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A METHOD FOR DEVELOPING ALTERNATIVE PRODUCT PORTFOLIOS AND ESTIMATING THEIR IMPACT ON COST AND VARIETY

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Abstract

Selecting an appropriate product portfolio is crucial for any company. A chosen product portfolio architecture must address variations in the needs of the customer base while satisfying the overall corporate need of mitigating the cost of the portfolio. In order to take care of these two variations, we have developed a tool for generating alternative product portfolios by sharing materials and processes across an existing portfolio, and for supporting their comparison with respect to functionality and cost of these portfolios.

Keywords: Product Variety, material-process combination, functional similarity

1. Introduction

A product portfolio is defined as the set of products offered by a company. This paper deals with the issue of generating alternative product portfolios with greater functional variety to cost ratio than that of an existing product portfolio. According to Ulrich and Eppinger [1] *variety* refers to the range of product models a firm can produce within a particular time period in response to market demand. We use variety here to mean functional variety among products.

In general, it is difficult to provide variety (i.e., alternative product portfolios) and at the same time keep the cost of providing variety low. Literature in this area considers sharing of components, assemblies and assembly processes as potential solutions to this problem [2]. However, sharing of materials and processes across the products in the company's portfolio has not received much attention. Here, we consider changing material-process commonality as a potential, alternative means of reducing the cost of product portfolios.

This paper provides a qualitative measure for comparing the functionality and cost of new, alternative product portfolios in reference to an existing portfolio. We generate new portfolios by varying the materials and processes of components of the products in an existing portfolio so as to increase sharing of materials and processes across the components. This is done by changing the material and process of one component in a product with that of another component in another product of the portfolio. The condition is that these components should be functionally similar for their materials and processes to be shared.

A Microsoft Excel based tool for supporting this activity has been developed. It supports changing a given product portfolio by 1) changing the material and process commonalities across the components of its products and 2) by supporting qualitative estimation of the resulting changes in cost and functionality of the portfolio.

2. Research Questions and Approach

Our goal is to change the material-processes commonality across the products in a portfolio so as to achieve equivalent functionality while keeping the cost of providing product portfolio low. Therefore, the questions are

(i) How can we share materials and processes of (these) components across the product portfolio?

(ii) How can we estimate the cost of production of a given portfolio?

(iii) How can we represent functional similarity in a given product portfolio?

(iv) How can we estimate changes in functional variety and cost of production after changing a product portfolio using these sharing options?

2.1 Sharing material-processes and estimating cost of portfolios

In order to study how changes made in the physical structure (as a result of changing material and processes of the components) affect functionality and cost of the portfolio, three approaches have been proposed. Functional variety in a given portfolio is represented here in terms of the variety in its components' functions. The cost of production of a portfolio is estimated by considering the material and process costs of all the components in the portfolio.

The first approach is called the '*copy model*'. It considers in pair all the components in the portfolio and copies their respective material-process (henceforth called m-p) combinations. Assuming that these m-p combinations are possible to be shared by these components, new portfolios are created. The m-p combinations, which incur minimum cost, while not compromising functional variety, can now be selected. Suppose there are two components c1 and c2 with m1, p1 and m2, p2 as their respective materials and processes; then the two possible new portfolios could be:

$$(m1p1)_1, (m1p1)_2$$

OR

$$(m2p2)_1, (m2p2)_2$$

The suffix outside the bracket refers to the component number.

Assuming that these material-process combinations are possible to be used for making the proposed components, we can make a choice between the existing and the new portfolio based on their costs.

Cost can be estimated as follows (considering only the main cost factors viz. material and process):

Cost $((m1p1)_1 + (m2p2)_2)$ ---------existing portfolio

Cost $((m1p1)_1 + (m1p1)_2)$ ------------ new portfolio1

Cost $((m2p2)_1 + (m2p2)_2)$ ------------new portfolio2

The second approach is called the '*extended copy model*'. Unlike the 'copy' model, the potential alternative m-p combinations for a component are copied from every other component of the products in the portfolio that is functionally similar (see Section 2.2) to this component.

The third approach is called the '*open copy model*', which differs from the second approach in that, all possible candidate materials and processes, both from within and outside the portfolio, can be considered for changing the portfolio. We have selected the 'extended copy model' for our method because, compared to the other two models, it offers more realistic alternative portfolios to be created, saving substantial redesign effort.

2.2 Functional Commonality (Fc)

Functional commonality between two components is calculated as the ratio of the number of functions common between them and the total number of distinct functions they together have. For example, if two components c1 and c2 have two functions as same out of a total of 6 distinct functions, then they together have

$$\text{Functional Commonality } (F_c) = 2/6 = 0.33$$

Using this, all the components are compared pair-wise and their functional commonality is calculated.

2.3 Cost of a product portfolio

The cost model used here for estimating the cost of providing a product portfolio considers material and process costs of all products in the portfolio. The cost factors considered are:

1) Material Cost: The direct cost of the materials used.

2) Setup Cost: The setup cost required for the process.

3) Tooling Cost: Cost incurred at the end of tool life.

4) Labor Operating Cost: Labor cost per unit time multiplied by the processing time per unit product.

2.4 Cost Value Index

When the m-p combination of one component replaces the existing m-p combination of another component, then the question is: how to estimate the change of cost of manufacturing of the second? Here, it is estimated qualitatively with respect to the existing cost of manufacturing for that component. Each cost factor is assigned a point from a three-point scale (-1, 0, 1). The points stand respectively for reduction of cost, no change in cost and increase in cost. The cost value index is the sum of all the points given for all the cost factors for one replacement. When we add all the cost factors for one portfolio option then it becomes the cost value index of that portfolio relative to the cost of providing the existing portfolio.

For example, suppose the existing m-p combination 'PC Blend-Injection molding' for a component is replaced by the 'LDPE-Extrusion' combination[1]. Say this change results in an increase in the *setup cost* of the product as compared to that using the existing process. Then, the point given is '1'. Similarly all the cost factors are analysed for all the combinations Table1 shows an example of cost value index analysis for one component, in which five potential m-p combinations could be used. The cells in the table give representative values of relative cost of using that combination, and the values in the last row 'Total', thus showing how expensive these alternatives are with respect to the reference (existing) combination.

[1] This method for process and material cost comparisons is approximate.

Table 1. Example of cost value index analysis

Component	Cost factors	PC Blend-Injection Molding	LDPE - Extrusion	Acrylic-Injection Molding	Steel-Automate Turning	Steel-Deep Drawing
10201(casing)	Material Cost	0	-1	-1	-1	-1
	Setup Cost	0	1	0	1	1
	Tooling Cost	0	1	0	1	1
	Labor operating cost	0	1	0	-1	-1
	Total	0	2	-1	-2	0

Existing m-p combination

Cost value index

Replacing m-p combination

<u>Cost model validity</u>:

The qualitative model has been compared with quantitative cost examples to check its reliability. For instance, the graph in Figure 2 shows the production costs of two processes with respect to their quantity of production. It compares the cost of production of the same component by two machines viz. capstan lathe and center lathe. When the quantity of production is more than 5 (Break Even Point) capstan lathe is the cheaper option.

Figure 2. Break Even Point

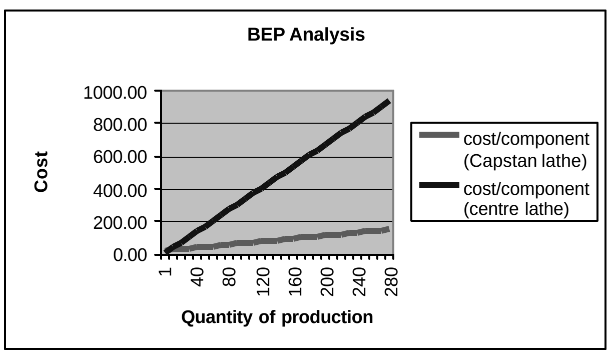

Table 2 shows a qualitative comparison for the two machining processes using the qualitative cost value index analysis (refer section 2.4). For comparison of values, data is referred from example16.7 in the book [3]. From the cost value figures, we can say that replacing capstan lathe machining by center lathe machining would be more expensive, which gives the same conclusion as the qualitative method for high volume production which is where we assume our qualitative method to be useful.

Table 2.Qualitative Cost Analysis Method

Sr. No.	Component	Cost factors	Center lathe Processing replaced with Capstan lathe	Capstan lathe Processing replaced with Centre lathe
1	A	Direct Material Cost	0	0
		Labor Cost	-1	1
		Process Cost	-1	1
		Tooling Cost	1	-1
		Total	-1	1

Therefore this model can be trusted if qualitative points are entered knowing the break even point for the processes to be compared.

2.5 Function Value Index

This index helps in estimating the changes made in the functionality of a product portfolio. Changing the material-process combination for a component leads to physical changes; therefore it must be checked whether and to what extent the new combination will fulfill the original function of the component.

If the replacing m-p combination fulfills a function in better way than the original, then the point assigned would be 1. If the replacement does not make any change, then the point assigned would be 0; otherwise it would be given –1,which means that the effect on function is not favourable. The points given for all the functions are added to form the total function value index for a replacement.

3. Method

A method has been developed that helps to interactively create alternative portfolios and supports evaluation of these portfolios using functions and cost-value indices.

3.1 Steps in the method

The steps in the method are:

Step 1: Find functionally similar components across products in a portfolio.

Step1.1: Disassemble all the products in the product portfolio. Construct assembly tree for each product and assign codes to all components. Create a database for the materials, processes and functions of each component.

Step1.2: Take each component from the first product and compare that with rest of the components from other products in a pair-wise fashion in order to calculate the functional commonality between them.

Step1.3: Group together components from all products that are functionally similar. These components are then considered for further analysis. The significance of selecting the components with similar functionality is that those parts are the prospective ones, which will help the analyst to increase the commonality or decrease cost after appropriate modification of their material-process combinations.

Step 2: Calculate Cost Value Index for each m-p combination:

A table is prepared in order to determine an index that indicates the effect on cost after changes in materials and processes of the components of the products. The components are considered separately for analysis. The cost factors are written in rows and the material-process combinations are written in columns. Then for each component, the material-process combinations are taken and the effects on the cost factors relative to the existing combination are noted. Then the effect on each cost factor is indicated by one of the three rank points: -1, 0 and 1 (refer to Section 2.4).

Step 3: Calculate Functional Value Index for each m-p combination:

In this analysis, all the components that are functionally similar are listed row-wise along with their functions. The material-process combinations of these components are placed column-wise. M-p combination in every column is considered as a replacement for the m-p combination of the component in the row. The effect of m-p combination replacements in a component on the functions of that component is evaluated and the qualitative points are given against each function. The same process is repeated for components in the next rows.

Step 4: Calculate Total Cost Value Index & Function Value Index for new portfolios

In the cost value index analysis (Step 2), we obtain possible alternatives to the existing component's material-process. Each alternative material-process has a cost and a function value index (as a sum of all the qualitative rank points). After adding all the rank points for the material-process combinations of all the components in the portfolio, we get the total cost index for the portfolio.

In this way, the value indices for the all the possible alternative portfolios are calculated and both of their rank points (i.e., cost value and functional value) obtained.

Step 5: Plot the cost value vs. function value for each portfolio:

After the analysis in Step 4 is complete, the material-process combinations with lower cost indices are selected. All such new alternative portfolios are identified with their cost value index and function value index. Each portfolio is plotted as a point in a graph of cost value index vs. function value index (Scatter diagram).

Step 6: Selection of optimal portfolios:

The plot acts as a portfolio selection aid for the designer. All alternative product portfolios are plotted as points in a graph where their cost values are represented on the abscissa and functional values are represented on the ordinate. Once the plot is ready, it shows the effect of material-process combination changes on the cost value and the functional value of an existing portfolio, in terms of various resulting portfolios with their relative capability of offering functional variety and cost-effectiveness. The optimal point selection is a trade off between cost value and function value expected, and can only be done by the designer.

4. Implementation

The method has been implemented using Microsoft Excel.

The GUI developed is used to enter the data for components for the portfolio to be used as the basis for generating alternative portfolios. Figure 3 shows one of the screens of the GUI. Once the data about the products, their components and their materials and manufacturing processes are entered by the designer, the tool calculates the functional commonality among the components. The components are now grouped into mutually exclusive groups of functionally similar components, which together constitute all the products in the portfolio. For each group, m-p combinations of the components are shared and varied, the most cost-effective combinations are chosen to form alternatives, and the resulting alternatives combined with those in other groups, so as to generate alternative product portfolios.

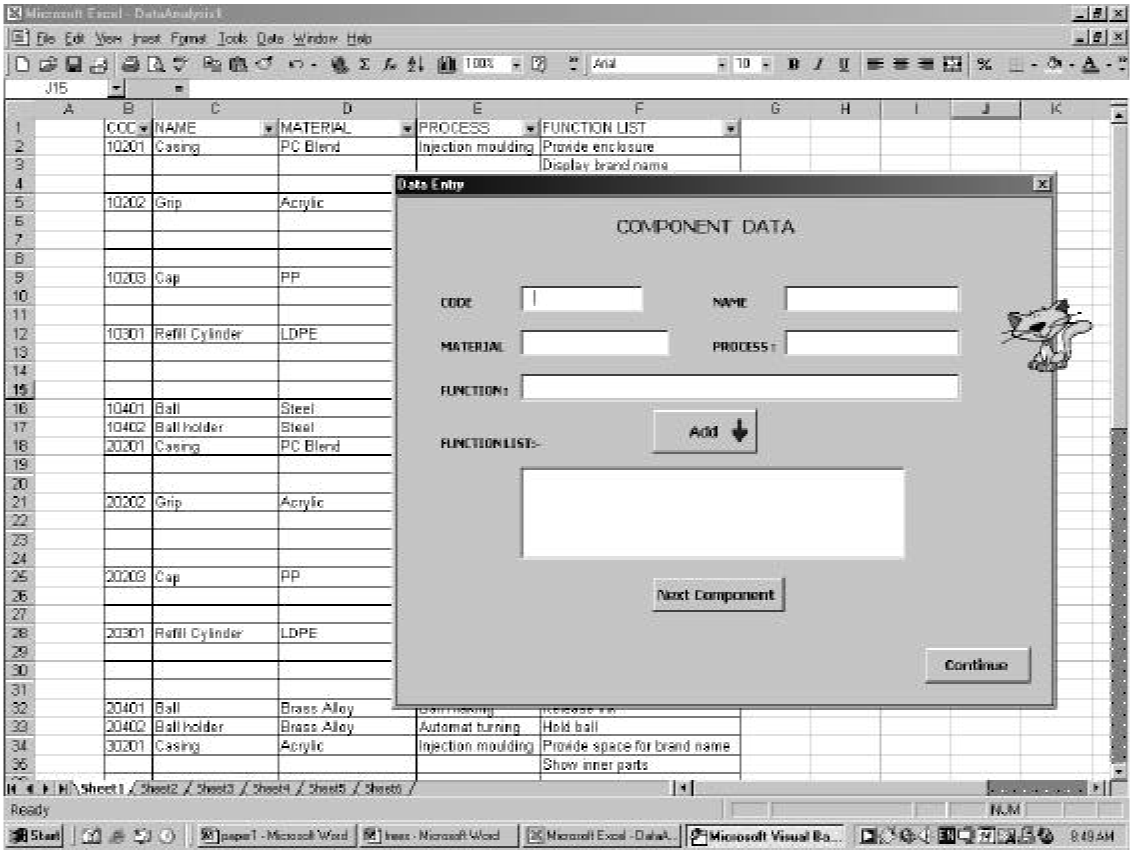

Figure 3. Data Entry form of GUI

The cost values and respective function values for each of these portfolios are calculated, and the result stored in Excel in the form of portfolio numbers and their respective cost and function values. The tool gives a function vs. cost scatter plot as an output, with each portfolio plotted as a point.

5. Analysis and Results

As a first step to evaluating the tool and its underlying method, the ‘extended copy’ model was implemented into the tool, and applied to generate alternative portfolios for a set of pens, consisting of about 30 parts, made by Reynolds, India. The objectives were to see whether any new portfolios were created that could potentially provide same or more functional variety with reduced cost. Tree diagrams in Figure1 shows the assembly structure of one of the pens and the component coding style. Figure2 shows all pens.

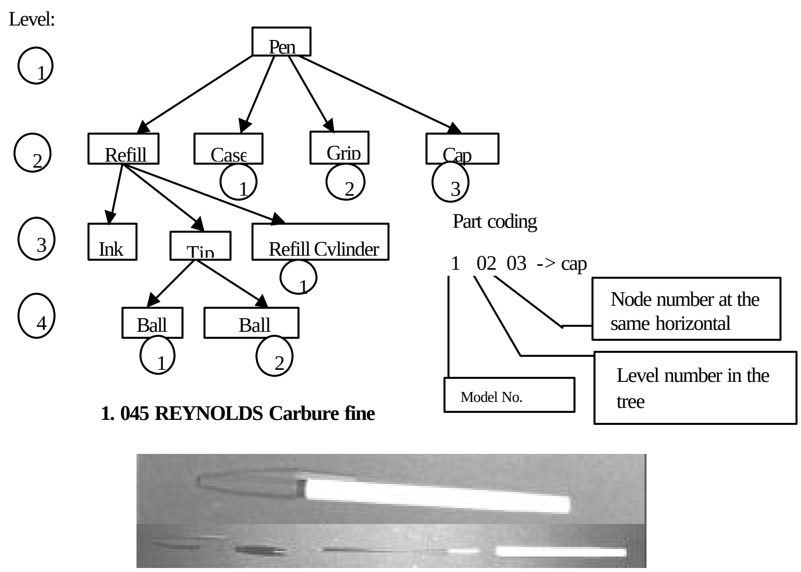

Figure 1.Tree diagram and part coding

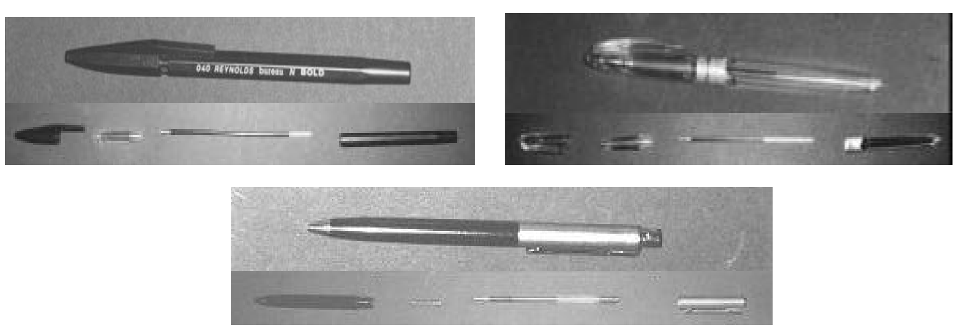

Figure 2. Pens and their parts

We grouped the components, from the pens, into six groups of functionally similar components that together form the pens. The top four groups were chosen as the basis for creating alternative product portfolios.

We analysed four groups of components for cost value index and function value index. For all the combinations of m-p combination we calculated cost value and function value.

This led to the creation of some 144 alternative possible portfolios, differing only in the m-p combinations of these components. The result is shown in graph shown in Figure 4. Many of the portfolios have same cost and function values. Portfolios in the third quadrant in graph shows that they reduce the cost of portfolio as compared to existing portfolio; but they reduce the functionality as well. The portfolios on negative x-axis reduce the cost but make no changes in functionality. The favourable region is the second quadrant, where the portfolios promise reduction in cost and increase in functionality.

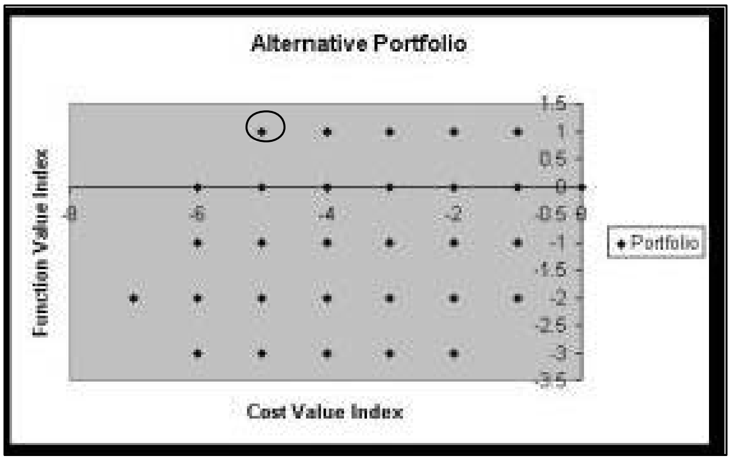

Figure 4. Graph for comparison of portfolios

The point (-5,1) is the most favorable point that reduces the cost and adds to functionality. Table3 shows the changes in portfolio for the portfolio for the point (-5,1) from graph. Here, "222122244445223" is the identification number for that portfolio.

Table3. Changes in existing portfolio

Sr. No.	Component	Existing M-P combination	M-P for portfolio "222122244445223"
1	10203(Cap)	PP-Injection Molding	Acrylic-Injection Molding
2	20203(Cap)	PP-Injection Molding	Acrylic-Injection Molding
3	30305(Cap Body)	Acrylic-Injection Molding	Acrylic-Injection Molding
4	40307(Button)	Steel-Sheet Metal Forming	PP-Injection Molding
5	10202(Grip)	Acrylic-Injection Molding	Acrylic-Injection Molding
6	20202(Grip)	Acrylic-Injection Molding	Acrylic-Injection Molding
7	30302(Plastic part of grip)	Acrylic-Injection Molding	Acrylic-Injection Molding
8	10301(Refill Cylinder)	LDPE-Extrusion	LDPE-Extrusion
9	20301(Refill Cylinder)	LDPE-Extrusion	LDPE-Extrusion
10	30301(Refill Cylinder)	LDPE-Extrusion	LDPE-Extrusion
11	40301(Refill Cylinder)	LDPE-Extrusion	LDPE-Extrusion
12	10201(Casing)	PC Blend-Injection Molding	PC Blend-Injection Molding
13	20201(Casing)	PC Blend-Injection Molding	Acrylic-Injection Molding
14	30201(Casing)	Acrylic-Injection Molding	Acrylic-Injection Molding
15	40306(Clip)	Steel-Sheet Metal Forming	Steel-Sheet Metal Forming

5. Summary, conclusions and further work

Research objectives of the work have been to effect and investigate changes in the structure made by changing material and process sharing among products of a portfolio. This paper proposes

- a method for generating alternative portfolios and for easy comparison and selection of alternative portfolios.
- a means of comparing new alternative portfolios with the existing portfolio by plotting the portfolios on a graph of cost value vs. function value.

The method has been implemented as a computational aid. A case study has been taken up to assess usability of the tool and whether it creates realistic, promising, alternative portfolios. It seems logical to assume that an analysis of a larger set of functionally equivalent parts will lead to creating a wider variety of product portfolios, thereby helping the designer to develop better portfolios that be otherwise difficult to develop and evaluate without a computational support. However, further case studies need to be undertaken and designers consulted to ascertain as to whether a proposed portfolio alternative could really make a difference in providing variety at a reduced cost.

This method seems fast and relatively easy to apply: generation and selection of portfolios by this method promises to provide effective suggestions for portfolio improvement. The method is more suitable for technical products than industrial design products. The qualitative method used for cost and function analysis, although not an exact analysis method, has the potential for providing reliable results. The cost model and the qualitative method of analysis could be improved further so as to make the method more reliable.

The analysis currently consists of the study of effects on function and cost and can be further extended to study the effect on function, cost as well as shapes and sizes of components, a direction in which further work is being pursued.

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