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Chinese Architects' Awareness of, and Attitudes towards, Low-Carbon Architectural Design

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Abstract Environmental issues have drawn increasing attention in China, and consequently low-carbon architectural design has become more in demand. By analyzing the results of a questionnaire survey, this paper aims to investigate Chinese architects' perception of low-carbon design, their current design practices as well as their expectations of future developments. From September to November in 2014, 168 Chinese architects participated in an online survey for this study. The findings suggest that although the awareness of low-carbon issue is relatively strong, Chinese architects confront many barriers in practice by the lack of design methods appropriate for local circumstances of architectural practice. The paper concludes that crucial for improving the status of low-carbon design in China is to integrate existing technologies with design methods.

Keywords Low-carbon architectural design, Design methods, Chinese architects, Questionnaire survey

1. Introduction

Environmental problems are an important issue around the world. In 2009, the Chinese State Council committed to reduce 40 to 45% of carbon emissions per unit of GDP by 2020 (compared with 2005) [1]. According to the carbon emissions prediction curve [2] as shown in Figure 1, it can be easily noted that the task and pressure for China's carbon emissions reduction are still enormous.

Between 2008 and 2050, the proportion of China's urban population will rise from 46.4% 75%. This means there are still 400 million people who will migrate into cities from rural areas [3]. In the construction sector, every year about two billion square meters of new buildings are completed; this figure accounts for nearly half of the world's new construction [4]. It will consume about 40% of global cement and steel production [5]. The final energy consumption of the construction industry accounts for 27.5% of the country's total energy consumption, and will gradually increase to around 40% [6]. These realities make the reduction of carbon emissions more difficult. Since 2002, with every 1 percent increase in the proportion of urban population, carbon emissions have risen by 414 million tons (correlation coefficient of 0.995) [7].

The reducing carbon emissions in the building industry is of great importance in achieving the national carbon reduction goal; in this, the architect plays a key role and assumes major obligations. In view of this, it is necessary to carry out investigations on the design practices of Chinese architects to understand the current status of China's low-carbon building design. Results of the data and statistical analysis in this survey will serve as groundwork and guidance for the future low-carbon design research and provide strategies for reducing carbon emissions. After the relevant literature reviews, this paper reports on an investigation using an online questionnaire that dealt with three aspects: low-carbon consciousness, the current design situation, and the expectations and vision of architects.

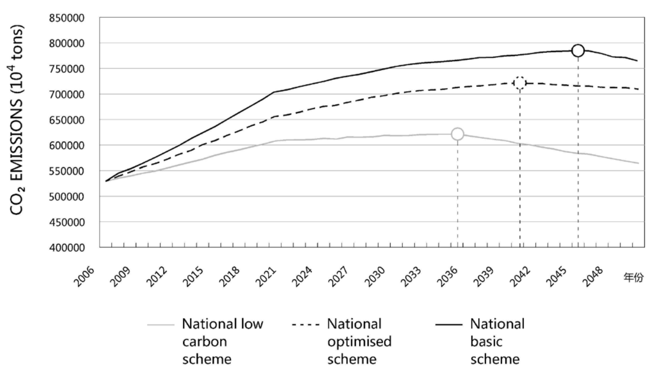

Figure 1. China's carbon emissions prediction curve

2. Previous Research

2.1. General Condition and Trend of Low-carbon Building in China

In China, the time is ripe for promoting large-scale construction of low-carbon building. First, low-carbon and

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energy-efficient buildings are entering a period of rapid development. According to the 12th National Five-Year Plan, the total of new green building area will reach 8.0×10^8 m^2. By the end of 12th Five-Year Plan, more than 20 percent of new urban buildings will meet green building standards and 20 percent of cities will have begun to plan and/or build various types of eco-city. Second, a social consensus on the development of low-carbon building has come into being, with flourishing and diverse education and outreach activities advocating low-carbon life. Third, China has established a three-level system of standards and management systems: master plan (e.g. Five-Year Plan), indicator requirements (e.g. Green Building Evaluation Standard and Public Building Energy Efficiency Design Standards), and implementation guidance (e.g. China Ecological Residential Technology Assessment Manual and Green Olympic Construction Implementation Guide). Fourth and finally, the solar PV, LED, and other green technology industries are steadily developing, strongly supporting the development of low-carbon buildings [8] [9] [10].

On the negative side, there are three main obstacles to the development of low-carbon buildings: 1) Various climates and building energy-use types in different regions have led to discrepancies in the degree of acceptance of low-carbon buildings, e.g. there are more areas of hot summers and cold winters than areas of severely cold winters where heating must be provides [10]. 2) Some implementations and adoptions of green low-carbon technologies are not satisfied, e.g. there is underutilization of solar water heating systems and adjustable external shading. At the same time, some low-carbon building equipment is not running as designed because of design defects such as shading of solar panels [11]. 3) For the architect, traditional design processes, the lack of multi-disciplinary cooperation methods, and insufficient knowledge constrain the achievement of low-carbon building design [12].

2.2. Current Condition Analysis on Architects' Design

Architects play an important role in the development of low-carbon buildings, so many scholars have conducted research related to architectural design practices and methods. As a survey on Australian architects reflects, although most architects consider low-carbon technologies to be important criteria for judging the success of contemporary architecture, they often are not expressed in virtual design practices. Reasons for this include architects being unfamiliar with the basic principles and methods for low-carbon building design. Other factors include the design process, economics, aesthetics, etc., which often overwhelm the importance of low-carbon goals, hence low-carbon is not deemed as the dominant factor of shaping design concepts [13] [14] [15]. A survey also showed that the main drivers of low-carbon buildings are regulations, clients, and the desire to improve the design competency of architects themselves.

Another study on the integration of solar architecture design revealed that architects, when facing new technologies, currently lack innovative design methods in the concept stage [17].

3. Research Methods

3.1. Layout of Questionnaire

Based on the literature noted, we based our research on three aspects: lower design perception, the status quo of low-carbon design, and lower design expectations. We hope through these three aspects of investigation to acquire a better understanding of the status of China's low-carbon building design.

The questionnaire consisted of 11 closed-end questions, divided into four groups (Table 1). Questions 1–3 mainly addressed the first aspect. Questions 4–6 were designed to measure the status of low-carbon design to address the second aspect. Questions 7–9 responded to third aspect. Two background questions (10 and 11) took the architects' professional experience and the types of units they serve as variables to enable further analysis of the data obtained.

Table 1. Structure of Questionnaire

Sort	No.	Contents
Perception	Q1	Is it necessary to introduce the low-carbon concept?
	Q2	What are the architects' responsibilities of achieving the low-carbon goal in a design team?
	Q3	In your design practice, what listed below are the main low-carbon design requirements from?
Status Quo	Q4	To what extent the low-carbon concepts affects your design conception?
	Q5	In which stage of design will you devote more to consider on low-carbon design?
	Q6	How do you evaluate your knowledge and proficiency in respect of low-carbon design?
Anticipation	Q7	In conceptual design , which methods are most helpful with low-carbon design for you?
	Q8	What do you think is the most difficult to realize low-carbon architecture design?
	Q9	Which learning channel is most efficient to enhance the low-carbon design ability?
Background	Q10	Your working years?
	Q11	What kind of entity do you serve for?

3.2. Distribution and Sampling

The survey was distributed online and completed surveys were collected. Specific steps were: create an electronic questionnaire on a professional survey web page (www.wenjuan.com), send architects the address of web page by email, after receiving a confirmation. These architects were randomly selected from a list of recent participants in ongoing education at the College of Architecture and Urban Planning, Tongji University.

Between September and November 2014, a total of 168 Chinese architects responded to our questionnaire, most of whom come from the major cities of China and various municipalities, including Shanghai, Nanjing, Hangzhou, Beijing, Wuhan, Guangzhou, Kunming, Lanzhou, etc.

Two factors could have affected the outcome of the investigation. First, the respondents were from China's major cities, which may affect the nationwide representativeness of the conclusions. The level of metropolitan architects' education and professional capacity are generally higher than that those of medium and small cities. Second, architects who have little interest in this issue may not have replied. This self-selection bias may have introduced some discrepancy between the statistical data and the actual situation.

3.3. Data Collection and Analysis Methods

The questionnaire web page had easy access to data processing and data analysis tools. After each interviewee completed all the questions, the answers were automatically rendered into a data chart. Cross-table analysis was used here to determine distribution and correlation, taking the answers of every two questions as variables.

4. Analysis

As shown in Table 2, of the 168 architects surveyed, most were young architects of around 10 working years, in which 61 (36.3%) has 1–3 years of work experience, 57 (33.9%) 3–10 years; among those with more than 10 years of experience, from 10 to 20 years are 36 (21.4%), more than 20 years accounting to 14 (8.3%).

Table 2. Sample Statistic According to Working Experience (Q 10)

Working years	Quantity	Percentage
1–3 years	61	36.3%
3–10years	57	33.9%
10–20years	36	21.4%
Over 20 years	14	8.3%

As indicated in Table 3, there were 113 architects from a large-scale design institute of more than 100 people , taking up the majority of surveyed (67.3%); the rest of the respondents were from professional design consultancies (11, 6.6%), design firms and studios (18, 10.7%), universities or research institutes (19, 11.3%) , real estate (5, 3.0%), and others (2, 1.2%).

Synthesizing the two factors above, the young architects from large design institutes constituted the main body of survey respondents. Currently, China's architectural design industry is still dominated by large state-owned institutes and the front-line designers are young people. Hence, the interviewee composition of this survey is basically in line with the real-world situation.

Table 3. Sample Statistic According to Type of Entity (Q 11)

Type of entity	Quantity	Percentage
Large design institute (over 100)	113	67.2%
Design consultancy company (20–100)	11	6.6%
Design firm and studio (below 20)	18	10.7%
University or research institute	19	11.3%
Real estate company	5	3.0%
Others, such as construction unit	2	1.2%

4.1. Consciousness of Low-carbon Design

The survey data showed that Chinese architects have a strong sense of responsibility for low-carbon design. More than 90 percent of the architects believed that the introduction of low-carbon ideas is necessary. On the contrary, only about 5 percent think it unnecessary, and about 4 percent gave a noncommittal answer. (Table 4)

Table 4. Answers to Q1

Answer	Quantity	Percentage
Necessary	153	91.0%
Not necessary	8	4.8%
No idea	7	4.2%

In contrast with the high degree of awareness, when asked: "Architects should bear what responsibility in achieving the objectives of low-carbon building?", most architects (67.9%) stated that they were only a subordinate participant, rather than a project manager who takes charge (Table 5). Some respondents stated that the architect is only a subordinate participant of no importance (8.9%). Figure 2 reflects the relationships between the age of the interviewees and their degree of low-carbon design consciousness; with increasing age and experience, the sense of responsibility of low-carbon design also gradually increases.

Table 5. Answers to Q2

Answer	Quantity	Percentage
Chief in charge	39	23.2%
Subordinate participant	114	67.9%
More dependent on engineers	15	8.9%

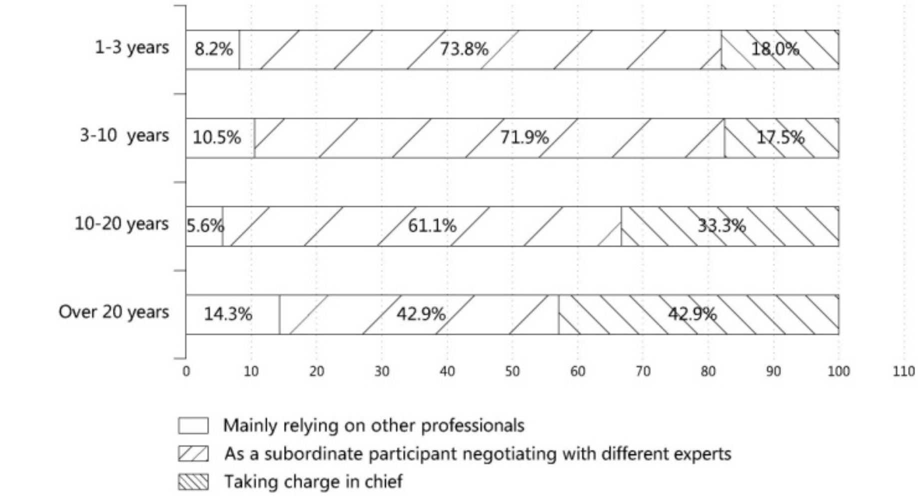

Figure 2. Cross-tabular analysis between Q2 and working years

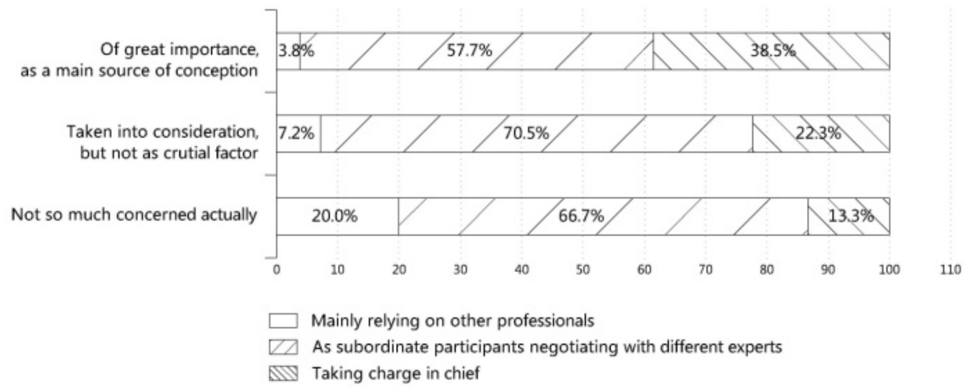

Figure 3. Cross-tabular analysis of Q2 and Q4

Accordingly, the predominant reason cited to promote low-carbon design was national mandatory standards (64.9%), which led business requirements of client accounting (16.7%), while only a handful of architects (14.9%) cited the pursuit of low-carbon design for improving their professional ability. The actual purpose of this question was to measure the initiative of the architects' low-carbon design; the outcome was clearly not as optimistic as we thought (Table 6). Put in other way, it proves the significance of design regulations for low-carbon building implementation [18] [19].

Table 6. Answers to Q3

Answer	Quantity	Percentage
National compulsory standards	109	64.9%
Client commercial demand	28	16.7%
Self-improvements requirements	25	14.9%
Others	6	3.6%

From the above analysis, it is not difficult to see that, in general, architects unconsciously avoid responsibility for low-carbon design while claiming its importance. Evidently, they do not actively pursue innovation out of their own field.

4.2. Status Quo of Low-carbon Design

In the concept design, two-thirds of the architects took low-carbon issues into consideration, but not as the determining factor; only 26 respondents (15.5%), deemed low-carbon design as the primary design factor and viewed it as a starting point of design creation. The number who said they do not consider low-carbon at all was 30 (17.9%) (Table 7). As apparently implied in Figure 3, architects' involvement and regard has a direct relationship to their consciousness of the role in the low-carbon design, but only 10 interviewees thought that architects should take the main responsibility for low-carbon design and implement it in concept.

Table 7. Answers to Q4

Answer	Quantity	Percentage
Very important, main source of design concept	26	15.5%
Not key factors although taking into consideration	112	66.7%
Not thinking much in design stage	30	17.9%

The next question reflected the methods architects use to achieve low-carbon targets. Although this question was not directly asked, it was implied in that the involvement at different design stages vary. In general, the conceptual design mainly comprises the relation of building and site, the partition of internal space, the architectural image, and involves most of the passive design techniques. The preliminary design stage deepens the conceptual design, and includes equipment selection and other technical issues. During the construction stage, architects focus on building construction, detail design, and technical cooperation with related professionals. In other words, the later a design stage, the less the extent to which architects rely on the architectural design skills, but increasingly rely on the help of technology and other professionals to achieve low-carbon targets. The survey revealed (Table 8) the involvement of architects in each design stage in descending order: conceptual design (39.9%), preliminary design (37.5%), and construction design (22.6%). In addition, it can be seen that those who are willing to take more responsibility for low-carbon goals and actively seek solutions tend to contribute more in the conceptual stage; this also shows the significant impact of conceptual design on a building's low-carbon performance (Figure 4).

Table 8. Answers to Q5

Answer	Quantity	Percentage
Conceptual stage	67	39.9%
Preliminary stage	63	37.5%
Construction stage	38	22.6%

The survey also revealed that Chinese architects have very little confidence in their low-carbon design ability. Only about 3% of the respondents believe their knowledge is very comprehensive and can be applied with ease in practice. Most of them (54.2%) answered that their knowledge and proficiency with respect to low-carbon design was "not proficient." More than forty percent (42.9%) said that their knowledge was not sufficient to use in the practice of designing a truly satisfying low-carbon energy building (Table 9). Figure 5 shows the comparison of responses by current employment status of the architect-respondents. It shows that teachers from universities and research institutes evaluated themselves highest, followed by those from design firms or studios and those from professional design and consulting companies, with those from large and design institutes rating themselves lowest. In other words, architects from larger work units are less confident in their low-carbon abilities. This result may be related to patterns of working organization. Architects from small design firms have more freedom to innovate.

Table 9. Answers to Q6

Answer	Quantity	Percentage
Comprehensive, reflected in the design process	5	3.0%
Know something, difficult in application	91	54.2%
Relatively lacking, less of rarely application in practice	72	42.9%

The above analysis shows that, in general, architects' application of low-carbon concepts is still insufficient and they rely more on other professionals and technicians, or other technical means, rather than their own design skills to achieve low-carbon goals. The reason for this may be that architects lack self-confidence in their knowledge of low-carbon design.

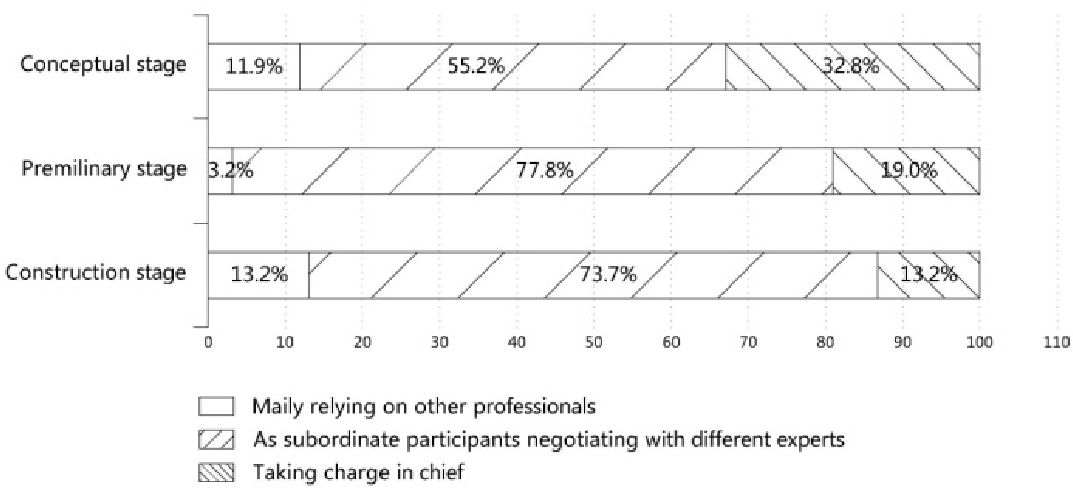

Figure 4. Cross-tabular analysis of Q2 and Q5

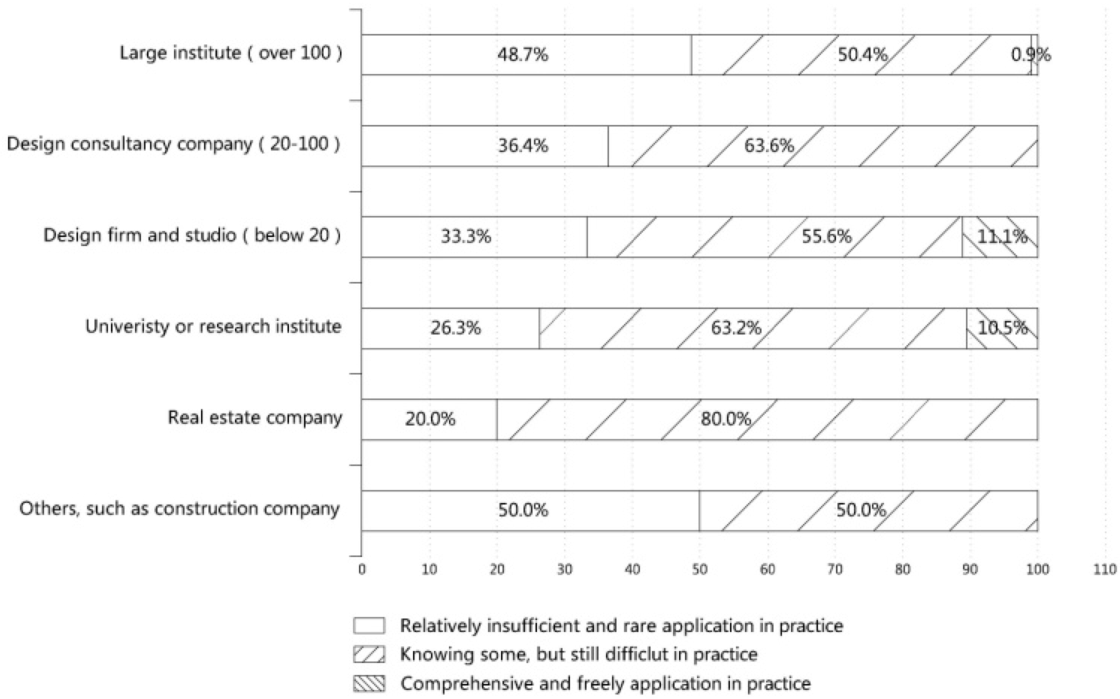

Figure 5. Cross-tabular analysis of Q6 and Q11

4.3. Anticipation of Low-carbon Design

The third part was to comprehend the architects' expectations for low-carbon design from the perspectives of design tools and methods, design difficulties, and design education.

Table 10 shows that each of the five listed design methods and tools has practically the same popularity. Reference to successful design cases (23.8%) and collaboration with energy experts (22.0%) were slightly more popular than the remaining three: reference to index (17.9%), BIM software (17.3%), and following general design principles (17.9%). This reflects that the analogy approach (case reasoning) describes most architects' thinking characteristics, which have a greater value in use. It is also noticeable that various design tools and methods were used in various design stages instead of only one. Even within a stage, various methods were used to compare, analyze, and confirm with each other.

Table 10. Answers to Question 7

Answer	Quantity	Percentage
Following the successful design work and experience accumulated oneself	40	23.8%
General low-carbon design principles	30	17.9%
Analysis through computer simulation	29	17.3%
Referring to index from design code	30	17.9%
Collaboration with experts	37	22.0%
Others	2	1.2%

Table 11 shows that about half of the architects (51.2%) thought that the biggest obstacle to implementing low-carbon design is the increased design cycle not being accepted by the client. It also suggests that future research should focus on how to quickly integrate low-carbon factors into design. Over two-fifths of the architects (43.5%) said that a lack of knowledge or a weak capability to apply relevant knowledge was the biggest obstacle. From this comparison it can be seen that most architects are confident with their own learning ability or potential, and think outside factors are the main restriction to the development of low-carbon design. Figure 6 also suggests that increasing experience correlates with a decreasing significance of lack of knowledge and coordination capability as obstacles. Architects of all ages, however, face the problems of increasing design difficulty, extended design cycles, and the difficulty of integrating low-carbon principles into building concepts.

Table 11. Answers to Question 8

Answer	Quantity	Percentage
Hard to corporate with other professionals due to lack of relevant knowledge	35	20.8%
Hard to grasp and integrate into the design conception although know of relevant knowledge	38	22.6%
Not admitted due to prolonging design duration and enhancing the difficulties	86	51.2%
Others	9	5.4%

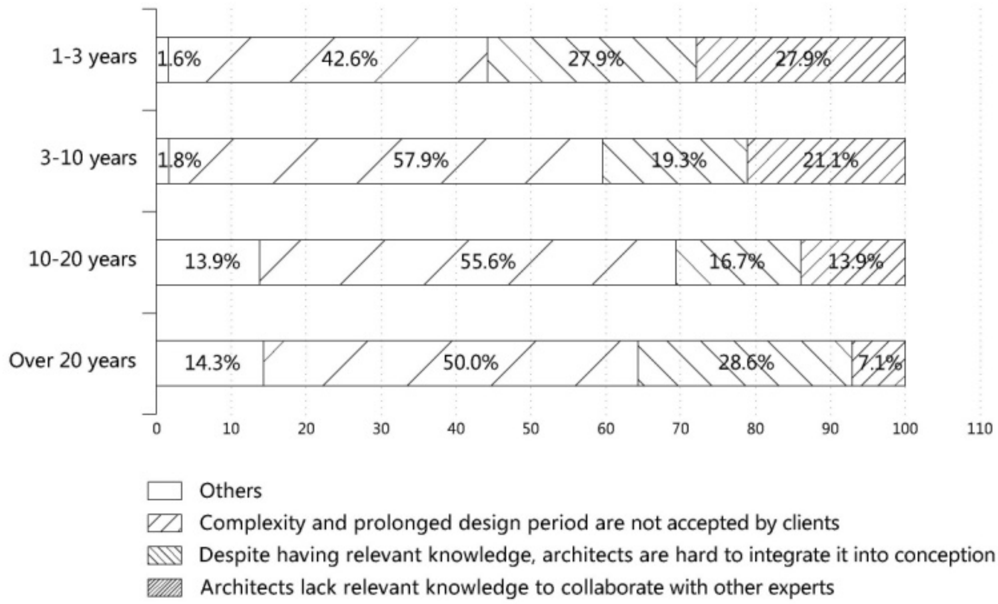

Figure 6. Cross-tabular analysis of Q8 and working years

Almost half of the architects (48.8%) reported that seminars were their preferred way to acquire knowledge. This may be related to the strenuous daily work of Chinese architects. They have no time to pursue comprehensive study. But 20.3% were willing to study systematic theory books to improve their proficiency when possible. In addition, 14.3 percent and 8.3 percent use professional literature and online forums as their primary way to learn about low-carbon design. (Table 12).

Table 12. Answers to Question 9

Answer	Quantity	Percentage
Lecture held by association or company	82	48.8%
Online professional forum	14	8.3%
Professional magazines and journals	24	14.3%
Systematic theoretical work	34	20.2%
Others	14	8.3%

5. Conclusions

The following conclusions can be drawn from the above analysis:

1) The development trend of China's low-carbon buildings has been good, and is advancing to a higher, better degree.
2) Even though Chinese architects have a strong awareness of design for low-carbon energy (even stronger than their colleagues in developed counties [14] [20] [21]), in the design practice, especially the concept design stage, they still encounter many obstacles, mainly due to the lack of good design methods that are suitable for working architects. This is also a common problem for architects worldwide who practice low-carbon architectural design [16] [17] [20].
3) The key to improving the situation of low-carbon design in China relates to combining innovative design methods with existing techniques and to find the appropriate ways to apply those methods and techniques.

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