Hindawi
Mathematical Problems in Engineering
Volume 2022, Article ID 7192152, 10 pages
https://doi.org/10.1155/2022/7192152

Research Article

Application of Product Life Cycle Management Method in Furniture Modular Design

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Received 16 February 2022; Revised 16 March 2022; Accepted 17 March 2022; Published 27 March 2022

Academic Editor: Weilin Xiao

With the rapid development of informatization and network technology, it has become an inevitable trend to use informatization to drive industrialization, industrialization to promote informatization, and high-tech to improve China's traditional manufacturing industry. In order to conform to the trend of furniture development, combined with the characteristics of China's furniture manufacturing industry, this paper analyzes the sustainability of multifunctional furniture based on the whole life cycle of the product, and improves the sustainable utilization rate of multifunctional furniture at each stage of the life cycle, and then apply the modular concept for structural design. At the same time, the paper studies the modular design of imitation solid wood frame cabinet furniture. This paper proposes a method of producing and designing imitation solid wood frame cabinet furniture by using the cabinet module of panel furniture. This design method makes it possible to change the shape and style through a wide variety of decorative modules, under the condition that the basic modules of the cabinet are the same as the panel furniture, to produce imitation solid wood frame furniture with different styles. The research results show that this paper redefines multifunctional furniture based on the product life cycle, proposes a new definition of multifunctional furniture under the sustainable concept, and proposes the design process of multifunctional furniture. At the same time, the application of a multifunctional furniture design process for furniture design can effectively improve the sustainability of furniture.

1. Introduction

With the advancement of science and technology, multifunctional furniture has developed rapidly in my country, but the current multifunctional furniture design life cycle is generally short, and the utilization rate in each life cycle is not very high. The problem of material waste is very serious, and the resource utilization rate is not very high, so the existing multifunctional furniture did not achieve sustainability. As my country is a large resource-consuming country, the problems of resource waste and environmental pollution are becoming more and more serious. It is imperative to solve the waste of materials in furniture design. Therefore, it is necessary to combine multifunctional furniture design with sustainable design concepts to achieve multifunctional furniture design. *Sustainability of furniture.* The development of sustainable multifunctional furniture design can reduce the waste of resources to a certain extent and realize the harmonious coexistence of man and nature [1–9].

Design is the soul of furniture and the key to realizing furniture modularization. Design determines the formulation of production plans, the procurement of raw materials, the ease of process production, the number of machine adjustments, the type of equipment and processing accuracy, the level of quality, the production cost of products, etc. Therefore, design standardization and modularization affect the overall standardization of the enterprise level is the most important factor [10–15].

Modular design (shown in Figure 1) realizes low-cost and high-level customization through the combination of different functional and structural modules to meet the individual needs of users. When the market changes, all designs do not need to be restarted but can be reorganized with the modules in the module library. Modular design is not only a new design method, but also a new way of

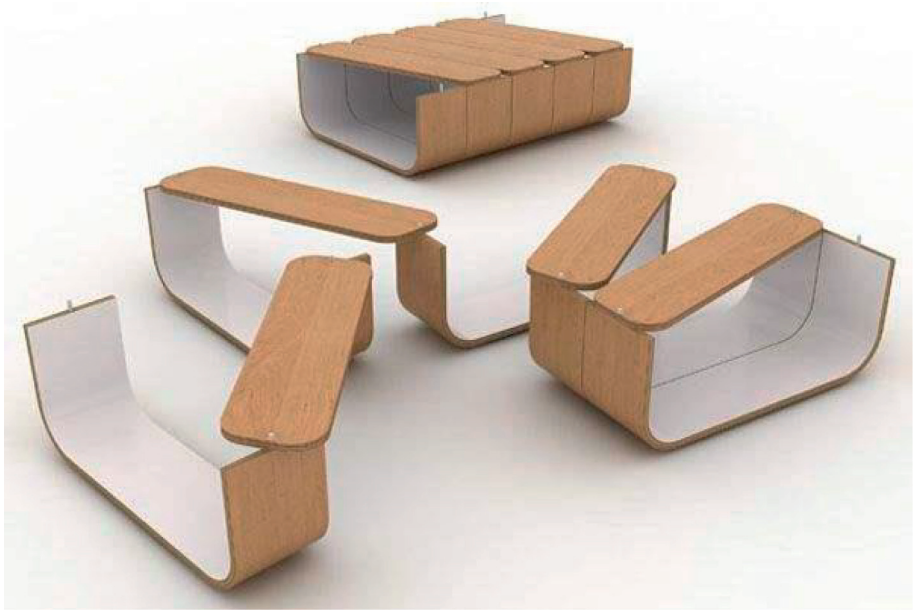

Figure 1: Modular design.

thinking, and it is also a great change in the field of design. It improves the ability to change the market and prolongs the life cycle of the product. In the product development stage, designers can use a large number of common modules in the system to innovate products through the combination of standard modules and nonstandard modules, thereby shortening product development time.

The current status of standardized design and management of domestic furniture enterprises:

(1) Furniture manufacturing materials, such as wood-based panels, fabrics, leather, hardware, etc., have too many specifications or colors of the same type, resulting in a large backlog. Over time, it will cause fading, aging, raw embroidery, etc., and reduce the use function, resulting in a large number of wasted items, taking up a lot of liquidity.

(2) The design lacks standardized ideas and specifications, resulting in a low degree of plate interchangeability and versatility, an increase in the number of components, and a lack of correlation between series products. This leads to heavy design tasks, increased drawing errors, and low design efficiency.

(3) Due to the large number of parts and the large differences in process production caused by the design, it is difficult to calculate the working hours, the material utilization rate is low, and the product quality and sales are affected. Production efficiency is difficult to guarantee, resulting in management difficulties.

(4) The production process is manifested as low production efficiency; long and unstable production cycle; increased rework rate; production planning and daily production tasks are difficult to arrange; the workshop is more crowded; the number of packaging increases; and errors are frequent.

(5) The impact on marketing is low-profit margins and increased sales costs; increased transportation costs; complicated parts and product numbers, resulting in complicated accounting and management difficulties; increased costs of supplementary parts; and increased quality complaints. Obviously, the impact of low standardization levels is very extensive and huge, especially the negative impact on production efficiency, which is extremely serious. Therefore, it is very important and urgent to enhance the awareness of standardization and establish a standardization system for improving production efficiency [16–20].

The first step of furniture function analysis is to determine the total function of the furniture according to the customer's use requirements and then perform a function analysis to decompose the total function into some simple and easy-to-implement subfunctions. According to the importance of the function, the overall function of furniture can be decomposed into basic functions, installation functions, special functions, adaptation functions, user functions, etc. The second step of furniture function analysis is to separate the functional elements that make up the subfunctions and then use the principle of standardization to summarize and analyze them and simplify them into typical functional units. These functional units are not only typical but also universal; they are the prototype of the module [21–23]. Some modules or a small number of special modules are added to combine the varieties that meet the user's ordering needs.

Multifunctional furniture in the traditional sense means that other functions will be added on the basis of the original functions of the furniture, and the purpose for the design is not particularly clear. In other words, there are many

purposes of design, for example, a rich user experience, a more convenient life, and some are even gimmicks made by businesses for furniture sales. In the existing furniture industry, there is no combination of multifunctional furniture and sustainable design concepts nicely combined. It is mainly manifested in the fact that the life cycle of traditional multifunctional furniture has not been effectively extended. The reasons are as follows: first, since multifunctional furniture needs to meet multiple functions, if these functions are unreasonably matched and cannot meet the needs of users, it is easy to be eliminated by users; second, it is easy to disassemble and install, it is easy to damage the parts and affect the use; third, the utilization rate of raw materials for traditional multifunctional home furniture is not high. These reasons directly lead to the fact that the existing multifunctional furniture cannot meet the sustainable design concept.

Any company wants to incorporate its product attributes into the design, and successful products are almost always produced by focusing on certain performance requirements, which depend on the industry the product belongs to and the process required to produce a specific design. Therefore, in order to effectively meet these requirements, it is necessary to have a reasonable product development process.

Today, most packaged solutions capable of supporting these product and process attributes in parallel are embodied in NX and Teamcenter, UGS' product lifecycle management solutions. It is the only company with such strong product and process coverage that provides a fully integrated product development solution. NX contains the most flexible and rich product modeling and definition capabilities, combined with advanced computer-aided engineering analysis and computer-aided manufacturing capabilities, integrated into a complete product development environment. Whether Teamcenter or NX, can provide a large number of solutions to define product requirements, integrate these requirements into 2 design concepts, and then plan and optimize design performance and product production according to these requirements. Customers can use it to easily define, measure, analyze, optimize, and validate these different engineering disciplines to effectively achieve product development goals [24–26]. Modular design is adopted, which can meet various needs at one time, which is conducive to fast and efficient product design and is suitable for flexible production methods of small batches and multiple varieties.

Furniture enterprises began to introduce the concept of generalization and standardization in the design stage, and since then, the initial prototype of furniture modular design has been produced. With the changes in the market environment, some enterprises have adopted modular design as the main design method of their office furniture production from beginning to end, and even some enterprises specializing in the production of standard cabinets have emerged, providing standardization for the modular design of other furniture enterprises. IKEA, an internationally renowned furniture manufacturer in Sweden, is the main furniture company in the world that spreads the Swedish design style. It is a very typical furniture company that deals in modular design. IKEA's business philosophy is that customers can freely combine furniture and daily necessities. Most of its products, including cabinets and other furniture, are based on modular design. At IKEA, customers can choose modules at will and combine them freely into their desired furniture products. The basic units of this furniture have achieved standardized production, and also implemented the design idea of "components are products" for panel furniture. Therefore, the modular design of furniture has become a new development trend.

2. Information Modeling of Furniture Modules

Furniture modular design refers to a design method in which modules are combined into furniture through standardized interfaces. Depending on the combination method, the final furniture form is also very different, so the modular design can quickly realize the diversification of furniture. The modular design of furniture products can decompose the furniture into several structural modules or standard boards with specific basic functions according to the functional structure requirements of the furniture. Such as box modules, cabinet modules, base modules, drawer modules, etc., determine their size according to the standard module. The most important things in modular design are to fully consider the versatility and ease of processing of modules, minimize the types of modules, divide furniture into appropriate modules, and reduce manufacturing indirect costs and supply chain costs. In particular, as long as the designer of the module follows the "clear design rules" to ensure that the modules can function correctly, they can freely and widely try various methods, so that the speed of module innovation can be significantly improved.

The modular design of furniture is developed and refined on the basis of the "three modernizations" of product specification serialization, component generalization, and standardization. It takes machine tool parts as the object and decomposes the product components into several functional units based on functional analysis and decomposition, that is, product components equivalent to nonmodular design. Then, according to the different needs of the division of labor, these functional units are further subdivided into several interchangeable and independent basic unit modules, which can also be subdivided step by step. These base unit modules are equivalent to generic widgets with few or single functions. For some one-time production products, it is only necessary to make some small changes in some structures and add one or two new functional modules (or basic unit modules). It can achieve a variety of designs with fewer changes, greatly shorten the design and manufacturing cycle, and provide users with satisfactory furniture products in a short period of time, thereby obtaining good economic benefits. Figure 2 shows the furniture modular design program diagram. A large number of modules are produced in batches, which can realize the mass production of a batch of products from cutting to processing, reducing costs, and reducing scrap rate.

Polychromatic set theory was proposed by Professor V.V. Pavlov of Russia, which is a new mathematical tool for

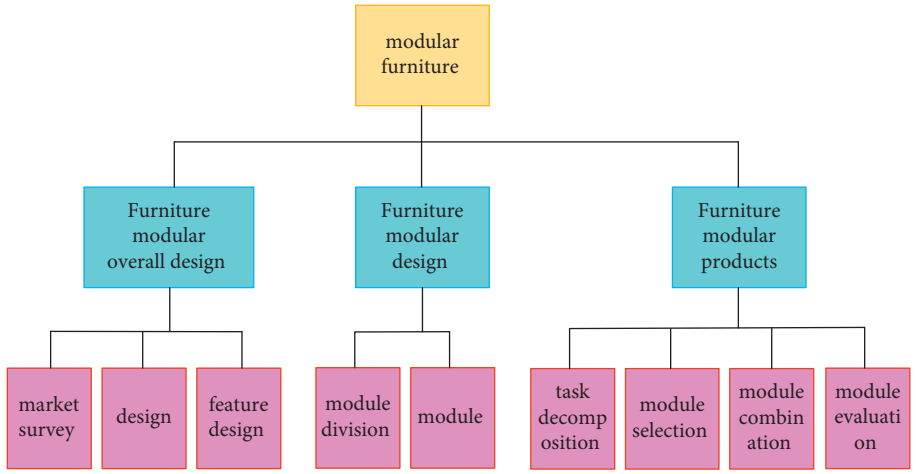

Figure 2: Furniture modular design program diagram.

system theory and information processing. Its core idea is to use the same mathematical model to simulate different objects and describe the hierarchical structure and complex relationships between elements. It is widely used in the fields of product conceptual design modeling, part manufacturing process modeling, and product assembly process modeling.

In addition, polychromatic set theory is also applicable to problems related to the modeling of product component information. Multicolor collections are also algorithmically adaptable, so when the product structure or the number of parts changes, the algorithm does not need to change. The traditional set mathematical expression is

$$A = (a_1, a_2, \ldots, a_n), \tag{1}$$

where any two elements ai and aj in set A are different. But its nature cannot be fully expressed in form. When a polychromatic collection is colored with different colors both in its constituent elements and in the whole itself, these colors indicate the properties of its object and its constituent elements. The percentage is shown in Figure 3. The elements of the traditional set A are also the constituent elements of the multicolor set, but the difference is that they correspond to the whole of the set and its constituent elements, and there are the corresponding color sets corresponding to it, among which

$$\begin{aligned} F(A) &= [F_1(A), F_2(A), \ldots, F_n(A)], \\ F(a_i) &= [F_1(a_i), F_2(a_i), \ldots, F_{m_i}(a_i)], \end{aligned} \tag{2}$$

where the color set F is called coloring, and they are all covered in a unified color set F, that is

$$F(A), F(a_i) \subseteq F(i = 1, 2, \ldots, n). \tag{3}$$

In a polychromatic set, the Boolean matrix formed by set A and the uniform coloring $F(A)$ of set A is

$$[A \times F(A)]. \tag{4}$$

The above formula can also be expressed as follows:

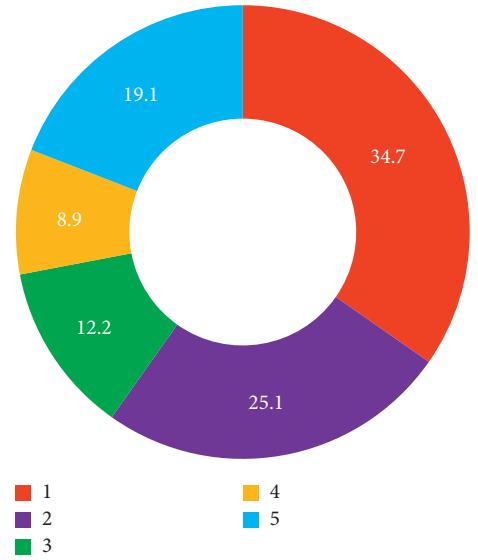

Figure 3: Percentage.

$$\begin{aligned} \left\| C_{i(j)} \right\|_{A,F(A)} &= [A \times F(A)], \\ [A \times F(A)] &= \begin{bmatrix} F_1 \ldots\ldots F_j \ldots\ldots F_m \\ a_1(1) \ldots a_1(j) \ldots a_1(m) \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ a_i(1) \ldots a_i(j) \ldots a_i(m) \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ a_n(1) \ldots a_n(j) \ldots a_n(m) \end{bmatrix} \begin{bmatrix} a_1 \\ \ldots \\ a_i \\ \ldots \\ a_n \end{bmatrix}, \end{aligned} \tag{5}$$

where

$$\begin{cases} 1, & \text{if } F_j \in F(a_i), \\ 0, & \text{otherwise.} \end{cases} \tag{6}$$

According to the analysis of the structural characteristics of furniture products, the division of furniture modules mainly considers the following key factors: order information, parts sources, parts characteristics, design and

manufacturing, after-sales service, etc. According to the characteristics of several major factors affecting furniture modules, combined with the theory of multicolor set, taking panel office furniture as an example, the structure of the product is regarded as the unified coloring of the multicolor set, and the connection between the product module and its modular design factors is established. Modularization is not only a change in design method, but also involves the reform of organizational production, process technology, and even management systems. Since the repetition of certain elements in the product series is avoided, the production mode of small-batch and multivariety can be realized with as little input as possible to produce the most varieties. It can control the overall quality and reduce the cost.

The set T is composed of different product structures, each element of which is an element of a multicolor set, and the mathematical expression is

$$T = (\tau_1, \tau_2, \ldots, \tau_i, \ldots, \tau_9). \tag{7}$$

In the formula, τi represents each component of the office furniture.

The color set $F(T)$ refers to the set of factors affecting each constituent structure, and the mathematical expression is

$$F(T) = (F_1, F_2, \ldots, F_j, \ldots, F_{20}). \tag{8}$$

In the formula, Fj represents the internal factors that affect the components of the office furniture. If the τi of the multicolor set is represented by all individual colorings with a Boolean matrix as follows:

$$\left\| C_{i(j)} \right\|_{T,F(T)} = [T * F(T)]. \tag{9}$$

Use Zi to represent the possible combinations, $F(Zi)$ to represent the vector matrix, we take $Z5$ as an example, it represents the possible combinations, and its Boolean vector is

$$F(Z_5) = (0,0,0,0,0,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0). \tag{10}$$

3. Modular Design of Multifunctional Furniture Based on Life Cycle

3.1. Design Principles of Multifunctional Furniture

3.1.1. Principles of Practicality. From the perspective of a sustainable design concept, the principle of practicality is based on the most simplified practicality. That is to say, on the basis of satisfying all functions and comforts, strive to simplify the processing technology, optimize the packaging, transportation, recycling, etc., And it will not cause unnecessary trouble for the user. Generally speaking, multiple functions will increase the green added value of furniture, but at the same time, attention should be paid to the dialectical measurement of multifunctional furniture, such as whether there is a cost increase that is greater than the increase in functions, whether there is unnecessary waste caused by the increase in functions, etc. problem. In addition to this, consider whether the size of the furniture is ergonomic and find the optimal size that is both ergonomic and easy to transport. The accuracy is shown in Figure 4, where it can be seen that the accuracy goes from good to better.

3.1.2. The Principle of Reduction. The principle of reduction is not only to reduce the volume, weight, etc. of the product, but more importantly, to improve the performance of the product and reduce unnecessary structures, and the premise is that it does not affect the use of the product. According to the different stages of the life cycle, the principle of reduction can be divided into the following points: to use raw materials with low pollution emission in the design and development stage; try to reduce the waste discharge in the production stage of the product; try to reduce the transportation cost in the logistics and transportation stage; reduced waste emissions in the process; and product recovery stage can be well recycled and waste reuse.

3.1.3. Principles of Recycling. The main reason why furniture can achieve sustainable development is that it embodies the principle of recycling. Recycling and reprocessing the raw materials of old furniture can be used in the manufacture of new furniture. In this way, continuous recycling can save some raw materials and form a closed flow of furniture recycling. By degrading and reproducing the raw materials that cannot be used, they can be put into the manufacture of other products in a new form.

3.2. Design of Multifunctional Furniture Based on Life Cycle

3.2.1. Raw Material Selection of Multifunctional Furniture. The selection of raw materials for multifunctional furniture is the first step in the life cycle of multifunctional furniture, and it is also the basic link of the entire life cycle. Because the environmental protection, easy generation, easy recycling, and degradability of materials are the keys to realizing the sustainability of multifunctional furniture, sustainable multifunctional furniture needs to meet the following requirements: reduce the emission of harmful substances; minimize raw materials types of use; use of materials according to their characteristics; and selection of recyclable raw materials.

3.2.2. R&D and Design of Multifunctional Furniture. The research and development design of multifunctional furniture is mainly reflected in the appearance and structural design. Because multifunctional furniture needs to be able to meet the conversion of multiple functions, the design process is bound to be relatively complicated. First of all, the appearance should not be designed to be too complicated. If it looks difficult to use, it will weaken the buyer's desire to buy. On the basis of its relatively simple appearance, its aesthetics should also be considered. Secondly, the structure should be flexible and easy to disassemble and assemble. In order to realize the sustainable concept by extending the life

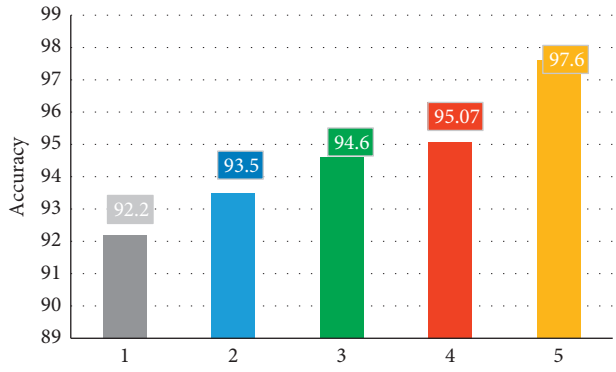

Figure 4: Accuracy.

cycle of multifunctional furniture, once the parts of the furniture are damaged, they must be replaced. Therefore, a standardized design method, that is, a modular design method, should be adopted in structural design. The multifunctional furniture is divided into several modules according to functions, and the transformation of multiple functions is realized by the mutual combination of the modules. Once a certain module is damaged, it can be easily exchanged. The result map is shown in Figure 5.

3.2.3. Design of Multifunctional Furniture in Recession Period. All modern products, no matter what type of materials are used, start from consumption, and resources will always be consumed one day, especially some nonrenewable resources. Once they are consumed, they will have a huge impact on the entire social system, so it is impossible to avoid the waste of resources only from the use process, we should realize the closed flow of resources from the source, establish a complete resource use process, and realize a virtuous cycle of resource use.

(1) *Build a multifunctional furniture recycling system.* For some families, the update speed of furniture is very fast, so the outdated furniture should be disposed of in a more environmentally friendly way. On the one hand, furniture companies should establish a complete furniture recycling system. For example, if users want to replace new furniture for some reason after purchasing furniture in the company, they can return the original furniture to the furniture company. Of course, the furniture company must also according to the degree of newness and oldness of the furniture and whether it can be recycled and reused, a professional evaluation will be carried out, and some economic compensation will be given to the user. Then the second-hand furniture recovered by the enterprise can be reprocessed and sold as new furniture, thus avoiding the wastage of furniture. If the furniture is seriously damaged, the raw materials can be reprocessed as new furniture panels, etc., or the well-protected parts can be reused. In short, make the best use of these recyclable materials as much as possible.

(2) *Downgrade utilization of multifunctional furniture products.* The downgrade utilization of furniture is divided into two types: one is to process the parts that can be reused and directly use them for new furniture after reprocessing, such as undamaged parts, boards, decoration, etc.; the other is to use raw materials degraded and processed into new materials; reused in furniture or other products. Both recycling measures are important components of a circular economy. The data is compared in Figure 6.

We use the method of functional analysis to decompose the system to form modules. The starting point for modularity is to decompose the system into modules. Therefore, as a designer, you must have the concept of holism, be able to use the method of functional analysis, and treat the system as an indivisible whole. Some parts of the system that have internal connections and undertake a certain function within the system and are indispensable components of the system constitute a module, and so on. The system can be decomposed into several modules. The division of furniture modules refers to the separation of identical or similar units through the functional decomposition of furniture. It is unified, merged, and simplified by the principle of modularization to form a general independent unit with a specific function and interface structure, that is, a module.

The division of modules needs to be checked whether it conforms to the characteristics of furniture modules. Fully understand the function of furniture, and then analyze each functional component. When designing modular furniture, in addition to considering the method of modular design, it is also necessary to divide and design the modules according to the original production conditions of the factory. The original size function and customer needs cannot be ignored. Modules are divided according to their basic characteristics:

(1) It must have relatively independent functions and relatively independent structures, and the furniture composed of furniture modules has great flexibility and strong adaptability.

(2) It must be versatile and can adapt to the needs of a variety of products. For example, a single drawer as a module can be used in desks, file cabinets, etc. as long as the size is suitable and its generalization degree is relatively high.

(3) It must be interchangeable. For the same sideboard, partitions, drawers, and glass partitions can be installed according to actual needs. Such sideboards are interchangeable. It should be emphasized that interchangeable module interfaces must be standardized.

(4) The furniture module needs to meet the requirements of serialization, and its specifications and dimensions must be designed according to the entire series.

The relationship between the number of modules and the scale should be considered when dividing modules. When decomposing furniture into modules, the ease of assembly and debugging should be considered when the modules

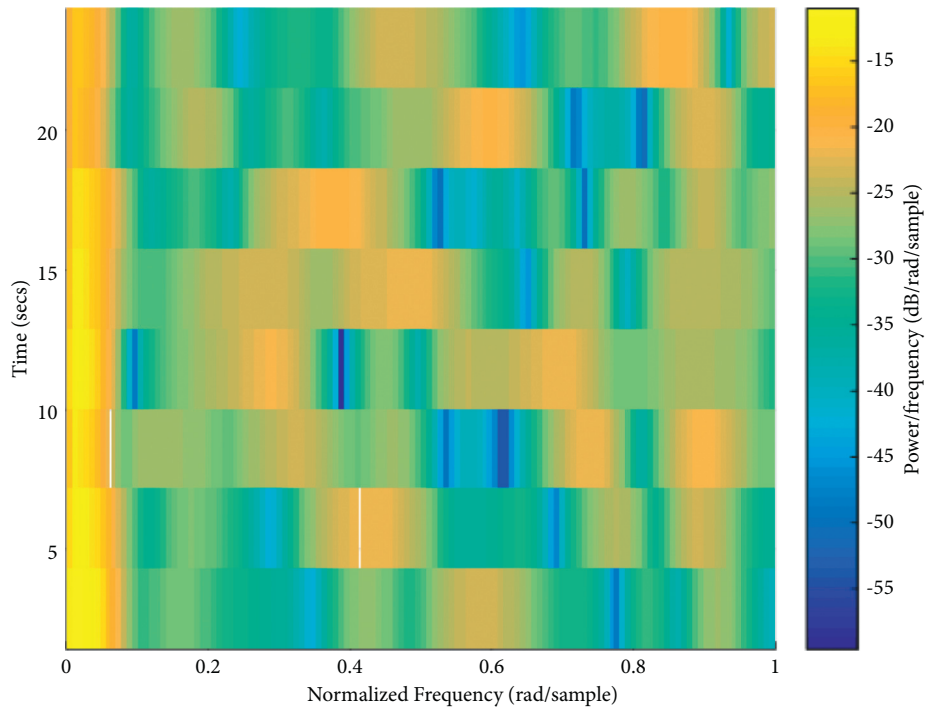

Figure 5: Results map.

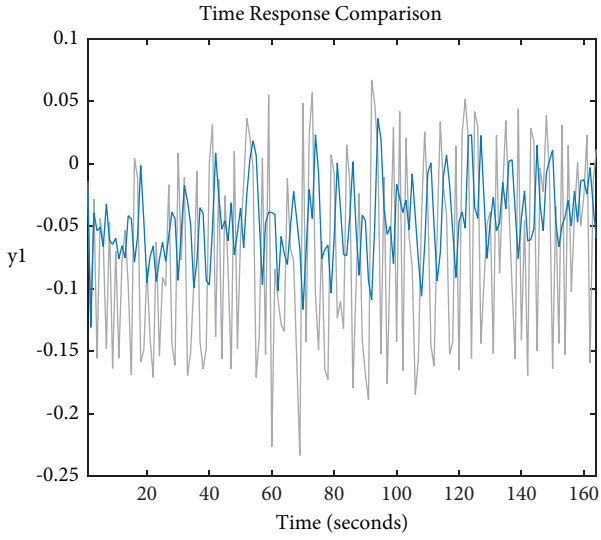

Figure 6: Data comparison.

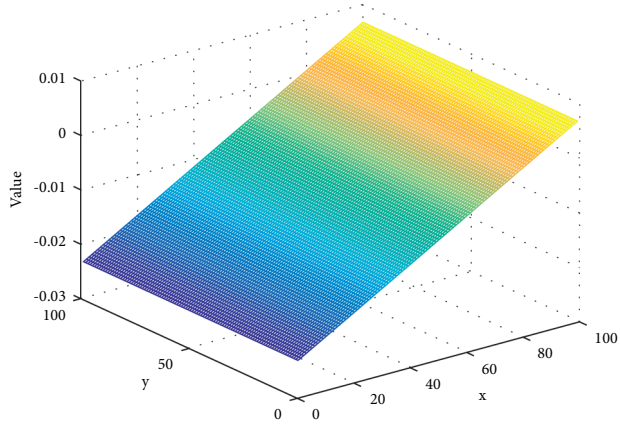

Figure 7: Predicted value.

Modules are divided into functional modules: functional modules (including interface modules) and decorative modules.

are combined into furniture. The smaller the scale of the module, the easier it is to design and modify, but the greater the number of corresponding modules, the more difficult it is to combine modules and the higher the cost of processing. The number and scale of modules are two contradictory factors. When dividing the modules, comprehensive consideration should be given to seek the best state. For different furniture products and different furniture manufacturers, the number of suitable modules is different. When dividing furniture modules, we try to find the best number of modules possible. The predicted value is shown in Figure 7.

(1) Functional Module. The module that determines the main functions of the product, and the functional modules of the product are mainly determined by the product function development designers. Product art designers often refer to the functional modules of the product as determined by the product functional designers to design the functional modules. final form. Functional modules are the main modules for building products. Combining functional modules, a functional product has been basically formed. For furniture modules, many physical modules are composed of lower-level functional modules. For example, functional modules such as the side panels, back panels, and

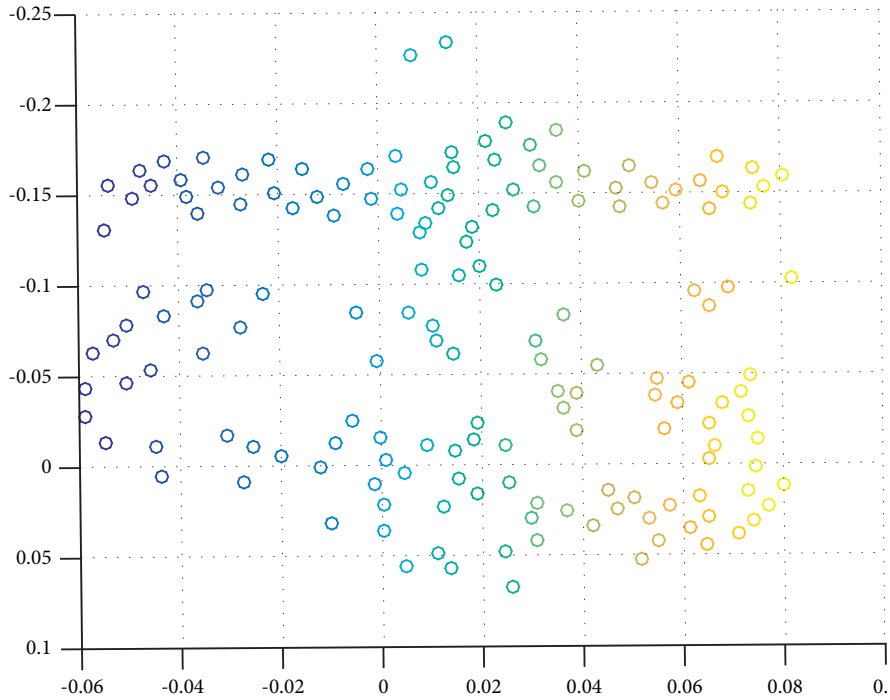

Figure 8: Evaluation.

top and bottom panels of the cabinet form the form module of the cabinet frame. The form module of furniture is usually formed by combining various functional modules.

Function modules are also divided into basic functions, auxiliary functions, special functions, and adaptive functions.

(1) Basic functions refer to the basic and indispensable functions in the system, which are basically unchanged in the system. For example, the storage function of the file cabinet is indispensable and is the basic function, and its corresponding functional module is called the basic module.

(2) An auxiliary function is the function that is required to realize installation and connection. It is used to connect the basic functions to form various total functions. The corresponding functional modules are called auxiliary modules. For example, eccentric connectors and door hinges belong to auxiliary modules.

(3) Special function refers to the special function of one or several products in the system to make it more complete or expanded, for example, the space for optical discs and floppy disks for office cabinet furniture. The corresponding functional modules are called special modules.

(4) An adaptive function is a function that can be temporarily changed in order to adapt to other systems or boundary conditions. The corresponding functional module is called an adaptive module, and its size is basically determined, but due to the above unpredictable conditions, some dimensions shall be changed according to the prevailing conditions to meet the predetermined requirements. The evaluation is shown in Figure 8, where it can be seen the evaluation agrees well with abovementioned content.

(2) Decoration Module. The product decoration module is a special kind of product body module, which is a special kind of product body module, which is the main module for constructing the functional environment and humanistic environment of the product. Design the decoration module of the product to change. The decoration module is the main module that expresses the semantics of product design. Appearance decoration modules mainly include decorative lines, moldings, and other decorative parts, color modules; text, logos, and other flat modules:

(3) Modules are Divided into Levels: Part-Level Modules, Component-Level Modules, and Single-Level Modules. On the basis of furniture function analysis and function decomposition, the furniture module is determined. It can be a part, a component, or a single piece of furniture. As long as it has the basic characteristics of the module, it is called a module.

Single module: the single module itself can exist in the form of a product or in the form of a module. When it exists in the form of a module, it is composed of a lower-level module, such as a part-level or component-level module.

Component-level module: it is a component of the product, and it can also be composed of component-level modules.

Part-level module: it is the lowest level and simplest module.

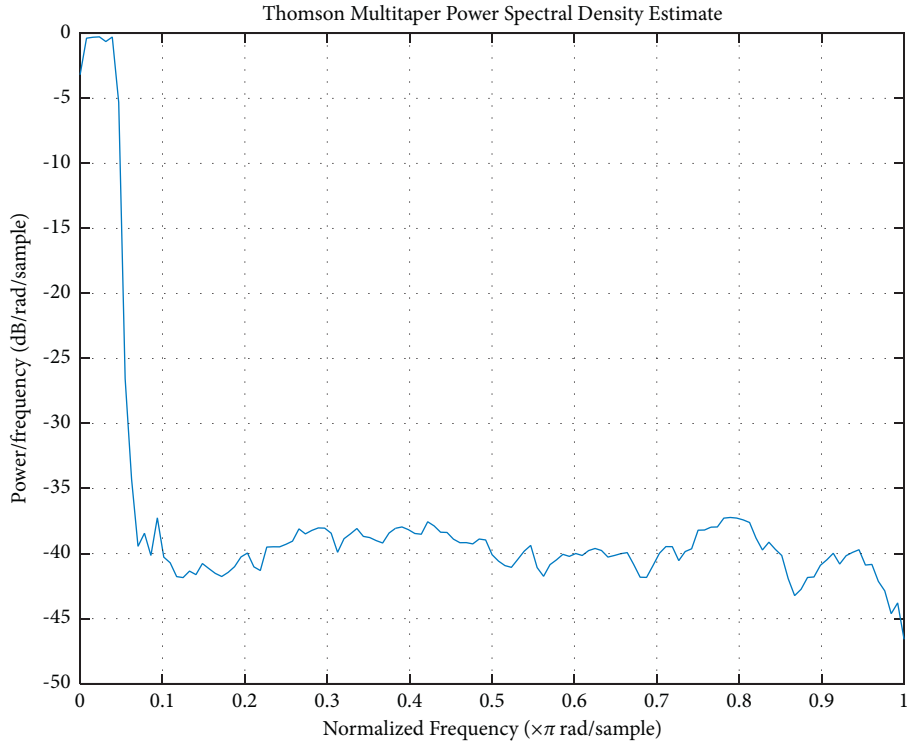

Figure 9: Estimated value.

(4) Modules are Divided from the Composition Structure: General Module, Proprietary Module, and Interface Module. Universal module: a module that can be applied in multiple products and is the focus of module design.

Proprietary module: a module dedicated to a product or a structure that cannot be applied to multiple products. In the modular design, the number of dedicated modules should be minimized to ensure smooth production.

Interface module: as a connection method, a standardized interface for connecting various modules. The estimated value is shown in Figure 9, where it can be seen that the evaluation agrees well with the above-mentioned content.

4. Conclusion

As a theory applicable to the whole life course of a product, the life cycle theory has more research significance than this. Life cycle theory is also used in many fields. This paper studies multifunctional furniture from various stages of the life cycle, discusses how to achieve the sustainability of multifunctional furniture, and uses modular design methods in structural design to provide design ideas for multifunctional furniture design.

In this paper, there is little research on the modularization of solid wood furniture; the research on the modular design of imitation solid wood frame furniture is still in-depth; the file and drawing management of modular design products and the retrieval method of the module library can be further developed. ground research.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest with this paper.

Acknowledgments

This work was supported by Guilin Tourism University.

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