STUDY ON THE CAPACITY OF NINE CITIES IN THE GREATER BAY AREA TO COPE WITH CLIMATE CHANGE BASED ON THE RISK CITY THEORY

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Introduction

To a generally acknowledged extent, climate change has changed this world, especially transformed human's attitudes towards development pattern of modern society and living pattern in man-made environment to more cautious ones, in the meanwhile driving people to realize that so called "inherent differences" among different social groups might collapse because negative effects brought by climate change, or risks in a more academically way, do not just aim at the weakness [1-4]. Risk society, of which the definition and theory framework have been constructed and developed by Ulrich Beck, Anthony Giddens and many other scholars since 1980s, stresses on this historical transformation, regarding modern society as an aggregation of endogenous risks [5]. It explains that, after modern industrial system was finally established, sources of the main risks that human need to face changed from exterior environment to our interior society, mostly due to shortsighted economic goals [6]. Also, this new type of risks could expand beyond boundaries of space and time and cover all societies globally, which are difficult to predict and control [7]. Therefore, how to recognize and manage these risks should be seriously considered to make the whole society more sustainable. Seen as the most representative creations by human society, cities would support over 75 percent of the global population in 2050 [8], providing them with spaces, facilities and services for daily life and production, while also exposing them to risks related to climate change more frequently. In a word, when cities are planned along modern industrial pattern, potential risks are likely to be overlooked, which would on one hand contribute to climate change and on the other hand cause lacking of capacity to protect people and property from these risks [9].

Risk city theory is put forward by Yosef Jabareen and could be seen as an extension from risk society theory. In this theory, “risk”, “trust” and “practice” together form the connotation of “risk city” (shown in Fig.1), with risk and trust both affected by local social and cultural cognition and affecting the relation between the public and the authorities, and practice being the representation of resource allocation to react to emergencies. Under the global background, Planning Coping with Climate Change (PCCC) is introduced to construct the practice and assessment framework of risk city theory, which consists of 6 parts as shown in Fig.2: Utopian Vision, Justice, Comprehensive Urban Governance, Ecological Economics, Adaptation and Mitigation. Utopian Vision serves as a key incentive for city reform. Justice is assumed to guarantee rational allocation of resources when facing climate impacts. Comprehensive Urban Governance provides systematically institutional support to managing the use of hardware facilities. Ecological Economics aims at creating guaranteed and energetic markets for cleaner production and consumption to improve economic development in a greener way. Adaptation mainly refers to reducing vulnerability to guard against potential climate threats with the analysis of indeterminacy, application of measures, and calculation of urban vulnerability matrix. Mitigation mainly refers to reducing occurring probability of climate risk by reasonably using natural capital, using more renewable energy and maintain natural form as far as possible [10]. More detailed information could be found in Fig.3. To be concluded, risk city theory regards risk as one kind of tool to allocate power and resource, which does not blindly pursue economic growth but seriously treats with climate change to make living conditions safer and fairer [10]. For cites in which economic development has reached a certain level, risk city theory could help assess their capacity to cope with climate change, therefore making more feasible plannings to construct more stable shelters for the people. Since the benefits of this theory has not been widely known in China, which has experienced a period of roughly rapid urbanization and faces the stern situation caused by climate change, there are both theoretical and practical meanings to apply it to assessing whether cities in China are prepared enough to cope with climate crisis and what efforts should be taken.

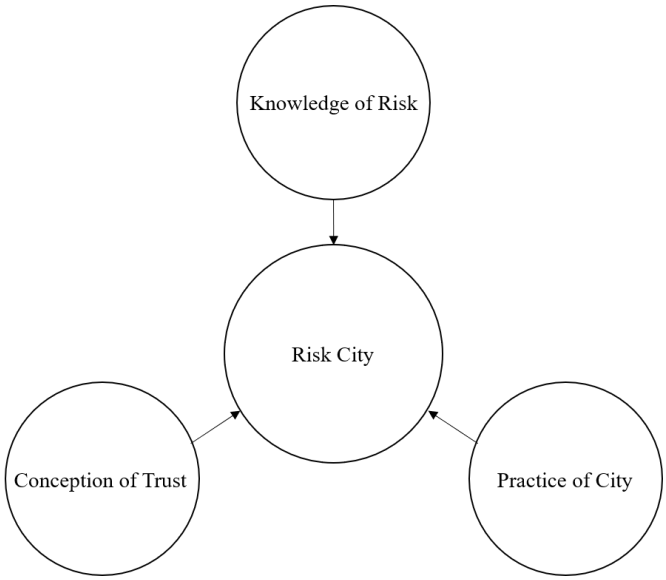


Fig.1 Connotation of risk city

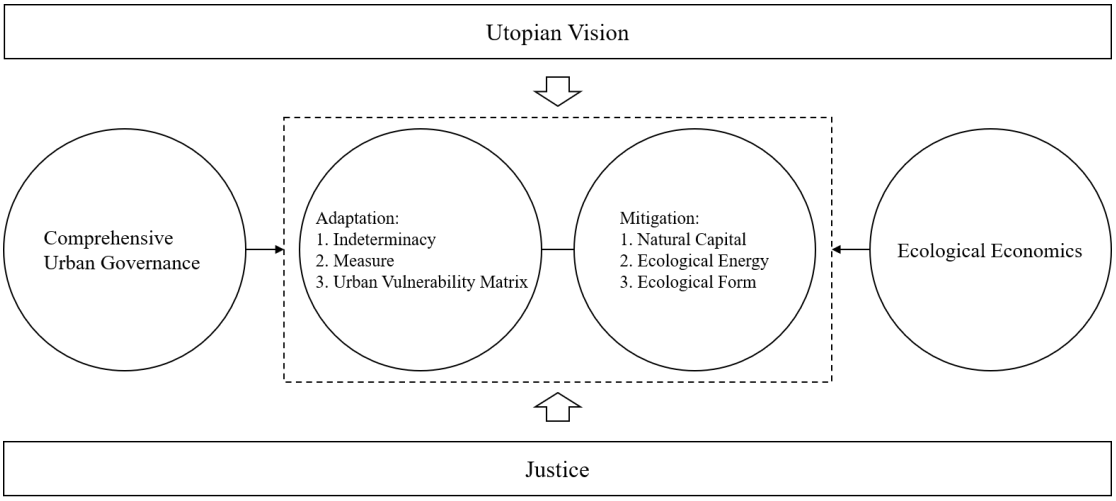


Fig.2 Practice and assessment framework of risk city theory

Utopian Vision
Scale and character of the vision; Relation between the vision and risks relevant to climate change; Dimensionality of the vision...

Justice
Groups who have rights to participate in decision-making and planning of risk city...

Comprehensive Urban Governance
Integration of relevant institutes, laws, social matters, economic matters and environmental matters...

Ecological Economics
Characters of ecological economics in current and planned situations...

Adaptation
1. Indeterminacy: effects on the city;
2. Measure: types and details;
3. Urban Vulnerability Matrix: age, sex, health and social organization characters of target people; spatial distribution of risks; scale, geographical, social, economic, population and physical characters of informal settlements…

Mitigation
1. Natural Capital: greenhouse gas emission levels and land resource conditions in current and planned situations...
2. Ecological Energy: targets and measures to decrease fossil energy use and increase clean energy use...
3. Ecological Form: compactness, transportation, density, mixed land use, diversity, passive solar design, virescence, renovation and reuse, plan scale...

Fig.3 Detailed information of the practice and assessment framework of risk city theory

Methods and Materials

In this paper, integrity, continuity and equity are selected as fundamental principles to assess the capacity of target cities coping with climate change. Integrity means considering matters that could promote or hinder climate crisis as much as possible, and plays the role to guarantee that the assessment results could cover enough items. Continuity holds the idea that this capacity should not be static but constantly adjusting both in time and space scopes, therefore driving the assessment work being able to consider dynamic changes as climate condition and city development stage changes. Equity, which comes from the core concept “trust” in risk city conception framework, helps make sure that each type of related groups could actually become a powerful force to prevent cities from climatic damages.

Upon these principles, the capacity is divided into 2 parts. One part is current capacity, which could be concluded from the efforts already taken into coping with climate change. The other part is future potential, which could be reflected from plans coping with climate matters specifically or referring to these matters under a more macroscopical background. Since both current capacity and future potential could consist of numbers of indicators to assess, it is quite essential to select several representative indicators.

Current capacity are made up of 5 indicators: ratio of investment in relevant public facility management industry, which is the specific value of investment in public facility management industry related to coping with climate change to total investment in fixed assets within one city; growth rate of energy consumption per unit of GDP, which could tell the degree to which one city’s economic development relies on energy consumption; growth rate of industrial waste gas emission, which could be clear to see whether the main part

of one city's production is being cleaner or not; per capita area of park and green space, reflecting one city's eco-friendly level in individual view; greening rate in built up area reflects one city's ecological moderation potential on climatical risks.

Based on the assessment framework from risk city theory, indicators representing future potential are still divided into 6 clusters, but given some more detailed items. For Utopian Vision cluster, "specific vision description" is needed to see if the plan of one city takes a more reasonable blueprint into consideration and how this blueprint could face climate crisis. For Justice cluster, "recognition on social differences", which means taking capacity gaps of groups from different economic and social levels into account, and "emphasis on public participation", which means placing bottom-to-top decision-making mechanism in an important position, are used. For Comprehensive Urban Governance cluster, the more relevant matters are brought into the plan, the higher "covering extent of relevant matters" would be got, which could be highly related to a more effective governance system. For Ecological Economics cluster, "green finance construction" and "cleaner production and consumption" are introduced, with the former aiming at creating a new pattern for the trading market, and the latter trying to change and perfect current producing and consuming habits into cleaner ones. For Adaptation cluster, firstly "potential risk forecast mechanism" is needed to observe whether emergencies would break out and what consequence would they cause, concentrating on the breadth of risks and the reaction speed to them; next comes to "systematic and detailed measures", calling for decision makers to formulate rigorous and feasible measures decreasing losses brought by risks; "vulnerability among territory space" and "vulnerability among population" are following, respectively describing differences of tolerance capacity among different types of territory space and population when facing similar risks and finding out which types of territory space and population should get more attention and aids. For Mitigation cluster, as one of the most hotspot topics, "target of greenhouse gas emission" is an indispensable item; since immoderate land use is also an important cause to frequency of occurrence of risks in one city, "reserve land for adjustment use" against the unordered construction and development is essential; "improvement on energy system" is fundamental to the whole assessment framework with the respect to the fundamental position of energy planning in risk city theory; last but not least is "emphasis on urban form", which explores whether spatial arrangement could strongly affect one city's environmental condition and how this potential link might take effect. The complete assessment framework is shown in Fig.4.

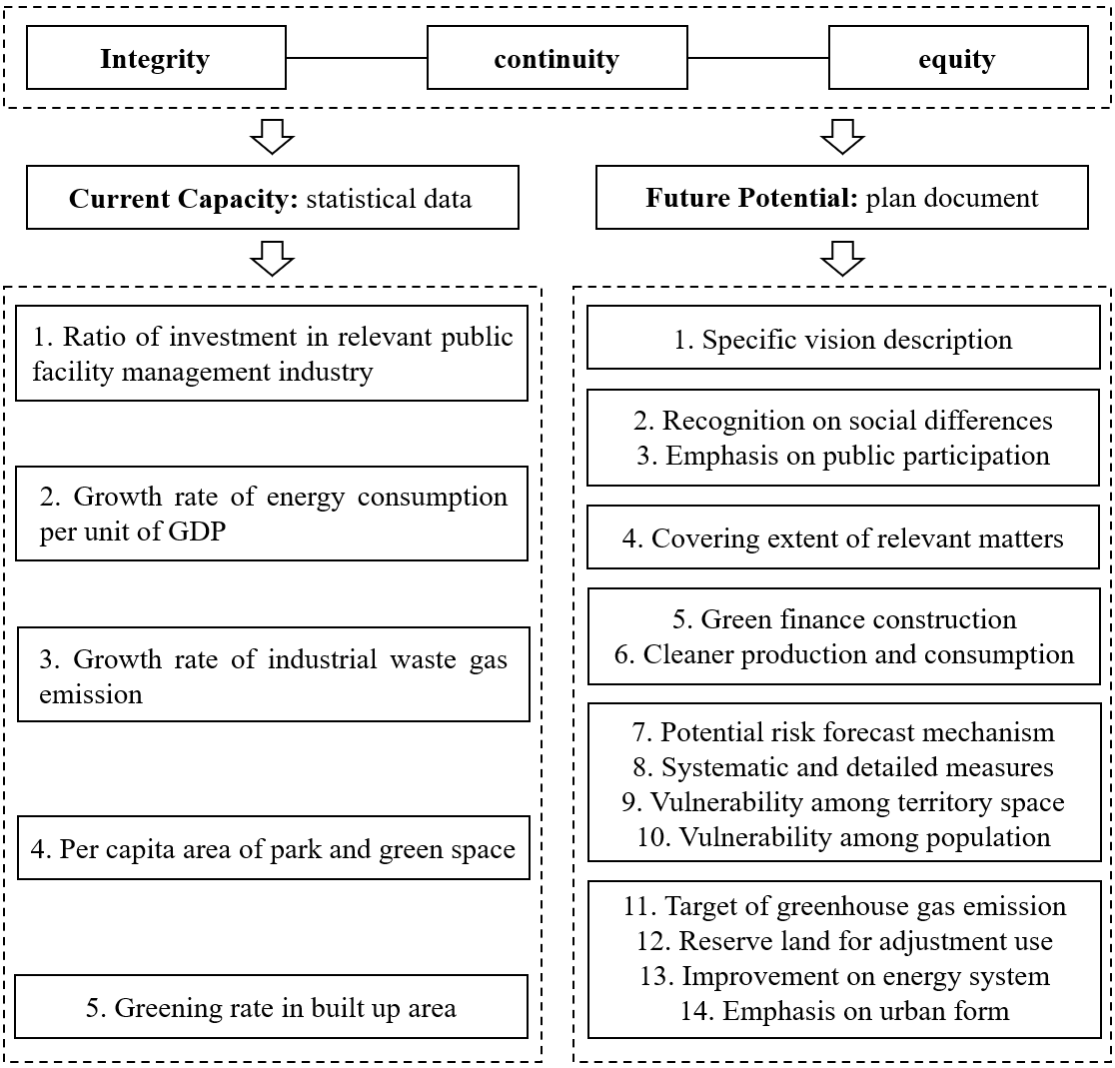


Fig.4 Complete assessment framework in this study

The study objects are 9 major cities located in the Guangdong-Hong Kong-Macao Greater Bay Area of China: Guangzhou, Shenzhen, Foshan, Dongguan, Huizhou, Zhongshan, Zhuhai, Jiangmen and Zhaoqing. Being the urban agglomeration with almost the highest urbanization rate (over 80%) in China, the contradiction between rapid expansion and high-quality development in urban area is quite prominent. Nearby the South China Sea with originally humid and hot climate, these cities are quite sensitive to global warming and have to face various of risks mainly from energy, water, ecological system and extreme weather aspects. In 2019, the *Outline Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area* was carried out by the top government of China, which could be seen as one of the most historic resolutions for China's new pattern of opening-up and gave huge chances and challenges to the included cities for exploring future-oriented urban development strategies. Since a more harmonious relationship between these cities and ecological system

and more attention on urban emergency management and related supporting facilities are called for, it is meaningful to apply the risk city theory to assessing the capacity to cope with climate change of these cities, with the target of providing the whole nation with possible demonstrate effects.

To assess current capacity of target cities, relevant data from each city's statistical yearbooks are analyzed, of which the statistic time scale is from 2015 to 2019. As for future potential assessment, 9 typical planning documents respectively belonging to target cities are selected as most recent, appropriate and authoritative as possible, with their overall information listed in Table 1.

Table 1 Overall information of the selected planning documents

City Name	Plan Name	Plan Type	Plan Maker
Guangzhou	Guangzhou Sponge City Special Plan 2016-2030	Special Plan	Guangzhou Land Resources and Planning Commission
Shenzhen	Shenzhen Geological Disasters Prevention and Control Planning 2016-2025	Special Plan	Shenzhen Land Resources and Planning Commission
Foshan	Foshan Territory Spatial Master Plan 2020-2035 （Public Draft）	Master Plan	Foshan Natural Resources Bureau
Dongguan	Dongguan Land Use Master Plan 2006-2020	Master Plan	Dongguan Natural Resources Bureau
Huizhou	Huizhou Land Use Master Plan 2006-2020 (Adjustment and Perfection Edition)	Master Plan	People's Government of Huizhou
Zhongshan	Zhongshan Territory Spatial Master Plan 2020-2035 （Public Draft）	Master Plan	Leading Group Office of Zhongshan Territory Spatial Master Plan
Zhuhai	Zhuhai Master Plan 2001-2020 (Revised in 2015)	Master Plan	People's Government of Zhuhai
Jiangmen	Jiangmen Master Plan Outline	Master Plan	Jiangmen Natural Resources Bureau
Zhaoqing	Zhaoqing Territory Spatial Master Plan 2020-2035 （Public Draft）	Master Plan	Zhaoqing Natural Resources Bureau

Results

Statistic distribution of the 5 indicators representing current capacity of target cities from 2015 to 2019 are shown in Table 2 and Fig.5- Fig.9. Generally speaking, among 9 target cities, 7 cities own full data during the specified time period, leaving Jiangmen lacking data of growth rate of industrial waste gas emission from 2018 to 2019, with the data from 2015 to 2017 only covering industrial sulfur dioxide and smoke dust emission. As for Zhongshan, data of growth rate of industrial waste gas emission from 2017 to 2019 are lacking while the

data from 2015 to 2016 only cover industrial sulfur dioxide emission, and data of per capita area of park and green space and greening rate in built up area from 2017 to 2019 are not counted. Statistical results are listed as followed:

Ratio of investment in relevant public facility management industry: Zhaoqing and Zhuhai owned the highest average levels while Dongguan and Zhongshan owned the lowest, while other target cities' levels ranged between 7% and 10%. From 2015 to 2019, Guangzhou, Shenzhen and Dongguan generally showed an annually increasing track. Foshan, Huizhou and Jiangmen almost remained steady. Zhuhai had an obvious decrease before the increasing track occurred and the level in 2019 still did not reach the level in 2015. Zhaoqing had a huge increase until 2017 and although it fell a little in the following 2 years, the level in 2019 was much higher than that in 2015.

Growth rate of energy consumption per unit of GDP: Foshan and Zhaoqing owned the most average decreasing rates while Huizhou is the only city owning a positive number rate, while other target cities' levels ranged between -6% and -3%. From 2015 to 2019, Dongguan, Zhongshan, Jiangmen and Zhaoqing generally presented diminishing tracks on this decreasing rate. Guangzhou, Shenzhen, Foshan and Zhuhai showed generally steady tracks. As for Huizhou, this item become positive number after 2016, which made it the only city whose economic development still quite relied on energy consumption.

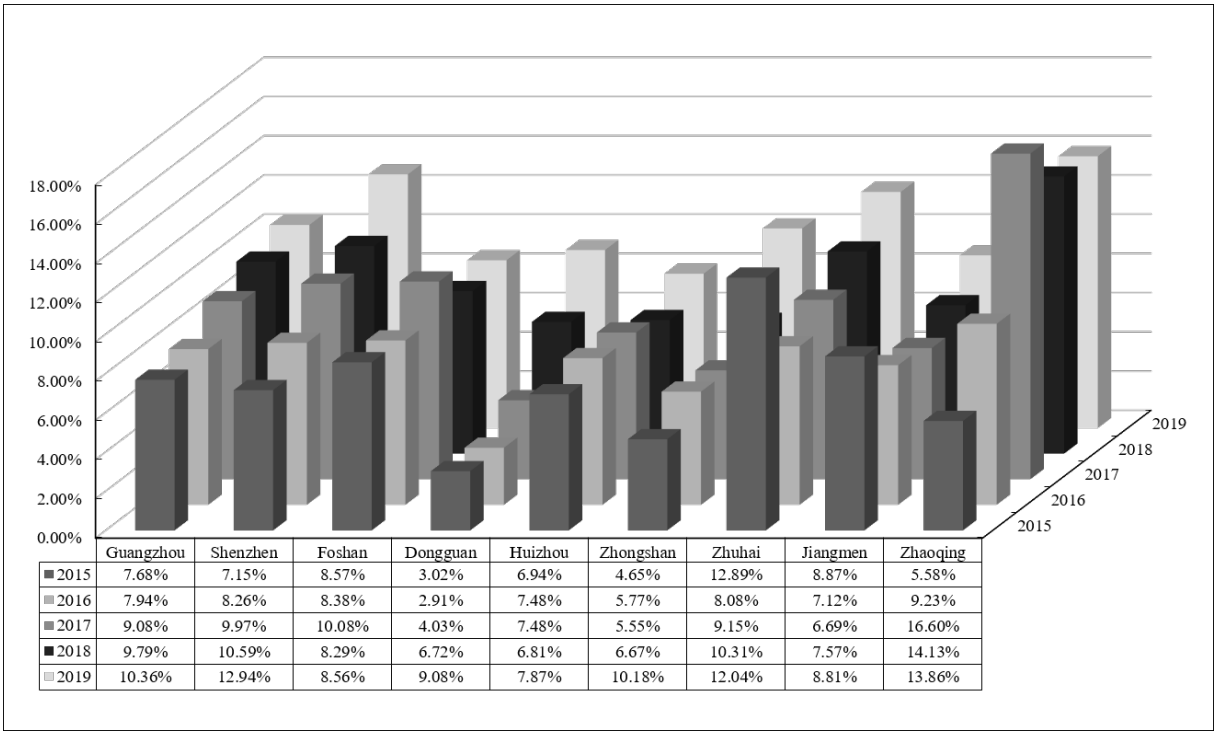
Growth rate of industrial waste gas emission: Huizhou was the only city whose average growth rate was negative number and Dongguan presented the highest average growth rate, while other target cities' levels ranged between 5% and 11%. From 2015 to 2019, Huizhou was the only city in which this item was all negative numbers during the 5 years. Zhuhai showed a generally decreasing track and the growth rate in 2019 become a negative number. Foshan once decreased its industrial waste gas emission but the later track was increasing. The industrial waste gas emission of Guangzhou, Shenzhen, Dongguan and Zhaoqing generally showed annually increasing tracks. Since enough statistics were not counted for Zhongshan and Jiangmen, these two cities were not analyzed in this part.

Per capita area of park and green space: Zhuhai owned the highest average level of this item and Foshan had the lowest, while other target cities' level ranged between 15.50 and 18.50. From 2015 to 2019, Shenzhen, Huizhou and Zhaoqing generally showed decreasing tracks in this item. Guangzhou, Foshan, Dongguan, Zhuhai and Jiangmen presented increasing tracks on the contrary. Since enough statistics were not counted for Zhongshan, this city was not analyzed in this part.

Greening rate in built up area: Zhuhai owned the highest level in this item and Zhaoqing owned the lowest, while other target cities' levels ranged between 40% and 47%. From 2015 to 2019, Guangzhou, Foshan and Jiangmen generally showed an annually increasing track. Shenzhen, Dongguan and Huizhou generally kept steady. Although Zhuhai behaved the best in average level, a decreasing track occurred during the 5 years. The greening rate of Zhaoqing increased from 2015 to 2017, however experienced a decreasing period in the later years. Since enough statistics were not counted for Zhongshan, this city was not analyzed in this part.

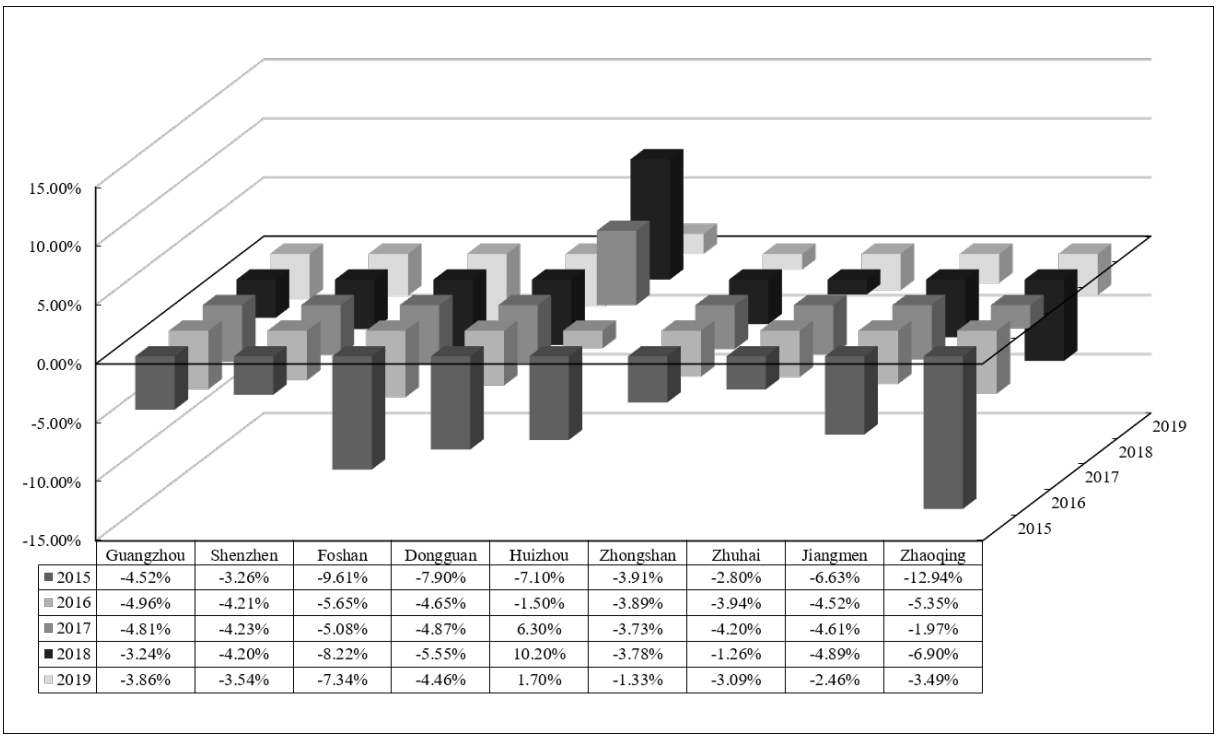
Table 2 Average levels of each city for each indicator during the 5 years

	Ratio of investment in relevant public facility management industry (%)	Growth rate of energy consumption per unit of GDP (%)	Growth rate of industrial waste gas emission (%)	Per capita area of park and green space (square meter)	Greening rate in built up area (%)
Guangzhou	8.97	-4.28	5.04	17.12	43.31
Shenzhen	9.78	-3.89	10.48	15.94	44.60
Foshan	8.78	-7.18	8.90	15.07	42.71
Dongguan	5.15	-5.49	13.57	18.40	46.51
Huizhou	7.32	1.92	-14.03	15.66	40.18
Zhongshan	6.56	-3.33	/	/	/
Zhuhai	10.49	-3.06	8.44	20.03	50.11
Jiangmen	7.81	-4.62	/	18.16	43.54
Zhaoqing	11.88	-6.13	10.61	17.10	39.63



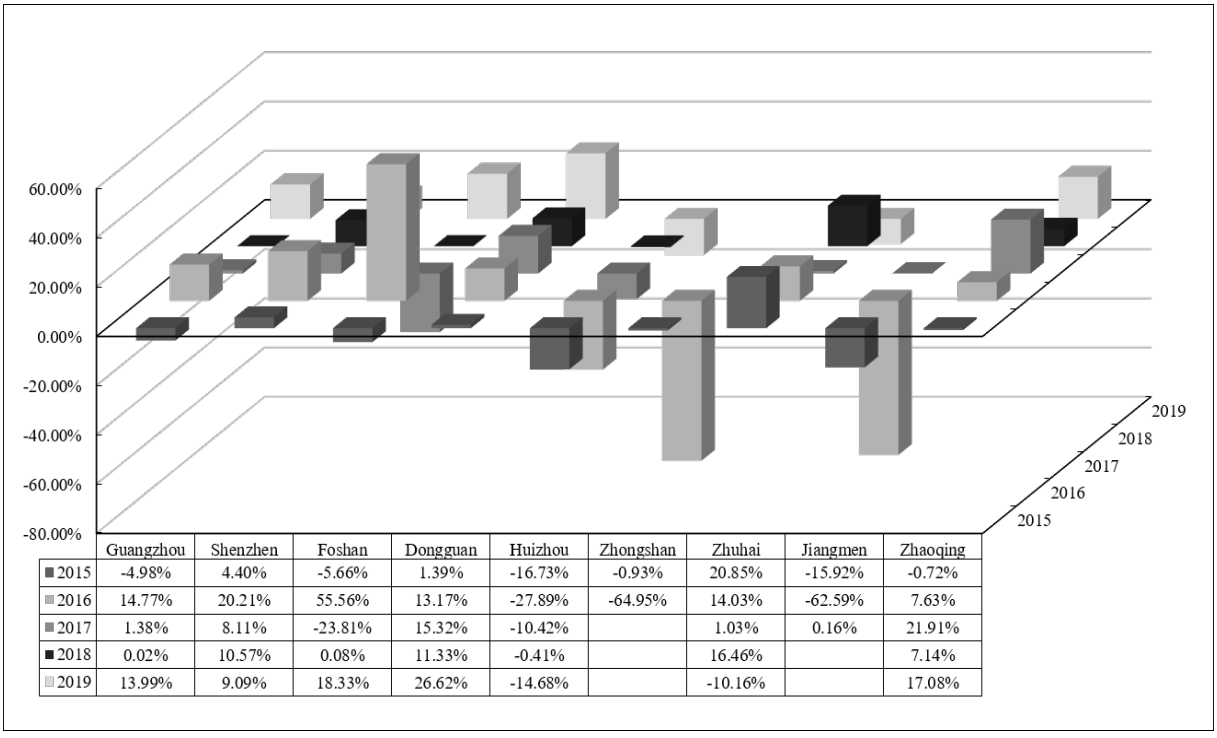
	Guangzhou	Shenzhen	Foshan	Dongguan	Huizhou	Zhongshan	Zhuhai	Jiangmen	Zhaoqing
2015	7.68%	7.15%	8.57%	3.02%	6.94%	4.65%	12.89%	8.87%	5.58%
2016	7.94%	8.26%	8.38%	2.91%	7.48%	5.77%	8.08%	7.12%	9.23%
2017	9.08%	9.97%	10.08%	4.03%	7.48%	5.55%	9.15%	6.69%	16.60%
2018	9.79%	10.59%	8.29%	6.72%	6.81%	6.67%	10.31%	7.57%	14.13%
2019	10.36%	12.94%	8.56%	9.08%	7.87%	10.18%	12.04%	8.81%	13.86%

Fig.5 Distribution of ratio of investment in relevant public facility management industry



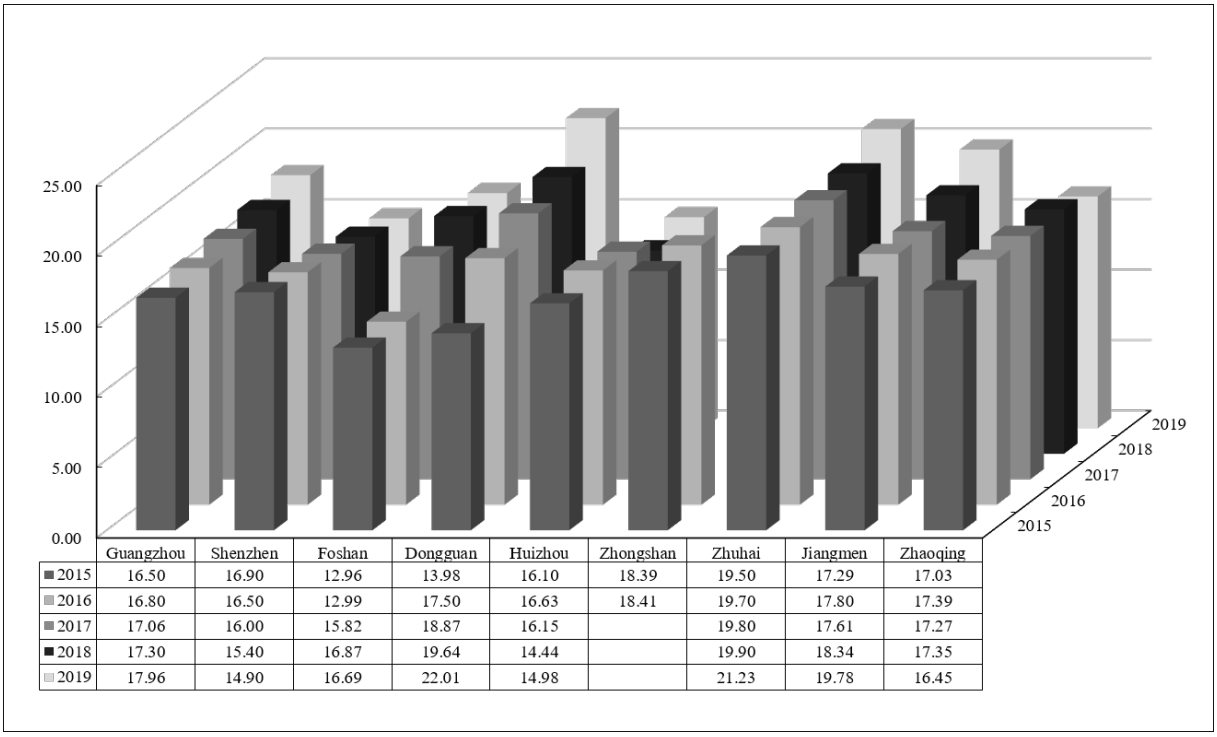
	Guangzhou	Shenzhen	Foshan	Dongguan	Huizhou	Zhongshan	Zhuhai	Jiangmen	Zhaoqing
2015	-4.52%	-3.26%	-9.61%	-7.90%	-7.10%	-3.91%	-2.80%	-6.63%	-12.94%
2016	-4.96%	-4.21%	-5.65%	-4.65%	-1.50%	-3.89%	-3.94%	-4.52%	-5.35%
2017	-4.81%	-4.23%	-5.08%	-4.87%	6.30%	-3.73%	-4.20%	-4.61%	-1.97%
2018	-3.24%	-4.20%	-8.22%	-5.55%	10.20%	-3.78%	-1.26%	-4.89%	-6.90%
2019	-3.86%	-3.54%	-7.34%	-4.46%	1.70%	-1.33%	-3.09%	-2.46%	-3.49%

Fig.6 Distribution of growth rate of energy consumption per unit of GDP



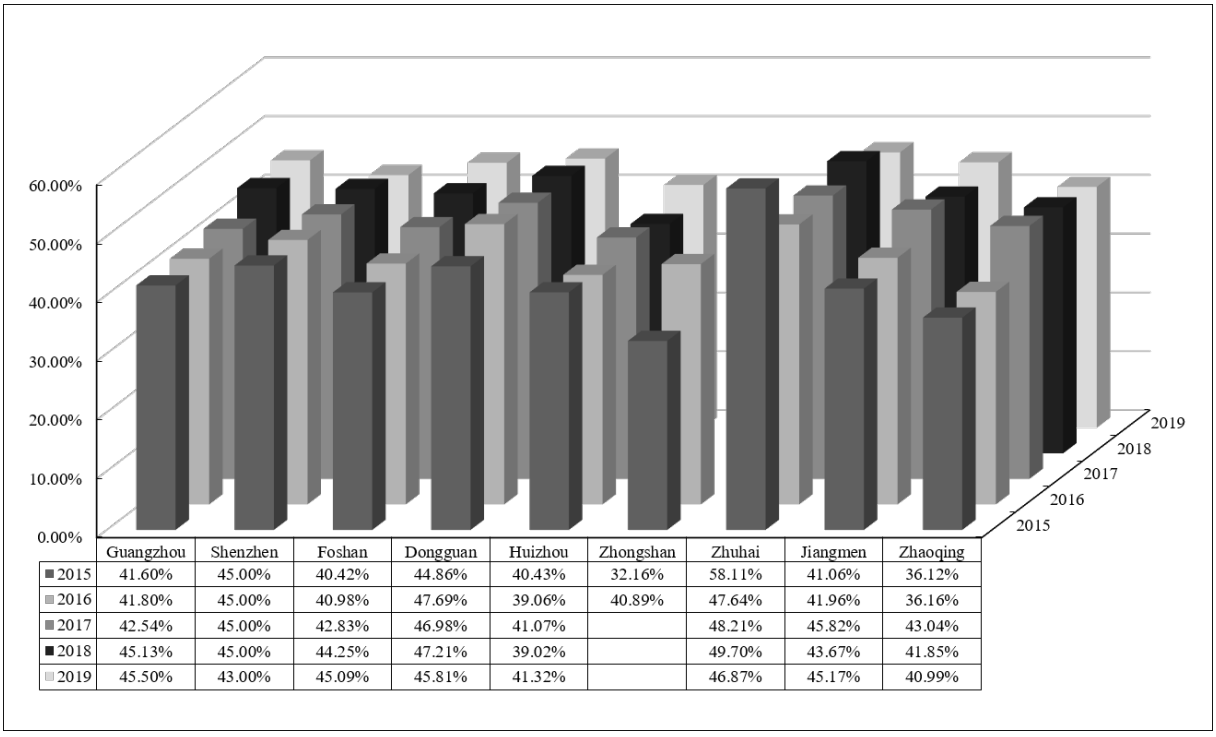
	Guangzhou	Shenzhen	Foshan	Dongguan	Huizhou	Zhongshan	Zhuhai	Jiangmen	Zhaoqing
2015	-4.98%	4.40%	-5.66%	1.39%	-16.73%	-0.93%	20.85%	-15.92%	-0.72%
2016	14.77%	20.21%	55.56%	13.17%	-27.89%	-64.95%	14.03%	-62.59%	7.63%
2017	1.38%	8.11%	-23.81%	15.32%	-10.42%		1.03%	0.16%	21.91%
2018	0.02%	10.57%	0.08%	11.33%	-0.41%		16.46%		7.14%
2019	13.99%	9.09%	18.33%	26.62%	-14.68%		-10.16%		17.08%

Fig.7 Distribution of growth rate of industrial waste gas emission



	Guangzhou	Shenzhen	Foshan	Dongguan	Huizhou	Zhongshan	Zhuhai	Jiangmen	Zhaoqing
2015	16.50	16.90	12.96	13.98	16.10	18.39	19.50	17.29	17.03
2016	16.80	16.50	12.99	17.50	16.63	18.41	19.70	17.80	17.39
2017	17.06	16.00	15.82	18.87	16.15		19.80	17.61	17.27
2018	17.30	15.40	16.87	19.64	14.44		19.90	18.34	17.35
2019	17.96	14.90	16.69	22.01	14.98		21.23	19.78	16.45

Fig.8 Distribution of per capita area of park and green space



	Guangzhou	Shenzhen	Foshan	Dongguan	Huizhou	Zhongshan	Zhuhai	Jiangmen	Zhaoqing
2015	41.60%	45.00%	40.42%	44.86%	40.43%	32.16%	58.11%	41.06%	36.12%
2016	41.80%	45.00%	40.98%	47.69%	39.06%	40.89%	47.64%	41.96%	36.16%
2017	42.54%	45.00%	42.83%	46.98%	41.07%		48.21%	45.82%	43.04%
2018	45.13%	45.00%	44.25%	47.21%	39.02%		49.70%	43.67%	41.85%
2019	45.50%	43.00%	45.09%	45.81%	41.32%		46.87%	45.17%	40.99%

Fig.9 Distribution of greening rate in built up area

According to the assessment method for future potential of target cites, performance levels of the 14 indicators are listed here, which are divided into “specifically mentioned”, “partly mentioned”, “slightly mentioned”, “barely mentioned” (for “covering extent of relevant matters”, levels are divided into “comprehensive”, “relatively comprehensive” and “remaining to be improved”):

Specific vision description: Guangzhou, Shenzhen, Zhongshan and Zhuhai belong to the “slightly mentioned” level, while other target cities belong to the “barely mentioned” level.

Recognition on social differences: Guangzhou belongs to the “partly mentioned” level, while Shenzhen, Dongguan, Huizhou and Zhuhai belong to the “slightly mentioned” level. Foshan, Zhongshan, Jiangmen and Zhaoqing belong to the “barely mentioned” level.

Emphasis on public participation: Guangzhou, Shenzhen and Zhuhai belong to the “partly mentioned” level, while Foshan, Dongguan, Huizhou and Zhongshan belong to the “slightly mentioned” level. Jiangmen and Zhaoqing belong to the “barely mentioned” level.

Covering extent of relevant matters: Zhaoqing belongs to the “remaining to be improved” level, while other target cities belong to the “relatively comprehensive” level.

Green finance construction: Guangzhou and Shenzhen belong to the “slightly mentioned” level, while other target cities belong to the “barely mentioned” level.

Cleaner production and consumption: Zhuhai belongs to the “partly mentioned” level, while Guangzhou, Shenzhen, Dongguan, Huizhou, Zhongshan and Jiangmen belong to the “slightly mentioned” level. Foshan and Zhaoqing belong to the “barely mentioned” level.

Potential risk forecast mechanism: Shenzhen, Huizhou, Zhongshan and Zhuhai belong to “partly mentioned” level, while Jiangmen and Zhaoqing belong to “slightly mentioned” level. Guangzhou, Foshan and Dongguan belong to the “barely mentioned” level.

Systematic and detailed measures: Zhuhai belongs to the "partly mentioned" level, while Guangzhou, Shenzhen, Dongguan, Huizhou, Zhongshan, Jiangmen and Zhaoqing belong to the "slightly mentioned" level. Foshan belongs to the "barely mentioned" level.

Vulnerability among territory space: Guangzhou, Shenzhen, Dongguan, Huizhou, Zhongshan, Zhuhai, Jiangmen and Zhaoqing belong to the "slightly mentioned" level, while Foshan belongs to the "barely mentioned" level.

Vulnerability among population: Shenzhen and Dongguan belong to the "slightly mentioned" level, while other target cities belong to the "barely mentioned" level.

Target of greenhouse gas emission: Zhuhai belongs to the "slightly mentioned" level, while other target cities belong to the "barely mentioned" level.

Reserve land for adjustment use: Foshan, Dongguan, Huizhou, Zhongshan and Zhuhai belong to the "partly mentioned" level, while Guangzhou, Shenzhen, Jiangmen and Zhaoqing belong to the "slightly mentioned" level.

Improvement on energy system: Zhuhai belongs to the "slightly mentioned" level, while other target cities belong to the "barely mentioned" level.

Emphasis on urban form: Guangzhou, Foshan, Dongguan, Huizhou, Zhongshan and Zhuhai belong to the "slightly mentioned" level, while Shenzhen, Jiangmen and Zhaoqing belong to the "barely mentioned" level.

To see the performance of each target city more intuitively, a simple calculation is introduced to this part that levels equal to and higher than "slightly mentioned" and "relatively comprehensive" are counted for each city. Seen in Table 3, Zhuhai gets the highest aggregate of recognized indicators, following which are Shenzhen and Guangzhou, while the performances of Foshan and Zhaoqing are at the bottom.

Table 3 Counting results of the recognized indicators

	Utopian Vision	Justice	Comprehensive Urban Governance	Ecological Economics	Adaptation	Mitigation	Aggregate
Guangzhou	1	2	1	2	2	2	10
Shenzhen	1	2	1	2	4	1	11
Foshan	0	1	1	0	0	2	4
Dongguan	0	2	1	1	3	2	9
Huizhou	0	2	1	1	3	2	9
Zhongshan	1	1	1	1	3	2	9
Zhuhai	1	2	1	1	3	4	12

Jiangmen	0	0	1	1	3	1	6
Zhaoqing	0	0	0	0	3	1	4

Conclusion

Climate change has become the primary challenge that we human have to face, pushing our cities to transform traditional plannings into more environment-friendly ones to cope with varieties of endogenic risks. Based on risk city theory, this study constructs an assessment system to look into the capacity coping with climate change of 9 major cities located in the Guangdong-Hong Kong-Macao Greater Bay Area of China, including current capacity assessing by using statistical data from the yearbook of each city and future potential assessing by setting indicators according to the assessment framework of risk city theory, and the assessing results show some leading cities, like Guangzhou, Shenzhen and Zhuhai, have presented a tendency of change to care more about the link between urban development and climate crisis prevention, with the planning projects of other target cities remaining insensitive to climate change. Due to the differences of city positions, economic development levels, accuracy of planning contents and other objective issues, the assessing results might not be enough to tell the whole truth of whether the target cities are able to cope with risks related to climate change and what preparations should be made to improve themselves. Even so, since excess fossil energy consumption and the following pollutions cause a relatively high level of vulnerability and sensitivity to the ecological environment for these cities, and the social differences among different kinds of groups make the weak more possible to suffer from damages related to climate matters, planning for one city's future must consider cleaner energy system and fairer participation mechanism for the public. Although it is not such easy to transform the planning thoughts from economic development direction to risk prevention direction, for cities which already own sound economic foundation it is quite essential and should be seen as a duty to plan a safer and cleaner shelter for the people.

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