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Study on Function and Appearance Design of Smart Street Lamps Based on Kansei Engineering: A Literature Review

Ge Junchao[ab*], Go Tze Fong[a], Teo Hiu Hong[a] & Wang Lipeng[b]

[a]*Centre for Advances Engineering Design,*

[a]*Faculty of Engineering, Built Environment & Information Technology, SEGi University, Malaysia*

[b]*Faculty of Intelligent Manufacturing, Hebi Institute of Engineering and Technology, Henan Polytechnic University, China*

**Corresponding author: SUKD2101768@segi4u.my*

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ABSTRACT

The potential of smart cities to alleviate the challenges of urban development in relation to population, resources, and environment is widely recognized, making it a key urban development trend for the future. Smart street lamps (SSLs) are a crucial component of smart city infrastructure. However, their current unreasonable function settings and appearance design do not meet the emotional needs of residents and come at a high construction cost, resulting in decreased user satisfaction. Based on WOS and CNKI databases, 39 literatures on the aspects of theory, steps and technologies of KE, 32 literatures on the development, basic functions, construction, existing problems, and key technologies of SSLs, and 6 papers on street lamps functions or appearance design research based on KE be reviewed in this paper. Therefore, the application of KE method in SSL design be extensively reviewed, with emphasis on the future development direction of KE, the design principles of SSLs, and the implementation of KE in SSL design. This review aims to summarize the research gaps, future research directions, and future development trends of KE and SSL. Ultimately, the review concludes that the integration of KE in SSL design research is crucial to improve SSL products' rationality, openness, and amicability, guided by scienti ic SSL design principles.

Keywords: Appearance design; functions; Kansei Engineering; smart street lamps

INTRODUCTION

The evolution of technology and the improvement of people's quality of life since the 1970s have led to a shift in users' product requirements, with the focus moving towards satisfying spiritual and emotional needs. In response to this trend, Japanese scholar Nagamachi (1995) introduced the theory and technology of Kansei Engineering (KE), which leverages quantitative methods to accurately understand users' emotions and sentiments towards the product. This approach has successfully guided designers in creating products that better align with users' emotional expectations, as evidenced by its application in various fields such as automobiles, home appliances, textiles, daily necessities, among others (Luo & Pan 2007; Su et al. 2012).

As cities worldwide continue to evolve and expand, new challenges have emerged, including population growth and traffic congestion. In response, smart cities have emerged as a viable solution to address these challenges while improving cities' competitiveness. As such, smart city development has become a trend in urban development worldwide.

Street lamps are a crucial public facility in urban areas. The advantages of orderly arrangement, efficient communication positioning, and stable power supply make SSLs the most suitable physical infrastructure for building smart cities (Hao & Li 2021; Nakajima 2005). SSLs have positively impacted cities by improving their image, utilizing urban resources fully, and helping to conserve energy and reduce emissions. However, current SSL design still poses specific issues such as functional redundancy (Leccese et al. 2014; Feng, 2021; Wang, 2009), casual design (Feng 2021), and neglect for the emotional needs of urban residents (Chen et al. 2018). These problems detrimentally impact residents' perception of SSL usage and hinder healthy SSL development. Kansei Engineering (KE) provides a theory and method to accurately capture users' emotional needs and is an effective way to tackle the previously mentioned SSL issues. Nonetheless, there is limited research investigating KE's application to SSL,

highlighting the need for further exploration. Designing SSL through KE offers several advantages. Firstly, it enhances the emotional and scientific aspects of SSL design and evaluation. Secondly, it improves SSL product environmental fit and increases user satisfaction. Thirdly, it reduces SSL application costs and conserves resources. Additionally, it creates higher product value and contributes to the development of smart city construction.

This paper aims to clarify KE theory and methods in the design and development of SSLs. To achieve this objective, the paper conducts an in-depth review of the current status and key technologies of KE, SSLs, and KE-based SSLs. The paper adopts the following structure: Firstly, address the background, research gaps, and research significance. Then provide relevant information on the key technologies and application steps of KE. After that outline the SSLs development and comprehensively summarize and analyze the research on SSL design based on KE. Finally presents the conclusions drawn from the the study.

KE'S PROCESS AND KEY TECHNOLOGIES

KE is fundamentally a design technique that measures users' emotional needs to create designs that align with their emotional requirements (Nagamachi, 1995, 2002, 2016). KE's process comprises three key aspects: perceptual image extraction, perceptual mapping construction, and sensibility-based product innovation. Since 2010, these facets have emerged as focal points of research in the KE domain, and significant strides have been made in this arena as illustrated in Table 1, resulting from thorough investigations and explorations by scholars worldwide.

TABLE 1. Comparison of KE steps and implementation methods in the past five years

Author (Year)	Step1: Image extraction				step2: Perceptual mapping		Step3: Product Innovation	
	1. Collection of perceptual vocabulary	2. Perceptual vocabulary screening and classification	3. Establishment of perceptual image space	4. Collection of product morphological elements	5. Key morphological elements are determined	6. Image element mapping is established	7. Product innovation	8. Design evaluation/ verification
Kang (2019)	Literature collection method	Expert Focus Interview Method	Not covered	Morphological analysis	KJ Method	Questionnaire survey, 7th order Richter scale, expert method	Rough set theory	7th Order Richter Scale
Zhang (2020)	Questionnaires, user interviews, literature inquiries	Expert screening	Richter scale method, cluster analysis method	Collect images through markets, the Web, books, and more	Panel discussion	Semantic difference method, SPSS principal component analysis, multiple linear	Quantified Class I theory	7th-order semantic difference method
Shu et al.(2022	Questionnaire literature interview	Semantic phase Similarity survey	SD, information entropy	Through journals, books Collect sample pictures through websites	cluster analysis	Simple shape, not involved	Use BP nerves Web, multi-imagery cobweb GTDM builds a product	Grey correlation analysis Multi-imagery cobwebs GTDM
Wang et al.(2022)	Magazines, experts, literature, articles, directories, websites, and users	Expert	Interview	Market Survey	Similarity matrix, FCM clustering method	Integrated data mining solutions, including RST and GST	SVR Machine Learning	Semantic differentiation method

IMAGE EXTRACTION TECHNOLOGY

In KE, designers employ perceptual image extraction technology to obtain users' product-related perceptual knowledge data. Based on the extraction of perceptual images, the process can be divided into four steps: collecting target samples, collecting image semantic vocabulary, establishing perceptual image space, and extracting and matching design elements. Perceptual measurement, among existing image extraction methods, constitutes the focus of research, with scholars consistently dedicated to developing more accurate and objective measurement techniques. The current measurement methods comprise subjective measurement methods, biological signal measurement techniques, and data mining methods (Lin et al. 2020).

The subjective measurement method involves using questionnaires or customer interviews to gather users' subjective perceptual image data. Commonly used subjective measurement techniques include semantic difference, interviews, questionnaires, and focus group methods. For instance, Wang et al. (2022) extensively used questionnaires and focus group interviews to discern users' emotional requirements. The subjective measurement method has been widely utilized in research and design practices and has achieved relatively favorable image extraction outcomes. However, this method has some limitations such as time-consuming image extraction, expensive investigations, and subjective and indefinite evaluations of perceptual words (Wang et al. 2019).

The biological signal measurement method entails measuring and gathering various physiological signals of the human body to deduce human perceptual experience and requirements. Currently, commonly used techniques encompass Eye tracking measurement (Liu & Zhang 2022), EEG measurement (Li et al. 2019), Infrared spectrum analysis (Zhang et al. 2013), among others. For instance, Liu & Yang (2022) employed the shape analysis method and eye movement tool to extract shape design elements in the side profile of nail gun products. They also utilized Quantitative-theory-type-I to evaluate the correlation between linear design elements and perceptual image vocabulary.

The computer data mining method refers to employing computer science to collect and analyze users' perceptual-cognitive data. Given the surge in online user reviews engendered by online shopping and the rise of big data and cloud computing technologies, user sentiment acquisition technology based on text mining has emerged as a significant research focus. For instance, Liu et al. (2020) extracted product attributes indicative of users' attention through word frequency analysis and the LDA model. Subsequently, they utilized the NLPIR emotion analysis tool to evaluate users' emotional tendencies and built a user needs assessment system. The primary benefit of the computer data mining method is it can obtain more comprehensive user perception from a large sample data. It also has a large data sample size and low cost. Nonetheless, it is still beset with issues such as untrue online comments, erroneous data influence accuracy, and complex calculations.

The preceding analysis evinces that perceptual image measurement technology no longer confines itself to mapping perceptual words. Instead, researchers delving into perceptual image mining increasingly employ physiological signal data and network usage data. In particular, the utilization of physiological signal data and network usage data has become a favored approach among researchers.

PERCEPTUAL MAPPING CONSTRUCTION TECHNOLOGY

The use of perceptual mapping construction technology aims to establish the correspondences between a user's perceptual image and specific design features of the product. This technology has been a primary focus of KE research. For example, Liu et al. (2023) expanded the Back-propagation Neural Network (BPNN) to create a mapping model between product parameters and KE evaluation values. The researchers evaluated the predictive performance of this model using smartphones as an example. Additionally, Huang et al. (2022) adopted the theory of Convolutional Neural Networks and Nerve style shift to establish a mapping model between product modeling elements and product semantics. The perceptual mapping construction technology has become increasingly diversified, nonlinear, and complex, with constructed models progressively narrowing the distance separating user cognition and designer cognition. Furthermore, the image analysis model is becoming increasingly sophisticated. This research is also rapidly advancing towards multi-dimensional images and intelligent design.

PARAMETRIC MODELING INNOVATION TECHNOLOGY

In traditional product modeling design, designers depended on their personal experience and subjective judgment, which could lead to design deviations. KE technology employs the user's perceptual thinking as a design input and relies on scientific and quantitative means to aid designers in optimizing and innovating the product's shape. This process enables designers to better meet user needs. On the basis of mapping relationships, image requirements

are translated into elements of modeling innovation. Subsequently, designers combine TRIZ theory, QFD theory, shape grammar, and other innovative theories with algorithms like Swarm intelligence algorithm, GA, Neural Networks, machine learning and others (Khamil et al. 2020; Nasir et al. 2020; Mamata et al. 2022) and apply mathematical models like quantitative-theory-type-I, Support Vector Machine, Partial Least Squares, and others to refine product perceptual image modeling optimization. These methods direct designers in executing optimization of product perceptual image modeling designs (Wang & Zhang 2020; Lin et al. 2020; Rahimi et al. 2021).

In conclusion, KE is an effective approach to enhance the market competitiveness of products by extracting users' emotional needs and incorporating them into product design features, thereby ensuring that products meet users' emotional requirements. As technology continues to evolve, the various key technologies associated with KE continue to grow and develop. The integration of information technology, artificial intelligence technology, big data, cloud computing, and data mining technology renders KE more comprehensive, objective, accurate, efficient, and intelligent.

SMART STREET LAMP

Within the context of smart city construction, SSL is amongst the critical components and assessment indicators that have garnered the attention of society at large. Starting from 2008, the United States has initiated a significant number of SSL projects, which has inspired China, Australia, Japan, South Korea, and other countries to replace traditional light poles with SSLs to optimize energy consumption. Currently, several countries worldwide have embarked on piloting smart lamp projects. According to a research report from Berg Insight, an Internet of Things analysis company, the global installed base of SSLs rose to 10.4 million—representing a compound annual growth rate (CAGR) of 24.5%—by the end of 2020. By 2025, the installed base is projected to reach 31.2 million (Yang 2021).

BASIC FUNCTIONS OF SSL

SSL is a multifaceted application that integrates several cross-border technologies. See Table 2 for a summary of the primary SSL functions.

Table 2 only displays the implemented and common SSL functions. Many expandable SSL functions will emerge in the future. It is crucial to determine the allocation of these complex functions reasonably, and some scholars have already initiated research in this area. To illustrate, Yan (2019) employed modular thinking to group SSL functions based on actual needs, enabling the development of only the necessary functions. This approach reduces the application cost of SSL. However, few studies currently exist on the modularity and scalability of SSL functions, emphasizing the need for further in-depth research by scholars.

TABLE 2. Common functions of smart street lamps (Al-Smadi et al. 2021; Qu et al.2022)

Function	Function description
Smart lighting	Adaptive control of brightness, number of lights, time to turn lights on and off, etc
Video surveillance	Safety monitoring, vehicle monitoring, real-time people flow monitoring, municipal facilities monitoring, special population identification, and early warning
Environmental detection	PM2.5, dust, smoke, light, temperature, and humidity are detected.
LED information screen	Publication of various types of information, including advertisements, traffic flow, public transportation information, parking garage guidance information, etc
WIFI coverage	Full WIFI coverage for specific areas
Public Broadcasting	It is used to publish news and regional information, provide background music, and for paging and forcibly inserting disaster emergency broadcasts, among others
5G micro base station	Ensure 5G signal coverage.
One-click alarm	In case of emergency, you can quickly dial the alarm phone with one button, and immediately obtain the alarm location information according to the GPS positioning of the light pole.
charge	Used for mobile phones, electric bicycles, electric vehicle charging

RESEARCH TRENDS OF SSL

By utilizing “smart street lamp” and “intelligent street lamp” as keywords, a total of 7559 papers were retrieved via the web of science from 1994 to 2022, as outlined in Table 3. The research predominantly focuses on the fields of engineering, instrumentation, and computer science.

TABLE 3. Web of Science database search results with the word “smart street lamp” and “Intelligent street lamp”

Discipline classification	Number of papers
Engineering	7457
Instruments Instrumentation	6732
Computer Science	2428
telecommunications	1888
Energy Fuels	1633
Product design	58
KE	6
Remanufacturing	3

The emergence of SSL research can be traced back to the early 90s. The research can be divided into three stages. The first stage, covering 1994 to 2009, was an enlightenment stage; the previous 15 years saw the publication of over 100 literature pieces on SSL research. The primary focus of research predominantly entailed automatic control of lighting brightness and time to achieve energy conservation. During the development stage from 2010 to 2015, the literature exceeded 1,000 articles and exhibited a steady upward trend. In this stage, research diversified, exploring new avenues in lighting control, function expansion, and the application of different sensors. The third phase, from 2015 to present, represented the climax of the research, centering largely on communication technology and the control system of SSL. Despite the growing literature on smart street lamps, it is worth noting that research into the industrial design of SSL remains lacking, with a current research focus on engineering, instrumentation, and computer science (Saokaew et al. 2021; Shruthi et al. 2019),

TABLE 4. Previous studies on Street Lamp

Author/year	Findings	Classification
Casavola et al. (2022)	Based on a digital twin, local dimmer, acoustic sensor, etc., an automatic dimming hybrid traffic model is proposed.	SSL technology research
Ai et al.(2021)	Combining fuzzy rules, wireless sensor network technology based on 6LoWPAN communication, and visual basic visual programming technology, an intelligent street lamp control system is designed to realize dynamic regulation, remote control, and data transmission of street lamps.	
Kamoji et al. (2020)	An intelligent management system for urban street lights based on wireless communication technology is proposed to improve the utilization rate of energy.	
Liu et al.,(2020)	A product design evaluation method based on visual tracking and aesthetic measurement is proposed. The design verification was carried out with the campus street lamp design as an example.	

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Xu & Wang (2019)	Through KE analysis technology, design requirements are accurately and systematically translated into modular functional elements.	
Ye et al. (2018)	Through a systematic evaluation index system to quantify personal aesthetic experience, the entire product design not only conforms to the concept of "everything starts from the consumer".	Street lamp appearance design research

as demonstrated in Table 4.

COMPARATIVE STUDY OF SSL CONSTRUCTION AROUND THE WORLD

Countries worldwide are placing increasing emphasis on the design and construction of SSL. They have implemented corresponding policies to support the sector while establishing standards aimed at guiding SSL construction. Table 5 provides more detailed information for the support policy, construction standards and design and construction data.

TABLE 5. Support Policies, Construction Standards and Design and Construction Data of SSL around the world

Country	Support Policies	Construction Standards	Design and Construction Data
USA	Support smart street lighting through various programs, including the “Accelerated Innovation Deployment” (AID) program (Federal Highway Administration, 2019).	The Illuminating Engineering Society of North America (IESNA) publishes guidelines and standards for street lighting design, such as RP-8-14 and RP-23-14(Illuminating Engineering Society, 2014).	United States has installed 16.2 million smart streetlights, and this number is expected to reach 40 million by 2025 (Northeast Group LLC, 2020).
China	Set a goal to replace all conventional streetlights with LED lights by 2025 (Xinhua News Agency, 2019).	The “Technical Specifications for Energy-saving Reconstruction of Road Lighting” provides guidelines for the design and construction of smart street lighting in China (Ministry of Industry and Information Technology of the People’s Republic of China, 2018).	The total sales of smart street lighting in China reached 15.5 billion yuan in 2019, and this number is expected to exceed 50 billion yuan by 2025 (China Association of Lighting Industry, 2020).
Japan	Implemented a “Smart City” policy to promote the use of smart technologies, including smart street lighting (Japan Lighting Manufacturers Association, 2020).	The Japan Lighting Manufacturers Association (JLMA) has published guidelines for smart street lighting design and construction (Japan Lighting Manufacturers Association, 2020).	The total market size of smart street lighting in Japan was 45.7 billion yen in 2019, and this number is expected to grow to 122.8 billion yen by 2024 (Japan External Trade Organization, 2020).
Europe	Launched the “Smart Cities and Communities” initiative to support the development and implementation of smart city technologies (European Committee for Standardization, 2019).	The European Committee for Standardization (CEN) has published standards for smart street lighting, such as EN 13201-5 and EN 17037 (European Committee for Standardization, 2019).	The total market size of smart street lighting in Europe was 1.9 billion euros in 2019, and this number is expected to grow to 3.9 billion euros by 2024 (European Commission, 2020).

The comparative analysis in Table 6 reveals that SSL construction in the United States centers on fortifying security functions (Wu et al. 2017). Conversely, Europe places greater importance on incorporating humanistic care and cultural characteristics throughout the SSL construction. Overall, Europe and the United States adopt a "one characteristic function + N basic functions" model in their approach to SSL construction. The advantage of this model resides in offering a feature function as a memory point, easily recognizable and remembered by users.

China's SSL technology has rapidly developed, thus becoming a world leader in this field. In China, local SSL is mostly achieved through upgrading pre-existing street lamps instead of new installations. This methodology can save energy and expenses; however, the street lamp's untimely shape and varied external function modules may interfere with the use of SSL by urban residents. China's forward-thinking SSL construction aims to encompass all functions presently feasible in one step via the "N functions" mode. This mode lacks prominent characteristic functions, which, in turn, raises SSL construction costs. The primary factor restricting SSL's advancement in China extends beyond technology itself, as it derives from a failure to grasp functional requirements adequately and satisfy design requirements scientifically.

The literature review on SSL outlined above highlights that current research is mostly concentrated in the technical field. However, despite representing significant urban furniture, SSL is not receiving adequate attention from the perspectives of user needs, user emotions, product aesthetics, and product remanufacturability. Therefore, it is urgent to conduct further research to address these omissions, resolve the key hindrances restricting the high-quality development of SSL, and establish a more comprehensive design view of SSL.

STREET LAMP DESIGN BASED ON KE

A total of six research papers were retrieved for analysis, comprising five papers based on KE that focused on street lamp design using "Kansei Engineering" and "Street Lamp" as subject keywords from Google Scholar and one relevant research paper from CNKI. Three representative papers have been selected from the total of six papers for analysis.

Cheng et al. (2018) based on emotional design, combined with the analytic hierarchy process, built a hierarchical model of USLE. Firstly, the priority and importance of the functional demand indicators of specific urban areas are obtained by using the fuzzy analytic hierarchy process. Then, taking the Haiwan University City as an example, built the relationship between perception image factors and user satisfaction. At the same time, the relationship model between USLE form elements and the perceived image of Shanghai Bay University City is constructed by using the quantitative theory I category. Finally, from the perspective of value co-creation, a multiple regression model of perception image, form design elements, and form satisfaction are established. However, Cheng et al. did not carry out perceptual evaluation experiments in the field of EEG, EMG, and other physiological signals, and did not analyze and explore the correlation between the corresponding signals and perceptual images and user satisfaction. Although the function and appearance design of SSL has been studied, the design function and appearance can only improve users' satisfaction with USLE products to a certain extent, and cannot fully meet users' perceptual needs. Therefore, how to balance various factors and conduct comprehensive and intelligent product perceptual design according to the changes of the times and users will be the follow-up optimization research direction.

Liu et al. (2020) began by using psychological theory to screen participants capable of representing public emotions and aesthetic experiences through the IAPS system. The authors then established an aesthetic evaluation index system consisting of four levels and seven aesthetic indexes, consistent with aesthetic theory. Additionally, they determined the conversion relationship between aesthetic evaluation indicators and physiological eye movement indexes. Finally, the authors proposed a visually tracked and aesthetically measured product appearance design evaluation method. This evaluation method was verified through campus street lamp design as a case study. Liu's research has broken free from previous psychological limitations by introducing aesthetic measurement technology.

Tong (2021) proposed a process and method for product perception design based on narrative theory. Analyzing and organizing the narrative theme, the author extracted three types of narrative keywords. To establish narrative text evaluation indexes, the author utilized the principal component analysis method in factor analysis. Subsequently, the analytic hierarchy process was applied to estimate the weight value of each index for subsequent evaluation and calculation. Employing the TOPSIS method, the author sorted the advantages and disadvantages of the narrative text scheme and extracted design elements from the excellent narrative text to apply it to product design, thus completing the cultural creative design of the product. The SSL design project of Xinhua West Road in Zhuzhou City was taken as an instance, verifying the feasibility and applicability of this approach. Nonetheless, this research only discusses the construction of narrative text elements of cultural themes; hence, it is superficial in scope, and the approach has certain limitations and one-sidedness.

TABLE 6. Implementation Characteristic of SSL around the world (Lohote et al. 2018; Bai et al. 2017; Chen et al. 2018)

Country	City	Characteristic
United States	City of Dubuque	The first to carry out SSL pilot construction
	Los Angeles	Base Station + Recognize Vehicle Collision +..." mode
	Santiago	"Find a parking space + detect gunfire + ..." mode
	Las vegas	"Solar + kinetic energy +..." mode
China	Xiong'an New Area	multifunction
	Yibin, Sichuan	Upgrade existing street lamps
	Xi'an, Shaanxi	Intelligent upgrade
	Qingdao, Shandong	China's first 5G smart light pole road
France	Paris	"Seat + wifi +..." mode
Greece	City of Patras	Assemble intelligent lighting controllers on the original street lamps

DISCUSSION

This paper provides a comprehensive summary of KE and SSL's construction and research, highlighting the existing research gap of KE, research trends of KE, and development trends of SSL.

RESEARCH GAPS IN SSL DESIGN BASED ON KE

Based on the retrieval and analysis conducted in section 4, this study revealed limited research related to urban public facilities utilizing KE, while the available research surrounding SSL based on KE is also scarce and in need of improvement. Currently, KE-based research on street lamps tends to rely on classical KE methods, such as the semantic difference method, resulting in several research gaps, including (1) a lack of perceptual evaluation experiments in EEG, EMG, and other physiological signal fields, which hindered the exploration of correlations between these signals, perceptual images, and user satisfaction, (2) limited perceptual design and evaluation of only one aspect, such as function, form, or color, which could only improve user satisfaction to some extent and cannot fully cater to user's perceptual requirements, and (3) a relatively conventional research method and a lack of sufficient application research concerning big data and AI technology. Future research could benefit from exploring advanced methods and tools and increase the application of big data and AI technology to optimize the quality and comprehensiveness of SSL design.

FUTURE TRENDS OF KANSEI ENGINEERING

The research conducted over the past five years on KE technology for product design has identified key areas for ensuring the universality of initial image vocabulary, the objectivity of artificial classification, the accuracy of physiological data measurement, and the effectiveness of basic data used in mathematical statistical analysis (Li et al. 2019; Li et al. 2018). As new technologies, such as big data and cross-domain knowledge, become more integrated, KE technology will progress through the effective combination of psychological and physiological cognitive measurement (Yang et al. 2018; Tan et al. 2019; Zhou et al.2019), learning and decision-making technology backed on artificial intelligence (Pi et al. 2019; Ge & Wang,2022; Gong et al. 2022; Lin et al. 2022), comprehensive analysis models that combine multiple methods (Wu et al. 2019;Akg ü l et al. 2022), and statistical analysis technology supported by big data (Zhou et al. 2019; Kim et al. 2019; Wang et al. 2021).

FUTURE DEVELOPMENT TREND OF SSL

A smart city is a more intelligent and humanized living space. In the future, SSL will also be an organic combination of technology and art, function and emotion, rationality, and sensibility. SSL design will actively integrate modern design methods based on focusing on green, environmental protection, and energy conservation, pay more attention to the satisfaction of users' emotional needs, and more accurately control the actual needs of functions, which will be more reasonable, truly bring convenience to people's life and production, and promote the better development of the city. Therefore, the future SSL design will follow

the following design principles:

MODULAR PRINCIPLE

Considering the wide spread of multi-functional SSL in smart cities, different regions have different functions according to the actual situation, and various functional devices need to use modular design to carry out the intelligent design and planning layout of SSL according to the actual needs (Zhou et al.2021).

STANDARDIZATION PRINCIPLE

Multi-functional SSL needs to focus on promoting the standardization construction of the internal structure and appearance of the pole and all intelligent equipment, breaking the technical barriers between the lamp pole and the functional module, and between the functional module and the functional module, improving the design and production and construction efficiency of multi-functional SSL, and reducing the technical difficulty and cost of the later operation and maintenance (Zhang et al. 2022).

EMOTIONAL PRINCIPLE

SSL will pay more attention to the satisfaction of residents' emotional needs, be more in line with the cultural characteristics of the region, be closer to the residents, and have more temperature (Cheng et al. 2018).

CONCLUSION

At present, KE technology is mainly used in the field of consumer goods in which consumers have an absolute voice, but less in the field of public facilities design and urban furniture design, which shows that users have a weak voice in these product fields. However, urban residents are the users of urban public facilities. Only by fully listening to the functional and emotional needs of users and carrying out a scientific design during the design process can the residents' satisfaction with the facilities and the city be improved, and then the residents' happiness is improved.

Currently, the main problems in SSL design are the matching of functions and use scenarios and the perceptual design of appearance. This is the problem area that KE is good at solving. For the matching of functions and use scenarios, we can explore the use of cutting-edge technologies such as psychology, physiology, or big data to mine and extract images and user needs. For the perceptual design of appearance, appropriate quantitative methods can be explored to establish the mapping relationship between product image elements and product design specialties. This paper believes that the development of SSLs guided by scientific SSL design principles and combined with appropriate design methods of KE will make SSLs more scientific, reasonable, open, and warm.

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DECLARATION OF INTERESTS

The authors declare no known competing financial interests or personal relationships that could influence the work reported in this paper.

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