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SUBJECTIVE EVALUATION OF THE ENVIRONMENTAL QUALITY IN CHINA'S INDUSTRIAL CORRIDORS

Jian XU[a,b], Mei ZHANG[c], Long SHAO[a], Jian KANG[b,a]

[a] *School of Architecture, Harbin Institute of Technology, Harbin 150001, China*
[b] *School of Architecture, University of Sheffield, Sheffield S10 2TN, UK*
[c] *School of East Asia Studies, University of Sheffield, Sheffield S10 2TD, UK*

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Abstract. Based on 270 questionnaire surveys in 8 cities of 5 industrial corridors in China, this study aims to examine the effects of industry construction on the evaluation of environmental pollution, natural environment, built environment, personal perception and development and policy. The results show that the evaluations on environmental pollution and landscape design are both below the medium level, but the evaluations of the living comfort and safety are both above the medium level. Further analysis, females usually give lower evaluation scores than males, and age and health situations are negatively related to the evaluation results; People indicate a great desire to reduce the environmental pollution and protect the natural environment. Moreover, the landscape was analysed using colour extraction techniques based on video recording, there are significant correlations between industrial pixel ratio and evaluation results of air quality, vegetation pixel ratio and evaluation results of river water quality, and public facilities pixel ratio and evaluation results of comfort levels.

Keywords: China, industrial corridor, attitude, subjective evaluation, environmental quality.

Introduction

Globally, at present, the industrial distribution experiences an evolution process from decentralized to centralized pattern, particularly in developing countries (Ellison, Glaeser 1999). Industrial cities are rapidly developing into a pattern of "industrial corridors", which are defined as a number of cities, with a maximum spacing of 150 km, say, that are connected by roads or railways that constitute an integrated industrial area and share economic development goals (Xu *et al.* 2015). Based on the statistics of 51 industrial corridors in China, they are normally 100–300 km in length, 30–100 km in width, and the number of cities in an industrial corridor ranges from 3 to 20. This is particularly the case currently in East Asian countries, India, the southwest America, Africa and some other manufacturing-dominant countries.

Over the past decade, as "world's factory floor", China has had a 10.42% average growth rate in Gross Domestic Product (GDP), to which manufacturing contributed 41% (National Bureau... 2014). Such large-scale industrial production activities for economic development significantly led to the serious environmental pollution/contamination: The air pollution index (AQI, including ozone, fine particulate matter, nitrogen dioxide, carbon monoxide, sulphur dioxide and total reduced sulphur compounds) of over 75% of the total number of cities is below health-based standards (HEI International… 2004), rapid increase in cancer incidence in industrial corridor areas (Chen *et al.* 1998) and PM10 and smaller particles (Quan *et al.* 2011) lead to an estimated 2.4 million premature deaths every year (Zhang *et al.* 2010). Half of China's water resources are considered to be unfit to be treated to make it safely drinkable (Zhou *et al.* 2014). Industrial solid waste (ISW) constitutes 75.9% of total waste and was rapidly increasing (Wang *et al.* 2008). Moreover, industrial noise pollution seriously jeopardises the health of workers and nearby residents (Nelson *et al.* 2005). The environmental pollution of industrial corridors influences both natural environment and built environment and the overall environmental quality (European Environment Agency 2012) is affected. Environmental quality is a set of properties and characteristics of the environment, either generalised or local, as they impinge on human beings and other organisms. It is a measure of the condition of an environment relative to

Corresponding author: Jian Kang
E-mail: j.kang@sheffield.ac.uk

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the requirements of one or more species and or to any human need or purpose (Johnson *et al.* 1997).

With the attention on worldwide industrial growth, it is equally important to study and understand citizens' attitudes towards the industrial corridor environment. A number of subjective studies on the urban environment (Zhang, Kang 2009), campus environment (Shi *et al.* 2005), residential areas (Wu *et al.* 1995), leisure satisfaction and quality of life of urban central districts (Ngai 2005) have been performed. However, the industrial environmental quality has not been subjectively evaluated.

Therefore, this study aims to subjectively evaluate the environmental quality of industrial corridors of China through a recent survey of 8 cities in 5 industrial corridors. According to a framework of subjective and objective evaluation method of environmental quality (Marans 2003), seventeen key research questions have been analysed, including environmental pollution, natural environment, built environment, personal perception and development and policy. First, this paper reveals the general public's attitude by analysing the preliminary results obtained regarding interviewees' subjective evaluation, and comparisons have been made with other cities like Beijing and some other industrial countries in Europe and America. Then, the correlations of all environmental and social factors are explained. Furthermore, we explain the correlations between contextual and demographical data and the relationship between the objective proportion of different pixels and the subjective results, understand the interaction of subjective evaluation and objective landscape elements. The conclusions can be used to understand people's subjective feelings under the fast industry development situation. Moreover, this paper puts forward some ideas which could be useful for industrial park planning and design.

1. Methodology

1.1. Study areas

To date, there are 51 industrial corridors supported by the Chinese government. Figure 1 shows the distribution of the provincial industrial corridors in China based on a systematic study of the provincial government documents (National Bureau... 2013). 87% of the provinces have one or more industrial corridors, then the cities which have industrial corridors are divided into five types according to the starting year of the development, which cover three consecutive "five-year plan" periods (Casey, Koleski 2011). Given the significant differences in industry type between north and south China, this paper concentrates on north China, and five industrial corridors were selected by stratified random sampling method based on the classification of starting year (Taleb 2005), and then most representative cities within the industrial corridors were selected. The eight selected cities are shown in Figure 1. Although the city population density varied, the population density of industrial areas was approximately the same. Thirty questionnaires were distributed in each city. For the sampled cases, the start years span over a relatively wide time range. The plan areas of the five industrial corridors range from 192 to 837 square kilometres. In addition, the GDP ranges from 4.8 to 10 billion dollars up to 2010.

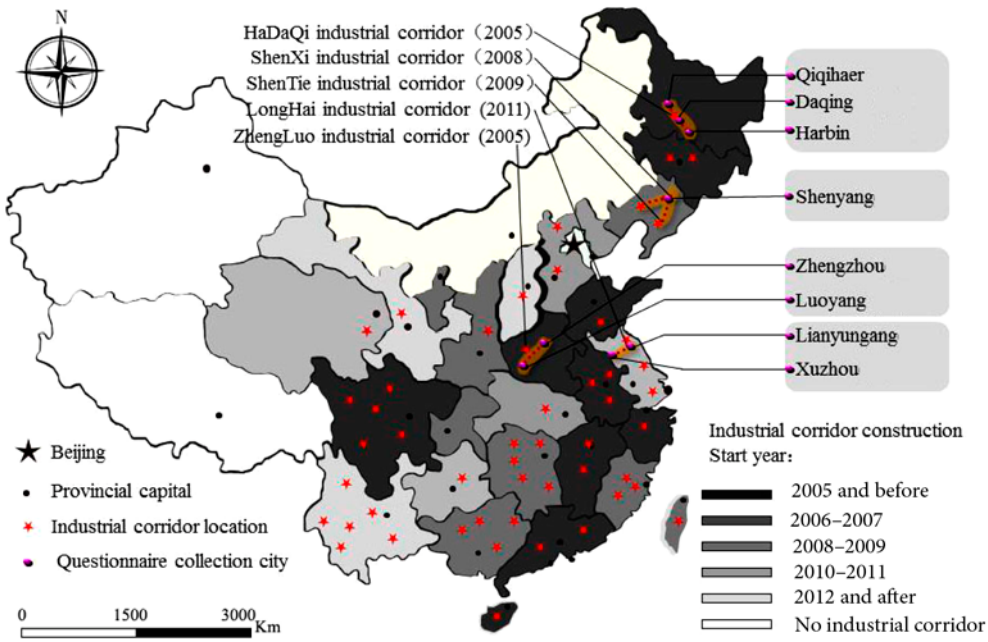

Fig. 1. Provincial industrial corridor distribution of China, including the construction start year and the case study cities, where the numbers in brackets after the industrial corridor refer to the start year of the industrial corridor development

1.2. Landscape characteristics

A video method was used to record and analyse the landscape characteristics in the main roads of industrial zones where questionnaire survey was made. Videos were recorded at noon in clear weather in May 2013, so the shadow colour effect of the environment was minimised. The videos were recorded at a constant normal run speed (9 km/hr) on the main road by motor vehicles, where the questionnaires were distributed in 5 industrial corridors. The average recording distance was 4 km (minimum sample distance ≥ 2 km). With this method, 45 videos were recorded in 8 typical cities of 5 industrial corridors, and the total of video recording distance was more than 180 km and the typical characteristics of the sampled main roads of the industrial zones in five industrial corridors are shown in Figure 2.

To identify different landscape/architectural elements (industrial, vegetation, public facilities), the video recording was analysed by developing a MATLAB program for colour identification. First, the distance from the shooting points, the architecture of all of the industrial corridor videos and the proportion of the video images occupied by sky were adjusted to the same values. Then, the video was split into images that comprehensively consider the shooting speed, depth of field and video frame rate. Based on these criteria, to ensure the image continuity as much as possible, an image was selected and extracted every ten frames. To effectively restrain the noise, we used median filter processing. First, we selected multiple objects and 24 * 24 samples for the training set from the centralised images; then, we extracted the colour histogram in the RGB colour space. Examples of actual video capture images and the colour characteristics of the "landscape elements of industrial corridors are shown in Figure 3, where the industrial pixels include industrial buildings, office buildings, fences and other industrial production facilities; the vegetation pixels include lawns and trees of the environmental greening and green sculpture; and the public facilities include roadways and sidewalks. The overall results are shown in Table 1. Further analysis shows that the industry has a correction coefficient of –0.817 ($p \leq 0.01$) with the vegetation, and the vegetation is also correlated with public facilities, with a coefficient of 0.667 ($p \leq 0.05$), using Spearman's rank correlation coefficient.

Table 1. Pixel proportion (percentage) of each landscape element of industrial corridors.

City	Industrial pixels (factory building)	Vegetation pixels (trees and grass)	Public facilities pixels (roadways and sidewalks)	The total percentage (except for the sky)
Zhengzhou	31.27%	14.22%	16.28%	61.77%
Luoyang	30.14%	16.28%	14.66%	61.08%
Xuzhou	21.54%	15.14%	11.92%	48.60%
Lianyungang	18.03%	27.24%	17.33%	62.50%
Shenxi	23.02%	16.78%	15.17%	54.97%
Shentie	26.10%	17.85%	12.02%	55.97%
Harbin	22.98%	18.79%	21.08%	62.85%
Daqing	19.08%	23.07%	18.35%	60.60%
Qiqihaer	19.42%	19.07%	17.32%	55.81%
Mean sore	23.51%	18.71%	16.02%	58.24%

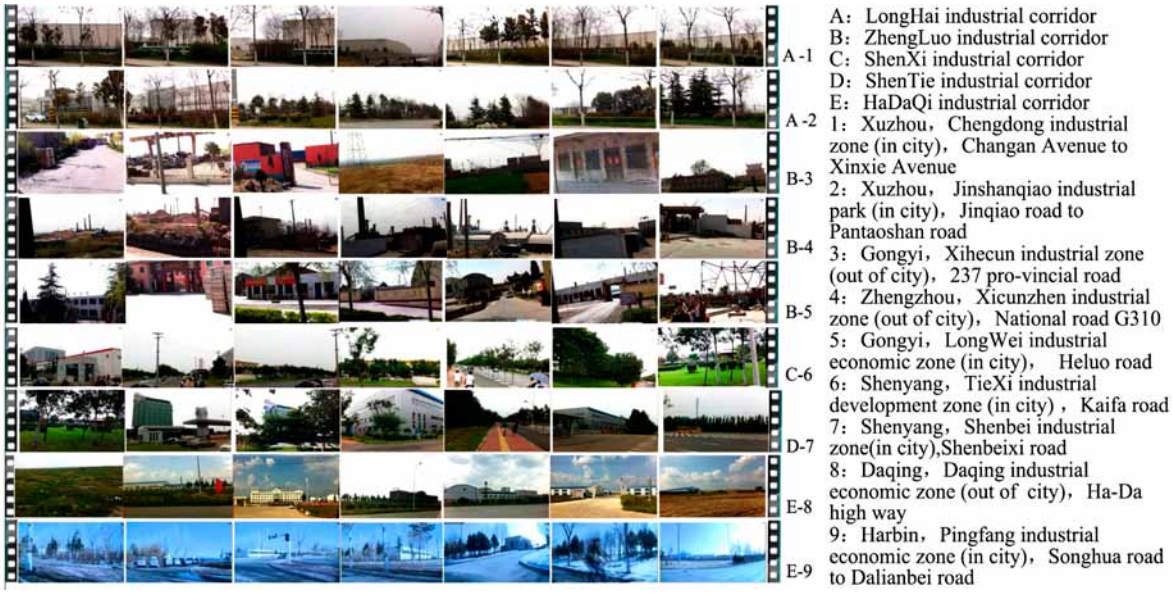

Fig. 2. Typical characteristics of the main sampling road of the industrial zones in the five industrial corridors

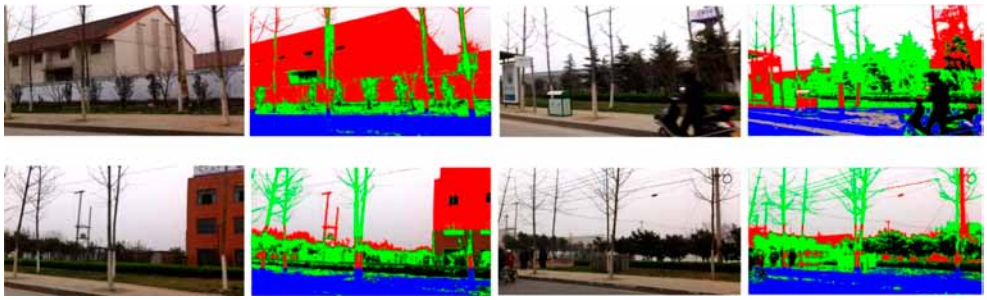

Fig. 3. Contrast images of the actual video-captured images and colour characteristics of landscape elements of industrial corridors

1.3. Questionnaire

The questions included environmental pollution, natural environment, built environment, personal perception and development and policy. These five aspects are not only complete interpretation of environmental quality evaluation index (Johnson *et al.* 1997), but also correspond to the five subsystems of "system dynamics model of industrial growth and landscape ecology" (Xu *et al.* 2015).

Environmental pollution involves the conditions of industrial corridor in terms of air, water, solid waste and noise pollution, based on the environmental elements morphological classification, which corresponds with the items included in two recent surveys of Beijing (Wong 2003; Zhang, Kang 2009). Natural environment includes a number of indicators. In general, "flora and fauna", relates to biosphere diversity and also landscape ecological situation (Goudie 2013; Wu 2013; Hobbs 1997). From the objective perspective, the number and survival situation of animals reflects the continuity of the ecological corridors, also reflecting the protection of the natural environment (Mörtberg, Wallentinus 2000). Consequently, the questionnaire was designed based on two topics: "the living situation of animals/birds/insects (bees, butterflies, dragonflies, etc.)" and "landscape greening". Built environment questions were designed to address human activities, public service facilities (Forsberg, von Malmborg 2004). Landscape design includes landscape sculpture design (includes pavilion, gallery, landscape architecture, art sculpture and other garden elements with the function of art and use), waterscape design and application and building height/density. Public service facilities are associated with the degree of public evaluation with recreational physical-activity facilities (fixed facilities and devices that can be used to develop sports fitness, teaching, training and competition and are open to the public) and leisure squares. Moreover, personal perception is an important part of environmental quality, which includes comfort levels (contain both psychic comfort and physical comfort, e.g. housing, catering, transport, infrastructure, health and inner feelings etc.) and security situation (industrial, construction, transportation, etc.) (Andersson *et al.* 2003). For these topics, five-point linear scales were used to indicate the five degrees of evaluation results listed in Table 1: –2, Not satisfied at all; –1, Not satisfied; 0, Medium; 1, Satisfied; and 2, Very satisfied.

Moreover, four questions regarding development and policy were designed at the end of the questionnaire. This set of questions appropriately reflects the public's willingness to slow the construction of an industrial zone to reduce environmental pollution and the destruction of natural environment, and indicates the degree of the public's willingness to complain to the government regarding industrial environmental problems that they face if there is a simple and convenient method to do so. An additional question concerned the public's willingness to donate 0.5% of their monthly income to improve the industrial environment. Five linear scales of agreement were generally used.

To avoid the randomness of questionnaire data, the sample size, statistical analysis of reliability and validity of questionnaires have been carried out, and it was shown that the sample capacity can meet the requirements (Taleb 2005).

1.4. Survey procedure and interviewees

The surveys were performed as face-to-face interview in public spaces as in previous studies (Yang, Kang 2005). In the 8 cities (9 sites), 270 interviews were performed, and 30 questionnaires were distributed in each location with the help of 6 university students; 59.6% of the 270 interviews were administered inside whilst 40.4% were administered outside in urban industrial parks. The interviewees were selected in the case-study sites. In terms of gender, by using simple random sampling method (Taleb 2005), there were 69.3% males and 30.7% females, which generally conforms to the general proportions of males and females in such industrial areas of north China. For each age category, as shown in Figure 4a, there were groups of people aged 10–20, 20–30, 30–40, 40–50, 50–60 and over 60 years; the population age distribution curve is generally close to the Chinese age distribution in 2010 (National Bureau... 2010). The interviewees' residence situations

were divided into three conditions, as shown in Figure 4b. Five types of areas in each industrial zone were chosen in which to issue the questionnaires, and the proportions of interviewees in different locations are shown in Figure 4c. Regarding the interviewees' occupations, 8 categories were considered: factory workers, factory managers, famers, business people, teachers, retirees and others.

1.5. Conceptual framework

Corresponding to the questions above, and also with reference to subjective and objective evaluation of environmental quality in previous studies (Marans 2003), the framework of this study is shown in Figure 5. This research is divided into two parts, the subjective questionnaire survey as its main part and objective environmental conditions as a minor part. The research method was designed to show the actual environmental situation of the industrial corridors clearly, and to explore the relationships between the objective environmental factors and the subjective evaluation. At the result analysis level, the conceptual framework includes subjective responses (questionnaire survey), objective conditions (analysis of landscape characteristics pixels), statistical analysis of the correlations among subjective factors (relationships among the 5 categories of factors), and, the effect of demographical/contextual factors and the effect of landscape features. The results will contribute to the understanding of actual conditions in the subjective and objective aspects of China's industrial corridors. Moreover, the results are useful for understanding the evaluation of people with different demographical and contextual background, which in turn can contribute to the improvement of the environment to satisfy different groups of people. Furthermore, by understanding the relationships between subjective

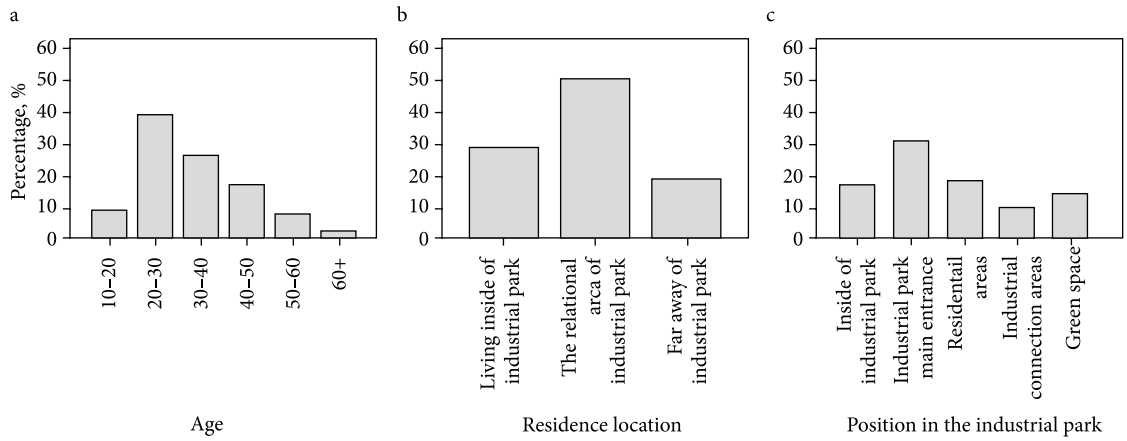

Fig. 4. The distribution of interviewees' age, residence location, and interview position in the industrial parks

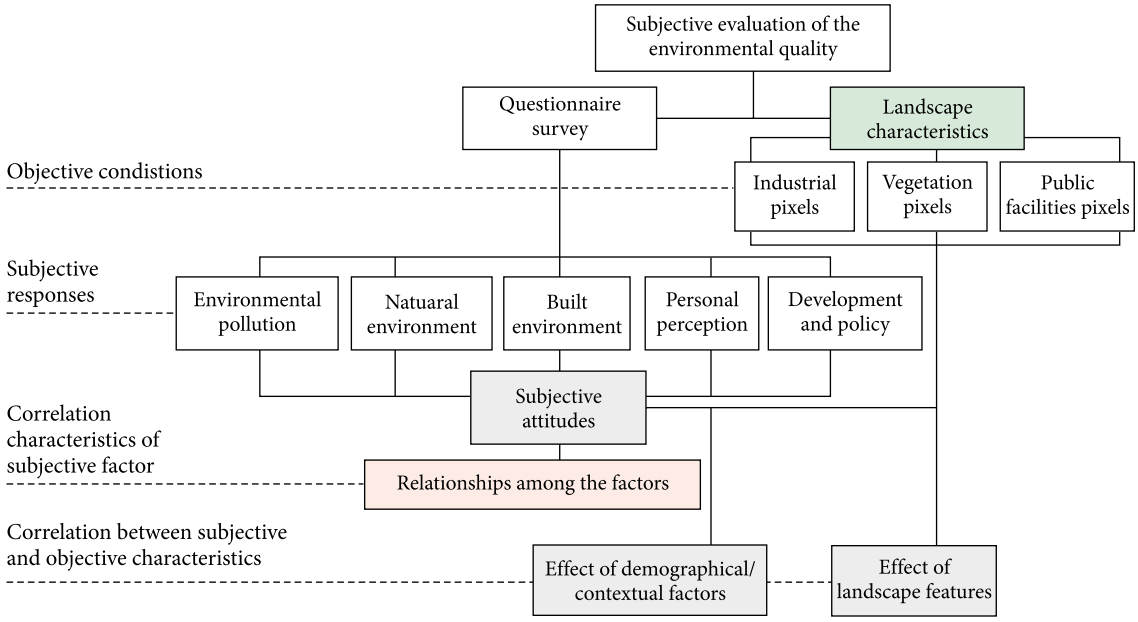

Fig. 5. The framework of the subjective evaluation of the environmental quality of industrial corridors

evaluation results and objective environmental conditions, better planning systems can be established, and this is also useful for developing prediction models on industrial environment system (Xu *et al.* 2015).

2. Subjective attitudes

The results of the statistical analysis of the 13 subjective evaluation questions in China's industrial corridors are shown in Table 2.

2.1. Environmental pollution

In terms of air quality, the mean score is –0.16. Compared with the survey results obtained for a typical seriously polluted city, Beijing (Zhang, Kang 2009) (–0.8, after conversion), indicates that people in this polluted city generally feel worse. In other words, although industrial pollution is the second most common cause of air pollution (Goyal *et al.* 2006), the public's satisfaction with the environment of the industrial corridor is not the lowest that has been reported.

For river water quality, the mean score of evaluation results is –0.16, which is considerably higher than that of a typical polluted city, Beijing (–0.9) (Zhang, Kang 2009). Untreated and insufficiently treated industrial wastewater discharge are the principal drivers of drinking water pollution in cities (Wang *et al.* 2008). Indeed, it has been reported that more than three-quarters of the water flowing through Chinese cities is unsuitable for drinking because of industrial pollution (Zhang *et al.* 2010).

For the ISW treatment, the mean score of evaluation results regarding industrial corridor public is 0.09; in Beijing, the score for litter contamination is –0.7 (Zhang, Kang 2009). It should be noted that the ISW evaluation of industrial corridor tends to be above the medium level, possibly because transportation, landfill, incineration and other treatment of ISW often stay out of the public interests, although ISW has had a huge and long term impact on the environment. Whereas in the city, the garbage recycling process is more relevant to every citizen. It is noted that, currently, 2.7% of the world's ISW is directly discharged into the environment from China; this number is rapidly increasing: compared with 1989, the quantity of ISW generated in 2002 increased by 66% (Huang *et al.* 2006). Therefore, this important environmental problem must be addressed in the industrial corridor development.

Noise has a mean score –0.31, and the SD is 1.001. Although the effects of noise on workers' hearing and work efficiency have been intensively studied (Barron 2002), environmental noise pollution is also an important part of the overall environment (Yang, Kang 2005). Compared with Beijing, –0.9 (Zhang, Kang 2009), the city square environment is subjectively considered to be noisier than the industrial corridors. A possible reason for this

Table 2. Interviewees' evaluation of the industrial corridor environmental quality

Digital codes and questions			Not satisfied at all	Not satisfied	Medium	Satisfied	Very satisfied	Mean score	SD (standard deviation)
			–2	–1	0	1	2		
Environmental pollution	1. Air quality		26.7%	33.7%	20.4%	15.6%	3.7%	–0.16	1.141
	2. River water quality		14.1%	26.7%	24.1%	31.5%	3.7%	–0.16	1.128
	3. Industrial solid waste (ISW) treatment		7.4%	30.0%	28.9%	31.5%	2.2%	–0.09	0.998
	4. Noise		12.2%	31.5%	33%	21.5%	1.9%	–0.31	1.001
Natural environment	5. Environmental greening		11.1%	24.1	38.9%	24.8%	1.1%	–	0.972
	6. Animals\birds\insects living situation		31.9%	17.8%	27.8%	19.6%	3.0%	–0.56	1.208
Built environment	Landscape design	7. Landscape sculpture design	30.7%	20.7%	25.6%	20.0%	3.0%	–0.56	1.202
		8. Waterscape design and application	38.1%	25.9%	19.6%	14.1%	2.2%	–0.84	1.149
		9. Building height/ density	2.6%	32.6%	38.1%	24.8%	1.9%	–0.09	0.864
	Public service facilities	10. Physical-activity facilities	7.0%	23.7%	24.8%	34.4%	10.0%	–0.17	1.113
		11. Leisure square	5.9%	24.4%	21.9%	36.3%	11.5%	0.23	1.121
Personal perception	12. Comfort levels		2.6%	7.0%	21.5%	55.6%	13.3%	0.70	0.881
	13. Security situation		4.8%	4.1%	23.7%	42.2%	25.2%	0.79	1.022

result is that industrial parks are generally located in relatively quiet areas, and the noise sources are mainly from industries and traffic, whereas in urban open public spaces there are much more noise types.

In summary, as shown in Table 2, people are generally unsatisfied with the pollution/contamination situation. It is interesting to note that this result corresponds to the results of two surveys that were carried out in Beijing (Wong 2003; Zhang, Kang 2009), where the top three environmental problems are air, water and noise. It should be noted that Beijing showed even lower environment evaluation scores than the industrial corridors (Zhang, Kang 2009). The subjective evaluation of air, river water, solid waste in industrial corridors are below the medium level in general, so that the eco-industrial park concept needs to be more implemented.

2.2. Natural environment

In terms of the living situation of animals/birds/insects, the mean score of evaluation results is –0.56. These results of living situation of animals/birds/insects reflect the total number of animals and migration situation, and demonstrate the health condition of ecosystem from the perspective of biology (Nasi *et al.* 2009). Ecological corridors are believed to facilitate movement between connected patches of a habitat, which increases gene flow, promotes the re-establishment of locally extinct populations, and increases species diversity in otherwise isolated areas (Tilman, Kareiva 1997). The mean score of landscape greening demonstrates that landscape greening of industrial corridors remains to be improved, to ensure the sustainable development of regional ecosystem.

It can be seen that, in terms of both living situation of animals/birds/insects and environmental greening of the natural environment, the evaluation results are under the medium level, suggesting that the construction of the industrial corridors has affected the natural environment of the region. Moreover, there was a possibility that the animal migration corridors and green corridors were cut off, seriously affecting the ecosystem (Mörtberg, Wallentinus 2000).

2.3. Built environment

As shown in Table 2, the scores of landscape sculpture are below the medium level. Moreover, the mean score of evaluation results associated with an artificial waterscape is the lowest among all elements of landscape design. In terms of building height/density, the mean score of evaluation results is notably close to neutral.

With respect to public service facilities, the average evaluation score of physical-activity facilities (public fitness equipment) is under the medium level (–0.17), whereas the average evaluation score of leisure square is above the medium level (0.23).

One possible reason for the lowest score of waterscape design and application is the limitations in waterscape design with cold weather (Ruying 2007) for the Shen Xi, Shen Tie and Ha Da Qi industrial corridors. Moreover, these results show that people have higher artistic requirements for environmental design beyond function; The neutral evaluation of building height/density suggests that the building planning conforms to people's expectation of the industrial corridor environment; In addition, the widespread demand in sports facilities need to be filled in industrial corridors.

2.4. Personal perception

Personal perception is the way a person forms judgements and makes conclusions concerning the characteristics and motives of others or surrounding environment (Gifford 2007). For the 2 relevant aspects of this survey, which are comfort levels and security situation, the evaluation mean scores are 0.7 and 0.79, respectively, which could be perceived as that most industrial corridor areas are relatively comfortable and safe with few accidents.

2.5. Development and policy

For the two questions concerning "Do you think it is right to slow down the construction of industrial parks in order to reduce environmental pollution?" and "Do you think it is right to slow down industrial park construction in order to protect the natural environment?", the agreement mean scores are 1.50 and 1.49, respectively. More details are shown in Table 3. This result is significantly higher than that obtained by the survey conducted in Beijing for "slowing down the construction of industrial parks to reduce environmental pollution" in 2003, in which 40% of the respondents indicated that the top priority should be economic development and the next highest priority should be to protect the environment in both rural and urban areas (Wong 2003). In another survey including the same question and conducted in Beijing in 2009, the average score was 0.6, and the number of "agree" and "strongly agree" responses accounted for 43.9% and 20.6% of the total responses, respectively (Zhang, Kang 2009). One possible reason for these findings is that people tend to gradually gain awareness of environmental pollution and natural environment protection over time. These results indicate that people in industrial polluted area have a greater awareness of the need to protect environment.

For the question "For complaining to the government for industrial environment, do you think there is a simple way?", the agreement mean score is 1.21, which is much higher than that obtained by the survey conducted in Beijing (Zhang, Kang 2009), in which the mean score was only 0.6. Again, there are two possible reasons for this result: change over the past 5 years and the greater

willingness of people in industrial corridors to complain. It is noted that before 2000, access to information about complaining to the government and local environmental protection bureaus was notably difficult (Chan, Wong 1994); however, since 2005, public environment hotlines have been established in every major city in China.

The agreement mean score of the item "would you like to give monthly donation for improving industrial environment (0.5% of personal income)?" is 1.35, which is higher than that gathered in the Beijing survey, 0.7 (Zhang, Kang 2009). A similar study on "willing to pay more for environmentally friendly products" show that, in 1989, 67% of Americans stated that they were willing to pay 5–10% more for ecologically compatible products. By 1991, environmentally conscious individuals were willing to pay between 15–20% more for green products. By 2001, 79% of their samples were willing to pay 40% more for green products (Laroche *et al.* 2001). Therefore, similarly to the above trajectory in industrial history, from pollution to governance and the recovery process, the increase in pollution leads to an increase in awareness of environmental protection, and people are willing to do more to protect the environment.

3. Relationships among the factors

Because the subjective evaluation of the industrial corridor environment is a complex affair that depends on

Table 3. Interviewees' evaluation of development and policy

Digital codes and questions	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Mean score	SD
	–2	–1	0	1	2		
14. Slow down the construction of industrial park to reduce the pollution of the environment	0 (0%)	1 (0.4%)	25 (9.3%)	83 (30.7%)	161 (59.6%)	1.50	0.678
15. Slow down the industrial park construction to protect the natural environment.	0 (0%)	1 (0.4%)	24 (8.9%)	87 (32.2%)	158 (58.5%)	1.49	0.672
16. Complain to the government for industrial environment, if there is a sample way.	0 (0%)	3 (1.1%)	41 (15.2%)	122 (45.2%)	104 (38.5%)	1.21	0.734
17. Monthly donation for improving industrial environment (0.5% of personal income)	1 (0.4%)	2 (0.7%)	31 (11.5%)	103 (38.1%)	133 (49.3%)	1.35	0.741

Table 4. Correlation coefficients and significance levels of the environmental quality factors, where the digital codes are shown in Table 2 and Table 3.

	Environmental pollution				Natural environment		Built environment					Personal perception		Development and policy			
							Landscape design			Public service facilities							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1	0.363**	0.281**	0.266**	0.103	0.100	0.105	0.118	0.041	0.225**	0.190**	0.117*	–0.090	0.069	0.059	–0.056	0.070
2		1	0.236**	0.163**	0.040	0.001	–0.028	0.044	–0.014	0.098	0.017	0.014*	0.042	0.096	0.089	0.060	0.133
3			1	0.250**	–0.031	0.051	0.018	0.031	–0.022	0.048	0.093	0.067	–0.025	0.045	0.007	0.037	–0.032
4				1	0.020	0.073	0.006	–0.054	0.022	0.157**	0.147*	0.078	0.016	0.058	0.018	–0.075	0.047
5					1	0.309**	0.283**	0.215**	0.173**	0.052	0.083	0.084	–0.004	–0.083	0.008	–0.092	–0.043
6						1	0.858**	0.664**	0.424**	0.203**	0.212**	0.109	–0.038	–0.097	–0.074	–0.101	–0.090
7							1	0.720**	0.403**	0.166**	0.196**	0.142*	–0.032	–0.087	–0.108	–0.164**	–0.102
8								1	0.500**	0.142*	0.164**	0.062	–0.010	–0.098	–0.146*	–0.096	–0.113
9									1	0.129*	0.110	–0.013	0.002	–0.070	–0.059	–0.073	–0.041
10										1	0.426**	0.087	0.102	–0.112	–0.059	–0.083	–0.056
11											1	0.097	0.050	–0.125*	–0.089	–0.021	–0.119*
12												1	–0.083	–0.082	–0.088	–0.258**	–0.037
13													1	.064	–0.004	0.138*	0.038
14														1	0.618**	0.235**	0.849**
15															1	0.232**	0.675**
16																1	0.203**
17																	1

Note: the marks * and ** indicate significant differences or correlations; * represents $p \leq 0.05$, and ** represents $p \leq 0.01$.

various factors, it is essential to study the correlations among those factors in terms of the Spearman correlation coefficient and significance level, Table 4 shows that the factors in each category are mostly closely related, but there are also interesting correlations among different categories.

The environmental pollution category has 6 correlations with built environment, among which air quality (1) is correlated to physical-activity facilities (10) and leisure squares (11), which is expected. Moreover, air quality and river water quality are both correlated to comfort levels (12).

There is a significant correlation between 3 factors of the natural environment category and 2 factors of the landscape design category. This result is identical to Hobbs' view of future landscape and the future of landscape ecology, the connectivity of natural environment is the basis of landscape ecological sustainable healthy development (Hobbs 1997). Based on the analysis of automatic linear modelling, the importance of landscape sculpture design, waterscape design and application, and animals\ birds and insects living situation to environmental greening are 0.043, 0.052 and 0.106, respectively. To further illustrate the correlation, the regression scatter diagrams between environmental greening (5) and the other 3 factors (6–8) are shown in Figure 6.

For the built environment category, interesting correlations with other factors are observed. Regarding public service facilities, both physical-activity facilities (10) and leisure squares (11) are related to air quality (1), noise (2), living conditions of animals/birds/insects (6), landscape sculpture design (7) and waterscape design and application (8), which can be concluded that improving the quality of the air, reducing noise, increasing the connectivity of greening and increasing the quantity and quality of artificial landscape will improve the movement desire of the public. In particular, physical-activity facilities and air quality have the highest correlation coefficient of 0.225**. Furthermore, building height/density (9) is positively correlated to physical-activity facilities, but there is no significant correlation with leisure squares, which shows that the people in industrial parks need more physical-activity facilities rather than square spaces. Regarding the relationship with development and policy, the evaluation result associated with leisure squares (11) is negatively correlated to environmental protection awareness (14) and donation willingness (17).

The comfort levels (12) of industrial corridors is what the public always focus on. The results in Table 4 show that air and water qualities are two strong influencing factors, again indicting they are the bottom line for ensuring basic health, and landscape sculpture design also plays an important role in creating comfort levels. In other words, strengthening the construction of a pavilion, corridor, or seat design and increasing the number of rest areas and the number of sculpture in a given region are useful in improving comfort levels. To further analyse the effect of other factors on the comfort level, automatic linear modelling is used, as shown in Figure 7, in which the comfort levels (target variable) and 15 other factors (predictive variable) are considered. It is observed that the ranking of the factors influencing the comfort levels is gender, location, protection awareness of natural environment, occupation, health condition and age.

For the development and policy category, it should be noted that the awareness to protect the environment is only significantly negatively correlated to the evaluation result of leisure squares, possibly because of the popular square dance, which represents a type movement therapy in China that has developed over the past 20 years (Sigel 1994). Moreover, the awareness to protect the natural environment is negatively correlated to waterscape design and application, although the importance of waterscape design and application to the awareness to protect the natural environment is only 0.176 based on the automatic linear modelling. Indeed, waterscape design is the highest form of landscape design. In general, people with higher design requirements for waterscapes have a greater desire to reduce environmental pollution and protect the natural environment (Litton *et al.* 1971).

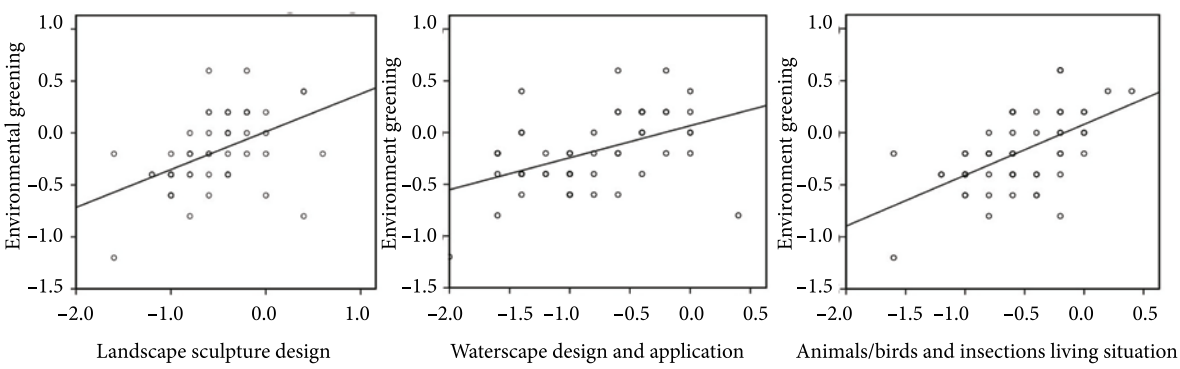

Fig. 6. Regression scatter diagrams between environmental greening and other factors

Complaining is an important aspect of environmental protection. The results in Table 4 show that complaining is correlated to landscape sculpture design, comfort levels and security situation, which suggests that the people who demand landscape sculpture are more demanding of a better living environment and are more willing to complain. It should be noted that complaint behaviour is negatively correlated to comfort levels but positively related to security situation, which suggests that beyond a certain level of comfort and safety, there is a desire to complain. Based on further analysis using automatic linear modelling, if the correlation coefficient increases to 0.20 (identical research method to Fig. 7), except above factors, environmental greening and sports facilities also could influence the willingness of complaining, and the importance are 0.021 and 0.019, respectively.

The willingness to donate monthly is negatively correlated to the evaluation result associated with a leisure square. Further analysis using automatic linear modelling shows that donation is also positively correlated to comfort levels and security situation with an importance level of 0.028 and 0.096, respectively, which suggests that those who like outdoor activities and feel more comfortable and safe are more willing to donate.

4. Effect of demographical/contextual factors

It is also essential to examine the effect of demographical/contextual factors on subjective evaluation, the results of which are shown in Table 5 based on Spearman correlations.

4.1. Demographical factors

In terms of gender, the difference between males and females is significant with respect to air quality (1), landscape sculpture design (7), waterscape design and application (8), personal perception (12, 13) and development and policy (14–17). As shown in Figure 8a, for air quality, landscape sculpture design and waterscape design and application, females feel more unsatisfied than males. However, males feel more comfortable than females, females feel safer than males. This result is similar to that in a previous study, where it was shown that the comfort demand of females is higher, while males have a higher sense of crisis in open air (Sasaki *et al.* 2000). For the four questions on development and policy, the results are shown in Figure 8b, which are similar to the finding of a previous study that "females would pay more for green products" (Laroche *et al.* 2001) and females have higher willingness to protect environment. Moreover, the result shows that males' capacity and tolerance of environment are higher than those of females.

Age correlates to environmental pollution (1–4), environmental greening (5), physical- activity facilities (10) and willingness to donate (17), and the importance levels are 0.708 (average value), 0.426, 0.913 and 0.107, respectively based on the automatic linear modelling. As shown in Figure 8c, people who are older than 50 feel less satisfied than younger people regarding air quality (1) and water quality (2). However, for the ISW treatment (3) and noise (4), there is no linear relationship between age and subjective evaluation. Figure 8d shows that the

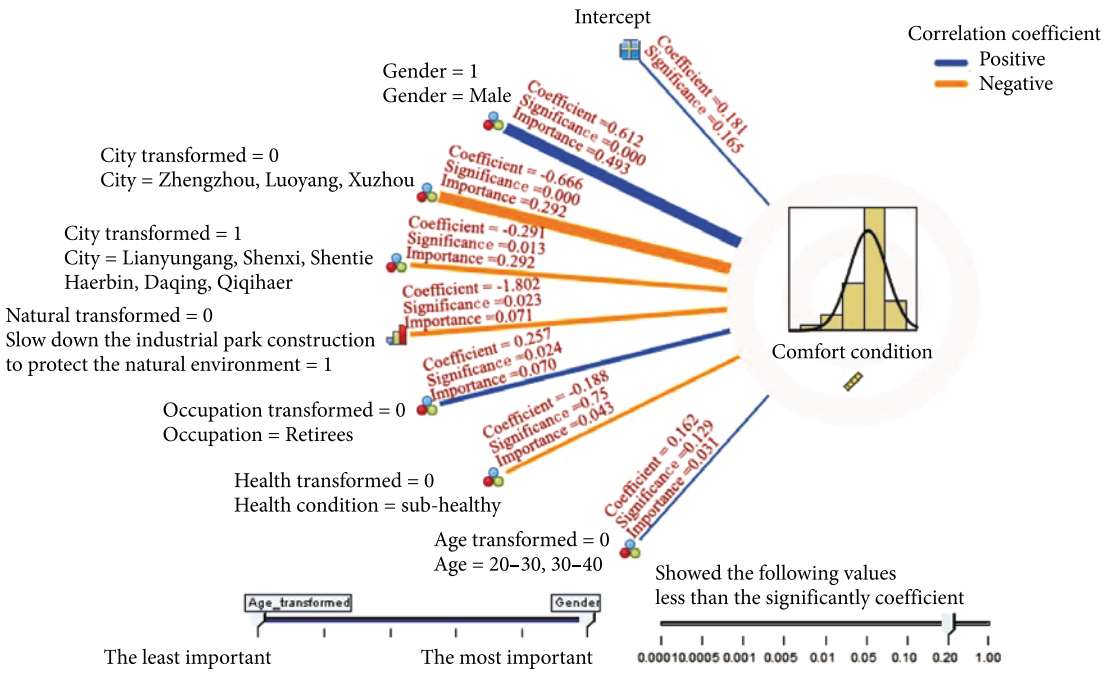

Fig. 7. The correlation between comfort levels and all other factors, based on automatic linear modelling

distribution curves of environmental greening (5) and physical-activity facilities (10) are similar; In addition, the figure shows that people over 50 feel more unsatisfied than the other age categories. This indicates that the elderly pay more attention to physical health, and are more concerned about environmental pollution and natural environmental quality, whereas those in the 10–20-year-old group feel more satisfied than the other age groups. Regarding willingness to donate, people who are aged 50–60 years show less willingness, possibly because people in this age group live under China's biggest economic pressures, they have financial burdens for their parents, children and grandchildren.

Occupation presents an obvious correlation with air quality (1), noise (4), natural environment (5, 6) and landscape design (7, 8), public serves facilities (10, 11), willingness to donate (17), with an importance level of 0.812, 0.673, 0.259, 0.542, 0.361 and 0. 947 (average value) respectively based on the automatic linear modelling. As shown in Figure 8e, retirees have the highest demand for fresh air and quietness; For noise, it is interesting to note that teachers feel more satisfied than others; As shown in Figure 8f, students and retirees, who like outdoor activities the most, feel the most unsatisfied with the landscape; the people who feel the most dissatisfied about the living conditions of animals/birds/insects (6) also feel dissatisfied with physical-activity facilities (10); regarding willingness to donate (17), factory managers, teachers and students, all of whom have better education than others, are the most willing, where the importance level of the factors above is with the range of 0.250–0.470 based on the automatic linear modelling.

The healthy condition correlates to air and river water quality (1, 2), environmental greening (5), landscape sculpture design (7), building height/density (9), public serves facilities (10, 11) and awareness of protecting the natural environment (15). As shown in Figs 8g and 8h, ill and sub-healthy people feel more unsatisfied with the abovementioned aspects, possibly because they have a higher demand for these factors. Correspondingly, they are more willing to protect the natural environment.

4.2. Contextual: location

As shown in Table 5, industrial corridor location correlates to the ISW treatment (3), natural environment (5, 6), landscape design (7, 8), physical-activity facilities (10), security situation (13) and willingness to donate (17). Figure 9a shows the mean scores obtained for environment greening (5), animals\birds\insects living situation (6), landscape sculpture design (7) and waterscape

Table 5. Spearman correlation coefficients among demographical/contextual factors considering location and people's subjective evaluation, with significance levels (2–tailed); mean differences in terms of the subjective evaluation between males and females and between residents inside/outside the city, with significance levels (t–test, 2–tailed). Digital codes are shown in Table 2 and Table 3

Question			Demographical			Contextual: location				
			Gender	Age	Occupation	Healthy condition	Industrial corridor	Inside/ outside of the city	Position in industrial park	Residence location
Environmental pollution		1	0.117*	–0.133*	–0.135*	–0.095*	0.008	0.001	0.002	–0.134*
		2	0.031	–0.126*	–0.003	–0.103*	0.089	0.006	0.054	–0.048
		3	0.011	0.125*	–0.010	–0.004	–0.182**	0.134*	0.081	0.033
		4	0.036	0.021*	–0.141*	–0.059	0.053	0.165**	–0.102*	–0.046
Natural environment		5	0.042	–0.118*	–0.184**	–0.361**	–0.111*	0.069	–0.058	–0.115*
		6	0.060	–0.061	–0.268**	–0.078	–0.116*	0.082	–0.050	–0.092
Built environment	Landscape design	7	0.220**	–0.044	–0.236**	–0.122*	–0.158**	0.094	–0.039	-0.090
		8	0.139*	–0.001	–0.145**	–0.089	–0.231**	0.016	0.016	0.039
		9	0.042	–0.071	–0.093	–0.127*	–0.070	0.062	0.020	-0.069
	Public service facilities	10	0.005	–0.136*	–0.228**	–0.055*	0.123*	0.059	–0.049	-0.031
		11	0.004	0.039	–0.127*	–0.135*	0.037	0.008	–0.065	0.049
Personal perception		12	0.351**	–0.079	–0.108*	–0.084	0.015	0.059	–0.024	0.025
		13	0.365**	–0.034	–0.125*	–0.097	–0.142**	0.085	–0.039	0.017
Development and policy		14	0.155**	–0.067	–0.024	–0.006	–0.022	0.171**	–0.100	–0.044
		15	0.199**	–0.080	–0.047	0.118*	0.076	0.133*	–0.070	–0.125*
		16	0.610**	0.060	0.143	0.056	0.013	0.061*	–0.003	–0.016
		17	0.123*	–0.118*	0.002**	–0.025	0.153**	0.187**	–0.086	–0.047

design and application (8) among the five industrial corridors. Overall, only the environmental greening of the Shen Xi industrial corridor can satisfy the public, with a mean evaluation score of 0.067. Moreover, all people feel dissatisfied with the living conditions of animals/birds/insects, landscape sculpture design and waterscape design and application. In this respect, the worst situation occurs in the Ha Da Qi industrial corridor. In general, the above-mentioned results suggest that the entire landscape of the industrial corridors should strengthen design and management. As shown in Figure 9b, in terms of the ISW treatment (3), physical-activity facilities (10), and donation issues, there are considerable differences among the industrial corridors, possibly due to different construction times, completion degree of construction, scale, and regional differences of industrial corridors. For security situation (13), all of the mean evaluations of the industrial corridors indicate that the respondents are "satisfied".

The survey locations of the cities (inside/outside of the city) significantly affect the evaluation result with ISW treatment, noise, development and policy aspects (17). As shown in Figure 9c, for the ISW treatment (3), the mean evaluation score inside the city is –0.25, but the mean evaluation score outside of the city is 0.083. For noise (4), it is interesting to note that the results show that people in the city consider their surroundings to be less noisy (–0.174) than do people outside the city (–0.505). One reason for this finding may be that most interview locations outside

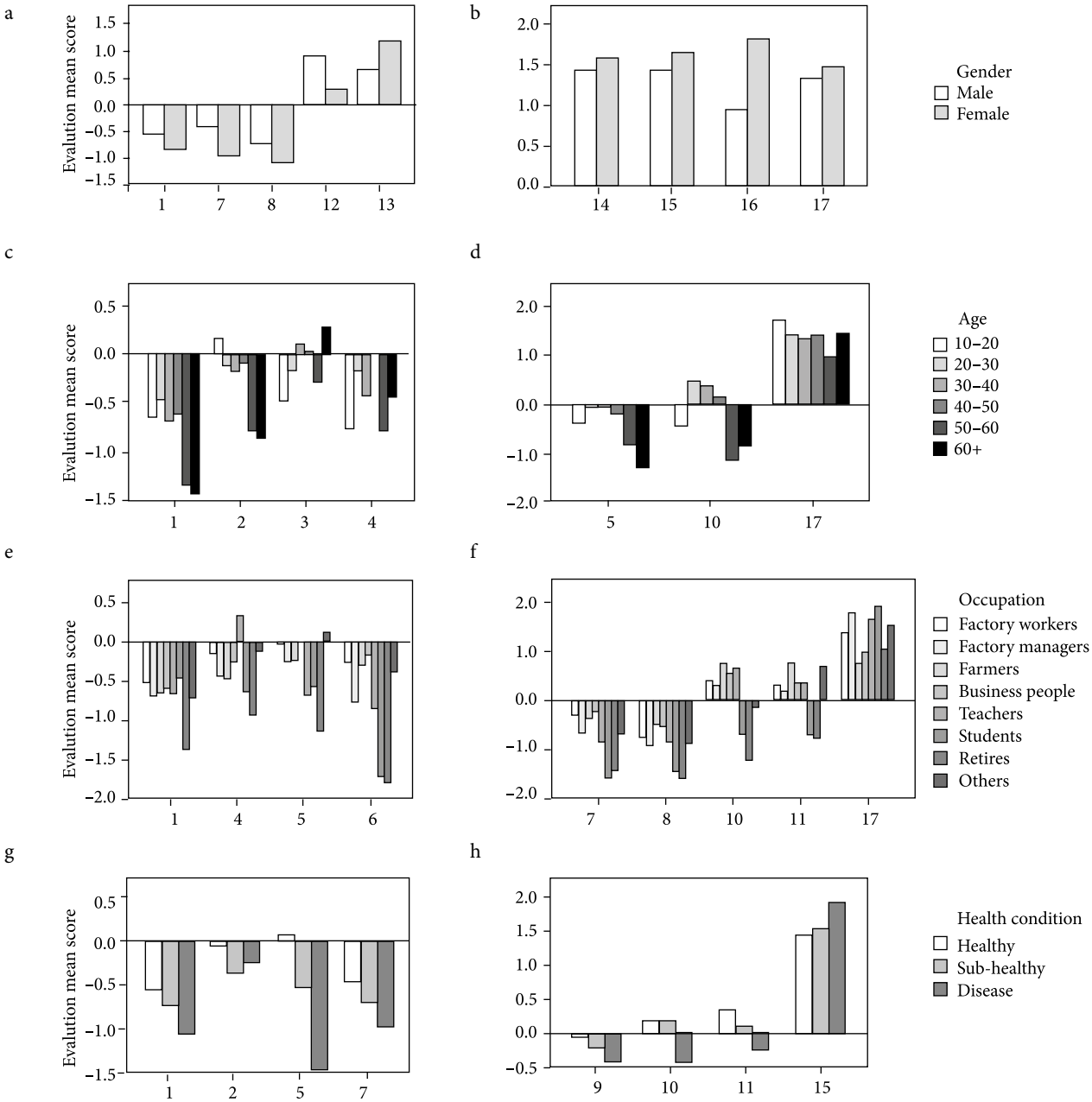

Fig. 8. Mean evaluation scores with different demographical factors, with the digital codes shown in Table 2 and Table 3.

the city are located on a highway, or the environment outside the city is relativity quiet, which raises awareness of industrial and traffic noise. For the 4 questions regarding development and policy (14–17), as shown in Figure 9d, the environmental protection consciousness of people interviewed inside a city is clearly greater than that of people interviewed outside of a city.

Figure 9e shows that the evaluation result on noise conditions (4) is associated with different positions in an industrial park, and the evaluation score of industrial connection areas and green space are lower than others. According to the measurement, traffic noise is present in 90% of the time, with a peak value reaching 72.7 dB, due to heavy trucks (Yong *et al.* 2012), which is higher than the environmental noise standards of urban regional (China) (State environmental... 1999), and also considerably higher than the comfortable level for people to have conversation (Yang, Kang 2005).

Residence location correlates to air quality (1), environmental greening (5) and environmental awareness to protect the natural environment (15). As shown in Figure 9f, for air quality and environmental greening, people who live inside an industrial park are more satisfied than others. Two possible reasons for this finding are the relatively low building density in such areas and adaptability (Sundstrom, E., Sundstrom, M. G. 1986). In addition, people who live far away are less willing to protect the natural environment, possibly because this industrial environment does not change their living environment immediately, leading a lack of sense of responsibility.

4.3. Effect of landscape features

Based on the analysis described in 2.2, the respective proportions of industrial elements, vegetation elements, and public-facility elements were calculated by the aforementioned MATLAB program using videos of the industrial corridors; the relationships between the landscape features and subjective evaluation are shown in Table 6. It is interesting to note that the industrial pixels is correlated to the subjective evaluation score of air quality and the

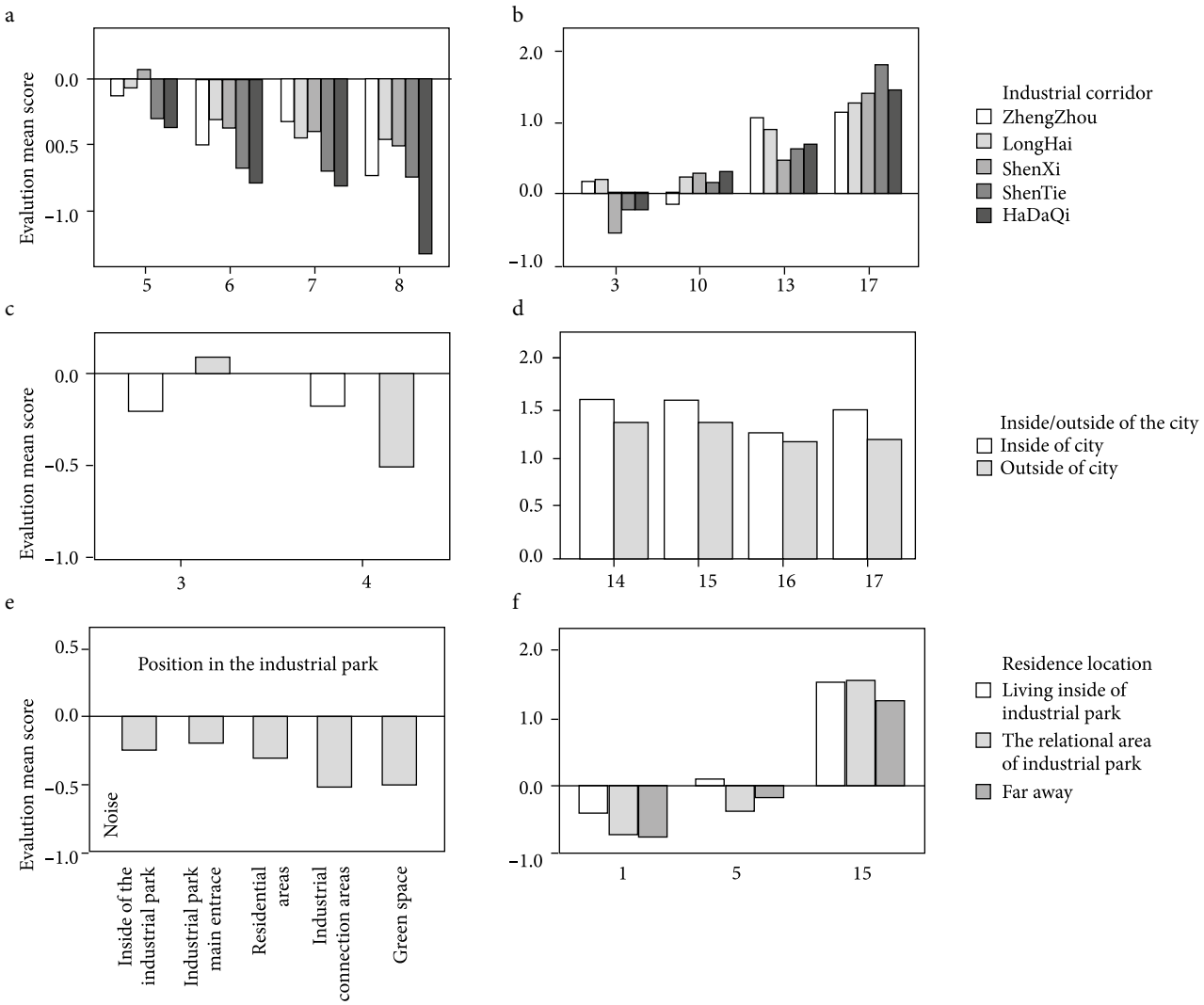

Fig 9. Mean evaluation scores with different contextual factors

Note: The digital codes shown in Table 2 and Table 3

building height/density with correlation coefficients of –0.733* and 0.210*, respectively. This clearly shows that industrial activity has affected the perceptions of air quality. Moreover, the vegetation pixels is positively correlated to the perceptions of river water quality, environmental greening and fauna, with correlation coefficients of 0.672*, 0.233* and 0.427*, respectively. Furthermore, the public facilities pixels is correlated with the perceptions of sports and comfort levels, with correlation coefficients of 0.636* and 0.050*, respectively, which demonstrates that building more public facilities and landscape sculpture can increase people's desire for sports and comfort levels. These correlations suggest that there might be a strong effect of visual characteristics on the subjective evaluation of environmental quality. Similar interactions have also been observed in other studies, such as visual-audio interactions (Yang, Kang 2005).

In terms of the development and policy aspect, Table 6 indicates that the proportions of industrial pixels and vegetation pixels are correlated with people's willingness to complain and the proportion of public facilities pixels is correlated with people's willingness to donate. These results suggest that people's willingness to complain derives from the imbalance between industrial development and natural environment. Moreover, if people find themselves in a better public infrastructure situation, their willingness to donate will be encouraged.

Table 6. Relationships between the landscape features and subjective evaluation. The digital codes are shown in Table 2–3, (* represents $p \leq 0.05$).

Questions			Industrial pixels	Vegetation pixels	Public facilities pixels
Environmental pollutions		1	–0.733*	0.533	–0.083
		2	–0.387	0.672*	0.471
		3	0.100	–0.300	–0.200
		4	–0.418	0.234	0.075
Natural environment		5	0.067	0.233*	–0.433
		6	0.042	0.427*	–0.544
Built environment	Landscape design	7	0.360	–0.460	-0.310
		8	–0.042	–0.210	-0.479
		9	0.210*	0.210	-0.269
	Public service facilities	10	–0.469	0.577	0.636*
		11	–0.170	0.094	0.145
Personal perception		12	0.083	–0.417	0.050*
		13	0.217	–0.500	–0.317
Development and policy		14	0.515	–0.194	–0.169
		15	–0.393	0.544	–0.033
		16	0.429*	–0.403*	0.311
		17	–0.234	0.577	0.318*

Conclusions

This study explores the subjective evaluation of China's industrial corridor environment based on field surveys and public attitudes towards environmental pollution.

In summary, although the evaluation results of environmental quality are generally at the medium level in China's industrial corridors, the evaluation result indicated by the environmental pollution evaluation of the industrial corridors is even higher than that observed for a typical polluted city, Beijing. In addition, the public generally feels satisfied with the comfort levels and security situation in the industrial corridors. Moreover, compared with Beijing, with respect to development and policy, people who evaluated lower score of pollution and natural environment, are more willing to complain to the government, and have a greater desire to contribute to improving the environment, but compared with developed countries, the consciousness of personal dedication to protect the environment is still relatively low.

Based on the relationship between all of the evaluation factors in the industrial corridors, it is observed that people have a greater demand for physical-activity facilities than leisure squares; Air and river water quality, landscape sculpture design and environmental greening have the greatest effect on comfort levels; the people who have higher requirements for waterscape design have a stronger desire to reduce environmental pollution and protect the natural environment; People, based on the premise of ensuring comfort and safety, desire to complain to the government regarding the environment; Moreover, people who like outdoor activities feel much safer and are more willing to donate.

In addition, this study expounds the effects of personal characteristics, location attribute and landscape factors on subjective evaluation. Regarding gender, females are more sensitive for the environment and landscape and are more positive about protecting the environment than males are; In terms of age and health condition, people who are over 50 years of age and ill and sub-healthy people are more sensitive to environmental problems; With respect to occupation, students and retirees have a greater demand for physical-activity facilities; Factory managers, teachers and students, who generally have a better education than others, have greater desire to donate for improving industrial environment; In terms of the willingness to donate, with respect to contextual factors, it is interesting to note that the interviewees who were located within an industrial park inside a city perceived less noise and indicated a stronger awareness of protecting the environment than did the interviewees located outside of a city; Moreover, it is interesting to note that evaluation of noise is related to survey location in industrial parks. Furthermore, people who live far away are less willing to protect the natural environment of industrial corridors.

In terms of the relationship between the landscape characteristics pixels and subjective evaluation, it has been revealed that the industrial pixels directly relate to the subjective evaluation of air quality, and vegetation pixels directly relate to the subjective evaluation of water quality. Moreover, the proportions of industrial pixels and vegetation pixels are related to people's willingness to complain. Furthermore, if people find themselves in a better public infrastructure situation, their willingness to donate will be encouraged.

China has a considerable contribution to worldwide pollution, and it would be interesting to understand Chinese people's subjective evaluation of industrial environmental quality, which would be relevant to the pollution control and environmental improvement. Moreover, it is also important to understand the attitude of people who work or live in the rapid developing industrial corridors in China, as reference to other developing countries and developed countries. Furthermore, the results of this research would be useful for making comparisons with the developed countries when they were in the similar historical process.

This research also puts forward some ideas which could be relevant to environment planning and design of industrial corridors and industrial parks.

It is noted that this research scope is industrial corridors of north China, so that the conclusions may not be generalised in general situation in China.

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Jian XU, BSc, MSc (North China University of Forest), is a final year PhD candidate, jointly at the School of Architecture, University of Sheffield, UK, and the School of Architecture, Harbin Institute of Technology. Her research field is landscape, planning and architectural technology. She has published 10 journal and conference papers.

Mei ZHANG, BA (Beijing University), PhD (University of Cambridge), is a Lecturer at the University of Sheffield, UK. Her field is environmental sustainability in East Asian, evidenced by over 40 publications.

Long SHAO, BSc, MSc, PhD (Harbin Institute of Technology) is a Professor at the School of Architecture, Harbin Institute of Technology, China. His research field is landscape. He has published 40 journal and conference papers.

Jian KANG, BEngArch MSc (Tsinghua University, Beijing), PhD (University of Cambridge), has been Professor at the University of Sheffield, UK, since 2003. His field is built environment sustainability, evidenced by 70+ prestigious engineering-consultancy projects, 80+ funded research projects, and 800+ publications.