Comparison of Criticality of Configuration Choices for Market Price and Product Cost

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Abstract. The paper presents a quantitative method for determining the criticality of components to costs and sales price in mass customization environments. The method is based information of historically sold configurations and uses backward elimination to arrive at a reduced linear model. The variables included in this model are then the most significant describing variation of (material/salary/total) costs, sales price or profit margin. The method is tested on data from a large manufacturer of mass customized products.

Keywords: Mass customization, backward elimination, linear model.

1 Introduction

In companies offering customized products, manufacturing costs and sales prices will depend on a particular configuration of a product and those companies often experience that it is not obvious which product properties drive cost and which properties allow for a high sales price. This leads to the fact that it is nontrivial to identify which products are profitable and which are not. In any company it is crucial to continuously evaluate the profitability of the product range, however in companies with a significant product variety such as mass customization or engineer to order companies, this is a challenging task. This evaluation and the resulting development of a product portfolio in mass customizing companies is referred to as solution space development, which is one of three fundamental organizational capabilities which differentiate successful mass customizers from the non successful [11].

In mass customization where it is uncommon to sell and produce more than a few identical products but rather sell high numbers of individually customized products, it makes little sense to evaluate the profitability of a single product. Instead the solution space must be evaluated as a whole. Evaluating the profitability of the solution space can be approached in several different ways. Fundamentally, a qualitative or quantitative approach can be chosen. However, due to the vast complexity of a mass customization solution space in terms of the number of product features and modules, usually leaving a practically infinite solution space, a qualitative approach seems unfeasible indicating that a quantitative approach should be pursued.

A number of manufacturing processes dependent methods have been developed for cost estimation, implying that the particular method of estimating cost can only be applied to certain processes e.g. casting or welding [4], [5], [12], [13], [13], [17]. Cost estimation methods dependent on the specific product type also exist. In particular much research has been presented within the area of estimating cost during product development for both the finished product and the development process [2], [8], [9], [16], [19]. Kingsman & de Souza [7] introduced a general framework for cost estimation and pricing decisions, but no practical methods for estimating cost are presented. Other studies focus primarily on describing mathematically using synthetic models how customized products can be priced, however primarily compared to similar non-customized products [1], [14].

One of the deficiencies of the approaches found in literature is that most are not specific to mass customization and do thus not take into account a large solution space but focus rather on a single product. Furthermore most are synthetic, meaning that a cost and pricing model must be developed in order to evaluate the product profitability which is complicated by a high variety. Finally a number of the approaches described in literature are product specific rather than generic.

The research objective of this paper is to create an analytic method which can assist companies in evaluating the profitability of a product family based on historical configuration data. By basing the method on historical configuration data, the combinations of modules and features actually sold are evaluated in contrast to a synthetic approach. The research questions of this research presented in this paper are:

1. Which method should be applied to identify which configuration variables are Critical to cost, sales prices and profit margin based on historical configurations?
2. How can the output be analyzed and utilized to identify relations between configuration variables, cost and sales price and profit margin?
3. How may the criticality of configuration variables with respect to cost and sales price be interpreted and utilized to develop the solution space to produce more profitable products?

2 Methodology

The aim is in a simple quantitative manner to establish which variables are critical for various costs (typically material and salary costs) and which variables are critical for sales price and high profit margin. The aim is then to identify where there is a gap between these models. I.e. which variables are critical for cost aspects, but not critical for price and profitability in the form of net margin (sales price – variable costs).

The paper utilizes the method for determining the critical of various parameters criticality to cost presented in Brunø and Nielsen [3], developed for Engineer-to-Order cost estimation, and adapts this to a method for comparing the cost aspects and the profit margin per sold product. Due to the complexity of the problem and the number of variables (large number of components and resources involved) considered multiple linear regression must be used [18]. However, since some manner of relations can be expected between the independent variables, all insignificant variables cannot just be removed in one step. To overcome this issue backward elimination is used since in product configuration it seems better to risk dropping variables that explain a given behaviour (in this case of cost or profit margin) than having an overly complex model with several variables explaining the same behaviour [3]. The latter being a potential consequence of using e.g. forward selection.

The principle proposed in this paper of applying backward elimination to the problem is to estimate a (simple) linear model for historical configuration data and corresponding costs or profit margins. This creates a linear model that can explain costs or profit margin for new configurations [10]. The way backward elimination simplifies the linear model is by iteratively removing variables from a large set of data describing a number of historical product configurations and fitting a model to the reduced set of data. The set of variables describing the configurations can contain different types of variables as they are typically related to processes used in the manufacturing/assembly process and Bill of material contents. Since the method reduces the number of variables considerably it is unnecessary to qualitatively select the variables before the method is applied, but merely provide a gross list of variables describing each historical product and a corresponding incurred cost, sales price or profit margin. The result of applying this method (see [3] for further details) is a net list of critical variables fitted to a given dependent variable. In the context of this research the dependent variables will as a minimum be a relevant cost per piece (e.g. registered salary or material cost) sales price and profit margin (preferably a contribution margin excluding the variable costs). An overview of the methodology can be seen in Fig. 1.

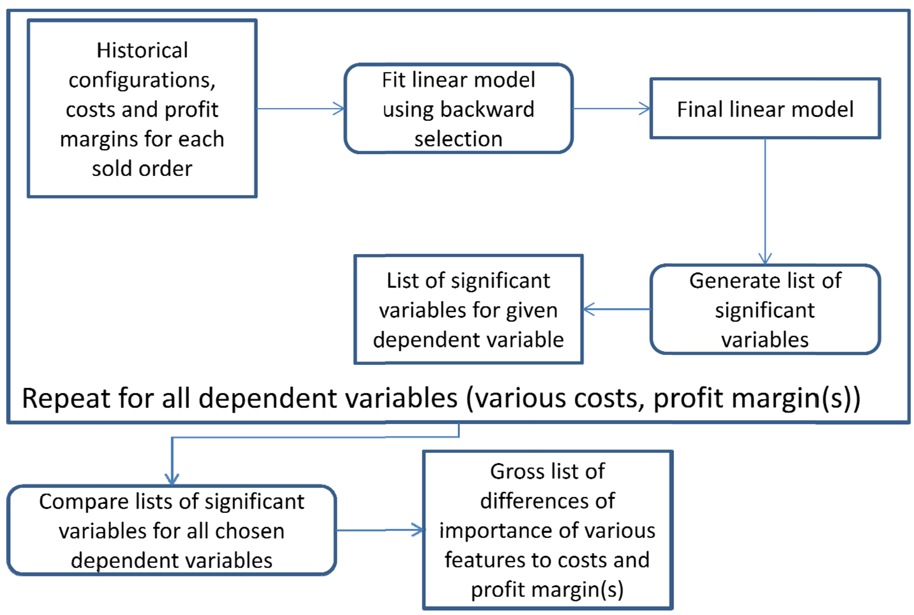

Fig. 1. Overview of methodology partly based on [3].

3 Case study application

The proposed method has been tested on data from a manufacturing company. The case concerns a medium sized company in Denmark producing technical products for domestic water installations which are configured within a predefined solution space. The products share a common structure. The company produces products configured with in a given set of fixed options. The company registers material and salary costs as well as net margin for all sold products. Furthermore a full route and Bill of material is available for all sold configurations.

The initial model contains 194 variables. This is through use of the method presented in Brunø and Nielsen [3] reduced to 22 variables. These results match results achieved by the authors when applying the method to a number of other cases. To simplify the case application of the method the 10 most significant variables for salary, material and profit margin respectively have then subsequently been identified using the method from Brunø and Nielsen (forthcoming). The results are illustrated in Table 1 below.

Rank of significance	Salary costs	Material costs	Sales Price	Profit margin
1	**Number of pieces**	**Var6**	Var13	**Var15**
2	**Var1**	**Var1**	**Var10**	Var17
3	Var2	**Var10**	**Var7**	**Var12**
4	**Var3**	**Var5**	**Var5**	**Var1**
5	**Var4**	**Var4**	**Var4**	**Var8**
6	**Var5**	**Var3**	Var14	**Var5**
7	**Var6**	**Var9**	**Var15**	**Var4**
8	**Var7**	Var11	**Var16**	**Var16**
9	**Var8**	**Var7**	**Number of pieces**	Var18
10	**Var9**	**Var12**	**Var9**	Var19

Table 1. Overview of the 10 most significant variables for material cost, salary costs, sales price and profit margin. The variables highlighted with **bold** occur more than once. All dependent variables are calculated per piece.

From Table 1 it is easy to conclude that there is a relative large overlap between the variables that cause a high material and salary cost (6 out of 10 are the same) although the significance of the variables varies between the two cost structures. It is also easy to conclude that only 5 out of 10 variables that are significant for profit margin are critical for material or salary costs or both. It is interesting also to note that the two most critical variables for profit margin (i.e. the two features most critical to establish the profit margin) are not even on the list of the ten most significant variables for material or salary costs. It is also interesting to note that 6 out of 10 variables that are critical for the sales price (i.e. the price a customer is willing to pay for a piece) are in fact also critical for determining the costs. However, in the same sense it is also very important to note that the variables that are critical for the sales price are only critical for the profit margin 4 out of 10 times. This could indicate that the company is unable to transfer the features that are critical for sales price in to features that are critical for the profit margin.

4 Discussion

The following discussion is based on a single case application. This of course somewhat limits the ability to generalize the results. An analysis identifying variables critical to cost and sales price can be utilized for a number of different purposes, however the most obvious opportunities are development of the solution space. Within this area the method could more specifically be applied in cost reduction projects to reduce the cost of expensive features, in adaption of pricing schemes for different features and for identifying non profitable features which should likely be removed from the solution space. However, the method has a main limitation, namely the requirement for a high volume of structured historical data including configuration variables, cost and sales price. As a result, this method cannot be applied for new products which have not yet been sold. Previous research indicates that the model fit increases the less variation is found in the product structure for different configurations. Finally, the method cannot react to changes in cost and pricing structure before a sufficient number of configurations are produced. Fig. 2 illustrates different scenarios for results regarding a specific variable.

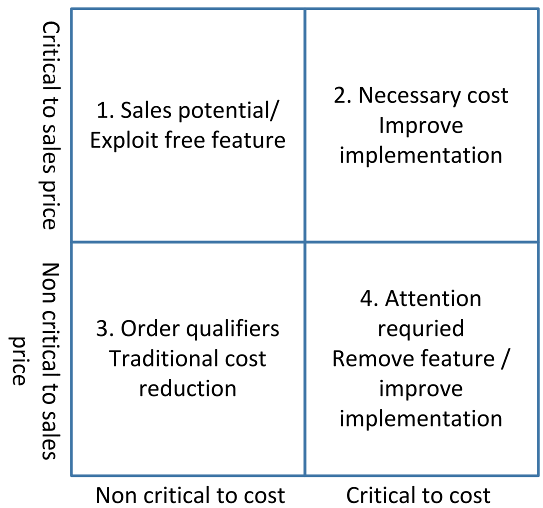

Fig. 2. Scenarios for variable criticality

In scenario 1 the variable is critical to the sales price but not the cost, indicating that this particular feature increases the sales price without adding extra cost to the product meaning that this feature can be exploited by e.g. increasing the sales effort for this feature. In scenario 2 the variable is critical to both sales price and cost indicating that the feature is probably necessary since it drives the sales price, however as it is also significant to the cost, efforts for reducing manufacturing costs should be focused here. In scenario 3, the variable is non critical to both sales price and cost, which indicates that these features are not influencing the profitability of the variety in the solution space. However, cost reduction efforts are still relevant in this scenario, but could presumably be addressed as cost reduction of standard product as little variation is found for these variables. In scenario 4, the variable is critical to cost but not to sales price, indicating that attention is required, since this feature basically being priced unacceptably low or the implementation of the feature is too expensive. This suggest that the feature should either be removed, priced higher or be significantly cost reduced to avoid decline in profit margins. The conclusions and suggested actions for the 4 scenarios are to be perceived as indications only. Although for example a variable in scenario 4 may not seem profitable, externalities may imply that it cannot be removed from the solution space or priced differently and thus a qualitative assessment should be performed for each variable. One simple way to apply the information generated and displayed in table 1 is to plot the variables in the matrix illustrated in figure 2. A display of this type comparing salary costs to sales price is presented in figure 3 below.

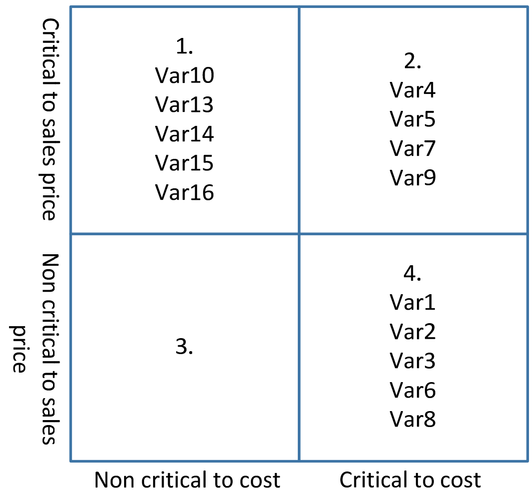

Fig. 3. Scenarios for variable criticality comparing salary costs and sales price

As seen from figure 3, there are no variables in the third quadrant. In reality all features not found to be significant by the method and displayed in table 1, are in the quadrant. From the example we can see that we can place 14 variables in the matrix out of a total of 22 variables to begin with. This matches the concept of value engineering seen in e.g. [6], where experiences on value engineering from the automotive industry are presented. The remaining variables then belong to third quadrant. The critical variables from this example then become the five in quadrant 4, i.e. Var1, Var2, Var3, Var6 and Var8. These five variables are insignificant for the sales price, but significant for the salary costs. When redesigning the product (family) it would then be relevant to first focus on these five and try to move them (at first) to quadrant 3 or even 1 or 2 if at all possible. The second step would then be to focus on the variables (features) found in quadrant 2 and investigate if they can somehow be moved to quadrant 1. However, there will always be some variables that are critical for cost variation, so better that they are placed in quadrant 2 than in quadrant 4. It is noteworthy that the variables seem to be equally distributed between the quadrants.

It is important to keep in mind that the approach presented in this paper only addresses the variation in sales price and cost and does thus not address the base cost, i.e. the intercept of the linear model. This cost and sales price is however expected to be defined by a common product platform, i.e. product properties and components which are part of all configured products and can thus be addressed as a non customized product.

5 Conclusion

It can be concluded that the method can be used to identify which variables are critical for the costs, sales price and profit margin. It is also noteworthy that in this particular case there is a significant difference between which variables are critical for sales price and costs. It is also possible to conclude that the variables associated with a given feature can be categorized using the developed matrix and that this can serve as a first quantitative step in a redesign process.

Future work will focus on two aspects. First, to further refine the quantitative method for identifying critical components / features. Second, to investigate and implement the method in several redesign processes in practice.

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