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A Dynamic Product Design Methods for Extend the Product Life Cycle

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Abstract. The life cycle of wooden furniture is long, representing a paradigm of green products. However, because of the high stickiness between furniture and users, the long-term use of wooden furniture in a fixed form may cause psychological burden to users who have constantly changing physiological conditions and requirements. To extend user willingness to use the product continuously, this study inferred and established a dynamic user requirements analysis method and product design concept development method combined with the concept of time axis based on user-centred design and proposed eight dynamic product design models. To evaluate the feasibility and effectiveness of dynamic product design methods, this study conducted evaluation in three stages. In the first stage, we invited sixteen students to examine the feasibility of the new method in the form of a workshop. In the second stage, the product users evaluate the effectiveness of the dynamic product design outcomes. In the third stage, two experts were invited to evaluate the dynamic product design process and methods. The evaluation results of the workshop showed that using the dynamic product design method yielded increasing proposal amounts. The students participating in the workshop had higher satisfaction regarding the thinking dimension of the dynamic product design method than that in the operating dimension. The product users also prefer redesign proposals that used the dynamic product design methods. Finally, the results of the expert evaluation on the design process showed that the dynamic product design development method could help students perform systemic thinking from diverse aspects.

Keywords: Dynamic requirements, green products, product lifecycle, user-centred design, wooden furniture.

1. Introduction

Durability of products is a crucial criterion of environmental-friendly products. In Taiwan, the useful life of a majority of wooden products is within 20 years. As the global awareness about the ecological conservation rises, wooden products are paradigm green products. From the perspective of wooden product manufacturing industries and designers, wooden products clearly possess the advantage of long useful life, which facilitates sustainable development in this crucial industry.

Wooden furniture has long useful life, is durable and stylish, and exhibits excellent texture performance, thus, corresponding with the requirement of long life cycle. However, because of the stickiness between furniture and users, using fixed forms of wooden furniture for a long time may cause psychological burden to the users. Users' constantly changing physical conditions and requirements (e.g., physical changes of children and teenagers during puberty who experience rapid body size changes in a short time, resulting in changing user requirements) may not be fitted to the fixed original design of wooden furniture, thereby causing physical burden.

A good design not only considers the outline, manufacturing, and cost, but also provides optimal user-centred usability to motivate users' continuous willingness to use the design. A user-centred design (UCD) plays a critical role in the process of product development [1]. Only by precisely understanding users'

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changing requirements in different time points can designers truly implement user-centred design to develop products that satisfy users' requirements and have a sustained useful life.

In the visual design field, a dynamic identity design concept has been proposed. Good brand identity image must change with the unstable requirements of enterprises and markets (dynamic), engendering a continuously innovating identity [2]. In different fields, many dynamic concepts have been proposed with a common feature of concepts generated in response to constantly changing and diversifying conditions, such as time, location, situation, environmental transitions, and changes in requirements. Regarding product design thinking, dynamic concepts refer to the inclusion of temporal changes in dynamic variables in response to constantly changing conditions of requirements. Thus, this study included the dynamic concepts into the pro-cess to understand user requirements, established dynamic design methods that can extend product useful life, and verify the feasibility and advantages of the dynamic product design method.

2. Literature Review

2.1. User-Centred Design Process and Methods

Based on UCD, this study proposed a dynamic product design method. According to the standard document ISO 13407, four crucial procedure steps exist in UCD: Understand and specify the context of use; specify the user and organizational requirements; produce concept designs and prototypes, and conduct user-based assessment. These four steps comprise a repeated cycle procedure. Before this study establishes the design method, we compiled commonly used methods in relevant studies over recent years.

(1) Data collection methods: commonly used methods include questionnaire survey, interview, and observation [3];

(2) Requirements analysis methods: These methods comprise mainly table analysis and statistical testing analysis;

(3) Design methods: according to the requirements and problems determined after requirements analysis, design norms are proposed;

(4) Evaluation methods: these methods primarily include usability tests and experiments.

After compiling the information mentioned above, requirements analysis methods that compile and conclude data and the design methods commonly have unclear boundaries or are used simultaneously, showing that the requirements analysis methods and the design methods are closely related and used concurrently. Thus, these two methods must be explored as a whole.

2.1.1. Use of requirements analysis methods

User requirements analysis can be divided into user, task, and environment. After compilation, requirements analysis methods in the three dimensions exhibit high consistency in encoded, tabulated, or listed patterns [4]-[7]. However, the analysis process and content were blurry and were not individually analyzed during data compilation and organization.

In this study, to more comprehensively and exactly understand user requirements, we should analyzed and explore user, task, and environment dimensions separately in requirements analysis to observe the details in each dimension. However, the three dimensions are interrelated. After separate analysis, the three dimensions must be connected to determine the mutual effects.

2.1.2. Use of design methods

After compiling 37 design methods, such as design methods [8] and Six Thinking Hats [9], this paper found that the convergent method characteristics are to help decision making and verification, whereas the divergent method characteristics are to determine developable directions after data collection. In addition, the number of convergent methods is greater than that of divergent ones.

Design methods are the channels for students to learn design [10]. Studies have mentioned that most students easily encountered problems of concept invention during the process of design teaching [11]. Thus, the divergent design method is used as the primary development direction in this study.

2.2. Establishing Dynamic User Requirements Analysis and Dynamic Product Concept Development Methods for Dynamic Product Design

2.2.1. Dynamic user requirement concept

The definition of dynamic user requirements is to include timeline concept into the design process. The timeline concept is to determine the user dynamics and collect data. In other words, before the first UCD step "understand and specify the context of use, users' dynamic change periods are defined. Subsequently, data collection in user, task, and environment dimensions is conducted according to various periods. The data collection list is provided as follows:

(1) User: psychosocial and physiological (sensory and motion control systems) conditions in different periods;

(2) Task: changes in operating tasks or main functions between users and products in different periods;

(3) Environment: different contexts of use or placement locations and space arrangement possibly generated in different periods.

2.2.2. Dynamic user requirements analysis methods

Dynamic user requirements analysis refers to applying dynamic user requirement concepts to the second step "specify the user and organizational requirements" in the UCD procedure. However, fixed requirements (traditional consideration of requirements at a single time point) still exist. Thus, this study proposed the dynamic user requirements analysis method that includes dynamic and fixed requirements analysis. However, to comprehend additional and more comprehensive user requirements, we expanded the requirements in user, task, and environment dimensions separately. The analysis dimensions of dynamic use requirements analysis method are summarized in Table 1.

Table1: Dynamic use requirements analysis definition

User requirement analysis	Dynamic and fixed concepts	
User analysis	Dynamic	Considering users' physical changes over time
	Fixed	Focusing on users' physical conditions at a single time point
Task analysis	Dynamic	Considering changes in user requirements regarding the main functions of product use
	Fixed	Focusing on single task requirements at a single time point
Environment analysis	Dynamic	Considering the changes in environmental arrangements or locations when users operate the products over time
	Fixed	Focusing on the arrangements and locations of product operation at a single time point

Thus, through dynamic user requirements analysis, we can observe comprehensive requirements in user, task, and environment and understand the requirements that have been changed or exist constantly. The analysis is a systematic summarization of requirements that help understand diverse requirement dimensions.

2.2.3. Dynamic product concept development method

After systematic and comprehensive user requirements were obtained, we matched user, task, and environment analysis contents and dynamic and fixed concepts to determine eight design models. The eight models were used to develop product concept invention. Table 2 shows the contents of the eight models.

2.2.4 Dynamic product design flow process and methods

The proposed dynamic product design method was based on UCD and incorporated with a dynamic concept. The flow process is shown as follows.

(1) Understand and specify the context of use: The dynamic timeline concept was integrated into the first stage to understand the range of use by considering the user changes in the timeline, dividing user periods. Based on user periods, we collected user data by using observation, interview, and questionnaire methods from the user, task, and environment dimensions.

(2) Specify the user and organizational requirements: The collected data underwent dynamic and fixed analysis.

(3) Produce concept designs and prototypes: The dynamic and fixed analysis results were implemented to design and develop eight models.

(4) User-based assessment: Finally, the design development proposals were made as samples and underwent usability testing to assess whether the product concept satisfied user requirements.

Table 2: Dynamic product design concept development model

Model	Dynamic or fixed	User	Task	Environment
1	All fixed	Fixed	Fixed□	Fixed
2	Single dynamic	Dynamic	Fixed	Fixed
3		Fixed	Dynamic	Fixed
4		Fixed	Fixed	Dynamic
5	Dual dynamic	Dynamic	Dynamic	Fixed
6		Fixed	Dynamic	Dynamic
7		Dynamic	Fixed	Dynamic
8	All dynamic	Dynamic	Dynamic	Dynamic

3. Research Methods

To verify the dynamic product design flow process and methods, the research methods comprise three stages. The first stage involved practical operation of the dynamic product design to verify the feasibility of the method. The second stage involved delivering the operating outcome to the product users to evaluate the effectiveness of the work. The third stage involved expert interviews to assess the outcome and applicability of the dynamic product design method.

3.1. Operational Verification Experiment

This study invited students from the Department of Industrial Design to operate the first to third stages in the UCD flow process in a workshop.

3.1.1. Participants

A total of 16 students from the undergraduate pro-gram at their third year in the Department of Indus-trial Design were recruited. The students were divided into four groups, each of which comprised four students. Two groups of the students used the dynamic product design methods established in this study, whereas the other two groups of students did not use the proposed design methods.

3.1.2. Experimental variables

(1) Independent variables: Whether dynamic product design methods were used sign methods.

(2) Control variables:

- Design theme: seat design for children at the age of 3-12 years
- Operating flow process: Design based on the UCD standard procedure
- Design project presentation methods: A3 drawing paper, hand drawing concept map

(3) Dependent variables:

- Design process record: data collection, requirements analysis, and design development process records.
- The operators' satisfaction and suggestions to-ward the method proposed in this study can be used as a subjective assessment. The satisfaction was measured using a 5-point Likert scale. The satisfaction dimensions include operating and thinking aspects. The operating assessment had the following characteristics: (a) reducing occurrence of errors: ease in operation; (b) helping summarization and analysis: ease in understanding; and (c) effectively completing design tasks: fluency in operation. Regarding the thinking assessment, the following characteristics are provided: (a) guiding design

thinking: guided thinking and systemization; (b) improving innovativeness: diverse thinking; and (c) helping summarization and analysis: systemization.

3.2. Product User Interview

The fourth step in the UCD flow process is user-based assessment. The workshop outcomes were delivered to product users to conduct interviews and assessment. The semi-structured interview method was adopted.

(1) Interviewee: children aged at 3-12 years and their parents.

(2) User interview content: Whether the work de-signed by the experimental and control groups met the user requirements and preferences.

3.3. Expert Interview

To verify the applicability of the proposed method in requirements analysis and design development, we interviewed experts who had product design teaching experiences.

(1) Interviewees: two product design course teachers with more than 5 years of experience in teaching. One was an industrial expert who worked as a part-time lecturer in a university, while the other was a full-time teacher of the Department of Industrial Design in a university.

(2) Interview method: semi-structure interview conducted by asking questions in the form of indirect interview

(3) Interview content:

- Commonly used user requirements analysis methods and product design development methods among the experts or students
- Opinions regarding the user requirements analysis results and dynamic product design development outcomes in the workshop
- Application suggestions for user requirements analysis methods and dynamic product design development methods.

4. Results and Analysis

Three stages of assessment results are provided as follows: The first section involves the workshop outcomes. The second section involves the product users' interview results. The third section comprises expert interview results.

4.1. Workshop Outcome

4.1.1. Operating process record

This stage summarizes the first 3 steps in UCD and the operating processes of the students in the experimental and control groups.

(1) Understand and specify the context of use

- Experimental group: The timeline concept was included in this stage. The four periods of children underwent data collection from the three dimensions: user, task, and environment.
- Control group: The participants in the control group also exhibited data in different times and locations; however, the data were scattered and unorganized.

(2) Specify the user and organizational requirements

- Experimental group: The collected data under-went dynamic and fixed analysis to further organize the data, thereby enabling the designers to systematically and clearly understand the requirements of users, tasks, and environments.
- Control group: Requirements analysis of user, task, and environment were conducted. The three dimensions were connected serially and analyzed as a whole.

(3) Produce concept designs and prototypes

- Experimental group: The dynamic and fixed analysis contents were incorporated into eight dynamic design methods. The requirements of user, task, and environment dimensions were connected, enabling thinking invention based on the eight design models.
- Control group: The concepts used by the control groups showed high repetitiveness. Invention was implemented mostly from identical requirement dimensions. Exploration into users was relatively simple and omitted. However, the vertical thinking concept was in depth.

4.1.2. Subjective satisfaction results of students operating dynamic product design methods (experimental group)

Table 3 shows the operators' satisfaction toward the operation of the dynamic product design flow process and methods

Table 3: Satisfaction results of operators

Questionnaire aspects	Innovative method effectiveness	Average (*SD*)	Total average (*SD*)
Operating	Reducing occurrence of errors	3.50 (0.53)	3.63 (0.38)
	Helping summarization and analysis	3.88 (0.64)	
	Effectively completing design tasks	3.50 (0.53)	
Thinking	Guiding design thinking	3.75 (0.46)	3.88 (0.35)
	Improving innovativeness	3.88 (0.35)	
	Helping summarization and analysis	4.00 (0.53)	

In both the operating and thinking aspects, the de-signers marked the method positively. Regarding the innovative method effectiveness, the evaluation on the thinking aspect was higher (mean = 3.88) com-pared with the operating aspect. The results showed that the proposed design method helped thinking in a greater degree. The operators evaluated the helping summarization and analysis variable with the highest score (mean = 4.00).

The operators suggested that fixed steps might limit thinking or prompting the contents to deviate from the theme. They also suggested that thinking from multiple aspects helped reduce the bottleneck encountered during design invention and numerous thoughts might occur to the designers' mind. How-ever, increasing time would be required for discussion.

4.2. Interview Results of Product Users

The fourth step of UCD "user-based assessment" was conducted based on the results of the experimental and control groups. After interview with six users, two parts were discussed: one was the users' preferred design group (experimental or control group), and the other was the user preferred proposals.

(1) User preferred group: Five of the product users (83.3%) preferred the proposals by the experimental groups.

(2) User preferred proposals: Among the six user preferences, two proposals received preference from four users and three proposals received preference from three users. A total of preferred proposals were produced, among which four were proposed by experimental groups and one by the control groups. The two proposals that received most user preference were both produced by the experimental groups.

4.3. Expert Interview Results

This stage comprised three sections: (a) commonly used design methods among experts and students, (b) opinions regarding the workshop outcomes, and (c) application suggestions for the dynamic product de-sign methods. Table 4 shows the organized results.

Table 4: Expert interview results

	User requirements analysis	Product design development
Commonly used design methods among the experts and students	• Interview, observation, and question-naire methods were used. • Collected requirements could not be employed practically. • The reliability of collected data could not be determined.	• Habitual use of design methods was lacking. • Only simple methods could be used. • Sitting without thoughts, encountering bottlenecks and inability to determine solutions to problems easily occurred.
Workshop outcomes	• Requirements were summarized and organized based on something. • Systemization expanded requirements dimensions and demonstrated specific and increasing requirements.	• Diverse and multiple perspectives could be used in thinking • Systematic organization enabled effi-cient use. • Later-period design concepts could be included to converge and assess the product.
Dynamic product design methods	• Dynamic user requirements would not become a focus; however, it is worth trying.	

5. Conclusion and Discussion

5.1. Dynamic Product Design Procedure and Methods

The dynamic product design procedures and methods proposed in this study were based on the UCD procedures, integrated with the dynamic user requirement concepts. Finally, the UCD dynamic product design procedures and methods are provided as follows:

(1) Understand and specify the context of use: The inclusion of timeline helped understanding users during which periods experienced substantial changes. The changing periods were used as the division boundaries, determining users' separate periods. Based on the users' periods, interview, questionnaire, and observation methods were conducted to collect user data.

(2) Specify the user and organizational requirements: The collected data were input into dynamic and fixed analyses according to user, task, and environment data in different periods before organization and classification. User requirements were completely expanded.

(3) Produce concept designs and prototypes: The cross-matching eight design models of dynamic and fixed analyses were incorporated in different thinking aspects to conduct invention of the eight dynamic design models.

(4) User-based assessment: Lastly, the usability testing or interview was conducted to examine whether the design met the requirements.

5.2. Disadvantages of Dynamic Product Design Procedures and Methods

Dynamic user requirements were easily ignored during daily design and development. However, the dynamic volatility helped design thinking development. The proposed method in exploring dynamic user requirements possessed satisfactory classification and summarization basis. In addition to improve design thinking, the proposed method can help data analysis in academic research. The disadvantages of the dynamic product design procedure and methods are provided in three sections: data collection, requirements analysis, and design development.

(1) Data collection: Collecting data based on a norm basis can systematically determine data.

(2) Requirements analysis: The data collection and analysis can become more systemized to present increasingly comprehensive requirements.

(3) Design development: Diverse aspects can be integrated into thinking and different design models may exhibit diversity in development, helping excite increasing creative thinking.

Based on the assessment experiment of this study, the dynamic product design procedure and methods can help students from the Department of Design improve their product design innovativeness. The design outcomes also achieved high evaluation and preference among users, satisfying the user-centred spirit. Teaching experts also approved the proposed dynamic product design methods. The research assessment results showed that through dynamic product design procedures and methods can increase user preference, enhance their willingness to use, extend the product life cycle, and elevate the environmental value of furniture. This study hope the proposed UCD concept can guide green product concepts and evoke additional research and innovative designs with increasing values.

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7. References

[1] C. C. Chen, and M. C. Chuang. Integrating the Kano model into a robust design approach to enhance customer satisfaction with product design. *International Journal of Production Economics.* 2008, 114 (2): 667-681.

[2] I. van Nes. *Dynamic Identities: How to create a living brand.* Amsterdam: BIS Publishers B.V, 2012.

[3] N. Tu, T. Zhang, Q. He, H. Zhang, and Y. Li. User-centered design in new product development: A case study in developing new sports earphone. In: Y. Lin. *Proc. of 2011 International Conference on Computer and Management (CAMAN).* Wuhan: IEEE eXpress. 2011, pp. 1-7.

[4] C. C. Lu, S. C. Kang, S. H. Hsieh, and R. S. Shiu. Improvement of a computer-based surveyor-training tool using a user-centered approach. *Advanced Engineering Informatics*. 2009, 23 (1), 81-92.

[5] F. Montignies, V. Nosulenko, and E. Parizet. Empirical identification of perceptual criteria for customer-centred design: focus on the sound of tapping on the dashboard when exploring a car. *International Journal of Industrial Ergonomics.* 2010, 40 (5): 592-603.

[6] J. Park. Developing a knowledge management system for storing and using the design knowledge acquired in the process of a user-centered design of the next generation information appliances. *Design Studies.* 2011, 32 (5): 482-513.

[7] J. Duarte, and A. Guerra. User-centered healthcare design. *Procedia Computer Science*. 2012, 14: 189-197.

[8] B. Hanington, and B. Martin. *Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions*. USA: Rockport, 2012.

[9] E. de Bono. *Six Thinking hats.* New York: Back Bay Books, 1999.

[10] D. Smith, P. Hedley, and M. Molloy. Design learning: A reflective model. *Design Studies.* 2009, 30 (1), 13-37.

[11] W. C. Chen. Professional learning problems and resource utilization in the industrial design. *Industrial Design*. 2009, 121: 216 -222.