Functional Requirements for Smart Libraries in Higher Education Based on the Kano Model: Postprint

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Abstract

[Purpose/Significance] To elucidate users' functional requirements for university smart libraries and clarify issues such as what functions users expect these libraries to implement and in what form they should exist. [Method/Process] By comprehensively utilizing expert consultation, group discussions, and other methods, 29 main functional items of university smart libraries were identified. The Kano model analysis method, hybrid category analysis, and Better-Worse satisfaction index analysis were employed to identify the four hierarchical characteristics and transformation pathways of users' functional requirement content for university smart libraries. [Results/Conclusion] Users' functional requirements for university smart libraries are hierarchical and dynamic, which dictates the morphological, phase, and process characteristics of university smart library development; university libraries need to benchmark against user requirements, clarify the actual current state of smart library development, and subsequently, according to their own needs, prioritize key areas and highlight distinctive features to advance smart library development in a hierarchical and phased manner, gradually achieving comprehensive coverage of user requirement levels; as user functional requirements continue to evolve, the development of university smart libraries must also adjust its strategies promptly.

Full Text

Preamble

Research on Functional Requirements of University Smart Libraries Based on the Kano Model

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Abstract: [Purpose/Significance] This study reveals users' functional requirements for university smart libraries, clarifying what functions users expect and how they envision these libraries should exist. [Method/Process] Through expert consultation and group discussions, we identified 29 major functional items for university smart libraries. Using Kano model analysis, mixed-class analysis, and Better-Worse satisfaction index analysis, we identified four hierarchical characteristics and transformation pathways of user functional requirements. [Result/Conclusion] Users' functional requirements for university smart libraries are hierarchical and dynamic, which determines the morphological, stage, and process characteristics of smart library construction. University libraries must align with user needs, identify their current construction status, prioritize key features, and advance smart library construction in a hierarchical and phased manner to gradually achieve full coverage of user requirement levels. As user functional requirements evolve, smart library construction must continuously adjust its strategies.

Keywords: University smart library; Functional requirements; Kano model
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Driven by intelligent technologies such as the Internet of Things and artificial intelligence, traditional libraries are inevitably evolving toward smart libraries. Smart libraries represent the future direction and new form of library development, with "intelligence" as the core focus and user service at the center, enabling interconnectedness between libraries, between libraries and users, among users themselves, and between devices and users. Current construction practices in university smart libraries encompass both "soft intelligence" and "hard intelligence." "Soft intelligence" refers to the backend organization of various information and data about libraries and users through intelligent systems to provide knowledge and intelligent services. "Hard intelligence" refers to the provision of intelligent services through technology, equipment, and physical spaces. Through these dual approaches, university smart libraries can better embody the concept of "intelligence" and 赋予 new connotations to their functions. User functional requirements serve as both the starting point and ultimate goal of university smart library construction, making user requirement analysis essential, particularly in clarifying what functions users want and how they expect libraries to exist. This paper synthesizes existing literature on general functional requirements of university libraries and employs expert consultation and group discussion to analyze major functional items, applying the Kano model for user requirement identification and using satisfaction index analysis and mixed-class analysis to optimize results and propose strategies for advancing smart library construction.

1. Related Research Review

A review of existing literature reveals abundant research on university smart libraries, yet studies focusing specifically on functional requirements remain relatively scarce. However, multi-type library smartification explorations in existing research offer valuable reference points for investigating university smart library functional requirements. Chen Jin[1] argues that functional requirements for smart library resources primarily include needs for paper resources, electronic resources, and other resource types. Luo Li[2] emphasizes the importance of characteristic resources in smart library functional requirements. Xu Tiancai[3] discusses resource needs across different user types: students require professional courses, research topics, and hotspot resources; teachers need curriculum resources; researchers require top-tier journals, authoritative databases, and research reports; and social readers need reading memory and social reading resources. Shan Zhen[4] categorizes smart library space requirements into information commons, learning spaces, maker spaces, and smart spaces. Liu Baorui[5] conceptualizes smart spaces as user-centered applications of IoT, cloud computing, and intelligent technologies across multiple spatial layers including perception, physical, and virtual spaces. W. Daniels[6] suggests that academic commons needs stem from researchers' requirements for specialized disciplinary knowledge and skills. A. Burdick[7] posits that academic commons needs can evolve into digital scholarship spaces employing visualization tools, digital evidence, and digital publishing. Ma Jing[8] identifies functional requirements for self-service smart library systems including borrowing, sales, feedback, finance, book selection, damage handling, complaints, and query functions. Zhang Jie[9] argues that university library functional requirements are transforming from traditional general functions to intelligent knowledge services. Guo Sujun[10] identifies user needs for smart library information services including intelligent inventory, precise book location, self-service borrowing, and personalized services. Zhao Yingchun[11] outlines mobile library functional requirements such as catalog search, reservation, reading notes, book updates, and online interaction. Zeng Ziming[12] advocates for transforming smart library service models into scenario-based services, creating a "user-requirement-scenario" ecosystem to enhance knowledge perception and understanding.

While existing research has actively explored smart library functional requirements, not all studies adopt a user needs perspective, potentially overlooking how the hierarchical and dynamic nature of user demands creates new requirements for smart libraries.

2. The Kano Model

The Kano model originated from the Two-Factor Theory proposed by American behavioral scientist Frederick Herzberg in 1959[13] and was further developed by Tokyo University of Science professor Noriaki Kano in 1984[14]. The Kano model is an evaluation method that makes implicit service quality attributes explicit, defining three types of customer needs: basic needs, performance needs, and excitement needs. Based on how the fulfillment of functional needs affects user satisfaction, requirements are classified into Must-be Requirements (M), One-dimensional Requirements (O), Attractive Requirements (A), Indifferent Requirements (I), and Reverse Requirements (R) [Figure 1: see original paper].

In [Figure 1: see original paper], the origin represents industry averages, the X-axis indicates the adequacy of service quality attributes, and the Y-axis represents user satisfaction. The right side of the X-axis indicates service quality and attributes exceeding industry averages, while the left side indicates industry averages exceeding quality attributes; higher positions on the Y-axis indicate greater customer satisfaction.

The Kano model has been widely applied in library and information science research. Xu Ruifang[15] combined the QFD model with the Kano model to analyze user requirements for university library mobile services. Qi Xianghua et al.[16] established factors affecting electronic service quality in libraries and classified these quality elements using the Kano model. Lei Xiaoqing et al.[17] first identified factors affecting public archive network information service quality through literature review and expert consultation, then applied the Kano model for classification and evaluation.

3. Determination of Functional Items for University Smart Libraries

Current research on general functional requirements of university libraries focuses on three perspectives: (1) library utilization purposes, such as Yan Ling's[18] Maslow-based hierarchy dividing needs into learning, work, entertainment, and self-actualization; (2) services provided, such as Yu Xi's[19] categorization of user needs into learning, teaching, and research types from a disciplinary service perspective; and (3) specific content usage, such as Liu Lihua's[20] identification of needs including disciplinary services, book borrowing, catalog searching, literature retrieval and downloading, training, space utilization, academic research, reference consultation, topic-specific services, and novelty searching.

Considering the unique connotation of "intelligence" in university smart library construction[21], this study adopts the specific content usage perspective, building on Li Chen's[22] framework of resources, services, collaboration, and tools. Combined with practical achievements in university smart library construction, we categorized functional requirements into service needs, information resource needs, learning tool needs, interaction needs, and environmental needs, extracting 38 initial functional items. We then invited two experts from the Hubei Provincial University Library Committee, three university librarians, and five heavy library users, employing expert consultation and group discussion to refine the list to 29 functional items .

The 29 items include: announcements, book due/overdue reminders, book reservations, seat reservations, personal borrowing information queries, disciplinary resource recommendations, RFID self-service borrowing machines, cloud reading, book delivery robots, full-text reading and access, audio/video resource downloading and playback, research updates, academic topics, photo-based searching, integrated resource retrieval, cloud storage, interactive reference consultation, online robot customer service, physical robot intelligent response, book reviews, library mobile community, mobile reading sharing, cloud sharing, multi-type learning spaces, intelligent temperature control systems, smart desks and chairs, book navigation, access to peripheral library services, and facial recognition equipment.

While user needs primarily fall into these five categories, the fulfillment methods have undergone profound changes. For service needs, users demand simpler information access, more understandable content, higher visualization, and more convenient notifications and seat reservations, requiring libraries to offer customized services, AI-powered seat reservations, and knowledge mining-based resource recommendations. For information needs, users require faster, more convenient research services with online application options, necessitating RFID and cloud computing technologies. For learning tool needs, users seek online cloud storage for resources rather than traditional downloads, requiring libraries to provide cloud storage space. For interaction needs, users demand online networking, discussion groups, and topic-specific conversations, requiring libraries to leverage social media tools. For environmental needs, users require intelligent guidance devices for automatic book location routing, necessitating modern smart equipment, NFC and AI-based automated access control using mobile phones and facial recognition.

4. Hierarchical Analysis of Functional Requirements Based on the Kano Model

4.1 Questionnaire Design and Collection

This study employed the Kano model method to investigate university smart library requirements, designing a questionnaire based on the 29 functional items. The questionnaire comprised three sections: (1) introduction explaining the survey's purpose; (2) demographic and basic usage questions covering gender, education level, major, library usage duration, and frequency; and (3) the main scale section. For each indicator, we paired positive and negative questions about service provision, highlighting "provided" versus "not provided" scenarios. A five-point Likert scale offered options of "I would be delighted," "It's expected," "I don't care," "I can accept it," and "I cannot accept it."

The questionnaire was distributed online from January to February 2019, taking one month to collect 342 responses. After excluding 76 invalid questionnaires (incomplete responses, contradictory answers, or respondents who had never used university library services), 266 valid responses remained, yielding a 77.78% validity rate. The sample included 121 males and 145 females. Due to random sampling, education levels formed a pyramid distribution: bachelor's degree

(45.86%), master's degree (40.60%), doctoral degree (9.39%), and other (4.13%). Regarding usage frequency, 41.72% used library services daily, 42.85% more than twice weekly, and 15.04% weekly, indicating high and frequent demand.

4.2 Data Analysis

4.2.1 Kano Questionnaire Results Analysis We analyzed the scale using Kano model procedures based on M. Kurt's three tools: Kano questionnaire, Kano evaluation table, and Kano results analysis table[23]. The evaluation table processed responses into the results analysis table. All 29 items were statistically analyzed and summarized , where "A" represents attractive needs, "O" represents one-dimensional needs, "M" represents must-be needs, "I" represents indifferent needs, "R" represents reverse needs, and "Q" represents questionable results (occurring when respondents answer both positive and negative questions identically with extreme responses).

The analysis identified 16 attractive needs, 1 one-dimensional need, 8 must-be needs, and 4 indifferent needs. Items 1, 2, 5, 7, 11, 15, 24, and 25 were must-be needs—services users consider essential. Their fulfillment doesn't increase satisfaction, but their absence causes extreme dissatisfaction. Items 3, 4, 8, 9, 10, 14, 16, 17, 18, 19, 21, 22, 23, 26, 27, and 28 were attractive needs, indicating services that greatly attract users who would be delighted by them, though their absence doesn't decrease satisfaction. Item 13 was the sole one-dimensional need, showing users are aware of and expect real-time research updates, with fulfillment directly affecting satisfaction. Items 6, 12, 20, and 29 were indifferent needs, whose fulfillment doesn't affect satisfaction. However, indifferent needs shouldn't be ignored as they may transform into attractive needs[24].

4.2.2 Mixed-Class Analysis Scholars M. Lee and J. Newcomb propose that when no dominant classification emerges, an indicator belongs to a mixed category[25]. Mixed-class metrics include Total Strength (TS), indicating whether an item drives satisfaction, and Category Strength (CS), indicating the degree to which respondents classify an item into a category. When TS $\geq$ 60% and CS $\leq$ 6%, the item is classified as mixed; when CS > 6%, categories are clearly distinct.

The formulas are:

$$TS = \frac{\text{Number of M, O, A responses}}{\text{Total responses}} \quad \text{(Formula 1)}$$

$$CS = \frac{\max\{A, O, M, I, R, Q\} - \text{secondmax}\{A, O, M, I, R, Q\}}{\text{Total responses}} \quad \text{(Formula 2)}$$

Mixed categories are marked with "H" followed by parentheses indicating the two most frequent Kano categories. TS and CS values were calculated for each item and dimension .

Mixed-class analysis changed some classifications: items 2, 3, 7, 8, 9, 10, 11, 13, 17, 22, and 27 became mixed categories. Items 2, 7, 10, 11, 15, and 27 were must-be + attractive mixes, requiring consideration of both characteristics. Items 3 and 13 were attractive + one-dimensional mixes, requiring both provision and quality attention. Items 9 and 22 were indifferent + attractive mixes, indicating currently unimportant services with potential to become attractive.

4.2.3 Better-Worse Satisfaction Index Analysis We employed C. Berger et al.'s customer satisfaction coefficient (CS)[27], or Better-Worse index analysis, to examine relationships between indicators and satisfaction. Better indicates how much an element increases satisfaction (normally >0; larger positive values indicate greater impact), while Worse indicates how much it decreases dissatisfaction (normally <0; larger negative values indicate greater impact).

The formulas are:

$$Better = \frac{A+O}{A+O+M+I} \quad \text{(Formula 3)}$$

$$Worse = \frac{O+M}{A+O+M+I} \times (-1) \quad \text{(Formula 4)}$$

Results for functional items and dimensions are shown in and . The average coordinates are (Better=0.604, |Worse|=0.433) for items and (Better=0.597, |Worse|=0.443) for dimensions. Items with above-average Better values include 1, 2, 10, 11, 14, 16, 17, 18, 21, 23, 25, 26, and 27; dimensions include interaction and environment. These significantly boost satisfaction. Items and dimensions with above-average |Worse| values include 1, 2, 3, 4, 5, 7, 8, 10, 11, 13, 15, 24, 25, 27, 28 and service, information resource, learning tool, and environment dimensions—these effectively prevent dissatisfaction.

To visualize distributions, we created quadrant plots with Better as the X-axis and |Worse| as the Y-axis, using average coordinates as origins [Figure 2: see original paper][Figure 3: see original paper].

Quadrant 1 (high Better, high |Worse|): Services here significantly increase satisfaction when well-implemented and are top priority. Nine items fall here: 1, 2, 4, 8, 10, 11, 25, 27, and 28. Originally identified must-be needs (1, 2, 11, 25) and attractive needs (4, 8, 10, 27, 28) all appear here, indicating critical impact on satisfaction.

Quadrant 2 (low Better, high |Worse|): Services here don't increase satisfaction but are essential. Six items appear: 3, 5, 7, 13, 15, and 24. Item 3 (attractive in Kano analysis) and item 13 (one-dimensional) appear here, indicating indispensable services unsuitable for major changes.

Quadrant 3 (low Better, low |Worse|): Services here have minimal impact on satisfaction, showing indifferent attributes. Seven items appear: 6, 9, 12, 19, 20, 22, and 29. Libraries should improve these to transform indifferent needs into attractive ones.

Quadrant 4 (high Better, low |Worse|): Services here greatly increase satisfaction but minimally reduce dissatisfaction. Seven items appear: 14, 16, 17, 18, 21, 23, and 26. These represent distinctive features that maximize user attraction and should be enriched.

[Figure 3: see original paper] shows environment as one-dimensional, while service, learning tool, and information resource dimensions are must-be needs, and interaction is attractive.

4.2.4 Comprehensive Analysis Comparing results across three methods reveals significant differences for many items . Items 1, 2, 3, 4, 8, 10, 11, 13, 15, 22, and 27 show substantial variation. Item 5 shows consistency across methods. Items 1 and 2 shifted from must-be (Kano and mixed) to one-dimensional (Better-Worse). Items 3, 4, and 8 shifted from attractive to one-dimensional. Item 22 shifted from attractive to indifferent. Item 10 shows particularly notable variation: attractive in Kano, must-be+attractive mixed, but one-dimensional in Better-Worse analysis because its Better value exceeds the average while its Worse value is below average.

Dimensional analysis also shows variations . Information resource and learning tool dimensions shifted from attractive to must-be, while environment shifted from attractive to one-dimensional. These differences arise from methodological variations and because Kano and mixed analyses only consider internal frequency distributions, whereas Better-Worse analysis compares all dimensions simultaneously.

4.3 Hierarchical Analysis of University Smart Library Functional Requirements

4.3.1 Must-be Requirements Must-be requirements are considered 理所当然 by users. When unfulfilled, satisfaction drops sharply; when fulfilled, satisfaction doesn't increase. Comprehensive analysis identifies these must-be items: 1, 2, 5, 7, 11, 15, 24, and 25—covering announcements, book due/overdue reminders, personal borrowing queries, RFID self-service machines, audio/video downloading, full-text access, integrated resource retrieval, multi-type learning spaces, and intelligent temperature control. These nine functions across all five dimensions represent essential, frequently used services meeting general user expectations.

4.3.2 One-dimensional Requirements One-dimensional requirements correlate linearly with satisfaction. When unfulfilled, satisfaction drops sharply; when fulfilled, satisfaction increases rapidly. The primary one-dimensional item is 13 ("Academic Topics"), defined as online applications with simple processes and fast responses. This indicates that research-oriented users, in particular, expect efficient online applications for academic information needs.

4.3.3 Attractive Requirements Attractive requirements don't significantly affect satisfaction when unfulfilled but dramatically increase satisfaction when fulfilled. After addressing must-be and one-dimensional needs, libraries should consider adding attractive items to boost satisfaction rapidly. Attractive items include: 3, 4, 8, 10, 14, 16, 17, 18, 19, 21, 22, 23, 26, 27, and 28. These include online robot reservations, seat reservations, cloud reading, photo-based searching, cloud storage, interactive reference consultation, online robot customer service, physical robot intelligent response, library mobile community, mobile reading sharing, cloud sharing, smart desks, book navigation, and peripheral services. Users were previously unaware of these services, but their implementation generates delight.

4.3.4 Indifferent Requirements Indifferent requirements minimally affect satisfaction whether fulfilled or not. However, Kano noted that user attitudes toward needs change over time, with a dynamic transformation lifecycle: I→A→O→M[26]. Libraries should monitor indifferent items during construction. Comprehensive analysis identifies these indifferent items: 6, 9, 12, 20, and 29—disciplinary resource recommendations, book delivery robots, research updates, book reviews, and facial recognition equipment. These represent unfamiliar, infrequently used services whose benefits users haven't yet experienced.

Conclusion

Kano model analysis demonstrates that user functional requirements are hierarchical and dynamic, determining the morphological, stage, and process characteristics of university smart library construction. First, smart library construction spans five dimensions—service, information resource, learning tool, interaction, and environment—encompassing 29 specific functions including both "soft" and "hard" intelligence components. Second, libraries must align with user requirement hierarchies, identify current construction status, prioritize key features, and advance construction hierarchically and in phases to achieve full coverage. Finally, as user requirements continuously evolve, smart library construction must dynamically adjust strategies, making it an eternal process of exploration driven by user needs.

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Author Contributions:
Yi Ming: Developed research framework and outline; finalized manuscript.
Song Jinzh: Collected and analyzed questionnaire data; drafted initial manuscript.
Li Ziqi: Consulted experts; optimized data analysis; revised manuscript.

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Research on Functional Demand of University Smart Library Based on Kano Model

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Abstract: [Purpose/significance] This paper reveals the user's functional requirements for the university's smart library, clarifying what functions the user expects the university's smart library to implement and in what form it should exist. [Method/process] Using expert consultation, group discussion, and other methods, the 29 major functional items of the university smart library were refined, and Kano model analysis method, mixed class analysis, and Better-Worse satisfaction index analysis method were used to identify the four-level characteristics and transformation paths of the user's functional requirements for the university smart library. [Result/conclusion] The functional requirements of the university's smart library are hierarchical and dynamic, which determines the morphological characteristics, stage characteristics, and process characteristics of the construction of the smart library. The university library needs to meet the needs of standard users, clarify the actual status of the current smart library construction, and then focus on key points and distinctive features according to their own needs, and promote the construction of smart libraries in a hierarchical and phased manner, gradually realizing the full coverage of user needs. With the continuous evolution of user functional requirements, the construction of university smart libraries must also adjust the construction strategy at any time.

Keywords: university smart library; functional demands; Kano model

Note: Figure translations are in progress. See original paper for figures.