USERS ACCEPTANCE MODEL ADAPTING SUSTAINABILITY-ORIENTED MODULARITY METHODS OF REPLACEABLE FILTER MASK (RFM) IN JINSHAN DISTRICT, CHINA

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USERS ACCEPTANCE MODEL ADAPTING SUSTAINABILITY-ORIENTED MODULARITY METHODS OF REPLACEABLE FILTER MASK (RFM) IN JINSHAN DISTRICT, CHINA

by

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
AVE	Average Variance Extracted
BI	Behavioral Intention
C.R.	Critical Ratio
CFI	Comparative Fit Index
CFI	Comparative Fit Index
CGM Co.	Chengao Mechanical Company
CMIN	Chi-Square Minimum Discrepancy
CMIN/DF	Chi-square Divided by Degrees of Freedom
COVID-19 Virus	Corona Virus Disease (year of identification) 2019
CR	Composite Reliability
DF	Degrees of Freedom
DT	Decorativeness
DV	Dependent Variable
EE	Effort Expectancy
FC	Facilitating Conditions
HB	Habits
HM	Hedonic Motivation
IFI	Incremental Fit Index
IoT	Internet of Things
IT	Innovativeness
IV	Independent Variable
MD	Modular Design
MDGs	The United Nations Millennium Development Goals
MGCFA	Multi-group Confirmatory Factor Analysis
MIEs	Manufacturing Industry Employees
MSPD	Modular and Sustainable Product Design
MV	Mediating Variable
NFI	Normed Fit Index
PE	Performance Expectancy
PLC	Product Life Cycle

PV	Price Value
RFI	Relative Fit Index
RFM	Replaceable Filter Module
RM	Reusable Mask
RMSEA	Root Mean Square Error of Approximation
ROs	Research Objectives
RQs	Research Questions
S.E.	Standard Error
SA	Coding Number SA
SB	Coding Number SB
SD	Sustainable Design
SDGs	The United Nations Sustainable Development Goals
SEM	Structural Equation Modeling
SI	Social Influence
SRMR	Standardized Root Mean Square Residual
Std.	Standardized Coefficient
TAM	Technology Acceptance Model
TLI	Tucker-Lewis Index
TLI -NNFI	Tucker-Lewis Index or Non-Normed Fit Index
TPB	Theory of Planned Behavior
UCD	User Centered Design
Unstd.	Unstandardized Coefficient
UTAUT	Unified theory of acceptance and use of technology
UTAUT2	Unified theory of acceptance and use of technology2
VIF	Variance Inflation Factor
WHO	World Health Organization

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MODEL PENERIMAAN PENGGUNA MENGGUNAKAN KAEDAH MODULARITI BERORIENTASI KEMAMPANAN DALAM TOPENG PENAPIS BOLEHGANTI (RFM) DI DAERAH JINSHAN, CHINA

ABSTRAK

Penyelidikan ini meneroka reka bentuk modular dan mampan, memfokuskan kepada pembangunan reka bentuk produk lestari modular (MSPD) untuk menggalakkan perlindungan alam sekitar. Menggunakan topeng modul penapis boleh diganti (RFM) sebagai kajian kes, ia mengkaji niat tingkah laku pengguna dengan menggunakan Teori Tingkah Laku Terancang (TPB) dan Model Penerimaan Teknologi (TAM). Setelah analisis perbandingan pelbagai model dilaksanakan (TPB, TAM, UTAUT, UTAUT2), kajian menyimpulkan bahawa Teori Penerimaan dan Penggunaan Teknologi Bersepadu 2 (UTAUT2) adalah paling sesuai untuk menilai MSPD sebagai teknologi baharu. Reka bentuk penerangan berjujukan kaedah campuran telah digunakan. Dalam fasa kuantitatif, data daripada 500 pekerja industri mekanikal (MIE) di Daerah Jinshan, Shanghai telah dianalisis menggunakan Pemodelan Persamaan Struktur (SEM) untuk meneroka kesediaan penggunaan RFM berasaskan MSPD. Kajian ini juga telah mengkaji kesan pengantaraan dan penyederhanaan melalui model struktur berantai. Dalam fasa kualitatif, analisis tematik temu bual berstruktur dan separa berstruktur dengan MIE memberikan pencerahan mengenai faktor-faktor yang mempengaruhi kesediaan mereka untuk menggunakan RFM. Penemuan utama menunjukkan bahawa pembolehubah terkandung dalam UTAUT2, seperti Jangkaan Prestasi, Pengaruh Sosial, Motivasi Hedonik dan Tabiat, memberi kesan positif kepada penggunaan MIE terhadap RFM MSPD. Pembolehubah yang baru ditambah seperti hiasan dan inovasi juga

memainkan peranan yang penting. Sumbangan utama kajian ini ialah penyesuaian UTAUT2 kepada reka bentuk produk, menawarkan pendekatan inovatif untuk meramalkan penerimaan pengguna terhadap teknologi baharu sambil menekankan potensi reka bentuk mampan untuk mengurangkan kesan terhadap alam sekitar. Selain itu, kajian itu menawarkan sumbangan praktikal dengan mengoptimumkan reka bentuk topeng muka untuk industri pemprosesan mekanikal, sekaligus menangani kedua-dua kebimbangan iaitu terhadap kesihatan dan alam sekitar semasa pandemik COVID-19. Ia menyerlahkan bagaimana MSPD boleh mengurangkan sisa sumber dan pencemaran alam sekitar, memberi manfaat kepada pekerja, pereka produk, pengeluar dan penggubal dasar. Ini adalah kajian pertama yang mengintegrasikan kebolehhiasan dan keinovatifan produk ke dalam UTAUT2, seterusnya meningkatkan kuasa penjelasannya dalam konteks reka bentuk produk lestari modular.

USERS ACCEPTANCE MODEL ADAPTING SUSTAINABILITY-ORIENTED MODULARITY METHODS OF REPLACEABLE FILTER MASK (RFM) IN JINSHAN DISTRICT, CHINA

ABSTRACT

This research explores modular and sustainable design, focusing on developing of sustainable modular product design (MSPD) to promote environmental protection. With the replaceable filter mask (RFM) as a case study, it examines user behavioral intentions by applying the Theory of Planned Behavior (TPB) and the Technology Acceptance Model (TAM). After a comparative analysis of various models (TPB, TAM, UTAUT, UTAUT2), the study concludes that the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) is most suitable for assessing MSPD as a new technology. A mixed-method sequential explanatory design was employed. In the quantitative phase, data from 500 mechanical industry employees (MIEs) in Shanghai's Jinshan District were analyzed using structural equation modeling (SEM) to explore the willingness to use MSPD-based RFM. The study also examined mediating and moderating effects through a chained structural model. In the qualitative phase, thematic analysis of structured and semi-structured interviews with MIEs provided insights into the factors influencing their willingness to use the RFM. Key findings indicate that latent variables in UTAUT2, such as Performance Expectancy, Social Influence, Hedonic Motivation, and Habit, positively affect MIEs' use of MSPD's RFM. Newly added variables like decorativeness and innovativeness also play a significant role. The study's main contribution is the adaptation of UTAUT2 to product design, offering an innovative approach to predicting user acceptance of new technologies while emphasizing

sustainable design's potential to reduce environmental impact. Moreover, the study offers practical contributions by optimizing the design of masks for the mechanical processing industry, addressing both health and environmental concerns during the COVID-19 pandemic. It highlights how MSPD can reduce resource waste and environmental pollution, benefiting workers, product designers, producers, and policymakers. This is the first study to integrate product decorativeness and innovativeness into UTAUT2, thereby enhancing its explanatory power in the context of modular sustainable product design.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The development of industrial design builds on the foundation and accumulated experience of traditional design methods, providing a solid basis for industrial design (Ferrari, 2017). In addition, industrial design requires continuous innovation, incorporating new design methods and concepts to address evolving market demands and technological advancements (Chang, Kim, & Joo, 2013; Conti & Chiarini, 2021). As the concepts of sustainable design and modular design converge, the diverse requirements of industrial design are met, product development cycles are shorten, and rapid responses to market changes are enabled while also mitigating the adverse environmental impacts of products, facilitating product recycling and reuse (Ma & Kremer, 2016; Sonego, Echeveste, & Debarba, 2018; Cheng, Zhou, Xiao, Liu, & You, 2020). In the midst of personalized demands, globalized markets, and product replication competition, leveraging industrial design methods to enhance product competitiveness, meet complex market demands, and uphold sustainable ecological principles constitutes a significant objective in the research within the field of industrial design (Ming, Kong, & He, 2017). Dr. Yang Zhenning emphasizes the critical role of industrial design in meeting the diverse market demands and advancing sustainable development objectives in contemporary society (Buchstaber, Igonin, Konstantinou-Rizos, & Preobrazhenskaia, 2020). The significance is particularly evident in the sectors of medical equipment and protective gear, where industrial design directly impacts public health and safety (Privitera, 2017). With the World Health Organization (WHO) advocating the daily use of masks as a preventive measure against COVID-19 (Bambra, Riordan, Ford, &

Matthews, 2021), their widespread adoption has led to a surge in mask-related waste, as noted by Hou et al. (2022). The surge in waste contradicts the principles of sustainability that underpin modern market concepts. Given the societal challenges caused by the pandemic, particularly environmental pollution due to disposable masks, rectifying unsustainable product design practices is essential. For researchers in the field of industrial design, the agenda is urgent and pressing. They must find a balance between environmental conservation and public health.

Modern design is constantly challenged by evolving markets, regulations, technology, and shifting audience demands. Concepts of modular design, once considered "classic," are now facing unprecedented challenges (Alli, Rashid, Sulaiman, Che Me, & Kamarudin, 2019; Mbugua, Korongo, & Mbuguah, 2022). The situation has prompted product designers to reflect deeply on the future of modular design. Designers need to find ways to achieve wider acceptance and embrace new concepts in their designs (Tezel, 2018; Buehring & Bishop, 2020). Over time, Ryu, Yeom, Herbert, and Dermoudy (2023) posit that users are gradually enhancing their independent thinking capabilities. This acknowledgment reinforces that design significantly impacts lives (Ullah, Tang, & Yin, 2016). Simultaneously, the trend towards sustainability-oriented modular design is rapidly evolving in response to consumers' personalized demands (Prastawa, 2018; Mesa, Esparragoza, & Ramirez, 2019). How consumers perceive a designer's products and whether their consumption choices can shape design concepts are factors that cast doubt on the acceptance of new design concepts (Beverland, Gemser, & Karpen, 2017; Mandaric, Hunjet, & Kozina, 2021). In summary, users' behavioral intention to embrace new product design concepts is a crucial factor that designers, manufacturers, and businesses cannot afford to overlook.

The traditional design of disposable masks for daily life focuses on the basic attributes of the product to meet functional and manufacturing process demands (Gao, Feng, & Tan, 2016). It is mainly designed based on indicators such as product performance, quality, and product demand. Designers usually have a weak environmental awareness, rarely considering the recyclability of disposable masks, the disposal of obsolete products, and the impact on the ecological environment (Qian & Zhang, 2003; Qian & Zhang, 2009). According to Hou et al. (2022), the disposable product completes its service life, it becomes a pile of waste, with a large amount of hazardous substances lacking the necessary recycling and degradation treatment, causing severe pollution to the environment, affecting human quality of life, and resulting in a significant waste of resources and energy (Li, Xiong, & Qu, 2023; Wang, Liu, Zhang, & Zeng, 2023). Due to the inability to estimate the disposal of masks quantitatively, this issue can be indirectly reflected in production volume. During the epidemic, the global use of masks increased exponentially (iMedia Report: Research Report on the Market Status and Trends of the Chinese Mask Industry from 2020 to 2022). Figure 1.1 illustrates this. Disposable masks are difficult to recycle, and their accumulation poses a significant environmental threat and waste of resources (Huang, Liang, Chuang, & Chang, 2012; Huang, Yang, & Gong, 2015; Wang, Harding, Chen, & Tu, 2023). Consequently, a design approach that allows the mask to be reusable while preserving its original functionality is needed, thereby reducing resource waste and environmental damage.

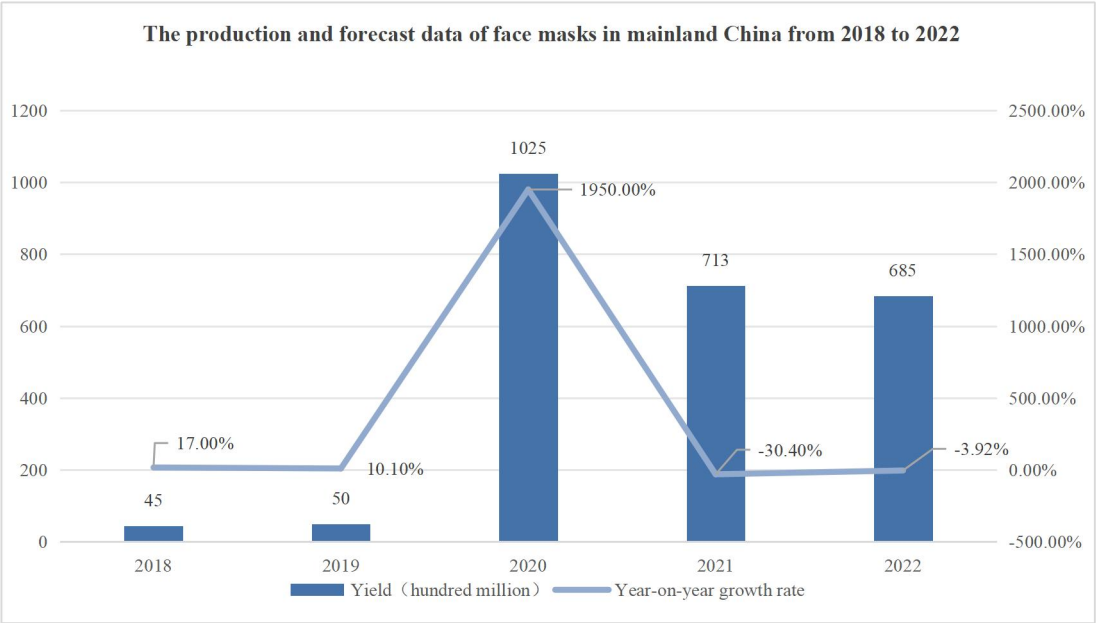


Figure 1.1 Growth Chart of Mask Production During the Epidemic
(Source: iiMedia Consulting, https://www.360kuai.com, 2022)

Repeated use of masks is an application of sustainable design, which reduces resource consumption and environmental pressure from material selection to use and maintenance (Wang et al., 2023; Fajarwati et al., 2023). Additionally, it involves the flexible application of modular design (Evans & Griffith, 1982; Prastawa, 2018), the materials and standard modules of replaceable masks are regarded as basic elements of modular design. According to Baldwin and Clark (2006), a modular system product is composed of units (or modules) that can be designed separately and then integrated together to perform specific product functions. For example, in 2020, reusable masks produced on the production line in Fengxian District, Shanghai, were composed of inner and outer layers of cotton yarn and a middle filter core, surpassing the performance of N95 masks. The middle filter core of this mask is considered a subsystem of modular product design (Sadaf, Munir, Saeed, Hassan, & Ahmad, 2023). This method reduces resource waste, thereby enhancing sustainability (Buford, Ranganathan, Roseway, & Seyed, 2021), and it addresses the high demand in the mask market at that time, considering user acceptance and preferences (Lobos, 2014;

Asión-Suñer & López-Forniés, 2021). Therefore, users' acceptance and preferences also influence the purchasing power of products that integrate modular and sustainable design, indirectly affecting environmental pollution and resource waste.

The preferences and evaluations of sustainable products are influenced by changes in consumer behavior (Bhamra, Lilley, & Tang, 2011). Furthermore, the heuristic forms utilized by users to evaluate the sustainability of products, as well as the methods in which users employ products to mitigate environmental impact, are bound to evolve over time (Lockton, Harrison, & Stanton, 2008; MacDonald & She, 2012). With increasing awareness of sustainability, it is widely recommended to consider sustainability principles as a crucial element in new product development (Yan et al., 2014). Therefore, sustainable design, considering environmental, social, and economic feasibility, is widely regarded as a significant transition towards sustainability (Jayal, Badurdeen, Jr, & Jawahir, 2010). The Reusable Mask (RM) that uses replaceable modules to address environmental issues represents a transition from "modular design" to "modern design." Tong (2011) considers this "modern design" to be a new design method that elevates experiential and analogical design from traditional design to a logical, rational, and systematic one (Watz & Hallstedt, 2018). Although modern design is an extension and development of past design activities, it enhances the intrinsic quality, aesthetic quality, and design efficiency of products (Xie, 2004; Qiu et al., 2022). Regardless of how design methods evolve, user acceptance and preferences are key factors in examining design integration and transition (Taherdoost, 2019; Van, Diep, Toan, & Quy, 2021). Future research on sustainable design and modular design should focus on achieving positive impacts on users' behavior intentions.

1.2 Background

The section introduces the core concepts of Modular Design (MD) and Sustainable Design (SD), highlighting their integration to address environmental challenges, particularly the issues posed by disposable masks. The importance of reusable masks (RM), along with the application of User-Centered Design (UCD) principles, is also discussed as a key aspect of solving these problems.

1.2.1 Modular and Sustainable Design

Modular Design (MD) offers several advantages that align with contemporary user needs, including flexibility, customization, and adaptability, while also facilitating faster design iterations and reducing production time (Zhang & Tang, 2014; Amend et al., 2021). These benefits make MD an important approach in industrial design, particularly in enhancing innovation and product efficiency (Salvador & Villena, 2013). However, as consumer demand shifts towards environmentally friendly solutions, the traditional advantages of MD are no longer sufficient to meet market requirements for sustainability (Zhang, Xu, & Tang, 2014; Lee, Case, & Marshall, 2016).

To address this gap, Sustainable Design (SD) is increasingly being integrated into modular approaches. SD emphasizes the need for collaboration among designers, manufacturers, marketers, and policymakers to encourage positive behavioral changes and reduce environmental impact (MacDonald & She, 2015). While SD has improved the eco-friendliness of materials and production processes, its full potential is limited without considering user behavior and decision-making (Lockton et al., 2008; Cheng et al., 2022). Therefore, the integration of SD and MD—known as Modular Sustainable Product Design (MSPD)—has emerged as a more effective

approach, addressing both environmental protection and user needs (Pang & Yang, 2023).

MSPD not only improves the technical and functional aspects of products but also ensures sustainability throughout the product lifecycle, including usage, recovery, and recycling (Wieser & Tröger, 2018). This approach helps reduce negative environmental impacts, which is critical as user preferences increasingly focus on a product's environmental compliance, beyond mere functionality (Smith & Yen, 2010; Huang et al., 2012). The exploration of user behavioral intentions related to MSPD is a crucial area for future research, especially in the context of industrial design and environmental awareness.

1.2.2 Reusable Masks (RM): A Sustainable Solution

In recent years, particularly during the COVID-19 pandemic, the excessive use of disposable masks has led to significant environmental problems, including increased waste and shortages of raw materials (Hou et al., 2022; Provenzano et al., 2020). Although sustainable design strategies have been promoted, the market is still dominated by disposable products (Yang & Zhang, 2020). To address this issue, Reusable Masks (RM), especially those designed with Replaceable Filter Modules (RFM), have gained attention as a sustainable alternative (Huang et al., 2015).

RM not only helps reduce resource waste but also offers a long-term solution for environmental protection, without compromising user safety (Chinaksorn & Sonthaya, 2023). By enabling modular replacement, RM products extend the lifespan of masks and provide more efficient resource utilization, making them a key example of MSPD in practice (Mesa et al., 2019). This approach aligns with the increasing consumer demand for sustainability, promoting both environmental benefits and user protection.

By combining modular and sustainable design methodologies, MSPD effectively addresses contemporary environmental challenges while meeting user demands. This integration, particularly in products like reusable masks, illustrates the potential for innovation in both design and sustainability. Addressing the growing need for reusable, modular products is essential for reducing waste and promoting long-term resource conservation.

1.3 Problem Statement

During the COVID-19 pandemic, disposable masks became essential protective tools. However, their widespread use has resulted in a significant increase in environmental waste and pollution, exacerbating the spread of viruses and contributing to environmental degradation due to improper disposal (Sangkham, 2020; Dharmaraj et al., 2021). Beyond the basic requirements for comfort and fit, the sustainability and aesthetic appeal of mask designs have also emerged as critical considerations (Liao et al., 2021). Therefore, the development of a sustainable, modular mask design that offers user convenience, comfort, and reduced environmental impact has become a pressing issue in the current market (Chua et al., 2018).

The sharp rise in global demand for masks during the pandemic has led to overproduction and excessive use of disposable masks, causing substantial resource waste and environmental pollution (Howard et al., 2021; Wang et al., 2023). Although increasing production capacity has temporarily alleviated market demand, the frequent replacement of disposable masks has raised concerns about their long-term environmental impact. Reusable masks, particularly those equipped with replaceable filter modules (RFM), present a viable alternative by minimizing

material consumption and supporting sustainability, while also providing users with superior comfort, safety, and portability (Thien & Congo, 2020). However, research on the acceptance and adoption of RFM masks remains insufficient.

In addition, while RFM masks offer a sustainable solution, there has been limited exploration into the level of acceptance and willingness of manufacturing industry employees (MIEs) to use them. Factors such as performance expectancy (PE), effort expectancy (EE), and social influence (SI) play a critical role in determining whether MIEs adopt new technologies (Venkatesh et al., 2012; Chua et al., 2018). Yet, empirical data on how these factors influence MIEs' intentions to use RFM masks during the pandemic is lacking (Sanjib et al., 2021). Although the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) provides a solid framework for analyzing these factors, further research is required to assess its applicability in the context of modular sustainable product adoption (Venkatesh, Thong, & Xu, 2012).

Design factors such as decorativeness and innovativeness are also becoming increasingly important in shaping user acceptance behavior. These factors may moderate how users perceive the value of a product, influencing their intention to adopt it (Johansson et al., 2013; Luchs et al., 2012). However, empirical research on how these factors impact MIEs' willingness to use RFM masks is still limited. Furthermore, demographic variables such as age, education, work experience, and gender may influence MIEs' decisions, yet the specific effects of these variables remain unclear (Tan et al., 2014).

Manufacturing industry employees face particular challenges when using RFM masks, such as issues related to comfort, fit, and ease of use (Greene, Clarke, Pakes & Holmes, 2019). Additionally, workplace regulations and peer influence can

further affect their behavioral intentions (Sanjib et al., 2021). Despite the functional and environmental advantages of RFM masks, barriers to user acceptance persist, and these challenges must be addressed to ensure the widespread adoption of these products in the market.

This study seeks to address several research gaps. First, there is a lack of comprehensive evaluation of the usage and acceptance of reusable modular masks (RFM) among MIEs. Second, research on the factors influencing user adoption of Modular Sustainable Product Design (MSPD) products is insufficient, particularly empirical studies within the UTAUT2 framework. Third, there is limited understanding of how design factors, such as decorativeness and innovativeness, and other moderating variables influence MIEs' behavioral intentions toward adopting sustainable design products (Luchs et al., 2012; Johansson et al., 2013). Finally, there is a need for a detailed analysis of the specific challenges MIEs face when using RFM masks during the pandemic. By addressing these gaps, this study aims to provide deeper insights into how modular sustainable designs, such as RFM masks, can be more effectively implemented to meet user needs, promote widespread adoption in industrial design, and contribute to environmental protection.

1.4 Research Purpose

The above research questions focus on three deficiencies that the study aims to address. The study investigates the behavioral intention of machine processing enterprise workers using RFM based on MSPD. To gain a better understanding of the behavioral intention of machine processing enterprise workers using RFM mask based on MSPD, the study also investigated whether there are any significant relationships between the independent variables (i.e., PE, EE, SI, FC, HM, PV, and

HB) and the behavioral intention of these workers using MSPD-based RFM mask. Additionally, the study examines whether product innovativeness and decorativeness serve as mediating factors in the relationship between the independent variables and the behavioral intention of machine processing enterprise workers using RFM mask based on MSPD. Furthermore, the study aims to explore the challenges faced by machine processing enterprise workers using RFM mask based on MSPD. Finally, the study aims to propose an effective framework that utilizes a sustainable design model incorporating modular methods as an assessment tool for implementing sustainable design methods. This framework is intended to enhance user adoption of sustainable design products, ultimately reducing disposable products and thereby protecting the environment.

1.5 Research Objectives (ROs)

Based on the above statement of research purpose, the following research objectives are formulated.

i) To investigate the factors influencing the intention of manufacturing employees to use RFM mask for protective behavior during the pandemic. This includes examining the correlation between independent variables (i.e., PE, EE, SI, FC, HM, PV, and HB) and whether MIEs engage in self-protection using MSPD (e.g., RFM mask).

ii) To analyses the mediation and moderation relationship of decorativeness and innovativeness variables in the intention of MIEs to use MSPD (e.g., RFM mask).

iii) To evaluate the key predictive factors influencing the intention of manufacturing employees to use MSPD (e.g., RFM mask) protective measures during the pandemic period.

iv) To propose an effective modular sustainable product design framework to evaluate sustainable tools. This framework aims to enhance the willingness of user groups to use RFM mask products, thereby mitigating environmental pollution and resource wastage.

1.6 Research Questions (RQs)

Based on the above research objectives, explore the next research questions.

i) What factors influence the behavioral intention of MIEs to use RFM mask for protection during a pandemic?

ii) How is the correlation between independent variables (i.e., PE, EE, SI, FC, HM, PV, and HB) and the intention of MIEs to use RFM mask during the COVID-19 pandemic?

iii) How do the factors of decorativeness and innovativeness moderate the relationship between independent variables and the intention of MIEs to use RFM mask?

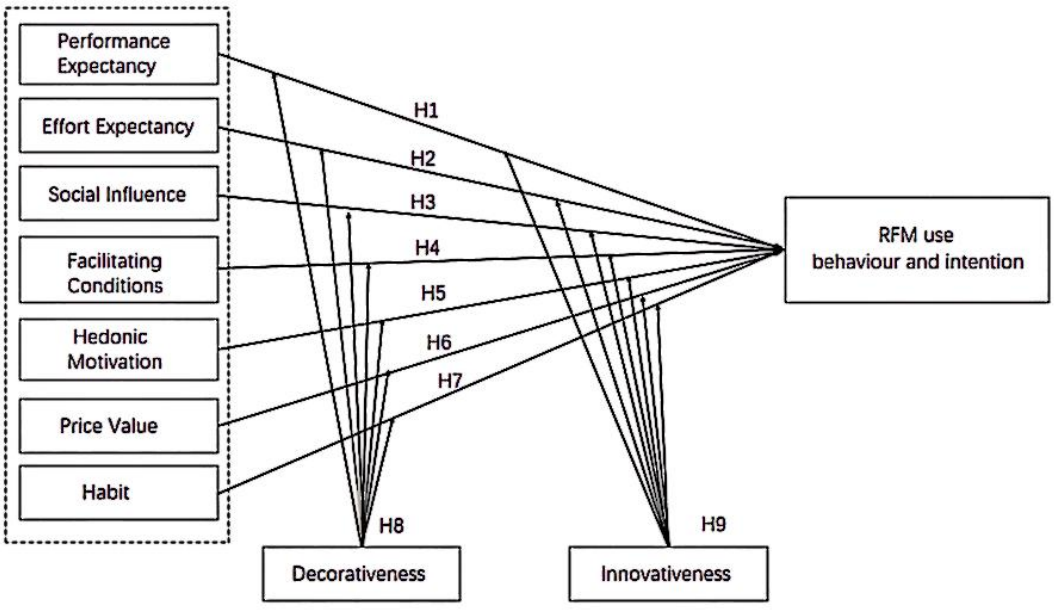
iv) What challenges do MIEs face when using RFM mask for protection during the pandemic?

1.7 Research Hypothesis

In the study, the researcher employed the UTAUT2 model (Venkatcsh et al., 2012) to investigate the behavioral intention (BI) of Manufacturing Industry Employees at Chengao Mechanical Co. (CGM Co.) in Shanghai's Jinshan District to

use RFM mask during the COVID-19 pandemic. The model comprises seven independent factors influencing dependent behavior: performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit (Venkatesh et al., 2003; Venkatesh et al., 2012). Wearing masks during the pandemic is essential for manufacturing industry employees, especially in crowded office spaces. Therefore, the challenges faced by MIEs in using RFM mask have not lessened. Within this context, this study not only adopts the basic framework of the UTAUT2 model but also introduces two critical mediating variables: decorativeness

Figure 1.2 Hypothetical Model for the Study
(Source:Venkatesh et al., 2003 & 2012; and the figure is drawn by the author)



and innovativeness (Candi et al., 2010; Mugge & Schoormans, 2012), to aid in understanding the relationship between independent variables and the protective behavior of MIEs using RFM mask during the pandemic. The hypothetical model of this study is illustrated in Figure 1.2.

Following the model structure in Figure 1.2, the hypotheses constructed in this study are as follows.

H1) Performance expectancy positively influences the behavioral intention of MIEs to use RFM mask for protection based on MSPD.

H2) Effort expectancy negatively influences the behavioral intention of MIEs to adopt RFM mask for protection based on MSPD.

H3) Social influence positively affects the behavioral intention of MIEs to use RFM mask for protection during a pandemic.

H4) Facilitating conditions positively influence the behavioral intention of MIEs to use RFM mask for protection during a pandemic.

H5) Hedonic motivation positively influences the behavioral intention of MIEs to use RFM mask for self-protection during a pandemic.

H6) Price value positively influences the behavioral intention of MIEs to use RFM mask for self-protection during a pandemic based on MSPD.

H7) Habit positively influences the behavioral intention of MIEs to adopt RFM mask for protection.

H8) The Decorative effect of the product moderates the behavioral intention of MIEs to use RFM mask for protection during a pandemic.

H9) The behavioral intention of MIEs to use RFM mask for protection during a pandemic is moderated by the product's innovativeness.

1.8 Research Aim and Scope

The primary goal of the study was to examine the variables affecting MIEs' propensity to use RFM mask based on MSPD as a form of preventive behavior during the epidemic in Jinshan District, Shanghai.

The study retains the original foundational variables of the model without any modifications, although there may be potential mediator variables among the independent variables (Hoegg & Alba, 2011). Additionally, during the COVID-19 pandemic, there may be other mediator variables influencing the willingness of Manufacturing Industry Employees to adopt MSPD and act as moderators (Candi, 2010; Mugge & Schoormans, 2012). Therefore, the study explores two mediator variables, namely, product decorativeness and innovativeness, that influence the willingness of MIEs to use RFM mask for protective behaviour during pandemics.

The study focuses on the impact of MSPD with RFM mask in the context of the COVID-19 pandemic on user adoption intentions. The study primarily targets the group of Manufacturing Industry Employees and will be conducted in Jinshan District, Shanghai. The research period is from December 2021 to January 2022. Data is performed through questionnaires and interviews, and analysis is performed using SPSS 26.0, Amos 24.0, and Nvivo 11.0. It is important to note that the study does not specifically target a particular occupational group and excludes individuals within specific age ranges (Creswell, 2014; Babbie, 2016). The outcomes of the research provide practitioners in the field of industrial design with a deeper understanding, aiding in comprehending user acceptance of MSPD. It leads to positive impacts on environmental protection and prevention of resource wastage (Sangkham, 2020; Dharmaraj et al., 2021). To integrate the influencing factors of MIEs' willingness to use RFM mask and the challenges encountered when using

RFM, the study conducted research based on the replaceable filter mask designed by predecessors. Ultimately, a new set of RFM mask conceptual products was designed for MIEs, experts and MIEs were invited to provide objective evaluations, aiming to offer a conceptual example that combines modular and sustainable design.

1.9 Significance of Study

The following stakeholders will greatly benefit from the study's findings. Firstly, the study makes a significant theoretical contribution to understanding the factors influencing the intention of MIEs to use Resourceful and Flexible Manufacturing RFM mask for protection during the COVID-19 pandemic. Furthermore, the research delves into Modular and Sustainable Product Design and assesses users' intentions to employ RFM mask, thereby fostering greater interest in MSPD products from the perspective of promoting environmental awareness. Additionally, researchers in the same field can utilize these findings to deepen their understanding of MSPD and user acceptance of new products and facilitate comparisons of sustainable design models across different regions and countries. In conclusion, the theoretical framework developed in this study can provide support for product designers in making informed design decisions, assist producers in enhancing production efficiency, and serve as a reference for policymakers in promoting sustainable development principles. Through the MSPD approach, the study iteratively updates the Respirator Face Mask product, aiming to safeguard the physical health of workers. This is particularly crucial considering the relocation of industrial factories from the city center in Shanghai due to wind direction and speed, potentially sacrificing the health of employees. While advocating industrial progress,

there is a simultaneous call not to overlook the sustainable development of human health.

Secondly, the study employs the MSPD method to design masks based on replaceable filter masks with a focus on optimizing for workers in the mechanical processing industry. It addresses the behavioral intentions of manufacturing employees to use MSPD-based RFM mask during the pandemic and addressing environmental pollution issues caused by inadequate supply and disposal of traditional disposable masks. Furthermore, the study reveals that users are more inclined to use products adopting modular methods for sustainable design, contributing to the reduction of resource wastage and environmental pollution. Therefore, the research results effectively integrate modular methods and sustainable design, providing a practical contribution to environmental protection and resource utilization. Lastly, the study assists workers in the mechanical processing industry in using masks more economically and conveniently during the pandemic, thereby enhancing their safety.

In conclusion, this study provides an in-depth analysis of the Theory of Planned Behavior and technology acceptance models (TAM, UTAUT, UTAUT2), ultimately adopting the UTAUT2 model. This model encompasses the impacts of modularity and sustainable design on user behavioral intentions (Xiong, Wu, & Yi, 2021; Chen et al., 2020). To reveal more clearly the research outcomes of MSPD (Modular Sustainable Product Design) on user intentions and adoption analysis, this study employs the RFM mask as a case study. Additionally, new variables (product decorativeness and innovativeness) were incorporated into the original UTAUT2 model variables, aiming to explore the willingness to accept using MSPD products in the context of the pandemic. This is the first time such work has been conducted

based on the extensive textual knowledge of previous research, enhancing the explanatory power of the UTAUT2 model both theoretically and empirically.

1.10 Operational Definitions

Important definitions of terms used in the study are given below.

1.10.1 Manufacturing Industry Employees

China has the largest population in the world, with 73.18 million industrial workers employed in manufacturing in 2020 (Xu et al., 2023). Data from the Ministry of Industry and Information Technology show that, on average, there were 73.18 million industrial employees in China in 2020, down from 99.77 million in 2014. In 2019, there were 4.08 million manufacturing employees in the United States (Li & Wei, 2019). Manufacturing workers were chosen as study subjects because China has the world's highest industrial output.

1.10.2 Product Sustainable Design

Sustainable design is such a design approach that focuses on product environmental attributes (detach-ability, recyclability, maintainability, reusability, etc.) throughout the product's life cycle and considers them as a design goal to ensure the product's proper function, service life, quality, etc. (Omole, Olajiga, & Olatunde, 2024), while meeting environmental goal (Tiwari, & Salunkhe, 2021).

1.10.3 Product Modular Design

A product using the modular approach can be considered a standardized product to some extent (Luttmer, Ehring, Pluhnau, Kocks, & Nagarajah, 2022; Efatmaneshnik, Shoval, & Ryan, 2017). It consists of a combination of standardized, common modules.

1.10.4 Modular and Sustainable Product Design

Modular and sustainable product design refers to an approach that integrates modular design and sustainable design principles into product development (Chakrabortty,, Elsawah, & Ryan, 2023; Zou, Li, & He, 2024).

1.10.5 The Unified Theory of Technology Acceptance and Use

The Unified Theory of Technology Acceptance and Use (UTAUT) model justifies technology acceptance (Venkatcsh et al., 2012).

1.10.6 Performance Expectancy (PE)

Users expect the quality and reliability of the product (Gao, 2016; Amend et al., 2022). In the study, performance expectation is the extent to which manufacturing employees used RFM during the epidemic to help protect them (Schischke et al., 2019), thus improving their opportunities, achievements, and productivity (Jaime et al., 2015).

1.10.7 Effort Expectancy (EE)

Effort expectancy refers to the ease-of-use technique associated with the user; in the research, it refers to how easy it is for manufacturing workers to use the RFM mask at work (Wang & Zhu, 2019; Biswas et al., 2021). It indicates the complexity of the system design (Lampo & Silva, 2023), how easy or difficult it is to use, and the amount of effort put into using the system.

1.10.8 Social Influence (SI)

Those who have close relationships with users or are involved in their educational activities, such as friends, family members, classmates, and decision-makers, are specifically referred to as social influences in the study (Zhan et al., 2023;

Manutworakit & Choocharukul, 2022). The measure indicates how much people believe influential figures affect the way they use technology (Lampo & Silva, 2023).

1.10.9 Facilitating Conditions (FC)

Facilitating Conditions is defined as a consumer's perception of the resources and support available to them when they engage in behavior (Michels et al., 2024; Lampo & Silva, 2023). In this study, FC includes technical and organizational elements and encompasses the technical support for product design.

1.10.10 Hedonic Motivation (HM)

Hedonic motivation refers to the enjoyment or pleasure derived from a technological tool (Otter & Deutsch, 2023; Karpurapu et al., 2024). In this study, it refers to the enjoyment, pleasure, entertainment, or joy experienced by the user while using REM mask.

1.10.11 Price Value (PV)

The user's perception of the benefits of applying the system versus the monetary cost of using it is critical to its adoption (Rejali et al., 2024; Karpurapu et al., 2024).

1.10.12 Habits (HB)

Structures and technologies are used automatically due to habit and can also be conceptual manifestations of behavior based on an individual's prior experience (Lima & Kubota, 2021; Wang et al., 2023). The study is based on user research on the brand effect and product awareness.

1.10.13 Decorativeness (DT)

The decorativeness dimension refers to the artistic effects of complementarity, alternation, and symmetry based on the sustainable design of cutting and dividing

materials and other means (Tong, 2011; Alli et al., 2019). The study is based on product aesthetics, weight, attractiveness, and other factors.

1.10.14 Innovativeness (IT)

The innovativeness dimension refers to product form innovation and belongs to the theme of the sustainable economy, which focuses on improving product performance by considering innovations (Chen et al., 2022). One of the most commonly used definitions of innovation is product novelty (Naik et al., 2021), which can be defined as the newness to the customer, company, or industry.

1.11 Summary of Chapter

This chapter introduces a study on the behavioral intention of users towards MSPD, using the RFM mask as an example. It emphasizes the importance of using sustainable design products in contemporary industrial design. The chapter briefly discusses the overproduction of disposable masks during the pandemic, which has led to resource waste and environmental pollution. It emphasizes the importance of using MSPD products and the necessity for Manufacturing Industry Employees to use the RFM mask. The aim is to explore the factors influencing MIEs' use of MSPD (e.g., RFM mask) and the mediators and moderators between them. Therefore, this chapter also presents four research objectives and four research questions. On this basis, the relevant research hypotheses and conceptual models were also constructed, forming the backbone of this study, followed by the scope, objectives, and significance of the research. Finally, this chapter provides important definitions of key terms used in the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The chapter explores how various aspects of MSPD research influence user behavior and decision-making, while constructing the corresponding theoretical framework. Initially, the first three sections are based on product lifecycle theory, providing an analysis of modularity, sustainability, and their integration into Modular Sustainable Product Design, focusing on how this innovative design impacts consumer behavior and intentions. As illustrated in the figure 2.1 below, the chapter begins with an examination of "Modularity" and "Sustainability," progressing toward an integrated framework for Modular Sustainable Product Design (MSPD). Subsequently, by reviewing MSPD case studies (RFM mask), an extensive analysis of the factors influencing user adoption of MSPD will be conducted, along with an evaluation of the strengths and weaknesses of the RFM method, which will provide insights for future optimization. Following this, a comparative analysis of technology acceptance models such as TRA, TPB, TAM, UTAUT, and UTAUT2 will be conducted, assessing how MSPD product characteristics influence user behavior, selecting the most suitable model, and determining study variables to establish a suitable theoretical framework for addressing the research questions. Finally, this chapter integrates the content of the previous sections to develop a comprehensive theoretical framework. In conclusion, the key points and findings will be reviewed and summarized to guide future research in subsequent chapters.

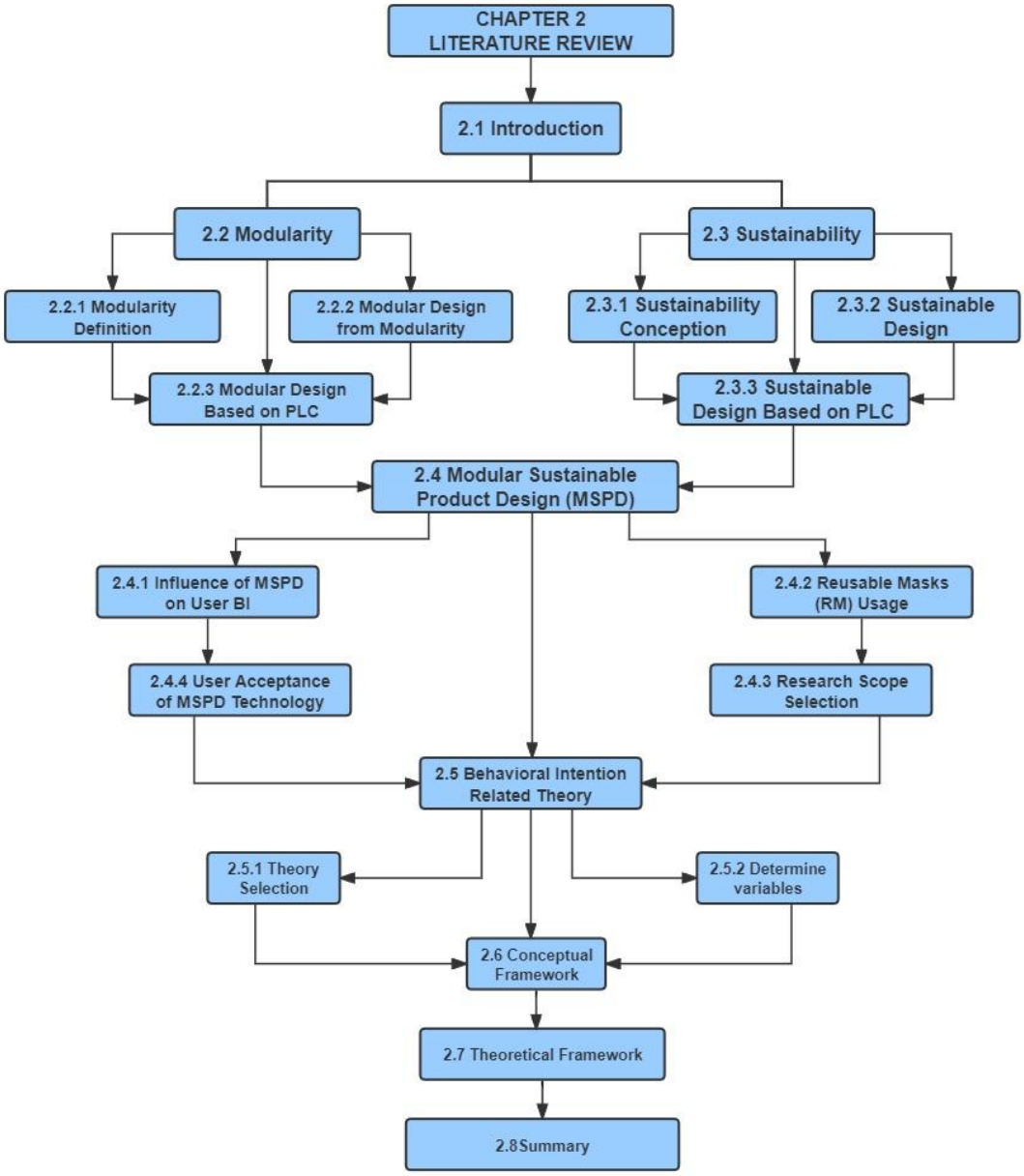


Figure 2.1 Chapter Flowchart

(Source: the figure is drawn by the author)

2.2 Modularity

The concept of modularity, as introduced by Simon (1962), originates from the perspective that a product is a complex system comprising numerous interacting subsystems. In order to simplify the system, a product can be designed into a set of subsystems so that the assembly of different subsystems can develop a new product (Sun & Qi, 2020). The pioneering work of Starr (1965) brought forth the concept of

modularity in the field of manufacturing. Starr proposed modular product production as a novel approach to promote the diversification of products (Clara, 2021). Modularity proposes that the components of a product are grouped into a module to achieve practical production goals (Jose & Tollenaere, 2005). According to some experts, the interchangeability of a product's replaceable parts should define modularity (Miles, 1974; Karl & Tilbrook, 1994; Bieringer et al., 2013). These parts are replaceable components or materials, similar to the value analysis of a product. Modularity refers to a hierarchical arrangement consisting of multiple independently developed small components. These components are linked through standardized interfaces, showcasing a remarkable level of loose coupling. Decoupling not only reduces complexity but also allows parallel task completion (Baldwin, 1997; Baldwin & Clark, 2000; Hari, Subramanian, & Ramkumar, 2021; Hayam et al., 2021). These tasks are organized to create a whole system (Kim & Ko, 2010; Kamrad, Weigelt, Schneider, & Althoff, 2013; Ramuhulu & Chiranga, 2018). The content above illustrates the evolution and impact of the modularity concept. Experts emphasize the interchangeability of replaceable components when defining modularity. Modular components achieve loose coupling through standardized interfaces, reducing complexity and supporting parallel task completion. In summary, modularity serves as a powerful tool in product design, fostering innovation and improving performance expectancy.

The concept of "near-decomposability" (Simon, 1962) represents a distinct form of modularity that enhances the organization of intricate designs and processes within complex systems. It achieves this by breaking them down into smaller, more straightforward elements (Jose, 2005). According to Gershenson et al. (2003), the decomposition of a product into subassemblies and components is what gives rise to