Journal of Physics: Conference Series

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To cite this article: Yuhan Ying *et al* 2022 *J. Phys.: Conf. Ser.* **2232** 012004

Journal of Physics: Conference Series **2232** (2022) 012004 doi:10.1088/1742-6596/2232/1/012004

# Kano-FBS model: a data-driven innovative design approach for smart product-service system development

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**Abstract**. Smart product-service system (Smart PSS), as an emerging digital paradigm, should meet user expectations and optimize their experience with a higher degree of sustainability. As a complex solution bundle with digital technology, its innovative design method differs from the existing method for traditional products. For a reason that massive user-generated data can be collected in the usage stage, which can be utilized to obtain new user requirements and calculate the user satisfaction degree. According to the real-time user preference information, some modules can be upgraded or adjusted in order to extend the lifecycle of the sustainable Smart PSS. Nevertheless, few studies focus on conducting innovative design by concerning massive information collected in the usage stage in a sustainable Smart PSS environment, let alone a novel approach to support the information re-use in product development of other fields. Aiming to fill this gap, a new innovative design methodology is proposed by combining Function-Behavior-Structure (FBS) and Kano model to guide Smart PSS development. User requirements and behaviors are predicted and analysed by forecasting and collecting information from the perspective of information. As an illustrative case study, a self-service medicine vending system is described to explain the proposed approach. This research provides guidance for Smart PSS in the medical field.

## 1. Introduction

With the rapid development of information and communication technologies (ICT), smart products and smart services have improved the overall quality of life. A new IT-driven business paradigm has appeared, named as “Smart-product service system (Smart PSS)”, which is defined as "*An IT-driven value co-creation business strategy consisting of various stakeholders as the players, intelligent systems as the infrastructure, smart, connected products as the media and tools, and their generated services as the key values delivered that continuously strives to meet individual customer needs in a sustainable manner* [1]". Unlike the current product development or service design process, Smart PSS owns unique design characteristics. Nevertheless, few study cases focus on Smart PSS innovative design method with concerning massive usage data, let alone supporting the information re-use in product development of other fields. To address this gap, the paper presents an innovative design model that targets the whole design process of Smart PSS. Based on the FBS model, the framework is integrated into Kano model to mine the user requirements. The framework profiles information collected during the usage phase and optimizes in-depth analysis of the design in a data-driven manner. The paper consists of the following sections. Section 2 gives a review of Smart PSS design and FBS model. Section 3 presents a new innovative design methodology (Kano-FBS model). Section 4 illustrates the proposed approach with an example. The conclusions and limitations will be explained in Section 5 respectively.

## 2. Review

In recent years, many researchers target related research to Smart PSS design, which provides users with tangible products and intangible services to meet users' financial and sustainable requirements and maximize benefits. Kuhlenkötter et al. (2017) conceptualized Smart PSS as a digital-based value creation ecosystem and proposed a more integrated engineering method [2]. Taking personalized smart wearable devices as an example, Zheng et al. (2018) proposed a system design framework for smart PSS service innovation [1]. Cong et al. (2020) presents a novel approach that focuses on developing Smart PSS by reducing the design entropy in its closed-loop lifecycle [3]. Considered user requirements, Bu et al. (2021) proposed a user-centered design method for Smart PSS with virtual reality technology [4].

FBS design model was presented by Gero (1990) [5] to analyze the transformation between function, behavior, and structure, as shown in Figure. 1. Zhang Weishe et al. (2018) combined Scene design and FBS model to more effective product innovation design methods and technologies [6]. Zhang Qing et al. (2018) introduced user demand analysis Ra into the FBS model and established a user-centered design model [7]. Zhou Qi et al. (2020) combined Scene design and FBS model with fussy Kano model to improve the satisfaction coefficient and innovative application of situational toys [8]. FBS model is mainly applied to design practice directly in previous design cases. Few pieces of research applied FBS model to the Smart PSS by utilizing Kano model to process user requirements.

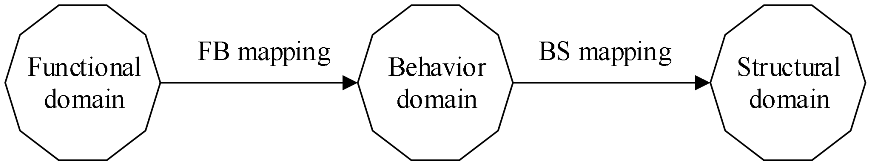


**Figure 1.** FBS model [7].

## 3. Method

The Kano-FBS model framework is presented for Smart PSS innovative design. The model can be summarized into three stages: the design stage, the production stage, and the usage stage. The key steps and significant operation methods of each stage are listed in Figure 2 and elaborated below.

***Step 1*:** The first step is to acquire user requirements and determine the function F in the Kano-FBS model. First, rely on user interviews, user portrait, and user journey map, user research can be completed. Then several design-related requirement indicators based on the research results should be drawn up. Meanwhile, according to the important types, the design requirement indicators determined by Kano needs assessment questionnaire [9] can be classified. In addition, the importance of various design requirement indicators and the importance ranking table can be obtained to determine which functions Smart PSS should be retained with the Kano satisfaction calculation formula [10], Better-Worse analysis diagram [11], and Kano importance questionnaire [12].

***Step 2*:** After determining the function F, relying on the previous user research results, Smart PSS should have a one-to-many mapping of the various functions and user behavior to obtain the user behavior B (i.e. behavior of using products/services, generally in the form of a verb + noun). Meanwhile, according to user behavior, information that should be collected (i.e. user information, physiological data, behavior data, physical environment data, etc.) can be classified by different attributes. Then each attribute should be subdivided to get the specific information category. Finally, all the information categories can be grouped together to form the overall information of Smart PSS, as shown in Figure 3.

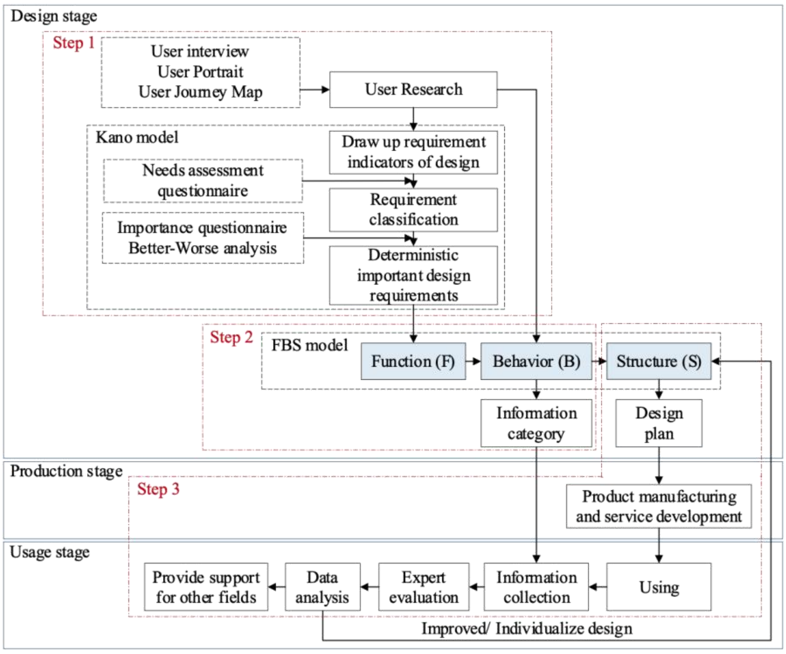


**Figure 2.** The presented Kano-FBS model.

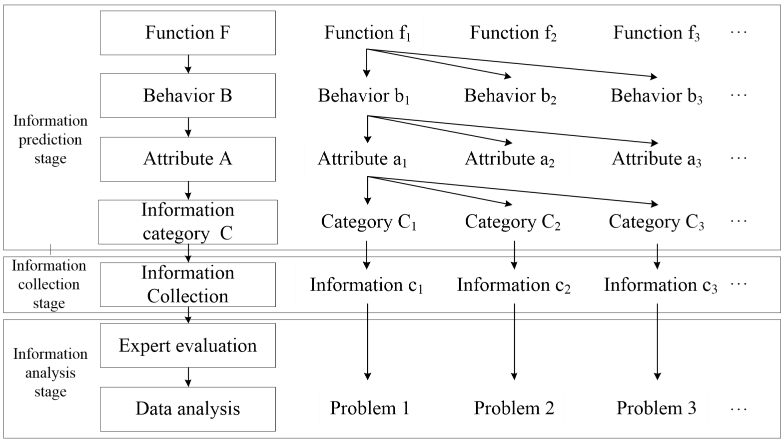


**Figure 3.** Data analysis of smart PSS based on Kano-FBS model.

***Step 3***: After determining function F and user behavior B, the structure S of Smart PSS is correspondingly obtained, and the design plan of Smart PSS should also be completed. Then put product manufacturing and service development into use. In the usage stage, real usage data of Smart PSS can be collected according to the information categories in step 2. Moreover, real usage information should be analyzed by experts who can scientifically evaluate the design plan of Smart PSS for further improved or individualized design. In addition, the information collected by Smart PSS can also be used in other fields to support product development so that it can create a greater value.

## 4. Case study

In order to show how this theoretical framework works, the following will take the self-service medicine vending system as an example.

***Step 1***: First, user requirements are obtained through user interviews, user portrait, and user journey map. According to the research results, 9 requirement indicators related to the design of the self-service medicine vending system App are drawn up in Table 1.

**Table 1.** Design requirement indicators table.

| | | | |
|---|---|---|---|
| $c_1$ | Health information | $c_6$ | Online consultation |
| $c_2$ | Medication reminder | $c_7$ | Online pharmacy |
| $c_3$ | Medication instruction | $c_8$ | Drug purchase record |
| $c_4$ | Medication record | $c_9$ | Family information sharing |
| $c_5$ | Overdue reminder | | |

Based on these 9 requirement indicators, Kano survey questionnaire is completed, and then these 9 requirement indicators are divided into Kano attributes. According to the Kano satisfaction calculation formula, the satisfaction of each of the 9 requirement indicators above is calculated. Then Better-Worse analysis diagram based on the calculation results is presented (Figure 4). Finally, Kano importance questionnaire is completed, and the importance ranking of each requirement indicator is obtained according to the importance degree (Table 2). According to the previous work, functions $c_1$, $c_2$, $c_3$, $c_4$, $c_5$, $c_6$, $c_7$, $c_8$ are implemented, and $c_9$ is excluded. In addition, according to the user research of self-service medicine vending systems, the map navigation function is realized for looking for a self-service medicine vending machine.

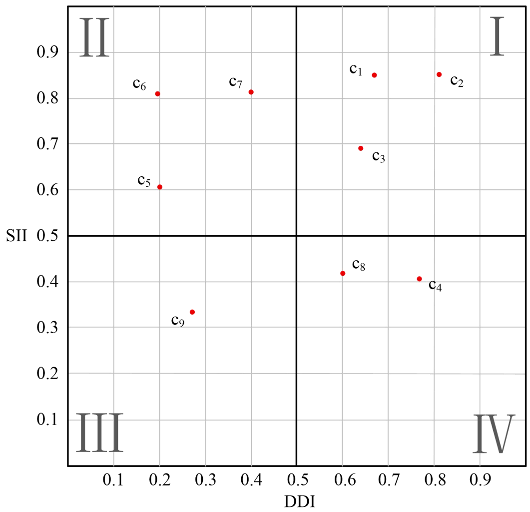


**Figure 4.** Better-Worse analysis diagram.

**Table 2.** Importance ranking table.

| Function | Importance degree | Importance ranking |
|---|---|---|
| $c_1$ | 0.23857 | 1 |
| $c_2$ | 0.13547 | 3 |
| $c_3$ | 0.20324 | 2 |
| $c_4$ | 0.06934 | 7 |
| $c_5$ | 0.06029 | 8 |
| $c_6$ | 0.09965 | 4 |
| $c_7$ | 0.09512 | 5 |
| $c_8$ | 0.07147 | 6 |
| $c_9$ | 0.02685 | 9 |

***Step 2***: After determining the basic functions of the self-service medicine vending system, according to the user research, one-to-many mapping between the functions of the self-service medicine vending system and the user behavior B are obtained (Figure 5). The behavior of a user selecting drugs on a self-service medicine vending machine is selected as an example to explain the data analysis phase of the Kano-FBS model. The information associated with this behavior includes user attributes, system attributes, and drug attributes. According to these three types of information attributes, the categories of information when a user selects drugs are collected. As shown in Figure 5, all the information categories are grouped together to form the overall information of the self-service medicine vending system.

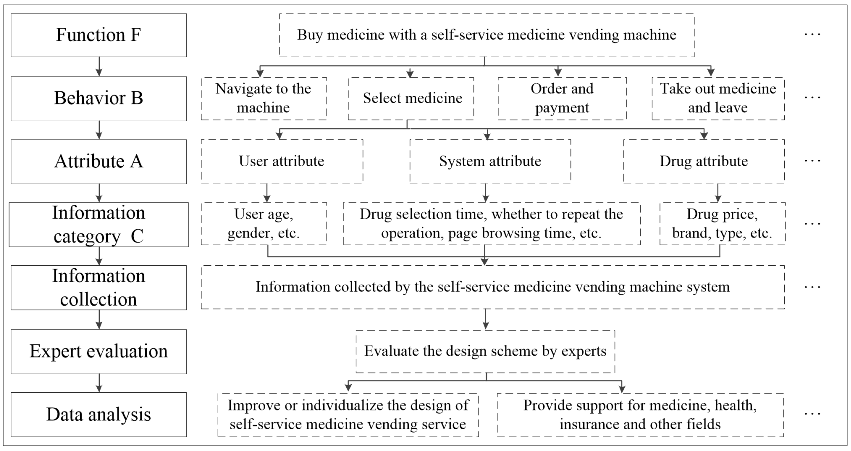


**Figure 5.** Data analysis of self-service medicine vending system.

***Step 3*:** After determining the function F and user behavior B of the self-service medicine vending system, the structure S is correspondingly obtained. Combining user behavior and user aesthetics, a set of design plans are completed, as shown in Figure 6. A QR code logo is added to the body of the self-service medicine vending machine so that users can enter the App by scanning the code. In the App, all the functions which are planed in step 1 are realized, and the user interface is scientifically laid out according to the importance degree of requirement indicators and user habits. After putting into product manufacturing and service development, user usage data of the self-service medicine vending system are collected, which should correspond to the information categories in step 2.

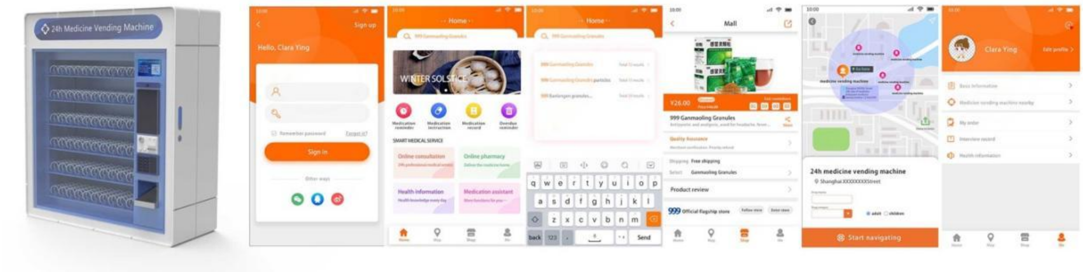

**Figure 6.** Design plan of self-service medicine vending system.

Meanwhile, a statistical analysis of the collected data is performed so as to obtain various types of information (e.g., drug sales and app user usage information). Moreover, the collected information is analyzed by experts to evaluate the design plan of self-service medicine vending system or make suggestions for improvement and individualized design. In addition, the information can also be used in other fields. For example, the incidence of a certain disease can be reflected by the sales amount of a type of medicine to a certain extent on the self-service medicine vending machines in a particular area, which has great research value in the health insurance industry.

## 5. Conclusion

This paper contributes to state of the art by proposing a new theoretical method for the design of Smart PSS, with the aim of improving the ideality degree of Smart PSS solutions; this is done by improving existing models. The exemplar case of the self-service medicine vending system emphasizes the workability of the proposed approach. The main contribution can be concluded as follows. First， a data-driven design method (i.e. Kano-FBS model) is presented for Smart PSS innovative design. Second, the proposed framework, which integrated FBS and Kano model, can improve the user research part of FBS to enable the adaptation of Smart PSS to different users with an extended lifecycle. Third, a Smart PSS in the healthcare field (i.e. a medicine vending system) is developed in the case study, which can add a typical application scenario for smart healthcare topics. However, some limitations of this study require more profound research in the future. Kano-FBS model is described without real usage data in the usage stage since the case study of self-service medicine vending machine did not really put on production.

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