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Structuring latent consumer needs using LISREL

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Executive summary

A LISREL (Linear Structural Relationships) model is formulated according to the hierarchical division of customer needs presented in the literature on Quality Function Deployment (QFD). The purpose is to evaluate the relative importance of first-hand impression and taste experience as regards food products. The empirical illustration is due to a cooperation with a Danish butter cookie company but the authors' opinion is that the model has a much wider application which is supported by the fact that a similar structure has been found in a dataset on peas.

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Introduction

Product quality is a broad concept which gives room for different interpretations depending on the actual context. The modern world of quality comprises two waves (Senge, 1992). In the first wave the focus was on the improvement of tangible work processes and on obtaining measurable improvements in production costs and customer satisfaction. In the second quality wave we have a new perspective of the consumer. The perspective has now moved from satisfying the consumer's expressed needs to meeting his latent needs. This means that a new set of measurement techniques and a new set of tools for analysis have to be employed. We feel that the LISREL technique has a very promising future in this setting. It allows for a very flexible handling of latent variables and furthermore it makes it possible at the same time to work with structural relationships between the variables. This means that the use of the LISREL technique makes it possible in an easy way to combine technical aspects of food quality with other aspects eg psychological or economic ones, and this makes it possible to break down barriers between the departments of the company at the product development stage. Such a breakdown will undoubtedly be to the benefit of the whole company.

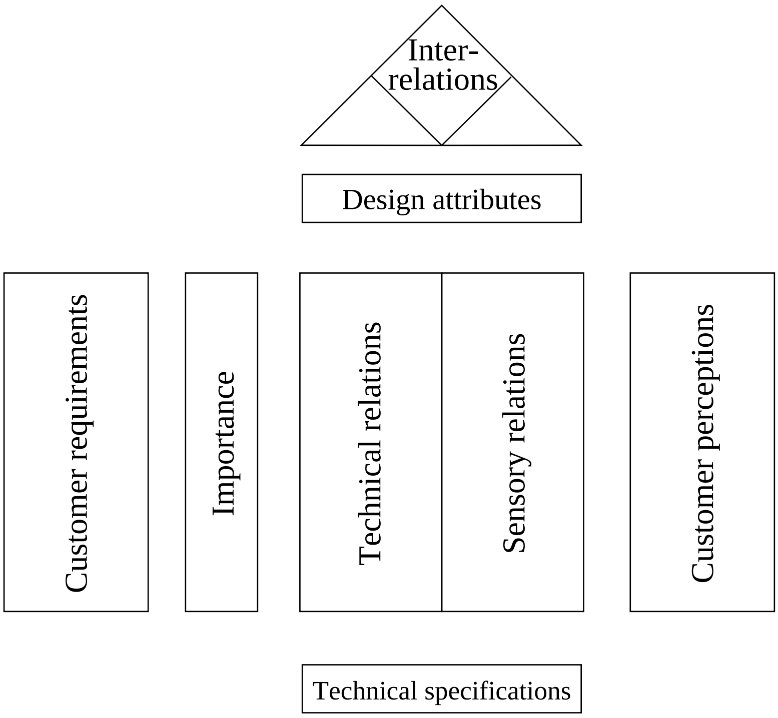
In relation to food products the technical aspects cover nutritional, hygienic, technological and sensory attributes among others (Martens, 1984; Molnar, 1993). Packaging and brand name are other product characteristics that the producer is able to change in an attempt to increase customer satisfaction. This study is limited to evaluating the importance of different sensory attributes as regards the perceived quality of butter cookies. We assume the sensory attributes to be observed sequentially. Before tasting the food a consumer may form a first-hand impression and when eating the product the consumer has a taste experience. A LISREL model is formulated and estimated and possible generalisations to other food products are discussed.

The model

Many factors influence the overall preference for food products. Shepherd (1989) gives a framework that interrelates the factors related to food with factors related to the consumer and those related to the social and economic environment. They include the sensory characteristics of food and consumer attitudes as regards price, nutritional requirements of the food and the sensory attributes. Other psychological factors such as personality, experience or mood are also included. This study has been limited to the study of the relationship between preference and the sensory characteristics of food assuming that all other factors are kept equal.

Customer needs are the necessary input to efficient development of food products, and QFD (Quality Function Deployment) is a process to deploy these needs throughout design, manufacturing and service. In Bech et al. (1994) the House of Quality was presented; it was especially designed for food products, here reproduced as figure 1. The general framework has been modified to illustrate more clearly the specific problems of developing new food products. Traditionally, three sets of data are available when proactive new food products are considered: (1) market research data on customer's preferences, (2) descriptive sensory data from a sensory panel, and (3) the recipe for making the products. However, more often than not the three data sets are treated as separate sources of information that may be linked in combinations of two, but which are hardly ever seen as an integrated entity. The risk is suboptimisation in terms of either customer benefits or production costs.

Figure 1. A revised House of Quality



In the revised House of Quality, the centre of transformation has been divided to reflect the physicochemical dimensions as given in the recipe, along with the sensory dimensions as measured by the panel. By this is indicated that descriptive sensory analysis is seen as part of the transformation process rather than the goal itself. Sensory panels are seen more as tools for measurement than indicators of customer demands. It appears that the fact that humans are used as instruments in sensory panels to produce measures in some instances leads to the false conclusion that they may replace customer measurements. By placing sensory analysis on an equal footing with the technical dimensions the proper perspective is retained. Rather than substituting market research, sensory panels complement it by facilitating the process of translating customer requirements into new food products.

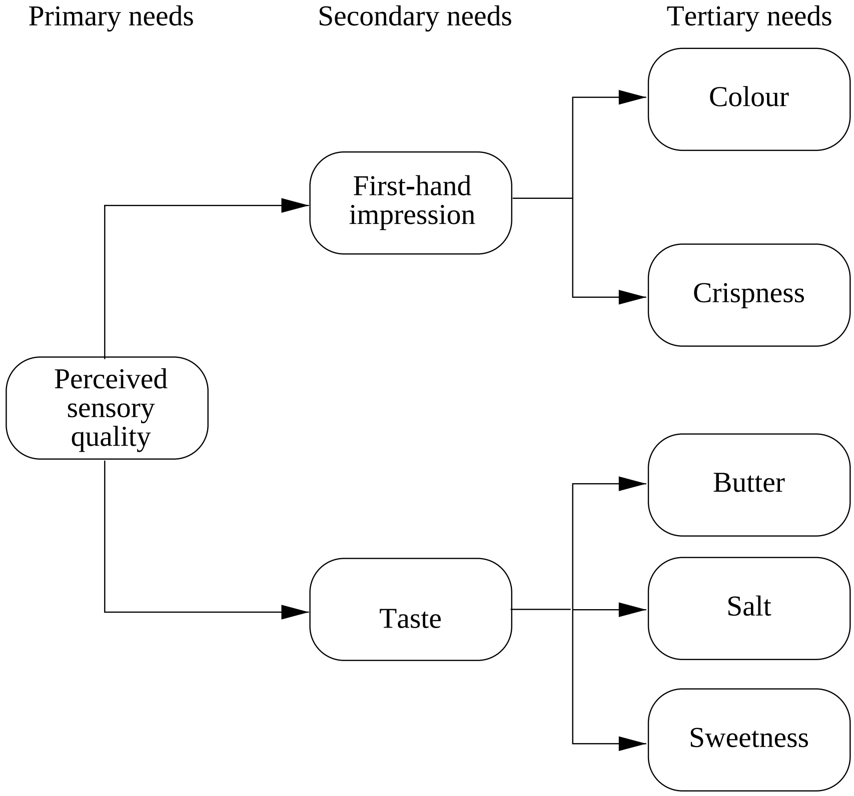
To make the House of Quality operational, it is necessary to develop the various matrices of transformation and requirements somewhat more. This task may be seen as having two aspects, a structural and a quantitative part. By structural we mean a numeration of the important concepts involved and their mutual relationship. By quantitative we mean a measure of the strength of these associations. Methods have been developed to cover both these areas. The purpose is to increase the understanding of the processes, thereby making cross-functional communication easier and more effective. In this study we focus on the left block of the House of Quality and apply LISREL in order to structure customer needs. It is the natural starting point for the whole development process. An identification of the needs structure leads to a more thorough understanding of the market and hence improved possibilities of transforming customer needs into technical specifications.

It is widely recommended to divide customer needs hierarchically into primary, secondary and tertiary needs. The primary needs may be regarded as the strategic needs. The secondary needs are known as the tactical needs and describe how the product development team satisfies the strategic needs. Finally, the tertiary needs correspond to the operational needs and provide detail so that R&D can develop solutions to satisfy the secondary needs. As a consequence of the hierarchical structure, normally no interaction between needs at a given level is assumed. In our model we start with this assumption, but the LISREL estimation procedure allows for possible interactions.

As mentioned earlier we limit ourselves to perceived sensory quality and see it as a function of taste and first-hand impression. To some extent it resembles Steenkamp and van Trijp (1989) who operate with the constructs *quality expectation* and *quality experience*. Quality expectation is the impression formed by the consumer when the product is bought, while quality experience relates to actual consumption of the product. Although Steenkamp and van Trijp (1989) assume a possible dependency between expectations and experience, this is not in accordance with the use of the constructs in service quality and related areas, where quality of a given service or product is defined as the difference between expectations and experience. This is the main reason why we have chosen the constructs *first-hand impression* and *taste* which do not demand an assumption of independence.

Figure 2 illustrates the structure of our preliminary model. The product category is butter cookies. The first-hand impression of a butter cookie is assumed to be a function of crispness and colour. The reason for treating colour as part of the first-hand impression should be obvious. Generally, colour imparts something about the ingredients and the baking process. As an example a yellow colour may leave an impression of butter. Crispness as a first impression may be more difficult to accept. This may be justified by the fact that crispness is sensed before tasting the cookie. Hence, the sequential process describing consumption of a cookie is our argument for including it as part of first-hand impression. The other part of the secondary needs is taste. It is assumed to be a function of the tertiary needs, butter, salt and sweetness.

Figure 2. Hierarchical presentation of consumer needs for a butter cookie



Introduction to LISREL

As researchers in sensory analysis cannot be expected to be familiar with the LISREL modelling framework, this section contains a brief introduction to the area. For more extensive expositions, see the references. LISREL is an acronym for **LI**near **S**tructural **REL**ations. Strictly speaking, it is the name of a computer program that appeared in 1972. Its purpose is estimation and testing of covariance structure models, but the program's name and the modelling approach have become synonymous.

The importance of the approach is derived from several sources. First of all, epistemologically it represents the very important distinction between theory construction and operations of measurement. Theories contain hypotheses on relations between theoretical constructs, while empirical testing involves translating these constructs into (imperfect) measures and relationships.

Secondly, it bridges the gap between two scientific disciplines, econometrics and psychometrics. Econometrics deals with modelling economic theory by way of systems of equations, reflecting 'cause and effects'-relations. Psychometrics deals with measuring unobservable or latent variables as they are reflected in observed or manifest variables. Combining the two traditions yields a potentially very powerful approach that allows the researcher to model structural or causal relations between latent and/or manifest variables. Hence, well-known statistical models such as regression analysis, canonical correlation, factor analysis, path models, and others are all contained in the general framework of LISREL as special cases.

Thirdly, the approach has been made available as a practical tool to the researcher in a series of versions of the computer program LISREL, now in its eighth enhancement on the PC. With the recent introduction of the command language SIMPLIS and graphical capabilities (Jöreskog & Sörbom, 1993), it has become user-friendly and more interpretable in its output.

The factor analytic model

The factor analytic model assumes that one or more latent variables, corresponding to the constructs of interest, generate the observed variables that are measured with errors. In its general form, the relationships between the manifest and latent variables are given by the matrix equation

$$\mathbf{x}=\Lambda_{\mathbf{x}}\xi+\delta \qquad \textbf{(1)}$$

where **x** is a vector of observed variables, $\Lambda_{\mathbf{x}}$ a matrix of factor loadings, ξ is a vector of common factors, and δ is a vector of errors in measurement. Statistically, the task is to explain the interrelationships among the observed variables, in terms of relationships among the observed and the latent variables defined by the equation (1).

The structural equation model

This model is widely used in the social and behavioural sciences. A simple case is the regression of a single measurable variable y on a set of measurable variables, $\mathbf{x}=(x_1,x_2,...,x_k)$. In matrix notation,

$$y=\beta'\boldsymbol{x}+e \qquad \textbf{(2)}$$

where **y** is a dependent variable, **x** is a vector of independent variables related to the dependent variable by the slope coefficient vector β, and e is an error in equation, denoting measurement errors as well as omitted independent variables.

In (2) it is usually assumed that the **x**-vector is measured without error. If this is not the case, these ‘errors in variables’ must be taken into account in order to avoid biased conclusions. Allowing for errors in x-variables as well as in y leads to the following specification, using standard notation in LISREL:

$$\eta=\Gamma\xi+\zeta \qquad \textbf{(3)}$$

where η is a vector of dependent latent variables, ξ denotes the vector of latent independent variables related to η by the coefficient matrix Γ, and ζ is a vector of errors in equation.

More general and realistic models allow for possible reciprocal causation between dependent variables, ie one or more elements of η appear as explanatory variables on the right hand side of (3). This leads to the formulation:

$$\eta=\mathbf{B}\eta+\Gamma\xi+\zeta \quad \textbf{(4)}$$

where **B** is the matrix of coefficients relating the dependent variables to each other.

Having assumed in (4) that dependent as well as independent variables are measured with errors, the structural equation model has to be complemented with two models of measurement, one for the η-variables, and one for the ξ-variables, cf. (2):

$$\mathbf{x}=\Lambda_{\mathbf{x}}\xi+\delta \quad \textbf{(1) repeated}$$

$$\mathbf{y}=\Lambda_{\mathbf{y}}\eta+\varepsilon \quad \textbf{(5)}$$

The general LISREL model

Equations (1), (4) and (5) form the basis of the covariance structure model LISREL. However, in order to be able to test the model and confront it with empirical data, additional statistical assumptions are needed. These assumptions involve the levels of measurement of the observed variables and the distributional properties of error terms in the structural and measurement models. In this regard the most fundamental assumption in structural equation models is that the error term in each relationship is uncorrelated with all the independent constructs.

In effect, the equations (1), (4), and (5) along with the statistical assumptions impose restrictions on the covariance matrix Σ between the observed variables **x** and **y**. The statistical inference involves (1) estimation of the parameters θ, unspecified by the model, and (2) testing, whether the model fits the data.

A number (seven) of methods for estimation is available in LISREL8, eg instrumental variables, two-stage least squares, unweighted least squares, and maximum likelihood. In general terms, the estimation step provides estimates of θ by minimizing some ‘distance’ function $F=F(\mathbf{S},\Sigma(\theta))$. The methods differ with respect to computations and to the particular function they try to minimize, but under general assumptions they all provide consistent estimates of the parameters.

Model testing involves comparing two matrices: $\Sigma(\theta)$, the covariance matrix restricted by the model, and **S**, the unrestricted covariance matrix, computed from the data. When the estimation step has provided estimates of θ by minimizing $F(S,\Sigma(\theta))$, testing means evaluating whether the obtained minimum distance between model and data are in fact tolerable, indicating an acceptable fit, or else the model has to be rejected. For this purpose, $c=N \bullet F$ may be used. If the model holds and the sample size N is sufficiently large, c will be approximately distributed as χ^2 with degrees of freedom determined as the difference between the number of independent data points in **S** and the number of independent estimated parameters.

In practice, it is more useful to consider c as a measure of fit rather than a test statistic. The model may not be expected to hold exactly in the population, and the researcher is merely looking for some guidance in model assessment and modification. In addition, since c is proportional to sample size, the researcher may be unable to fit any models to his data merely because of large samples. One way of going about this problem is to evaluate the fit based on moderate sample sizes like N=100 or 200.

The data

In Denmark there is a wide range of cookies. The main ingredients are usually flour, sugar, fat and eggs and some kind of flavour such as vanilla, chocolate, nuts etc. In order to examine consumer use, habits and preferences for butter cookies a market analysis was performed. Ten products were selected for the analysis and a description is given in table 1.

Tabel 1. Description of cookies included in the analysis

Code	Shape	Flavour	Fat %	Butter %	Veg-fat %
1	star	vanilla	High	High	Low
2	star	vanilla	High	Low	High
3	star	vanilla	High	Medium	Medium
4	star	vanilla	Low	High	Low
5	star	vanilla	Low	Low	High
6	star	vanilla	Low	Medium	Medium
7	round	chocolate, fruit, coconut	Low	Low	High
8	round	chocolate	Low	Low	High
9	rectangular	sugar, fruit	Low	High	Low
10	star	fruit	High	High	Low

The investigation was carried out as a hall test with an incomplete block design. Each of the 210 consumers was asked to evaluate their unique combination of four out of ten cookies on five sensory attributes, to indicate overall preference and to indicate the degree to which the cookie tasted and looked like a home-made cookie. The four cookies were presented and served one at a time in random order. A plate with a sample of the product was presented and the colour of the cookie was assessed by the consumer. Hence the consumer was asked to select one of the cookies from the plate and assess the intensity of crispness, saltiness, sugar and butter taste. Finally, the consumer evaluated home-madeness. After the four cookies had been assessed on these six attributes all four products were presented and the consumer was asked about overall preference for each of the products.

In the model formulation we have assumed a sequential experience with the butter cookie. In the empirical part crispness is evaluated together with butter, salt and sweetness and maybe the joint evaluation gives rise to reversible effects. Hence equilibrium is modelled and not the process. The sensory attributes were measured on a 9-point relative-to-ideal scale. Where the scale “5” represents ideal, “9” indicates much more than ideal and “1” indicates much less than ideal. Home-made and preference are measured on a monotone 9-point scale and 9 indicating an extremely good cookie. The measurements of each of the sensory attributes were transformed to deviations from ideal by the following formula: (Dev = 16 - (Observed value - 5)^2). The transformation treats positive and negative deviations from ideal equivalently and ensures that high values are closer to ideal than low values. Subsequently the polychoric correlations between the seven variables given in table 2 were calculated and applied as input to the LISREL-analysis.

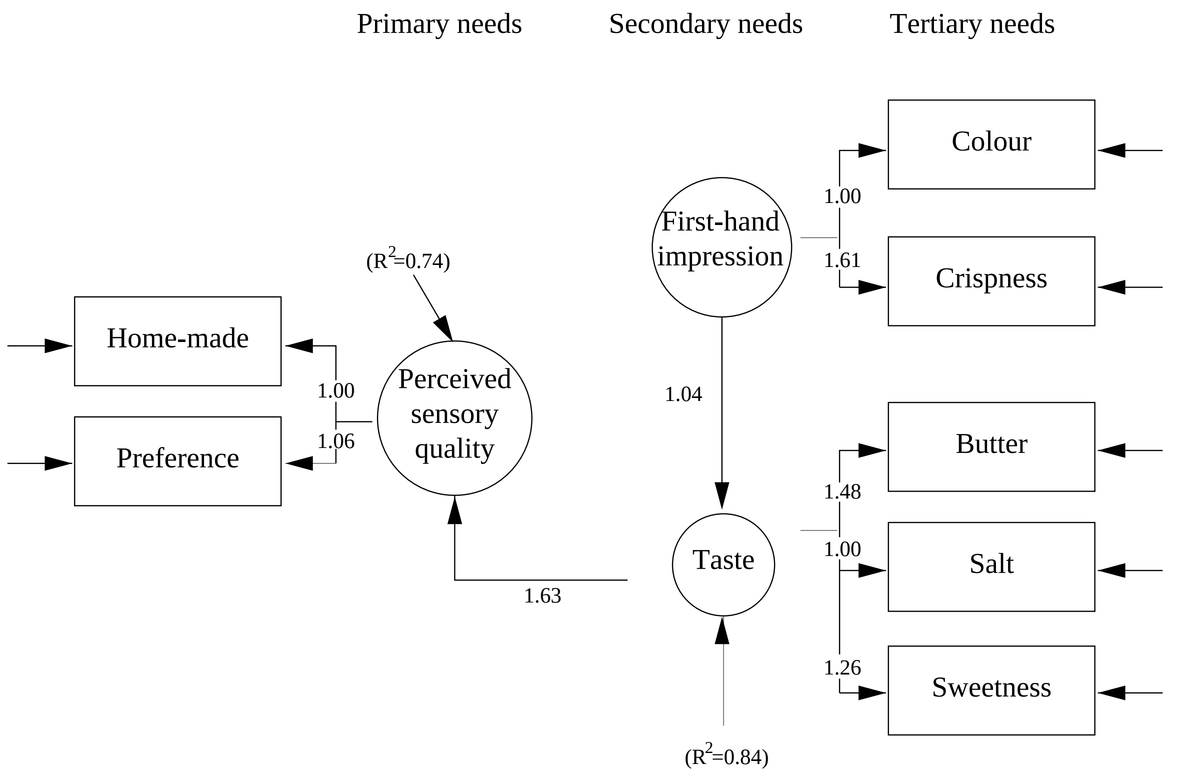
Table 2. Correlations between variabes included in the analysis (n=840)

	salt	sweet	butter	home-made	prefer-ence	crispness	colour
salt	1.00						
sweet	0.20	1.00					
butter	0.27	0.32	1.00				
home-made	0.29	0.32	0.43	1.00			
preference	0.31	0.33	0.40	0.65	1.00		
crispness	0.11	0.29	0.31	0.33	0.39	1.00	
colour	0.05	0.22	0.15	0.21	0.25	0.22	1.00

Estimation

Due to the ordinal measurement level a LISREL model corresponding to the structure in figure 1 is formulated and estimated using weighted least squares as recommended by Jöreskog and Sörbom (1993). Perceived sensory quality is operationalized by the variables preference and home-made. In the first place the model was formulated according to the hierarchy in figure 2, but a significant improvement in fit was obtained changing the structure according to figure 3. There has been an extensive discussion of the insufficiency of the c-statistic due to its dependence upon sample size (Browne & Cudeck, 1993). We have decided to accept the model, if the model is acceptable when the number of observations are set to 100. The c-statistic is equal to 5.02 with a number of degrees of freedom equal to 12 and hence acceptable at any reasonable level of significance.

Figure 3. LISREL estimation results



The numbers in figure 3 are the estimated coefficients in the underlying measurement models and the structural model. These coefficients may be interpreted as the importance of each of the consumer needs, derived as a part of the LISREL formulation. As regards the secondary needs the most striking result is the high importance of first-hand impression. It can be seen that 84% of the variation in taste is explained by first-hand impression, and 74% of the variation in perceived sensory quality is explained by the sequential influence of first-hand impression and taste. This result is in good accordance with the slogans "You never get a second chance to make a first impression", "First impressions last". It also reflects the fact that reintroduction of a product is a very difficult task with a low success rate. It may be of considerable interest to evaluate whether this particular structure can be identified in other product groups. At the moment the authors are working with a similar dataset on peas but of course with other measurement variables. It seems as if the same structure may be found in this very different product group.

As regards the tertiary needs in our butter cookie example, crispness is the most important determinant for first-hand impression and butter is not surprisingly the most important taste determinant.

A natural extension of our model is the inclusion of the sensory profiles of the butter cookies obtained from a panel in order to give R&D a more comprehensive guide for developing butter cookies with the secondary needs demanded by the consumer. Finally, the tertiary needs and the sensory profiles have to be connected to the technical specifications of the butter cookies covering such variables as sugar percentage, butter percentage and fat percentage. This may be done in a LISREL setting by adding more levels to the structure in figure 3.

Conclusion

The QFD model has been used to systematise consumer needs for a butter cookie into three hierarchical levels. The application of LISREL results in estimated importance for each of the consumer needs. It has been shown that first-hand impression is a very important direct determinant for taste experience and hence indirectly for perceived sensory quality of the butter cookie. It may be of considerable interest to evaluate if and under which conditions this particular structure can be identified in other product groups. At the moment the authors are working on a similar dataset on peas but of course with other measurement variables. Preliminary analysis on the very different group point to a structure similar to the one found in that very different product group. Both datasets include a sensory evaluation of the products by an expert panel and some technical data. Hence it is possible later to widen the analysis as described in the former section.

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