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Fuzzy logic programming and adaptable design of medical products for the COVID-19 anti-epidemic normalization

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ABSTRACT

Background: The COVID-19 prevention and control constantly affects lives worldwide. In this paper, household medical products were analyzed using fuzzy logic. Considering the household anti-epidemic status, economic and environmental benefits, the adaptable design method of anti-epidemic products in the vestibule was proposed. The measure of adaptable design method still have shortcomings. Therefore, an improved method that is based on fuzzy logic programming is required.

Method: Firstly, common medical product types used in vestibules and household anti-epidemic products were identified and summarized into product sets. Then matching degree matrix was obtained by functional configuration decomposition and matching calculations. Secondly, experts were invited to evaluate the paired comparative probability matrices and linguistic variables, and the evaluation data were converted by trapezoidal membership functions, fuzzy numbers and the defuzzification method to obtain the usage probability values (PR) for product functions. Finally, the matching degree value (P) and the product function (PF) were calculated by adaptability measure formula, and product function, the adaptability factor and the adaptability (A) were obtained.

Results and Discussion: Our results show that the degree of adaptability of each product function in the product set from PF_1 to PF_{10} can be evaluated. Based on the principles of sorting of values from high to low, the top five PF ($n = 10$) for P value is PF_{10}, PF_5, PF_6, PF_8 and PF_1; The top five PF for P value is PF_2, PF_1, PF_3, PF_7 and PF_8; The top five PF for A value is PF_2(0.242), PF_1(0.232), PF_5(0.225), PF_8(0.222) and PF_3(0.221). These values allow us to summarize and draw visual charts according to the above data sorting mode. The higher the value of the product function, the more it can be prioritized for design development with functional cost savings, simplification or clustering.

Conclusion: This study proposes an adaptable design method based on fuzzy logic programming. The data results in this study can guide the development and programming of the vestibule anti-epidemic products. The higher adaptability value of a product function indicates that it is more capable of being simplified, clustered, and adapting to changes in the product set.

1. Introduction

Since 2019, coronavirus (COVID-19) has spread to many countries [1–3]. During the COVID-19 epidemic, "social distancing measures" is still recognized as the most effective approach [4–8] in the absence of any vaccine or treatment. Considering the epidemic situation, "home quarantine" was recommended as a preventive measure to protect both oneself and others by physically isolating the infected from communities and preventing second- and third-generation cases development [9]. "Self-quarantine" was originally proposed, namely COVID-19 infected individuals were prevented from contacting with others; eventually it evolved to that all public "stay at home" for quarantine as much as possible to prevent epidemic spread, regardless of a person with or without infected symptoms of COVID-19 [10].

Since 2020, the number of confirmed COVID-19 cases in China has been on a downward trend. The government has begun to coordinate epidemic prevention and control with economic social development efforts. China began to fully promote work and production resumption under the anti-epidemic normalization. The concept of "new normalization" is introduced and discussed by

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numerous social media posts, online newspapers, portals and forums, and academic platforms [11].

The "normalization" concept will eventually become a stable reality and normality state, influencing the future lives and work of the public. However, due to the sudden outbreak of the COVID-19 epidemic, the preparation in the households is not adequately made for home self-quarantine and residential spaces are not designed for epidemic prevention factors. As a result, anti-epidemic supplies are temporarily placed in specific locations in the house during the epidemic period; there is a lack of standard design patterns for placement and usage due to different types and conditions of residential spaces. Under the "COVID-19 anti-epidemic normalization" concept, the placement and usage of household anti-epidemic items need to be improved from the perspective of the long-term usage. As a connecting area with outdoor, the vestibule is an important separating part from outdoor with protective and purifying characteristics. In this study, the residential vestibule space is used as an important area for home epidemic prevention, and a design and development method is proposed, in which general household anti-epidemic products are combined with common products used in residential vestibules. Finally, epidemic prevention functions are integrated into houses to extend the usage time and application of anti-epidemic products. Besides, an improved adaptable design methodology is used for the design development of household anti-epidemic products at vestibules.

2. Literature review

2.1. Fuzzy theory

Previous method of evaluating usage probability or frequency of the product functions, which is predicted by specific information such as previous sales records and market research. Many decision-making methods, such as the Analytic Hierarchy Process (AHP), Elimination Et Choice Translating Reality (ELECTRE) and Borda count method, are based on paired comparative judgment matrix. In other words, these methods greatly rely on the decision maker's intuitive judgment to evaluate things that cannot be physically measured. With the decision maker's relevant knowledge and experience, the real situation could be reflected [12–14]. Since the usage probability of product functions is influenced by lifestyle and culture, there is randomness and fuzziness in PF usage. In usage probability of multiple products often is uncertain and imprecise. The use of fuzzy theory allows uncertain and subjective probabilities to be evaluated.

Fuzzy set theory, and probability theory are no substitutes, but they complement each other. Although fuzzy set theory has quite a number of "degrees of freedom" in the intersection and union operators, different kinds of fuzzy sets (membership functions), Probability theory is well-developed and uniquely defined in the operation and structure. Fuzzy set theory seems to be more adaptable to different contexts. This, of course, also implies the need to adapt the theory to a context if one wants it to be an appropriate modeling tool. Therefore, in this study, the paired comparison judgment matrix technique in the usage decision-making method is proposed and combined with fuzzy theory to obtain the usage probability value of PF through expert evaluation.

Linguistic variables, trapezoidal membership functions, and fuzzy sets of the probability are selected. Experts use the linguistic variable of the probability to evaluate, and then translate the values into fuzzy numbers, and finally defuzzification is carried out.

2.1.1. Linguistic variable

The linguistic variables provide a basis for dealing in a systematic fashion with systems that are too complex or too ill-defined to be amenable to analysis by conventional probability-based methods. The concept of a linguistic variable reflects the fact that most of human reasoning is approximate rather than exact, and that the values of variables in human discourse are usually expressed in words rather than numbers. Linguistic Variable takes words in the natural language as values, providing appropriate subjective judgment expressions. Linguistic Variable is used to process complex, unclear or ambiguous information to express the computable "Possibility" [15]. Since subjective expressions have a considerable degree of ambiguity, the fuzzy logical concept can be employed to describe the usage probability of product functions. Van Laarhoven and Pedrycz applied the fuzzy concept to paired comparison matrix in order to deal with subjectivity, inaccuracy and ambiguity in decision-makers' judgments [16]. Buckley used ladder fuzzy numbers transforming expert opinions into a fuzzy matrix [17]. Zimmerman proposed a classical set of "probabilistic" linguistic variables examples based on Zadeh's fuzzy logic and fuzzy probability, such as: {Almost impossible, Not very probable, Very probable, Almost certain} [18]. Halliwell proposed a linguistic Bayesian network method to measure the linguistic probability and fuzzy numbers, such as: {Impossible, Very unlikely, Nearly impossible, Quite unlikely, Even chance, Very likely, Quite likely, Nearly certain, Certain}20 [19]. Lower et al. proposed the probability affiliation function of the semantic variable for event occurrence and the use of degree adjective language expressions, like: {Extremely improbable, Very rare, Average, Probable, Frequent} [20], allowing assessors to use semantic vocabulary to judge the probability occurrence degree.

2.1.2. Trapezoidal membership functions

The trapezoidal membership functions is to solve the problem in uncertain environment. In the study shall characterize some transformation functions between the linguistic and numerical expression domains. Any linguistic label has its associated fuzzy number. In this study, the probability of product function (PF) usage is determined, the fuzzy set corresponding to the semantic variable is denoted using trapezoidal membership functions with parameters (*a, b, c, d*). As shown in Fig. 1, the positive trapezoidal fuzzy number is defined as $\tilde{N}$, and $\tilde{N} = (a, b, c, d)$, and its membership function [21] is defined by the following formula:

$$\mu_{\tilde{N}}(x)\begin{cases}0,\ (x \le a)\\ \dfrac{x-a}{a-b},\ (a < x \le b)\\ 1,\ (b < x \le c)\\ \dfrac{x-d}{c-d},\ (c < x \le d)\\ 0,\ (x > d)\end{cases} \tag{1}$$

According to the nature of trapezoidal membership functions and the expansion principle [22], it is assumed that there are two trapezoidal fuzzy numbers $\tilde{N}_1 = (a_1, b_1, c_1, d_1)$ and $\tilde{N}_2 = (a_2, b_2, c_2, d_2)$, which are calculated as follows:

$$\tilde{N}_1 \oplus \tilde{N}_2 = (a_1 + a_2, b_1 + b_2, c_1 + c_2, d_1 + d_2) \tag{2}$$

$$\tilde{N}_1 \otimes \tilde{N}_2 = (a_1 \times a_2, b_1 \times b_2, c_1 \times c_2, d_1 \times d_2) \tag{3}$$

The semantic variables and trapezoidal fuzzy numbers used in this study are shown in Table 1.

2.1.3. Defuzzification method

Delgado et al. defined a Linguistic-Numerical Transformation Function, which obtains a numerical value from a given label. The process of converting fuzzy numbers to clear values is called "Defuzzification" [23]. Therefore, the method of Defuzzification is the

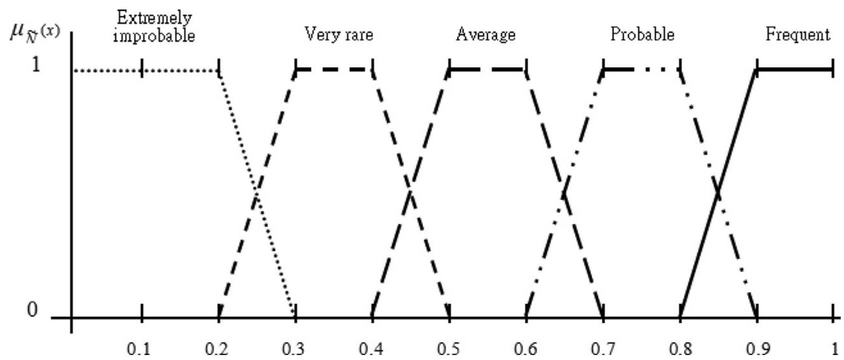

Fig. 1. Linguistic variable probability in logarithmic form.

Table 1
Linguistic variable and trapezoidal fuzzy number.

	Linguistic variable	Trapezoidal fuzzy numbers
L_1	Extremely improbable	0,0,0.2,0.3
L_2	Very rare	0.2,0.3,0.4,0.5
L_3	Average	0.4,0.5,0.6,0.7
L_4	probable	0.6,0.7,0.8,0.9
L_5	Frequent	0.8,0.9,1.0,1.0

value of a fuzzy number. From the overall perspective of a positive trapezoidal fuzzy number, the central part is the region expressing the best importance, and the fuzzy assessment value$\tilde{N}_{ij}$= (a_{ij}, b_{ij}, c_{ij}, d_{ij}) can be defuzzied (In terms of $R\tilde{N}_{ij}$) by the center-value method formula as follows:

$$R\tilde{N}_{ij} = \frac{(b_{ij} + c_{ij})}{2} + \frac{\left[(d_{ij} - c_{ij}) - (b_{ij} - a_{ij})\right]}{2} = \frac{a_{ij} + 2b_{ij} + 2c_{ij} + d_{ij}}{6} \quad (4)$$

2.2. Household anti-epidemic products recommendation

Home self-quarantine behaviors can effectively delay virus transmission [24,25]. Although COVID-19 transmission risk between individuals is much greater than that through surfaces, using cleaning products such as disinfectant wipes or disinfectant sprays to clean and disinfect high-frequency contacted surfaces at least once every day (even if you do not go outdoors) is recommended by the Center for Disease Control and Prevention (CDC) [26]. The recommendations of anti-epidemic products proposed by World Health Organization's (WHO) are as follows: (1) clean hands regularly and thoroughly with alcohol-based hand sanitizer, or wash hands with soap and water; (2) avoid contact with eyes, nose and mouth; (3) ensure that the public around a particular individual maintain good respiratory hygiene; (4) seek medical attention if the individual suffer from any fever, cough, and difficulty breathing, call in advance if possible and follow the instructions of local health authorities. Household anti-epidemic products [9] include thermometers, disposable medical masks, medical-surgical masks or N95/KN95 masks, and household disinfection products, etc.

This study presents the definition of household anti-epidemic products. Firstly, according to the recommendations of anti-epidemic products proposed by World Health Organization's (WHO) and Center for Disease Control and Prevention (CDC). Secondly, obtain data of Product selection through online survey. Finally, Major household anti-epidemic products were analyzed by the Chi-Square test.

2.3. Residential vestibule

In practice, residential space usage is defined by resident preferences [27]. It is not just a structure but a space created for a set of complex purposes [28]. With the change of cultural values and practices, the psychological needs and the residential function are changing [29]. Abercrombie believes that an architecture entrance is both a physical and psychological turning point, which brings out people's memory of indoor and outdoor environment here, and the psychological expectations based on this memory [30]. The East Asian traditional residential entrance is a transitional area between indoor and outdoor, generally known as the vestibule in China [31], "Genkan" in Japan, and "Hyun-gwan" in Korea [32]. After the introduction of Western architectural forms into China in the 19th century, vestibule space in modern Chinese houses remains the progressive concept of barrier and protection. Besides, influenced by Japanese Genkan the additional purifying function, vestibule functions that blend Eastern and Western living styles are gradually developed.

At present, functionality is more emphasized by vestibule, and vestibule is connected with purification rituals to remove "impurities from outdoor". For example, before entering vestibule, you may need to remove your shoes, jacket and hat, making sure the clothes are neat and tidy. Therefore, the selected product is related to concept of barrier, taking off shoes and clothes.

2.4. Adaptable design

Adaptable design was proposed by Gu for efficient and effective products design for functionality, manufacturing, customization and environment. Adaptable design is a design model that balances economic and environmental benefits. The basic idea of adaptable design is to design products with adaptability to meet new demands, or to reuse products and designs as the environment changes, and adaptability is defined as an extension of the product's utility (service) [33]. The principle of existing solutions remain essentially unchanged, and local changes are made to existing products to extend the product life or to expand products' applications. "Adaptable design" achieves "saving" by adapting and reusing existing products based on their functionality, and comparative analysis in the design decision process can be made in a quantifiable way along with other design criteria. Adaptable design includes both design adaptability and product adaptability. Design adaptability aims at reusing the same "design" for the creation of different products. Product adaptability refers to the ability of a product to be adapted to various usages or capabilities.

Sand and Gu developed modular and upgraded planning methods for the adaptable design, and applied them by examples [34]. Fletcher et al. proposed a quantitative calculation method for adaptability [35]. Xu et al. proposed an adaptable redesign and improved the metrics by quantifying the structural similarity and performance brought by adaptable design [36]. Since the adaptable design theory concept was proposed, many adaptable design methods and applications have been further developed and improved in the past decade [37]. To quantitatively evaluate the resource-saving effect of product platform design, Chen et al. proposed an adaptability-oriented parametric product platform construction method [38]. Based on the similarity analysis, Chen et al. combined the information entropy concept with the product modularity principle, and proposed an improved adaptability calculation using the adaptable information entropy function to characterize the product boom complexity and uncertainty [39].

Adaptable design method is the process of “adapting” an existing design, usually results in savings in development time, design and production costs. If the product itself is adaptable, it benefits the user by replacing several products with one or by providing more functionalities. In any case, there are also environmental benefits based on the fact that adaptable design encourages the reuse of existing entities. The adaptable design is often used for discrete products. Since vestibule anti-epidemic products consist of multiple sub-products, each sub-product is independent and related to each other, and has the characteristics of discrete products, it is suitable to use the adaptable design method for design and development. In order to integrate anti-epidemic products into the vestibule, while reducing the cost and time of design development and extending the life cycle of the products, and thus, they are able to adapt to the changes in the COVID-19 anti-epidemic normalization and the social environment.

3. Methodology

3.1. Research process

Firstly, the recommendations for household epidemic prevention and the characteristics of residential vestibules are explored through the literature review in this study. Then a combination of literature and questionnaires is used to summarize the categories of household anti-epidemic supplies and products commonly used in the vestibule, and the two product categories are aggregated into a target adaptable set. Secondly, the functional configuration of each product is then separated one by one. Finally, the adaptability metric is then carried out, and adaptable design applications are developed based on the adaptability value level of the PF (Fig. 2).

3.2. Survey design

A survey was designed based on WHO, CDC and expert recommendations for anti-epidemic, combined with a focus group approach to further identify acceptable household anti-epidemic products for families. Focus groups are becoming increasingly popular in health research for exploring what individuals believe or feel as well as why they behave in the way they do.It can be used to understand, and explain, the meanings, beliefs and cultures that influence the feelings, attitudes and behaviours of individuals. Properly conducted focus groups are not necessarily inexpensive; unless one is in the business of conducting and analyzing focus groups, the time saved in interviewing may be lost in recruitment, logistics, and trying to make sense out of data that are complex and messy. Krueger and Casey suggested that focus groups can be used to assess demands and assets, develop social marketing efforts, pilot-test ideas and products, and evaluate services or programs [40]. Group members linked their experiences and reflection, and some common reference frames may emerge among members [41]. The number of focus group members is usually 5–8, as smaller groups show greater potential [40]. Eight criteria for focus groups work based on Krueger’s research was proposed by Rabiee [42], serving as the main basis for the implementation of the focus group approach in this study. Eight criteria are as follows: Words, Context, Internal Consistency, Frequency, Intensity of comments, Specificity of Responses, Extensiveness, and Big picture.

The focus groups consists of members ($n = 6$) with design-based backgrounds including Health attendant, Medical product engineer, Medical doctor, Nurse and Medical trainee (Table 2). The purpose was to discuss the influencing factors of "household anti-epidemic" from multiple perspectives, so as to develop a questionnaire.

After three rounds of discussion, a consensus was reached as follows: factors such as family members, living conditions, knowledge of epidemic prevention information, disinfection habits and acceptable cost of epidemic prevention have a great influence on household epidemic prevention. Therefore, a questionnaire on "household anti-epidemic condition" was drafted in four parts including " participants’ personal information", "knowledge of epidemic prevention", "household epidemic prevention habits" and " household anti-epidemic products consumption". Besides, the descriptive language was used to make it easier for participants to make judgments based on their actual situations. Through the "Questionnaire Star" software, the online survey was conducted between April 1 and May 4, 2020.

3.3. Adaptability measure

Based on the adaptable design theory proposed by Gu [33], an improved adaptability measure is developed by combining the paired comparison matrix technique and fuzzy theory in this study. The formula for matching adaptability factors to product functionality is as follows:

$$\mathrm{AF}(Tpi) = pr\left(\mathrm{PF_i}\middle|\mathrm{PF_j}\right)\cdot p\left(\mathrm{PF_i}\middle|\mathrm{PF_j}\right) = pr\left(\mathrm{PF_i}\middle|\mathrm{PF_j}\right)\cdot\frac{Inf\left(\mathrm{PF_i}\cap\mathrm{PF_j}\right)}{Inf(\mathrm{PF_i})} \tag{5}$$

$$\mathrm{P}(Tpi) = \sum_{i=1}^{n} p\left(\mathrm{PF_i}\middle|\mathrm{PF_j}\right) = \sum_{i=1}^{n}\frac{Inf\left(\mathrm{PF_i}\cap\mathrm{PF_j}\right)}{Inf(\mathrm{PF_i})} \tag{6}$$

In Eq. (5), Tp=$PF_i|PF_j$ denotes a Tp, PF denotes a product function unit with a functional configuration set, and Tp is the conversion of the product from PF_j to PF_i through an adaptable process. p ($PF_i|PF_j$) denotes the functional configuration matching degree when converting PF_j is converted to PF_i through an adaptable process. pr ($PF_i|PF_j$) denotes PFi usage probability when users have PF_j, and is the weighted value for the functional configuration matching degree. As the adaptability factor (AF) of Tp, AF (Tpi) is defined as the degree of adaptable conversion from PF_j into PFi, i.e. the product of PFi matching degree and PF_i usage probability. Note that p denotes the functional configuration matching degree when converting PF_j is converted to PF_i through an adaptable process. P is the summed average of the column entries in the P_{Tp} matrix.

In Eq. (6), $PF_i \cap PF_j$ represents the PF_i and PF_j shared functional configurations set; Inf ($PF_i \cap PF_j$) represents the sum of generalized costs of PF_i and PF_j shared functional configurations set, i.e. the resources sum consumed by shared functional configurations set; these shared configurations cost is preserved during the PF_j to PF_i conversion; Inf (PF_i) represents the sum of broad costs of all functional configurations of PF_i, i.e. the sum of resources consumed in designing the product.

AF (Tpi)=AF ($PF_i|PF_j$) indicates that the adaptable capacity of PF_i to become PF_j. Similarities in function or constraints between PF_i and PF_j can be one or more. The adaptability factor (AF) has a value range of [0, 1]. If AF = 0, then PF_i has no common part

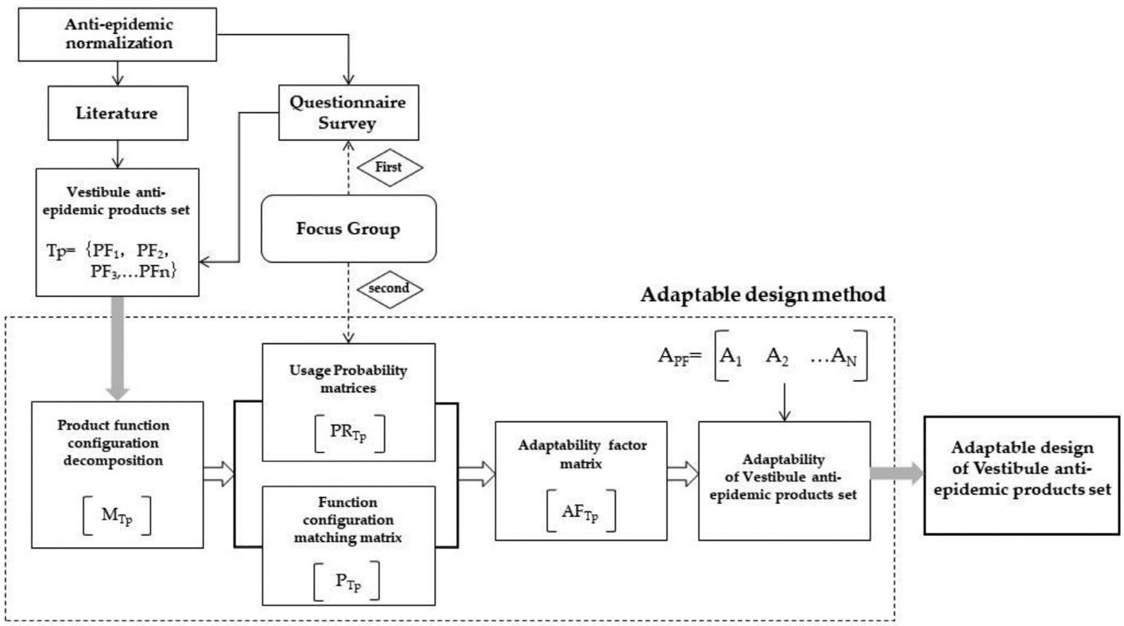

Fig. 2. Fuzzy logic based adaptable design process of vestibule anti-epidemic products.

Table 2
Profile of focus group members.

Member	Gender	Education	Professional background	Years of working
A	Male	Postgraduate	Medical product engineer	11
B	Male	Postgraduate	Medical product engineer	10
C	Female	Postgraduate	Health attendant	6
D	Female	Postgraduate	Medical doctor	6
E	Female	Postgraduate	Nurse	5
F	Female	Postgraduate	Medical trainee	3

at all and the PF_j and the PF_i cannot be reused by modifying the PF_j; if 0<AF<1, PF_i and PF_j have common parts, and partial PF_i can be reused in PF_j through modification; if AF=1, PF_i and PF_j are the same, and no modification is needed.

The summed average of the adaptability factors for each PF_j transformed into a PF_i within the Tp is the adaptability for each PF_i, given by the following formula:

$$A(PF_i) = \frac{1}{n}\sum_{i=1}^{n} pr\left(PF_i|PF_j\right)\frac{Inf\left(PF_i \cap PF_j\right)}{Inf(PF_i)} \quad (7)$$

In Eq. (7), A (PF_i) denotes the PF_i adaptability, the larger the value, the better the adaptability of the PF_i.

The “vestibule anti-epidemic products set” mentioned in the literature and collected in the questionnaire was defined as “Target Adaptable Set”, and then adaptability measurement was conducted. The specific steps are as follows:

1. Definition of adaptable design objectives and products: the types of products commonly used in the vestibule and household anti-epidemic products are determined according to customers’ demands.
2. Solution planning for product function configuration: Customers’ requirements are matched with corresponding functions to determine the main functions and restraints of target products, and functional configuration is established through case studies.
3. Commonality check of the functional configuration: compare and analyze the commonalities between "product functions", including the similarities between functions and usage states. The determination of these commonalities can be used to develop shared or clustered content for new product designs.
4. Judgment of the product usage probability: based on the expert evaluation method, the usage probability of "product functions" with each other is judged to get usage frequency of each product in the whole system, which is as the weight of the common functions for the function configuration.
5. Adaptability measurement and design: the adaptability value of the " vestibule anti-epidemic products set" is calculated, and the results are ranked according to the adaptability degree. The "product function" which should be prioritized for adaptable design is determined to save costs and adapt to demand.

3.4. PF configuration analysis

Literature and questionnaires were used to obtain basic types of vestibule products and household anti-epidemic products, as the basis for establishing the image relationship between products and functions. A function-based design process model was developed, which was derived from a process model similar to the Axiomatic Design proposed by Suh [37]. Axiomatic design categorizes design activities into customer domain, functional domain, physical domain and process domain, which provides a framework for mapping between the function-structure of a product, and parametric techniques, which combine to provide a model for rapid product design. In this study, the function and anti-epidemic requirements of a residential vestibule correspond to Customer Domain, the required product types correspond to the Functional Domain, and the function configuration consisting of numerous functions and constraints corresponds to Physical Domain. The function configuration expression is defined as a functional structure consisting of matter, energy, and signal [43,44]. The transfer of matter, en-

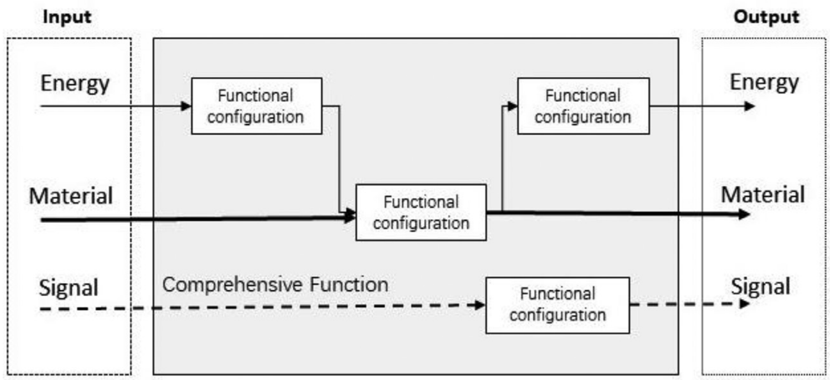

Fig. 3. Functional configuration decomposition of product.

ergy and signal of a product is an inherent property of its physical functions, which is used to identify the product's operational activities and utilities, and the function is achieved through its physical structure [45]. Fig. 3 shows the functional configuration decomposition of Product.

3.5. Assessment of usage probability of product functions

In Eqs. (5) and (7), *pr* ($PF_i|PF_j$) is the usage probability or frequency of the product functions, which is predicted by specific information such as previous sales records and market research. In this study, the usage probability of product functions is expressed as the probability of needing PF_i when using PF_j, however, the usage probability of the vestibule anti-epidemic product functions is difficult to be predicted by this method. Therefore, The usage probability of a product is obtained by comparing pairs of products and is suitable for the use of the paired comparison judgment matrix technique. Many unmeasurable objects or phenomena can be understood and judged with a precise and reliable relative scale, which can be ensured by integrating the experience of several experts.

A focus group of experts was formed to assess the usage probability of vestibule anti-epidemic product functions. Since the study involved the requirements of household usage and epidemic prevention measures, 13 experts with professional and technical experience in design and health care were gathered, ensuring the relative high validity of the assessment results for the interoperability probability of product functions. Group discussion was performed to promote the consensus of judgment, ensuring the high confidence of the results. Moreover, the consensus of judgment was promoted with high results reliability. In the group discussion, the purpose and content of this study were introduced, the evaluation method was explained, as well as the product functions, usage scenarios and states. After discussion, the assessment was carried out using probabilistic semantic variables and paired comparison matrixes, and the assessment probability value was combined with fuzzy theory to obtain the probability value of PF usage in the end.

The values of usage probability assessments for product functions were transformed into a matrix of probabilistic semantic variables, and then transformed into fuzzy probabilities, as shown in Table 1. The geometric mean algorithm was used to synthesize 13 experts' fuzzy probability matrix Eq. (8). and finally the central value method (Eq. (7)) was used to obtain the probability judgment value $R\tilde{N}_{ij}$ for defuzzification. In this study, $R\tilde{N}_{ij}$ is used instead of *pr* ($PF_i|PF_j$) to obtain the likelihood of defuzzification of the usage probability for vestibule anti-epidemic products. Where $\tilde{\tilde{N}}_{PR}$ is the fuzzy probability matrix for integrating the *k*th member; $\tilde{N}^{k}_{PR}$ is the fuzzy probability matrix evaluated by the *k*th member; and *k* is the number of members.

$$\tilde{\tilde{N}}_{PR} = \sqrt[k]{\tilde{N}^{1}_{PR} \otimes \tilde{N}^{2}_{PR} \otimes \tilde{N}^{3}_{PR} \otimes \cdots \otimes \tilde{N}^{k}_{PR}} \tag{8}$$

Table 3
Participants basic information.

Question	Options and data				
Age (Years)	Under 18	19–20	21–30	31–40	Above 40
	22 (10.23%)	51 (23.72%)	74 (34.42%)	24 (11.16%)	44 (20.47%)
Gender	Male 57 (26.51%)			Female 158 (73.49%)	

4. Results

4.1. Survey consolidation and outcome analysis

In the context of China, the main participants of this Survey were concentrated in Fujian (37.21%) and Jiangsu (24.19%), followed by Beijing (5.58%) and Zhejiang (5.12%). Because the epidemic was stabilized earlier in Jiangsu and Fujian, and also the work and production resumption started earlier, thereby giving respondents in both regions a higher level of understanding of the normalization of the epidemic. 215 participants were involved, among which 204 completed it. The majority of the respondents were between 19 and 30 years old (58.14%), with the majority of the female, and their basic information is shown in Table 3.

More participants have selected "Simple disinfection before entering the house" (53.14%). 50.86% of participants were disinfected for 5–10 min daily and 42.29% were willing to disinfect once a day. In contrast, 40% were willing to disinfect 2–3 times a week. Participants' price acceptance range for household anti-epidemic products was more likely to be within 60 USD, and more households during the survey period have spent between 30 and 60 USD (32.09%), followed by 90–150 USD (27.44%), as shown in Table A1.

In summary, more women than men have participated in the questionnaire survey, lived with their elders in three-bedroom houses, known more about personal epidemic prevention measures, and paid more attention to the daily epidemic changes in the city. Most participants have simple disinfection behaviors at the door side when entering houses, and are willing to spend 5–10 min for disinfecting once daily or 2–3 times a week. There is also a consensus among the participants that three main types of products should be available at home: masks, disinfectants and thermometers. Chi-square test was conducted for gender using software (Fig. 4). The results show that there is no significant difference between men and women in the question of nec-

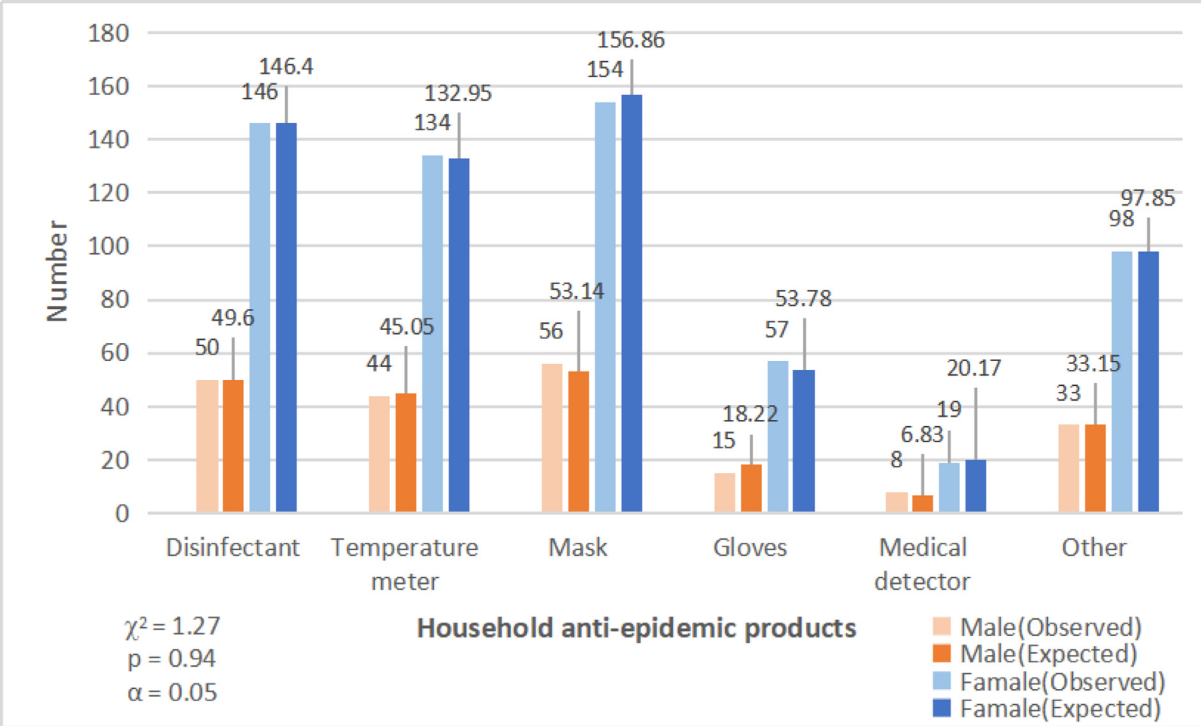

Fig. 4. Chi-square Test for gender about household anti-epidemic products.

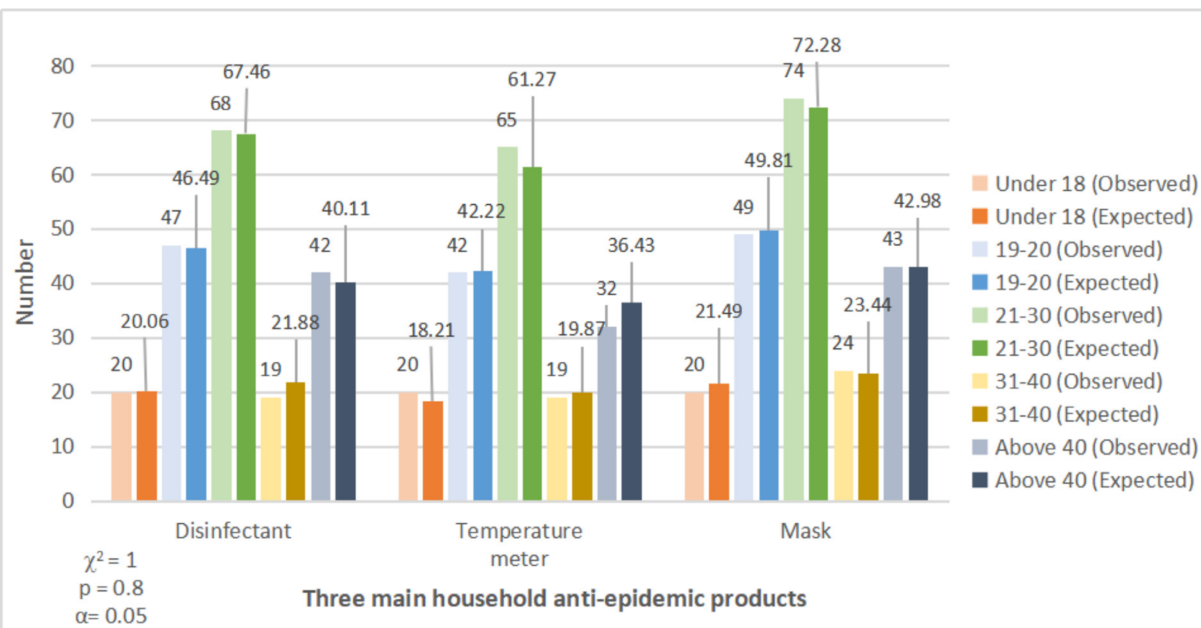

Fig. 5. Chi-square Test for age about three main household anti-epidemic products.

essary anti-epidemic products stocking at home ($\chi^2 = 1.27$, $p=$ (0.937>0.05); in addition, Chi-square test of different ages reveals that there is a significant difference between ages in the question of the necessary anti-epidemic products stocking at home ($\chi^2 = 19.56$, $p=$ (0.001 < 0.05). However, after performing a Chi-square test for different ages for the three generally accepted types of anti-epidemic products, it is learned that there is no significant difference ($\chi^2 = 1.00$, $p = 0.80>0.05$) (Fig. 5). In order to test for differences in the types of household anti-epidemic products demanded by different genders and ages. If there are no differences, this indicates that the subjects have a consensus on the choice of household anti-epidemic products. By comparing the price acceptance of anti-epidemic products with the current spending of households on that, it can be judged that most of them can accept less than 60 USD.

4.2. Functional configuration for vestibule anti-epidemic products

Vestibule anti-epidemic products based on the literature and recommendations of experts (WHO and CDC), a commonly used and inexpensive product was chosen as the prototype for this study. The main household anti-epidemic demands are as follows:

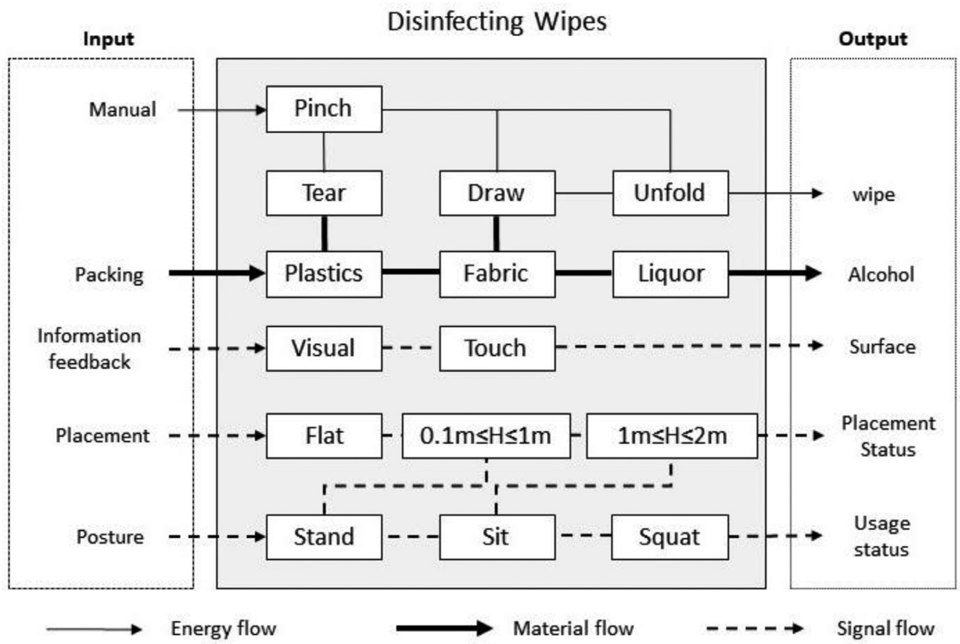

Fig. 6. Functional configuration of disinfectant wipes.

hand cleaning and disinfection, cleaning and disinfection of frequently contacted surfaces, respiratory hygiene, close attention to symptoms such as fever, and maintaining social distance. Corresponding to anti-epidemic demands, the items are disinfectants, masks and thermometers. The disinfectants include products derived from disinfectant wipes and disinfectant sprays, and thermometers are the common handheld infrared ones (Table A2).

Based on the literature [31,32], the basic functional needs of the vestibule include: removal of shoes, coats and hats, social interaction between hosts and guests, and space blocking. Common products corresponding to the vestibule functions are: shoe cabinets, shoe pullers, shoe changing stools, coat racks, doorbells, and partitions (Table A2).

Product is originally a single entity, but in this study, product is defined as a product function (PF) that consists of multiple functional configurations. Since it was known from the survey that affordable and practical anti-epidemic products are more popular, 10 vestibule anti-epidemic products (Tables A3 and A4) are defined as Tp, and each product was defined as product functional Unit (PF) in this study. Based on the principle of basic (essential) functional requirements, the corresponding product prototypes are selected from the market and the functional separation is carried out in terms of energy, matter and information. Fig. 6 shows the functional configuration structure of the disinfectant wipes. This is an abstract and direct way to translate requirements into functional configurations, and the remaining nine products are constructed by this method to perform the adaptability measurement.

The configuration construction of PF is conducted by two steps: (1) decompose the elements or constraints that constitute the PF, and (2) express them in common terms. Multiple PFs can be decomposed through configuration analysis into configurations consisting of energy, matter, and signal. But since each PF is different, the described configurations also differ. Therefore, describing similar types of configurations using common words allows for easy consistency, quantitative analysis and comparison of PF configuration expressions. As a result, the consistency of functional description is ensured, and the easy design analysis and quantification are realized. Meanwhile, different types of product functions can be compared to find the similarity of design concepts from the essence. Common words are used to express the configuration and draw a functional configuration matrix. The amount of configuration information is expressed as the numbers "0″ and "1″. "0″ indicates that PF does not have this configuration, while "1″ indicates that the PF has this configuration (Table A5).

4.3. Functional configuration matching analysis

According to the Table A5, Eq. (6) is applied to calculate the matching degree between the functions of each product. After calculation, the matching degree matrix P (Tp) is obtained. From the table, we can see that "PF_1″ is disinfectant wipes, PF_1={$Pinch_1$, $Draw_1$, $Unfold_1$, $Press_1$, $Cloth_1$, $Plastic_1$, $Liquid_1$, $Stand_1$, Sit_1, $Squat_1$, $0.1m \le H \le 1m_1$, $1m \le H \le 2m_1$, $Flat_1$, $Visual_1$, $Tactile_1$}; "PF_2″ is disinfectant spray, PF_2 = $Hydraulic_2$, $Pneumatic_2$, $Pull_2$, $Press_2$, $Grip_2$, $Plastic_2$, $Liquid_2$, $Stand_2$, Sit_2, $Squat_2$, $0.1m \le H \le 1m_2$, $1m \le H \le 2m_2$, $Flat_2$, $Standing_2$, $Visual_2$, $Tactile_2$}. The *p*-values of "PF_1″ and "PF_2″ are derived and calculated as follows:

$$p\left(PF_1\overline{)PF_2}\right) = \frac{Inf(PF_1 \cap PF_2)}{Inf(PF_1)} = \frac{10}{15} = 0.67. \quad (9)$$

Table 4 shows the function match matrix for the 10 product categories, indicating the matching degree between PF_j and PF_i when "PF_j" is adaptable transformed into "PF_i". The higher value, the better match of the functional configuration. P is the summed average of the column entries in the matrix, A higher value indicates a higher similarity that the PF is to other PF in this set. P is between 0.51 and 0.64, and the larger the value, the more appropriate the matching of PFj to the functional configuration of PFi. It can be seen that the functional configurations of the products for different applications match each other differently. For example, p-value is 0.67 if PF2 (disinfectant spray) is converted to PF1 (disinfectant wipes), but p-value is 0.63 for the conversion of PF1 to PF2. It indicates that the functional configuration of the disinfectant spray can be more adaptable when converted to disinfectant wipes.

4.4. Evaluation of the usage probability

When hand sanitizing, it is necessary to obtain the antiseptic wipes or disinfectant spray from a shoe drawer, or retrieve them

Table 4
Results of p ($PF_i|PF_j$)(P_{Tp}).

No.		PFi									
		1 DW	2 DS	3 M	4 TM	5 SS	6 SH	7 SC	8 CR	9 D	10 S
PFj	**1 DW**	1.00	0.63	0.73	0.61	0.50	0.53	0.47	0.47	0.50	0.57
	2 DS	0.67	1.00	0.53	0.56	0.60	0.60	0.53	0.67	0.40	0.64
	3 M	0.73	0.50	1.00	0.56	0.40	0.67	0.53	0.53	0.40	0.50
	4 TM	0.73	0.63	0.67	1.00	0.60	0.67	0.59	0.60	0.80	0.64
	5 SS	0.33	0.38	0.27	0.33	1.00	0.60	0.41	0.53	0.20	0.50
	6 SH	0.53	0.56	0.67	0.56	0.90	1.00	0.53	0.73	0.50	0.71
	7 SC	0.53	0.56	0.60	0.56	0.70	0.60	1.00	0.87	0.50	0.79
	8 CR	0.47	0.63	0.53	0.50	0.80	0.73	0.76	1.00	0.40	0.79
	9 D	0.33	0.25	0.27	0.44	0.20	0.33	0.29	0.27	1.00	0.29
	10 S	0.53	0.56	0.47	0.50	0.70	0.67	0.65	0.73	0.40	1.00
	P	0.59	0.57	0.57	0.56	0.64	0.64	0.58	0.64	0.51	0.64

Table 5
Results of pr ($PF_i|PF_j$)(PR_{Tp}).

No.		PFi									
		1 DW	2 DS	3 M	4 TM	5 SS	6 SH	7 SC	8 CR	9 D	10 S
PFj	**1 DW**	1.00	0.56	0.27	0.22	0.20	0.19	0.27	0.20	0.25	0.19
	2 DS	0.56	1.00	0.60	0.21	0.19	0.19	0.23	0.21	0.26	0.23
	3 M	0.27	0.60	1.00	0.24	0.16	0.16	0.23	0.21	0.19	0.18
	4 TM	0.22	0.21	0.24	1.00	0.19	0.16	0.19	0.21	0.18	0.16
	5 SS	0.20	0.19	0.16	0.19	1.00	0.27	0.29	0.27	0.19	0.21
	6 SH	0.19	0.19	0.16	0.16	0.27	1.00	0.28	0.23	0.17	0.18
	7 SC	0.27	0.23	0.23	0.19	0.29	0.28	1.00	0.26	0.20	0.23
	8 CR	0.20	0.21	0.21	0.21	0.27	0.23	0.26	1.00	0.18	0.23
	9 D	0.25	0.26	0.19	0.18	0.19	0.17	0.20	0.18	1.00	0.21
	10 S	0.19	0.23	0.18	0.16	0.21	0.18	0.23	0.23	0.21	1.00
	PR	0.33	0.37	0.32	0.28	0.30	0.28	0.32	0.30	0.28	0.28

while sitting on a shoe changing stool. Hence, there is a usage correlation between the need for hand sanitizing and the use of multiple products. In this study, a paired comparison matrix of product functions is used to evaluate usage probability through the re-use of focus groups. The group consists of 13 experts in both Design, Engineering, Medical and Health care fields with years of experience in practice, research and education (Table A6). Firstly, experts with experience in vaccination work are selected. Secondly, focus groups are used so that the experts have a good understanding of the problem, and finally, multiple discussions are held before making an assessment.

The focus group discussion was conducted in the context of the anti-epidemic normalization in family life, focusing on prevention and maintenance of personal hygiene and safety in thoughts and behaviors. Group members were asked to make initial judgments based on their professional experience. Usage probability semantic variable (Table 1) determines the likelihood (probability) that "PF_i" will be used when "PF_j" is used. Instead of probabilistic semantic variables, members make assessments using values of "1,2,3,4,5″ to express the probability. For example, when "PF_j" is used, the need to use "PF_i" is straightforward and frequent, the number "5″ is used; when the needing is average, “3″ is used; when it is extremely improbable to be used at all, "1″ is used. After group discussion and evaluation, there were 45 paired comparisons with a Cronbach α coefficient = 0.965, indicating the high quality of the study data confidence level. After analyzing the variation degree assessed by members, the standard deviation was found to be between 0.73 and 1.58, with a standard deviation < 1. There were 16 comparisons and 29 comparisons with standard deviations ≥ 1 (Table A7).

The values of usage probability assessments for product functions were transformed into a matrix of probabilistic semantic variables, and then transformed into fuzzy probabilities (Table 1). The geometric mean algorithm is less influenced by extreme values, so it is reasonable to use this method to respect the views of the experts and synthesize their assessments hierarchically. The geometric mean algorithm was used to synthesize 13 experts' fuzzy probability matrix Eq. (8), and finally the Eq. (4) was used to obtain the probability judgment value $R\tilde{N}_{ij}$ for defuzzification. In this study, $R\tilde{N}_{ij}$ is used instead of pr ($PF_i|PF_j$) to obtain the likelihood of defuzzification of the usage probability matrix PR_{Tp} (Table 5) for vestibule anti-epidemic products. Finally, PR is the summed average of the column entries in the matrix. The PR value of "PF" is 0.28–0.37. A higher value indicates a higher probability that the PF will be used in the set.

4.5. Adaptability of vestibule anti-epidemic products

According to Eq. (5), the adaptability factor AF ($PF_i|PF_j$) is the product of product function usage probability pr ($PF_i|PF_j$) and the matching degree p ($PF_i|PF_j$). In this study, pr ($PF_i|PF_j$) is replaced with the probability judgment value of defuzzification, so $AF(PF_1)$ is calculated as in Eq. (10). AF_{Tp} matrix is derived (Table 6), from which the adaptability factor of the target adaptable set is known, and the higher value indicates the higher feasibility when PF_j is transformed or clustered into PF_i. According to Eq. (7), the adaptability A (PF_i) is 0.18–0.24, the higher the value, the higher the adaptability of PF.

$$AF(PF_1) = R\tilde{N}_{12} \cdot \frac{Inf(PF_1 \cap PF_2)}{Inf(PF_1)} = 0.93 \times 0.5 = 0.47 \quad (10)$$

The highest value of adaptability in the set is PF2 (A = 0.24) and the lowest probability is PF9 (A = 0.18).

Table 6
Results of AF (AF_{Tp}).

No.		PF_i									
		1 DW	2 DS	3 M	4 TM	5 SS	6 SH	7 SC	8 CR	9 D	10 S
PF_j	**1 DW**	1.00	0.35	0.20	0.13	0.10	0.10	0.13	0.09	0.13	0.11
	2 DS	0.37	1.00	0.32	0.12	0.11	0.11	0.12	0.14	0.11	0.15
	3 M	0.20	0.30	1.00	0.14	0.07	0.11	0.12	0.11	0.07	0.09
	4 TM	0.16	0.13	0.16	1.00	0.11	0.11	0.11	0.13	0.15	0.11
	5 SS	0.07	0.07	0.04	0.06	1.00	0.16	0.12	0.14	0.04	0.10
	6 SH	0.10	0.10	0.11	0.09	0.24	1.00	0.15	0.17	0.09	0.13
	7 SC	0.14	0.13	0.14	0.11	0.21	0.17	1.00	0.22	0.10	0.18
	8 CR	0.09	0.13	0.11	0.11	0.22	0.17	0.20	1.00	0.07	0.18
	9 D	0.08	0.07	0.05	0.08	0.04	0.06	0.06	0.05	1.00	0.06
	10 S	0.10	0.13	0.09	0.08	0.15	0.12	0.15	0.17	0.08	1.00
	A	0.23	0.24	0.22	0.19	0.22	0.21	0.22	0.22	0.18	0.21

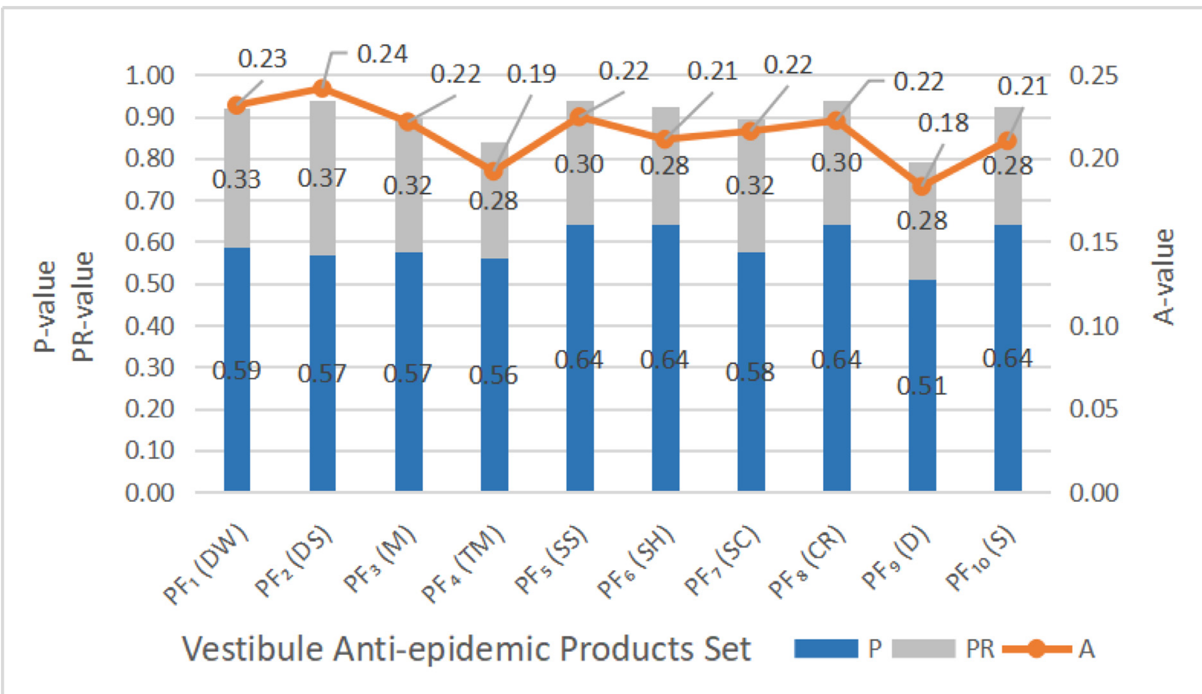

Fig. 7. Results of Adaptability (A), Probability (PR) and Matching degree (P).

5. Discussion

In this study, the functional decomposition of matter, energy and information in the product is based on the input and output case, and the matching degree *p*-value is calculated based on the segmentation of functional configuration, and the product functional matching degree matrix (P_{Tp}) is obtained. The usage probability of product functions in space is a rather vague concept, and there are independence and connectedness in various product usage. To accurately explore the interconnectedness of product use, a focus group approach is proposed by the paired comparison matrix technique in this study to assess PF usage probability. Subsequently, a focus group approach is combined with fuzzy theory to obtain more accurate probability values and matrices of product use. Finally, the probability matrix and the matching degree matrix are multiplied to obtain the Adaptable Factor Matrix (AF_{Tp}), and adaptability A values (Fig. 7). If the functional configuration between all products in the set is the same ($p = 1$) and the usage probability is also the highest value (pr=1), then AF=1, the ideal maximum A value for the set should be 10. However, the highest A value in the set of actual product functions is 0.24, which is a large difference from the ideal maximum A value, indicating that the similarity of the product functional configurations in a set and their mutual use are not strong. Since the relative adaptability values among the products are mainly investigated in this study, the higher A value of a product indicates that it is more capable of being simplified, clustered, and adapting to changes in the set.

Based on adaptability (A) values, prioritized product functions for simplifying or clustering in design thinking can be determined by a comparative analysis. The most adaptable one in this set is PF_2, followed by PF_1, and the third ones are PF_3, PF_5, PF_7 and PF_8, indicating that they are simplified or clustered with other products to a high degree. Therefore, disinfectant sprays can be prioritized for adaptable design development.

6. Conclusion

This study is based on Chinese households and respondents, but the vestibule anti-epidemic products selected are internationally available. The fuzzy logic programming and adaptable design method proposed in this study are not limited by regions and can be applied to other countries and regions.

Previous research on adaptable design methods has been applied to single products, modular products, and product families. In this study, an adaptable measure of products set within a specific functional space is innovatively proposed and a new method for assessing the functional product usage probability is introduced. Besides, focus group method was used twice: (1) the first use for discussing and developing a questionnaire on the "household anti-epidemic state"; designers, researchers and educators with design backgrounds were involved to generate additional concepts; (2) the second use for improving the assessment of PF usage probability in the adaptability metric; experts from design and health care backgrounds were involved to obtain accurate and broad-valued probability results. However, the results produced by the focus group method are limited by the professional background, experience and cultural factors of the members.

Since the adaptable design method in this study is based on the existing products and requirements, reuse of the existing product functional configurations for developing new designs, there are some limitations on the presumption of new product functional development. Moreover, in the calculation of the adaptability degree, a detailed degree of decomposition for product functional configuration will affect the adaptability degree and design development. The adaptable design in this study is aimed at design adaptability. Therefore, considering that specific physical parameters can constrain the diversity and possibilities of design thinking, the PF configuration analysis is not refined to specific physical parameters in order for the results to guide design ideas and make the product more creative. Based on the basic configuration and product functions usage probability, physical attributes such as quantity, size, and form corresponding to the functional configuration are not evaluated. In future studies, product parameters can be refined and Taguchi methods can be used to conduct product optimization design through the experimental process.

Declaration of Competing Interest

The authors declare that there is no conflict of interests.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.cmpb.2020.105762.

Table A1
Household anti-epidemic habits and consumption.

Question	Options and data				
Because of the epidemic, what are the habits of disinfection at home?	Simple disinfection before entering the house 53.14%	Regular simple disinfection of household items will be carried out 33.71%			Forget it after the epidemic 13.15%
How much disinfection time would you like to accept?	Less than 5 min	5–10 min	10–30 min		More than 30 min
	25.14%	50.86%	19.43%		4.57%
What is the frequency of disinfection?	Once a day	2–3 times a week	1 times per week		2–3 times a month
	42.29%	40%	13.14%	4.57%	
How much do you accept for home epidemic prevention products? (USD)	0–30	30–60	60–90	90–150	More than 150
	30.23%	31.63%	18.6%	10.7%	8.84%
How much have families spent on Epidemic prevention products so far? (USD)	0–30	30–60	60–90	90–150	More than 150
	17.67%	32.09%	27.44%	18.6%	4.19%

Table A2
Household anti-epidemic products and common products in the vestibule.

The main needs of family epidemic prevention	Household anti-epidemic products			
	Disinfecting wipes	Disinfectant sprays	Mask	Temperature meter
Clean and disinfect hands	√	√		
Disinfecting the areas that are hot-spots for germs	√	√		
Respiratory health			√	
Pay close attention to fever and other symptoms				√

Basic functional requirements of the vestibule	Common products in the vestibule					
	Shoes changing stool	Shoehorn	Shoe cabinet	Coat rack	Doorbell	Screen
Changing the shoes	√	√				
Storage of shoes			√			
Take off your coat and hat				√		
Host/guest social interaction					√	
Space separation						√

√:That means the two are related.

Table A3
Vestibule anti-epidemic products set —legend of product types.

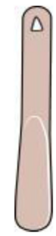
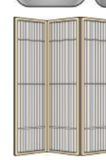
No.	Products	Schematics	No.	Products	Schematics
1	Disinfecting Wipes (DW)		6	Shoehorn (SH)	
2	Disinfectant Sprays (DS)		7	Shoe Cabinet (SC)	
3	Mask (M)		8	Coat Rack (CR)	
4	Temperature Meter (TM)		9	Doorbell (D)	
5	Shoes Changing Stool (SS)		10	Screen (S)	

Table A4
Vestibule anti-epidemic products set (Based on this research).

Vestibule anti-epidemic products set (Tp)					
No.	Products	Explain	No.	Products	Explain
1	Disinfecting Wipes (DW)	Non-woven fabric containing 75% alcohol.	6	Shoehorn (SH)	This item can be inserted into the heel of the shoe to avoid direct contact with the shoe by hands, making it convenient and hygienic to wear the shoe.
2	Disinfectant Sprays (DS)	A spray bottle containing alcohol or other disinfectant.	7	Shoe Cabinet (SC)	A cabinet for storing shoes and sundries.
3	Mask (M)	Disposable medical mask.	8	Coat Rack (CR)	A bracket for hanging clothes, hats, etc.
4	Temperature Meter (TM)	Infrared thermometer.	9	Doorbell (D)	The control signal generated by the button drives the electrical energy to make the doorbell sound.
5	Shoes Changing Stool (SS)	A chair for changing shoes in a sitting position.	10	Screen (S)	An object used to keep out the wind, to separate or to block the line of sight.

Table A5
Product set function configuration matrix (MTp).

Module configuration of function			Vestibule anti-epidemic products set (No.)									
			1 DW	2 DS	3 M	4 TM	5 SS	6 SH	7 SC	8 CR	9 D	10 S
Energy	Electricity		0	0	0	1	0	0	0	0	1	0
	Light		0	0	0	1	0	0	0	0	0	0
	Hydraulic		0	1	0	0	0	0	0	0	0	0
	Pneumatic		0	1	0	0	0	0	0	0	0	0
	Manual	Pinch	1	0	1	1	0	0	0	0	0	0
		Draw	1	0	1	0	0	0	1	0	0	0
		Unfold	1	0	0	0	0	0	0	0	0	0
		Pull	0	1	0	0	0	0	0	0	0	0
		Press	0	1	0	0	1	1	0	1	0	0
		Hold	0	1	0	1	1	1	1	1	0	1
		Carry	0	0	1	0	0	0	1	0	0	0
		Hang	0	0	1	0	0	1	0	1	0	0
		Push	1	0	0	1	1	1	0	0	1	1
		Support	0	0	0	0	1	0	1	1	0	0
	Mechanical	Slide	0	0	0	0	0	0	1	0	0	0
		Fold	0	0	0	1	0	0	1	0	1	0
Material	Metal		0	0	0	1	0	0	1	1	1	0
	Fabric		1	0	1	0	0	0	0	0	0	0
	Wood		0	0	0	0	1	1	1	1	0	1
	Glass		0	0	0	1	0	0	0	0	0	0
	Plastics		1	1	0	1	0	0	0	0	1	0
	Liquid		1	1	0	0	0	0	0	0	0	0
Signal	Posture	Stand	1	1	1	1	0	1	1	1	1	1
		Sit	1	1	1	1	1	1	1	1	0	1
		Squat	1	1	1	1	0	1	1	1	0	1
	Height	Bottom	0	0	0	0	1	1	1	1	0	1
		0.1m$\le H \le$ 1m	1	1	1	1	1	1	1	1	1	1
		1m$\le H \le$ 2m	1	1	1	1	0	1	1	1	1	1
		2m$\le H \le$ 3m	0	0	0	0	0	0	0	0	0	1
		Top	0	0	0	0	0	0	0	0	0	1
	Placement	Flat	1	1	1	1	1	1	1	1	0	1
		Side	0	0	1	1	0	1	0	0	0	0
		Erect	0	1	0	0	0	0	1	1	0	1
		Suspensory	0	0	1	0	0	1	0	0	1	0
	Information feedback	Visual	1	1	1	1	0	0	1	1	0	1
		Auditory	0	0	0	0	0	0	0	0	1	0
		Touch	1	1	1	1	1	1	0	0	0	0

Table A6
Demographics of focus group members.

Category	Member	Gender	Education	Professional background	Years of working
Engineer	A	Male	Postgraduate	Medical product engineer	10
	B	Female	Postgraduate	Medical product engineer	7
	C	Female	Postgraduate	Product engineer	30
	D	Male	Postgraduate	Engineer and Researcher	5
	E	Male	Postgraduate	Engineer and Researcher	12
	F	Female	Postgraduate	Engineer and Researcher	18
Medical	G	Female	Postgraduate	Medical doctor	4
	H	Male	Undergraduate	Medical doctor	3
	I	Female	Postgraduate	Medical doctor	14
	J	Female	Postgraduate	Health attendant	3
	K	Male	Postgraduate	Health attendant	25
	L	Female	Postgraduate	Nurse	4
	M	Female	Postgraduate	Medical trainee	10

Table A7
Comparator with standard deviation of probability value.

Paired comparison (No.)	Number of probabilistic values					Mean	SD
	1	2	3	4	5		
1 DW−−5 SS	5	3	5	0	0	2	0.91
1 DW−−6 SH	5	5	2	1	0	1.92	0.95
2 DS−−5 SS	5	4	4	0	0	1.92	0.86
2 DS−−6 SH	5	5	3	0	0	1.85	0.80
3 M−−4 TM	3	2	7	1	0	2.46	0.97
3 M−−5 SS	7	4	2	0	0	1.62	0.77
3 M−−6 SH	7	4	2	0	0	1.62	0.77
3 M−−10 S	6	4	2	1	0	1.85	0.99
4 TM−−5 SS	5	4	4	0	0	1.92	0.86
4 TM−−6 SH	7	4	2	0	0	1.62	0.77
4 TM−−9 D	6	3	4	0	0	1.85	0.90
4 TM−−10 S	7	4	2	0	0	1.62	0.77
5 SS−−9 D	5	5	2	1	0	1.92	0.95
6 SH−−9 D	6	5	2	0	0	1.69	0.75
6 SH−−10 S	6	4	3	0	0	1.77	0.83
8 CR−−9 D	5	6	2	0	0	1.77	0.73
1 DW−−2 DS	0	4	4	3	2	3.231	1.09
1 DW−−3 M	2	3	4	3	1	2.85	1.21
1 DW−−4 TM	4	3	5	1	0	2.23	1.01
1 DW−−7 SC	3	1	4	5	0	2.85	1.21
1 DW−−8 CR	6	2	3	2	0	2.08	1.19
1 DW−−9 D	4	1	3	4	1	2.77	1.42
1 DW−−10 S	6	3	3	1	0	1.92	1.04
2 DS−−3 M	0	3	4	3	3	3.46	1.13
2 DS−−4 TM	5	2	4	2	0	2.23	1.17
2 DS−−7 SC	4	2	4	3	0	2.46	1.20
2 DS−−8 CR	5	3	3	1	1	2.23	1.30
2 DS−−9 D	3	1	6	2	1	2.77	1.24
2 DS−−10 S	4	3	3	2	1	2.46	1.33
3 M−−7 SC	5	2	3	3	0	2.31	1.25
3 M−−8 CR	5	3	3	2	0	2.15	1.14
3 M−−9 D	6	3	3	1	0	1.92	1.04
4 TM−−7 SC	6	3	1	3	0	2.08	1.26
4 TM−−8 CR	4	5	1	3	0	2.23	1.17
5 SS−−6 SH	3	3	1	3	3	3	1.58
5 SS−−7 SC	3	1	2	4	3	3.23	1.54
5 SS−−8 CR	3	1	4	5	0	2.85	1.21
5 SS−−10(S	4	5	2	2	0	2.15	1.07
6 SH−−7 SC	3	1	3	4	2	3.08	1.44
6 SH−−8 CR	4	3	2	4	0	2.46	1.27
7 SC−−8 CR	3	1	7	1	1	2.69	1.18
7 SC−−9 D	5	4	3	1	0	2	1
7 SC−−10 S	4	2	5	2	0	1.77	1.12
8 CR−−10 S	3	4	5	0	1	2.39	1.12
9 D−−10 S	5	3	3	2	0	2.15	1.14

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