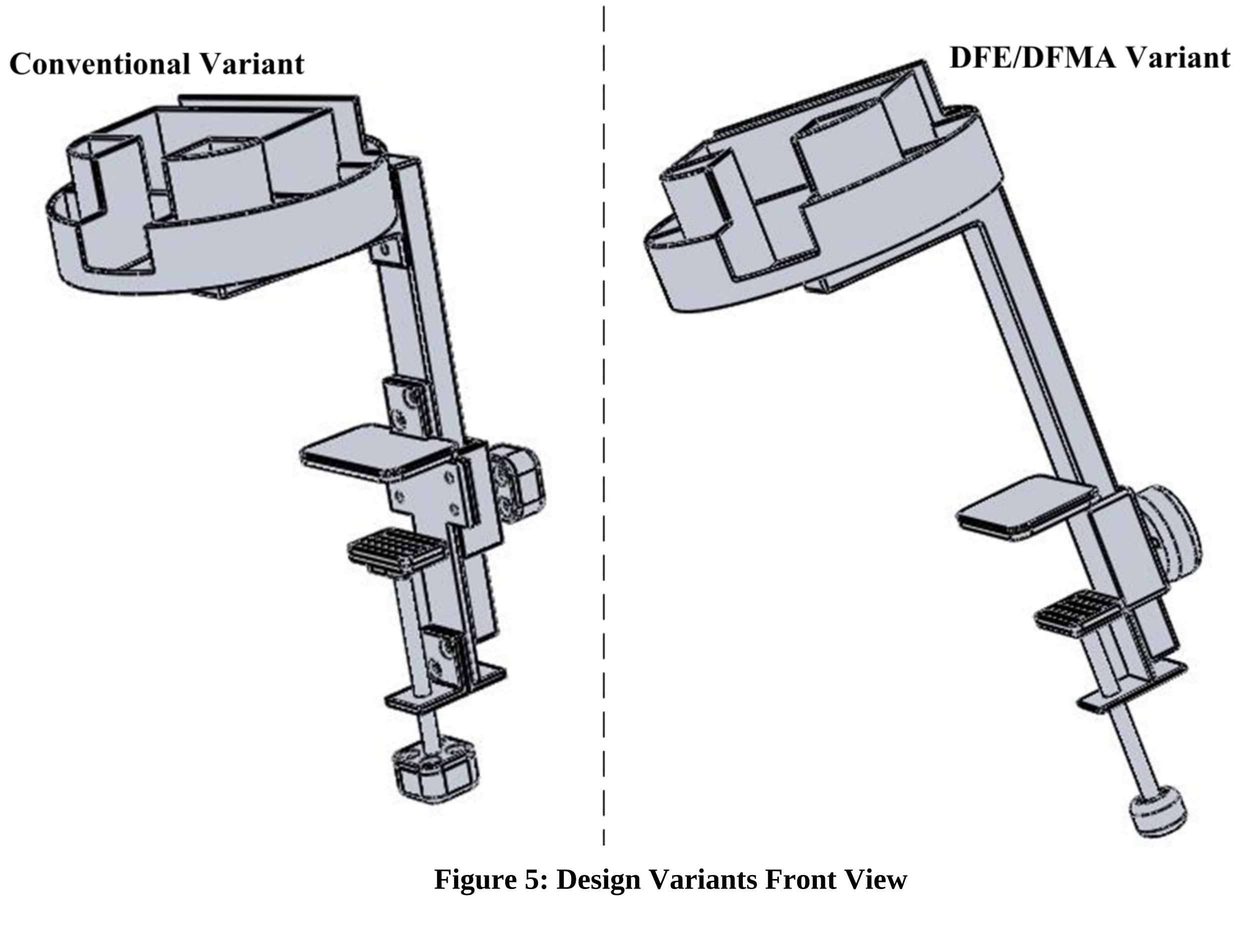


**Figure 5: Design Variants Front View**

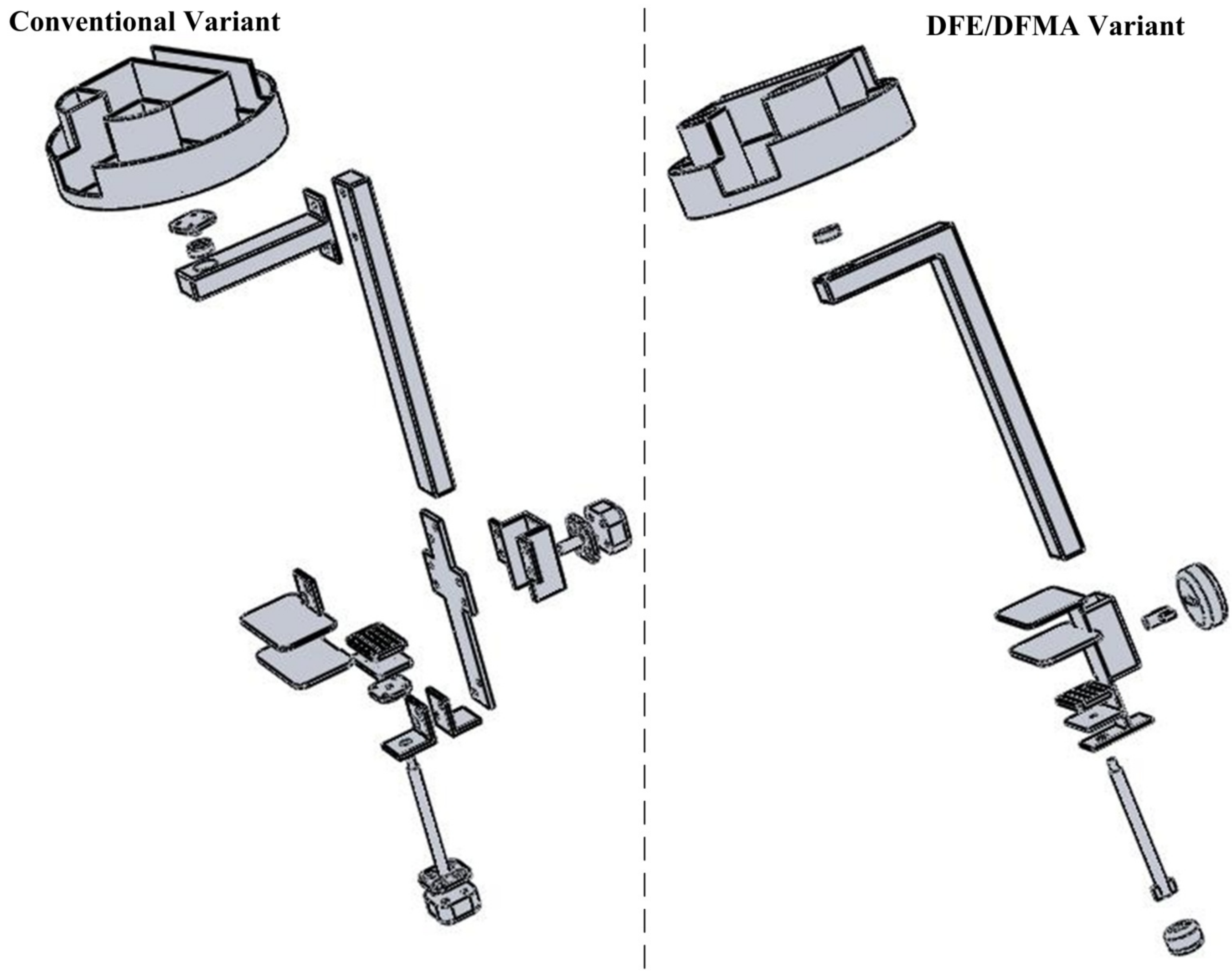


**Figure 6: Exploded View of Design Variants**

To reduce the complexity of the conventional variant, fasteners were not illustrated.

## DISCUSSION

The concept that was developed with the DFMA and DFE methodologies showed significant reductions in cost, material assembly time, eco-indicator 99 value and the number of parts. The designs were similar in architecture and form, the main difference being in the methodology used. For DFE, material choice played a more important role in determining impact. Focus was on the use of recycled materials whereas conventional design used 100% virgin material.

DFMA mainly focused on the reduction of parts from 45 to 19. Many parts were combined allowing material reduction as a result. Assembly times estimated were greatly reduced allowing more units to be produced in a given time. SolidWorks 2008 played an important part in model creation and as an evaluation tool to assess the design in terms of mass and part count. Environmental impact assessment of the design was done using SimaPro7 demo software.

The manufacturing cost model was based on a volume of 65,000 units, approximately 20% of households in Trinidad & Tobago. The same cost model was used for the design variant so that the cost difference would be solely reflected by the application of DFMA and DFE methodologies. A more detailed environmental assessment however, can be made using full version DFE and DFMA software. The work in this direction is in progress.

## CONCLUSION

DFE and DFMA tools are useful in reducing the time taken to evaluate designs and therefore it should be implemented as part of the design selection process. Furthermore, these methodologies are handy in evaluating the product design concepts allowing designs to be produced at a lower cost and lower environmental impact, thus enabling organisations which employ these principles to be more profitable.


## ACKNOWLEDGMENTS

Christian Phillips, Navin Chatelal, Kimberly Kanchan, Jevon Adams, and Vaalmiki Saroop for their cooperation in the successful completion of the market research and product research


## REFERENCES


Boothroyd, G., Dewhurst, P., & Knight, W. (1994). *Product Design for Manufacture and Assembly*. New York: Marcel Dekker.

Budinski, G. K. (1996). *Engineeing Materials: Properties and Selection* (5th ed.). Prentice Hall.

Chowdary, B. V., & Gittens, A. (2008). Design development through an integrated approach: a case study of battery operated passenger cart. *Int J Product Development , 5* (1/2), 191-198.

Fiksel, J. (1996). *Design for Environment: Creating Eco-Efficient Products and Processes.* McGraw-Hill.

Giudice, F., La Rosa, G., & Risitano, A. (2006). *Product Design for the Enviroment: A Life Cycle Approach.* CRC press.

Juvinall R, C., & Marshek K, M. (2006). *Fundamentals of Machine Component Design.* John Wiley & Sons, Inc.

Kalpachan, S., & R.Schmid S. (2001). *Manufacturing Engineering and Technology*. New Jersey: Prentice Hall.

Ministry of Housing, Spatial Planning and the Environment. (2000, October). *Eco-indicator 99 Manual for Designers: A damage oriented method for Life Cycle Impact Assessment.* The Hague, The Netherlands.

Otto, K., & Wood, K. (2001). *Product Design: Techniques in Reverse Engineering and New Product Development.* Prentice Hall.

Ulrich K, T., & Eppinger S, D. (2004). *Product Design and Development.* New York: Mc Graw Hill Irwin.