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THE FACTORS WITCH AFFECTING PRODUCTS FUNCTIONALITY

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Abstract: *It is well recognized that functional design plays a central role in ensuring design quality and product innovation; products with problems in their main functions do not sell well, no matter how sophisticated their details. Numerous examples exist of products marketed and sold as sophisticated but routinely fail to perform the intended functions or do so in a very unsatisfactory manner. The paper reviews functionality in design, with a special emphasis on the different definitions of function as well as the models and tools used to represent function in a product.*
Key Words: *design process, functionality, reliability, concurrent engineering*

1. INTRODUCTION

Historically, a variety of factors, both internal and external to a company, influenced its product design goals. For instance, the mass production paradigm pioneered by Henry Ford resulted in the concepts of building products on assembly lines, using of interchangeable parts, and standardization of parts and components with a view toward reducing product cost [5],[7].

Customers' demand for high quality products prompted manufacturing companies to consider quality as their key product design goal[11].
The establishment of the U.S. Consumer Product Safety Commission in 1972 prompted manufacturers to project product safety as their key design goal.[4], [6].

The advent of the computer screen and the resulting digital interface may be the primary reason for companies projecting product usability as their prime product design goal. Similarly, the need for product manufacturers to reduce assembly time and cost prompted product designs built from design for assembly processes. [1], [2], [9]

Recent US and European legislation has prompted Design for Environmental Friendliness or Green Design as an important product design goal [12].

Simultaneous optimization of a number of design goals (design for *X*, where *X* could stand for assembly, manufacturability, safety, reliability, or any of the other design goals) is the latest in the research agenda.

While all these design goals have gained recognition and acceptance, product performance (or what is broadly known as *product functionality*), as a design goal, often has been taken for granted by designers. Indeed, the provision of functionality in a product often is considered the purpose of design.

2. CONTENT

2.1.Concurrent engineering in product design

An understanding of the key elements involved in the design and manufacturing (for functionality,(see Figure 1) of consumer products and the tools used to model these elements should help shed light on why functionality is not ensured in products.

Is it the design process? Or, is it manufacturing? Or, is it a lack of close correspondence between design and manufacturing? Are the current criteria for product functionality adequate? Are there problems in translating customer expectations into product functions? Is the definition of functionality adequate?

2.2. Functionality in Design

Designs exist to satisfy some purpose or function. Knowledge of functionality is essential in a wide variety of design-related activities, such as generation and modification of designs; comparison, evaluation, and selection of designs; and their diagnosis as well as repair. Beyond agreement among researchers and designers that function is an important concept in determining a product's fundamental characteristics, there is no clear, uniform, objective, and widely accepted definition of *functionality*.

Function has been interpreted historically in a variety of ways.
Examples of this interpretation are:
• As an abstraction of the intended behavior of a design.
• As an index of its intended behavior.
• As a relationship between a design and its environment.
• As the external behavior of a design.
• As the internal behavior of a design.

The definition of *function* also has been influence by design methodologies in use. If the designer follows the traditional conceptual design methodology, the entire functions first determines by analyzing the specifications of the product to be designe and built. This function is then divided recursively into sub functions, a process that produces a functional structure.

For each sub function, the next step is to use a catalog to look up the most appropriate functional element: a component or a set of components that perform a function. Finally, the designer composes a design solution from the selected elements. Since the results of the design process using the traditional conceptual design methodology depend entirely on the efficacy of the decomposition of the function, the role of functionality is critical in using such a methodology.

A number of new models for abstracting and representing function, in addition to numerous computer-aided design tools for managing the modeling of function in a product, emerged recently. A conceptual or theoretical model represents concepts and ideas in the form of diagrams and other conventional representation methods.

2.3. Function and Functional Representations

While functionality is considered an intuitive concept dependent on the designer's intention, traditionally, there have been three approaches to representing function in a design:
1. Representing function in the form of verb-noun pairs[14]. An example would be the function of a shaft. Its function is represented by two words: "transmit torque."
2. Input-output flow transformations, where the inputs and outputs can be energy, materials, or information [11].
3. Transformations between input-output situations and states. The essential difference between this and the preceding definitions is the type of input and output.

Miles[8] developed the function analysis method of expressing a function as a verb and direct object (a noun or an adjective). This function usually can be described by a two-word definition, such as provide light, pump water (for a domestic water pump), or indicate time (in a clock). In addition to primary functions, secondary functions may be involved in a product. For instance, if the primary function of a light source is to provide light, a secondary function could be that the light source is required to resist shock; a pump for domestic use, with pumping water as the primary function, may have to operate a low noise level.

Although this definition of a function is general, owing to the lack of a clear description of the relationships between product function and product structure, this representation is not considered powerful enough for design applications. Miles's definition of *function* has been use primarily in value engineering, representing function in the form of "to do something" as well as by comparing the value of function with respect to product cost.

Rodenacker [11] defined *function* as the transformation between the input and output of material, energy, and information.

A coffee mill is an example using Rodenacker's definition. In this case, the input can be conceptualized to consist of the coffee beans, energy, and information to the user in the form of electrical signals.

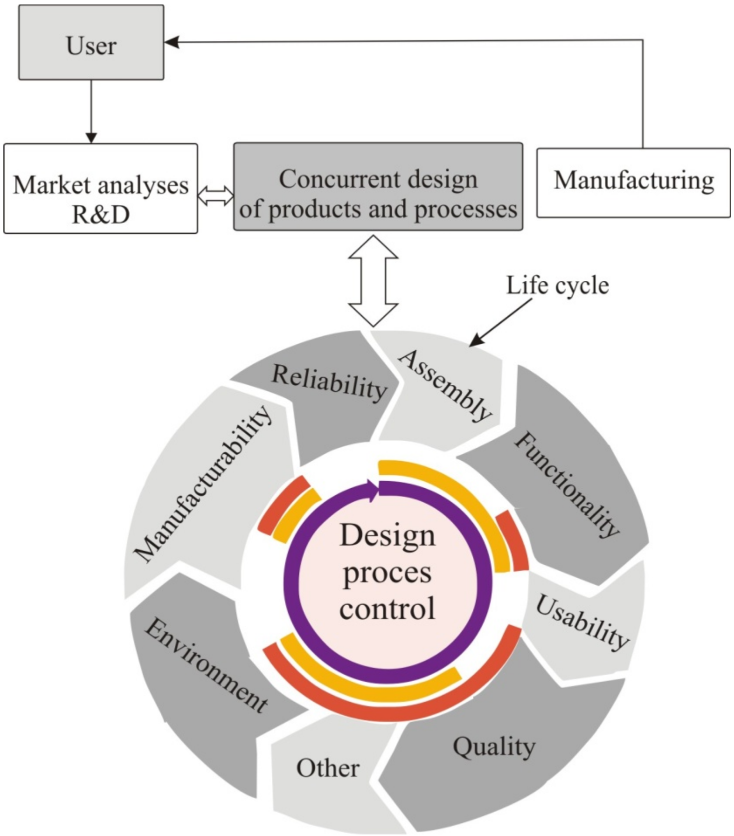

Figure 1. Concurrent engineering in product design.

Umeda[12] proposed the FBS (*function behavior state*) diagram to model a system with its functional descriptions. An example is depicted in Figure 2. According to this definition, function is a description of behavior abstracted by the human through the recognition of the behavior to utilize that behavior. The underlying concept in this definition is that it is difficult to distinguish clearly between function and human behavior. It is also not meaningful to represent function independent of the behavior from which it has been abstracted.

Function, in the FBS diagram, is represented as an association of two concepts: the symbol of a function, represented in the form of "*to do something*," and a set of behaviors that exhibit that function. For instance, some behaviors, such as "ringing a bell" and "*oscillating a string*," may be used to realize the function "*making a sound*." Although the concept of symbolic information is meaningful only to a human, this information, associated with its behavior, has been found to be essential to support design.

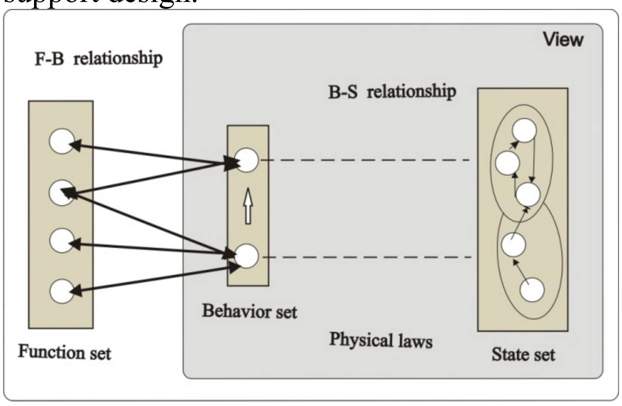

Figure 2. Relationship between function, behavior, and state (modified from Umeda et al., 1990).

Examples of this include the reuse of design results and clarification of specifications. It is easy to see that function and behavior have a subjective, many-to-many correspondence in their relationship. On the other hand, the representation of behavior of an entity can be determined more objectively based on physical principles. The FBS diagram is intended to assist the designer in the synthetic as well as analytic aspects of conceptual design.

The designer is assisted by the computer in this process in terms of systematic identification of functions, allocation of constraints to each function, the interrelationship between functions, and functional evaluation. The approach supports the designer mainly in the identification, articulation, and evaluation of function structures, rather than the search for design solutions. Therefore, it applies to later stages of task clarification and the early stages of conceptual design.

According to Welch and Dixon,[13],function is a set of causal relationships between physical parameters, as described by the outward physical action of a device. An example is depicted in Figure 3. Behavior is the detailed description of the internal physical action of advice based on established physical principles and phenomena. Functional design is the transition between the three stages.

A design problem is stated in terms of a set of functions that must be met. For instance, the conversion of force to displacement is the description of one such design problem. The functional information is transformed by the phenomenological design process to behavior information based on physical principles and phenomena. If the function is conversion of force to displacement, the physical principles of Hooke's law are used to accomplish the function.

The embodiment design process, using behavior graphs, models the required behavior as a guide to select and configure systems of embodiments. An embodiment is an abstraction of a physical artifact, such as a spring, gear pair, or electrical motor, that contains not only behavior information but also constraint and evaluation information. In the conversion of force to displacement, a spring could be used to accomplish the function.

2.4. A generic, guideline-based method for functionality

A method has been developed to design consumer products for functionality. It is depicted in Figure 4.This method gains importance in light of the absence of design systems that successfully address product functionality and include the design process. The work is split into two distinct phases: development of criteria for functionality and testing and validation of developed criteria and process.

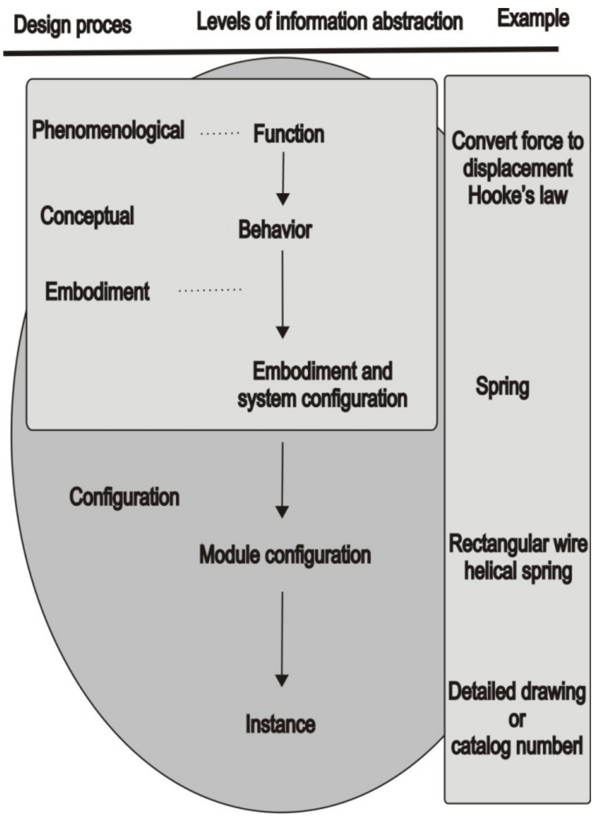

Figure 3. Classification of design information and processes (modified from Welch and Dixon, 1992).

<u>**Phase 1.** Development of Generic Criteria for Functionality</u>

Current criteria for product functionality are based mainly on product performance. There is anteed to consider, during design, downstream manufacturing materials and process variables to ensure product functionality. The current criteria are extended through the following preliminary activities that are focused on generating generic functionality for product design and manufacturing.

A complete, critical review of the research and practice literature, individual experiences, and user complaints with present consumer products was carried out. Since different products have different functions and manufacturing processes, a comprehensive list of design and evaluation guidelines across different consumer products is difficult, if not impossible, to generate and validate. This requires extensive study of a large sample of consumer products. But it is possible to develop generic product functionality criteria applicable across different consumer products.

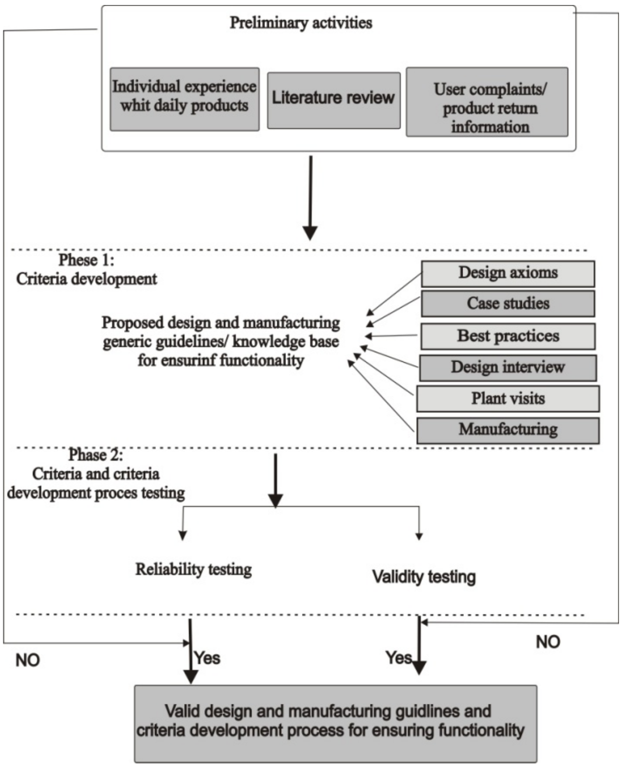

Figure 4. Relationship between function, behavior, and state (modified from Umeda et al., 1990).

To overcome this problem, broad generic criteria for consumer products were developed, then extensive product design and evaluation guidelines were developed for each functionality criterion for specific products and product families; for example, a family of coffeemakers.

Information from design handbooks, data from other sources, such as best design and manufacturing practices, designer interviews, and plant visits were used to generate a comprehensive list of product-specific guidelines for the consumer product family chosen for this research. In addition to these sources for criteria and detailed guideline development, case studies of transformation of product function into manufacturing process variables were performed for products using transformation matrices (similar to quality function deployment matrices).

Sufficient data were generated to deductively reason out generic criteria for functionality for a particular consumer product family.

The product family was chosen such that the product was not too simple(such as a can opener) but had a main function and multiple functions supporting the main function.

This product family provided a large scope in broadening and extending the traditional defi -nitions of functionality to include designer-related and user-related factors, such as reliability of the function and usability and safety of the function. The systematic process used in developing the functionality criteria and the detailed design and evaluation guidelines for ensuring functionality for a specific product family were modeled.

This model can be used by any consumer product designer for ensuring functionality for specific products. An integrated approach to ensure functionality in product design and manufacturing is illustrated in Figure 5.

Phase 2. <u>Validation and testing of developed criteria and processes</u>

The hypothesis of interest in methodology development is whether the new and extended criteria and guidelines, developed as a result of consumer product design and manufacturing information for ensuring functionality, indeed ensure functionality.

Since the final criteria and guidelines were expected to be in the from of design checklists or questions, the goodness of the criteria and guidelines developed as a result of the research were tested using statistical validity and reliability measures. Validity tests how well a technique, instrument, or process measures the particular thing it is supposed to measure. Reliability test show well or consistently a measuring instrument (or technique or process) measures whatever it is measuring.

For testing the validity of questionnaires, it is standard practice to compare the scores with what is considered standard information.

A high correlation score for the criteria and guidelines for a specific product family implies a high degree of validity for the process used to generate the criteria and guidelines.

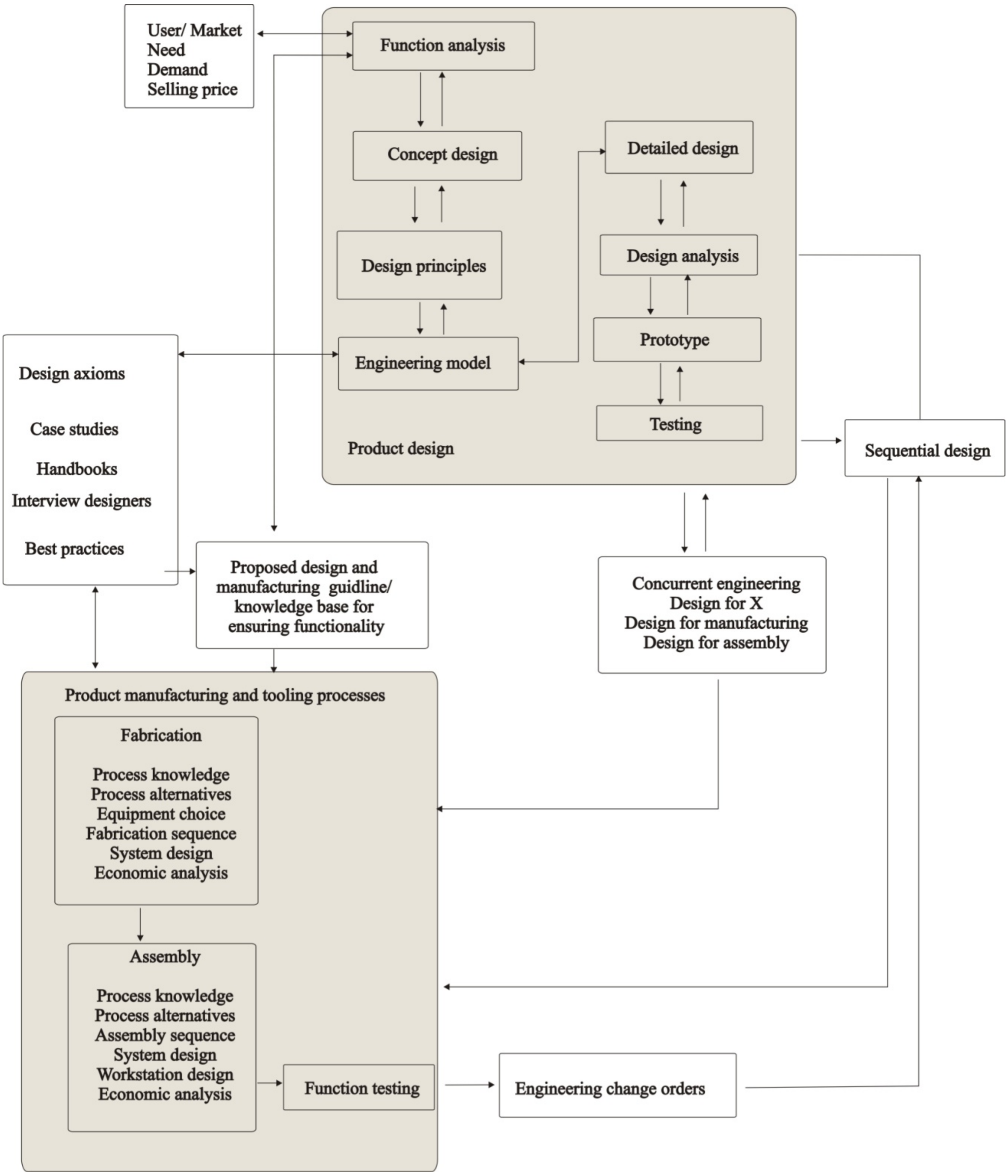

Figure 5. An integrated approach to ensure functionality in product design and manufacture.

This developmental process then can be replicated for other products and product families.

Two types of reliability were tested in this research: interterm consistency and iterate consistency.

The internal consistency of measures of the homogeneity of the items was tested by computing the *Cornbrash alpha score* for each functionality criteria.

The integrate consistency was tested by comparing the responses of designers to specific items in the criteria.

Both measures of reliability used the guidelines of product families, and the response from designers of the product families was elicited. If the response (on a suitable scale such as 1 through 5, ora Yes/No response) from the designers of different specific products are consistent for the items in the criteria list, then both interterm, and integrate consistency (hence, the reliability of the criteria) are expected to be high.

If the reliability and validity of the guidelines are found to be too low, the guidelines are revisited (as indicated by the feedback loop in Figure 4) and revised.

9.4 The procedure for guideline development

The major research activities carried out to achieve this objective are as follows:

Step 1 deals with the extension of the definition of *product functionality*. The traditional definitions of *functionality* need considerable extension to include the notion of function in consumer product design. At this point, we use our extended definition as the starting point. We define *function* as "to do something (performance), safely, reliably, in a usable manner, in a high-quality manner, with concern for manufacturability and environment friendliness."

Step 2 deals with the development of specific product functionality criteria based on the extended definition of *functionality*. The purpose of this step is to develop a checklist of generic terminology for generating specific product design and manufacturing guidelines. The assumption was that, in each criterion, we would find important factors (specific functionality criteria) that need to be controlled through design variables, material variables, and manufacturing process variable. Doing so would improve the overall product functionality.

Step 3 deals with the classification of each criterion into different design stages (conceptual, embodiment, detailed) for future generation of guidelines. Most DFX tools fail to make a clear distinction as to when and how they should be used but merely provide a list of recommended design rules with little direction on their use. Only the broad phases of task clarification, conceptual design, embodiment design, and detailed design are required for this classification.

Step 4 deals with the systematic identification of the important design and manufacturing variables that affect product functionality. The criteria to select such design variables are based on evaluation against functional requirements to determine whether the design variable satisfies the requirements.

Manufacturing variables include both material variables and manufacturing process variables that are closely related. In selecting a material for a product or a component, the primary concern of engineers is to match material properties to the functional requirements of the component. Some material-related variables that can affect product function significantly include the type of material, material toughness, hardness, and fatigue resistance.

Step 5 deals with the determination of the links (relationships) between product functionality criteria and design and manufacturing variables. Here, we provide a systematic procedure for generating guidelines to ensure product functionality. If the specific generic criteria are obvious, guidelines are introduced to illustrate what needs to be controlled. If the specific generic criteria are not sufficiently obvious, the relationship needs to be illustrated with a different set of variables.

Step 6 are iterative and deals with the systematic development of the design and manufacturing guidelines incorporating the links identified in step 5, the guidelines for controlling design and manufacturing variables, and the major design activities involved in any design.

We can add new concepts and information at any time and, finally, the guidelines reach an optimal stage. The hypothesis of interest in this procedure is that the new and extended criteria and guidelines, developed as a result of a synthesis is of consumer product design and manufacturing information for ensuring functionality, indeed ensure functionality.

4. CONCLUSION

It is well recognized that functional design plays a central role in ensuring design quality and product innovation; products with problems in their main functions do not sell well, no matter how sophisticated their details. Numerous examples exist of products marketed and sold as sophisticated in the features they provide customers but routinely fail to perform the intended functions or do so in a very unsatisfactory manner.

An understanding of the key elements involved in the design and manufacturing for functionality, of consumer products and the tools used to model these elements should help shed light on why functionality is not ensured in products. A thorough examination of these concepts is critical to fully understand the chief drawbacks that exist in current design information and possibly outlook.

Following an in-depth examination of current methodologies, we conclude that some anomalies and deficiencies existed that could be overcome by the development of a new design methodology for product functionality.

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FACTORII CARE AFECTEAZĂ FUNCȚIONALITATEA PRODUSELOR

Rezumat: Este bine cunoscut faptul că designul axat pe funcționalitate joacă rolul central în asigurarea calității şi competitivității produselor, în sensul că cele cu probleme în realizarea funcției lor principale vor eşua pe piață, indiferent cât de sofisticate sunt detaliile lor. Există numeroase exemple de produse promovate pe piață şi vândute, dar din nefericire nu reuşesc să-şi îndeplinească funcția pentru care au fost create, sau o realizează într-o manieră nesatisfăcătoare. Articolul face o trecere în revistă a necesității asigurării funcționalității prin design, cu accentuarea diferitelor definiri şi concepte. Un loc important este consacrat necesității elaborării unor criterii generice de funcționalitate, a fazelor aplicării acestor criterii şi a procedurii pentru elaborarea unor linii directoare în proiectarea pentru funcționalitate şi fiabilitate a produsului.

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