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Product Design and Development by Functional Analysis

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Abstract

The paper describes facets of functional approach in product design. A road map of television shows functional evolution with time. Functional analysis scrutinizes the performance of the product and is illustrated by an example of television. Knowing the functions of the product, alternative designs can be created by morphology. A customer survey for helmet established primary and secondary needs which identify the functions. The needs are ranked in relative importance to highlight important functions.

Keywords: Morphology, Functional analysis, Product development.

Introduction

Product design and development efforts must result in profits for enterprise and the satisfaction of the users. The customers will demand that the product meets the functions entirely. This paper also stresses that the product functions are key to its design. In order to know the relative importance of functions and to make trade off customer survey is essential. The dissection of functions of an existing product becomes more important for redesign or adaptive design. This paper describes how the functional

approach applies to adaptive design [I] and to develop a competitive customer driven product.

Functional Approach in Product Design

The needs of the customers are transformed into functional means of the product. The evolution of functional means and sub functional means with the advancement of technologies is conspicuous in many inventions around us. In this evolution besides satisfying the new needs of the society the other motives might be a market promotion strategy or to enhance the capacity, quality, efficiency, flexibility, safety, environmental safety and incorporation of high technology. This technological evolution in functional development is evident in the road map of many products. As an example the road map of the television is shown in Figure 1.

In product design and development customer needs are transformed into functions. The needs are weighted and metric assigned to needs and target specifications are set by bench marking with existing products. In bench marking the existing or related products are disassembled and performance or characteristics of components in terms of metric is noted. Also components are classified into those whose functions satisfy the customers and into those whose functions displease the customer. The existing product can also be improved by redesigning the bad components. Target specification step is followed by concepts generation, concept selection and final specifications.

A product should be compact, light, having minimum parts to achieve the overall function of the product. So in depth study of functions is important so as to eliminate irrelevant functions, exploring the possibility of integrating components to achieve the combined function. This analysis is useful for the critical study of the existing product for improvements, redesign or adaptive design. An example of functional analysis of television is presented in Figure 2. All system elements of a television are listed in a column and their tasks are specified in the adjacent column in verb-noun phrase. All these tasks execute so as to achieve the sub functions whose accomplishment results in the achievement of function of the television. All these sub functions are the members of the black box shown in Figure 2.

A structural approach in design is how to express the functions and how the functions could be used to yield a good design. In this context, a technique called FAST is being developed with the objective to explore function and its dependencies. It gives a good thinking of the design right from the start and guides to a simple and optimized design. Here design function is expressed in noun–verb phrase. In FAST diagram each function should be linked to form a network. Each function is asked the question

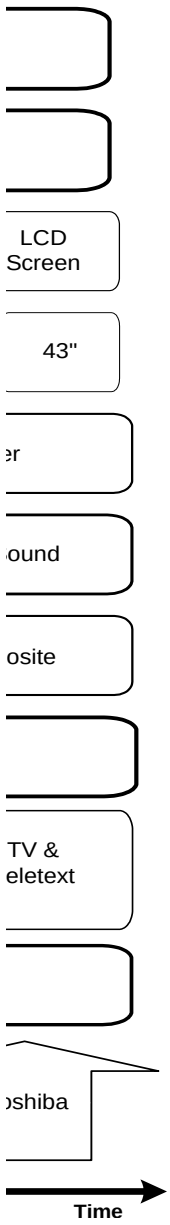

Figure 1. Technology roadmap of television

Why and How. The answer to Why is placed right in a box and the answer to How is placed left in a box. So the box on far right represents the ultimate function and boxes to the left represent the parametric function for the system operation. The method can stimulate generation of new ideas. A simple example of tea making process by FAST is shown in Figure 3. The functions are in abstract form and metrics and the values need to be assigned from customer's response or the upper or lower limits of failure. Thus

the function diagram binds the relationships between the parameters that control the function, the function itself, output from functions and their associated latitude and failure modes. John Fox has elaborated at length the merits of FAST [II].
In order to generate ideas from functions a Functions Tree is constructed which represents basic and secondary functions [III]. The top shows the basic function. The alternate succeeding lower levels show the means for the upper level. Function Means Tree tells what must be done and how it can be done. As a simple example Figure 4 shows the Function Means Tree for the tea making. Functions are shown in rectangles and means are shown in trapezoids.

Morphological approach is a comprehensive structural approach to generate a number of alternative solutions from the functions and sub functions. The functions called parameters are arranged in column and the way to achieve the parameters are arranged in rows in a matrix form. Selecting one way from each row and combining them so as to satisfy essential functions or all functions gives one solution. Several combinations can be made to furnish various solutions. As it is obvious that morphological study generates large number of solutions it is essential to reduce these solutions to a few feasible solutions for detailed analysis and evaluations. Some solutions will be deleted because of the incompatibility among some ways to meet the functions. Moreover, solutions not fitting initial specifications are also not wanted. Finally, the remaining solutions could be compared on cost estimate, and the time cost requirement for research and development.

In order to illustrate the application of morphology Figure 5 shows the morphology matrix for an ash tray which generates several designs of ash tray. The functions of the ash tray are listed in the parameter column. Some parameters have been divided into sub-parameters. Each parameter and/or sub-parameter has been brainstormed to find the possible ways to achieve the objective of a parameter or sub-parameter. These ways are listed in row as parameter steps. To get a design solution select one parameter step from each row of parameters or sub parameters and combine them. Examine for incompatibility in the combined parameter steps, for example, metallic, wooden, clay, or marble container can not be transparent.

Though the decorative and social value parameter is not an essential function, yet, it has been included because any importance given to this factor will affect the whole design. If the ash tray is solely for decorative purpose then the idea of making the ash tray as a grave will be surely appreciated by the customer, because putting the cigarettes butts in the ash tray has a similarity to laying a dead in the grave. Similarly smoking is dangerous for health and this warning can be conveyed to the smoker by giving the ash tray an alarming shape.

It is interesting to note that various solutions obtained from this study are already in use, for example, some ash tray designs in terms of the following parameters terminology are usually familiar.

a) la-1, lb-7, lc-2, 2a-5, 2b-4, 3-4, 4a-1, 5-3. A light colour china clay tray with flat bottom support.
b) la-4, lb-6, lc-3, 2a-2, 2b-2, 3-4, 4a-2, 5-3. A square shaped anodized aluminum ash tray with a hinged lid as cover and supported by small studs fixed to the bottom.
c) la-6, lb-7, lc-3, 2a-5, 3-2, 4a-1,5-3 Bowl shaped china clay made ash tray supported by flat bottom and having grooves in the flange for resting the cigarettes.
d) la-6, lb-6, lc-2, 2a-3, 3-2, 4a-1,5-3. Bowl shaped aluminum ash tray having light color with a split cover attachment; the cover splits wide with a push button mechanism. The flange is formed of grooves to rest the cigarettes. The tray is supported by a flat bottom.
e) la-5, or la-7, lb-5, Ic-3, 2a-2,3-5,4c-1, 5-3. A consideration of these parameters gives a design which, more or less, resembles with the ash tray fixed in cars. Note that the idea for a side support of an ash tray is novel and it is hard to believe that an ash tray needs a side support, but note that this need arose for providing ash trays in the car.

Moreover, the hinged cover itself acts as a container. This is an illustration as to how the functions of two or more parameters can be obtained only by one solution.
From this study the following rather some rare designs of the ash tray are obtained.

a) la-6, lb-6, or lb-5, lc-2, (for lb-6, or lc-3 (for lb-5), 2a-4, 2b-1, 3-2,4a-2, 5-3. A bowl shaped ash tray made of anodized aluminum or stainless steel with two circular concentric discs cover having identical holes. One of the disc is fixed to the top of bowl, while the other disc can rotate over it. The upper disc is rotated to obtain the holes of the fixed disc to put the extinguished cigarettes in the container and then rotated to close the holes of the fixed disc. The formed grooves at the flanges provide the resting place for the burning cigarettes and small heat resistant rubber studs are fixed at the bottom.
b) lb-7, 2b-4, 3-5, 4a-1, 5-l.A simple functional ash tray made of china clay having a shape of grave for decorative purpose.
c) lb-7, 2b-4, 3-5, 4a-1, 5-2. A simple functional ash tray made of china clay having some horrifying shape to warn the smoker that smoking is dangerous.

From above this is clear that for product development the understanding of product functions is crucial. The product functions will vary in their importance from customer to customer. Some functions will be essential, some less essential and some optional. A simple way of gathering the functions is self brainstorming to list the functions with their importance rating, but more objective listing will be the one uttered by the customers. Who are customers? All associated with the product can be customers for the purpose of identifying need.

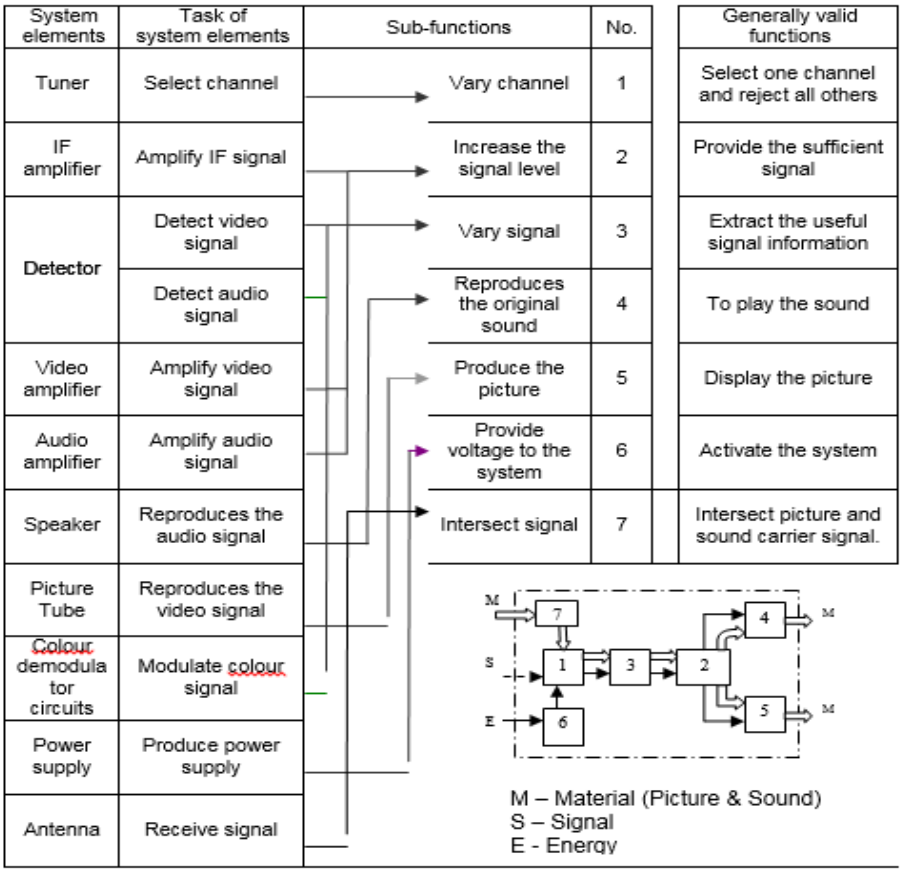

Figure 2. Functional diagram of television

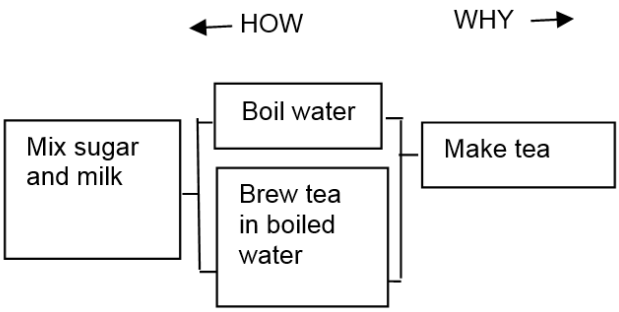

Figure 3. Fast for making tea

Hence a customer can be common user, lead user, sales man, manufacturer, standard part supplier, service centers, transporters etc. In addition, product development or introduction of new product is not limited to only needs of customer, but also the designer can introduce new features to create new needs or functions based on the

current or future technological development. Kano calls it woo requirements [IV].This makes the product competitive with opportunities of expanded market segments and the firm stays dynamic. Customer requirements may be related to functional performance, appearance form, life cycle aspects, environment and manufacturability.

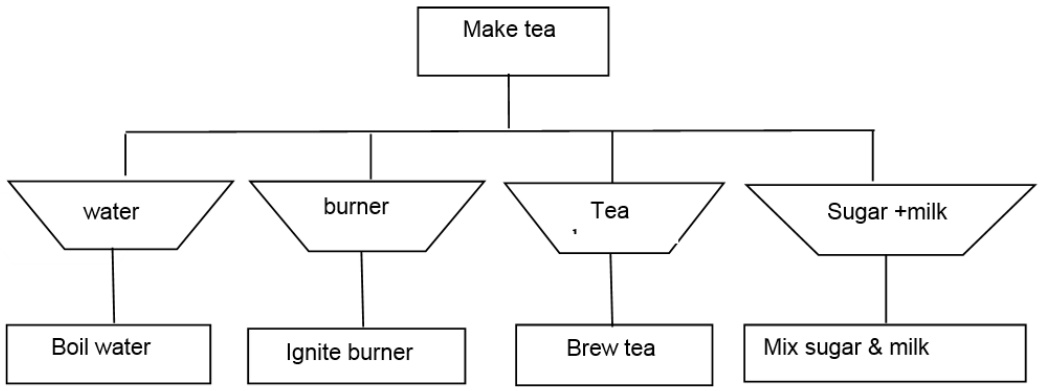

Figure 4: Functions means tree

Parameters	**Sub Parameter**	**Parameter steps**						
		1	2	3	4	5	6	7
1. Container to keep extinguished cigarettes	**a.** Shape	Tray	Spherical	Cylindrical	Square	Rectangular	Bowl	Conical
	b. Material	Tin	Aluminum	Plastic	Wood	S. Steel	Anodized Al	China clay
	c. Color	Transparent	Any Light colors	None				
2. Cover to prevent smoke from extinguished cigarettes	**a.** Type	Plate	Plate hinged at one point	Split cover	Rotating cover	None		
	b. Shape	Circular	Square	Semi-spherical	None			
3. Resting for burning cigarettes		Hole in flange of ash tray	Formed grooves on the flanges to place cigarettes horizontally	Flange shape	Container itself	None		
4. Support	**a.** Bottom	Flat	Stand fixed to bottom					
	b. Top	Strings	Flange fixed to top					
	c. Side	Flange fixed to sideways	Flange clipped to sideways					
5. Decorative		Grave of burnt cigarettes	Horrifying appearance	None				

Figure 5. Morphology of an ash tray

Customer survey for product development

A customer survey was conducted for helmet used by motorcyclists. The customer gave statement of his use of helmet, his likes and dislikes of the existing helmets and any improvement he suggests. From all statements the needs are derived. At this stage solutions to needs are not sought. These needs indicate the functions and sub functions of helmet. Similar needs are grouped together and are labeled which reflects the need of that group. This is primary need and needs of the members of this group are secondary needs. This may also be called as function and sub functions. The Table 1 shows the primary and secondary needs. The primary needs are in bold letters. These needs have different importance ratings from the customer point of view. Also the importance will differ with type of customer or user. Importance ratings helps in deciding trade off between cost and performance of the functions and hence allocation of resources. The secondary needs are rated with stars (*) the high number of stars means critically important need. The needs are expressed in abstract form and are to be transformed in measurable units or metrics to set the target specifications. A need is subjectively rated when a quantitative metric could not be assigned. The competitive target specifications will be set by bench marking with existing helmets. A number of concepts of helmet will be generated taking into account the customer needs or functions using creative techniques.

Table 1. Primary needs and secondary needs derived from customer survey of helmet.

The helmet protects head.

***-Helmet is safe to use.
***- Helmet absorbs shock and impact in case of accident.
***- Helmet does not injure user in case of accident
*- Helmet illuminates in dark at its back and front.

The helmet protects face.

*****-** Helmet protects face, eyes from dust, water and hard object.

The helmet is user friendly

******- Helmet protects from rain, sunlight and smoke.
*- Helmet is comfortable to use for a longer time.
*- Helmet allows surrounding sound audible.
**- Helmet gives clear vision when raining.
**- Helmet is easy to wear.
*- Helmet is lockable to motorcycle.
***- Helmet is light.
**- Helmet has sizes for all heads.
*- Helmet has parts which are washable.
**- Helmet has replaceable parts.
*- Helmet can house small radio and hand phone.

The helmet homes to head and it remains in place.

**- Helmet has no relative movement with head when in use.

The helmet is durable.

*- Helmet is scratchproof
**-Helmet does not crack.
*-Helmet parts last long.
**-Helmet is water/ rust proof.
*-Helmet has varying colors , patterns trendy for the taste of all.

Helmet has soft contact with head and ears and face.
Helmet conforms the standards of safety.
Helmet has trade off between cost and quality.

Discussion

For a customer driven product understanding of its functions is crucial. There is possibility of combining functions and thus reduction of number of components, reduction in manufacturing, assembly and maintenance costs. Functional analysis is a good tool for dissecting the existing product when embarking on redesign. For alternative concept generation morphological study and brainstorming when combined can render a number of concepts. Prior to start of product design project a well thought customer survey is important. The survey should spread on all type of customers. Important customers are lead users as they know extensively about the merits and demerits of the product.

Conclusion

A functional analysis gives an insight of the product and produce alternative designs. For a competitive design customer survey is imperative in order to know the obvious and hidden needs of the customers. All customer statements should be transformed into functions in the abstract form. From the customer survey of helmet it is found the users are not fully satisfied and helmet need to be redesigned.

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