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A guiding methodology for "urban physical examination": Indicator checklist, benchmark setting and empirical study

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ABSTRACT

Fast urbanisation development has brought rampant sprawl of cities, where various urban diseases have been emerging. Therefore, how to effectively understand the health status of a city, diagnose root causes of urban diseases, and implement proper policy measures and effective actions to address these diseases have become critical issues for achieving urban sustainability. Via regarding city as an organic system, from the perspective of sustainable urban development, this study proposes a generic guiding methodology of urban physical examination. The guiding methodology provides a set of indicator checklist, indicator benchmark setting approaches, and urban physical examination principles, as guidelines for urban governors to dynamically investigate the healthy status of their cities, so that potential aspects of urban diseases can be identified. An empirical study taking Chongqing Municipality in Southwest China is exemplified to demonstrate the validity of the proposed methodology. The results demonstrate that, 1) sustainable development perspective-based urban physical examination methodology is effective in investigating urban health status, capturing evolving trend of urban health status, and diagnosing potential urban diseases; 2) In Chongqing, significant urban diseases across urban social, economic and environmental facets have been identified, and targeted "treatment" has been tailored to help tackle these urban diseases and improve urban healthy status to realise the mission of sustainable and healthy urban development.

1. Introduction

Cities, traditionally refer to the places for human beings living and working. According to United Nations (2018), 68% of the global population is estimated to be inhabited in cities by 2050. The rapid urbanisation process in the past decades has brought multiple socioeconomic benefits, such as economic growth, the increase of employment opportunities, the enhancement of medical and education services, and the expansion of infrastructure delivery (Ren, 2023; Ochoa et al., 2018). Whilst in line with the unprecedented urbanisation progress and technological advancement worldwide, factors affecting city's health status and sustainable development have been emerging and become increasingly complicated (Huang et al., 2021).

Various urban diseases[1] have emerged across different countries and regions, which would sabotage urban health and sustainability if the underlying risks and root-causes cannot be diagnosed and proper intervention measures cannot be adopted timely (Wang et al., 2020a; He et al., 2023). For example, traffic congestion is a typical urban problem affecting cities' economic efficiency, which has occurred and been reported in cities globally, such as the severe traffic congestion in Beijing (Zhao & Hu, 2019), and traffic congestion in the majority of Ghanaian cities (Agyapong & Ojo, 2018) and also city of Melbourne (Nguyen-Phuoc et al., 2018). Urban traffic congestion, not only sabotaging urban socio-economic efficiency, would also aggravate air pollution and bring environmental burdens (Jia, 2021).

Other critical urban diseases also increasingly emerge across the

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[1] "Urban diseases" refers to multifaceted social, economic, and environmental problems brought by and emerged during the rapid urbanisation and rampant urban sprawl. Typical urban diseases include air pollution, traffic congestion, environmental damage, shortage of public services supply, rocketing housing prices, low living standards, low utilisation of land resources, emergence of urban slums, enlarging urban-rural gap, among others (Wang et al., 2020a; Ren, 2023). The emergence of these urban diseases would jeopardise the long-term healthy development of urban society.

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social, economic and environmental facets in line with the rampant urban sprawl. Environmentally, for example, air pollution is a critical urban disease triggered by high-intensity and pollutant emission of urban socio-economic activities. According to Delfino, Sioutas and Malik (2005), exceeded exposure of PM 2.5 can cause a variety of respiratory diseases and increase mortality by damaging human immune system. From the aspect of urban water resources, both waterlogging and water shortage are considered as critical challenges restricting the long-term development of cities. According to Roy et al. (2021), rainfall-induced urban waterlogging has become a significant environmental barrier, imposing frequent threats upon urban infrastructure damage and economic losses. Guan et al. (2018) pointed out that more than 400 cities in China are suffering from severe water shortage challenge. For the aspect of social justice and urban equality, Zhang et al. (2016) argued that rapid urbanisation has aggravated urban poverty, heightened urban unemployment, inequality and crime. In addition, the housing insecurity caused by rocketing housing prices in those fast-growing cities has become a pressing urban social challenge particularly in the developing countries such as China and Latin America (He & Xia, 2020; Soyinka & Siu, 2018).

The emergence of urban diseases across economic, social and environmental aspects would threaten cities' healthy and sustainable development if these urban diseases cannot be timely diagnosed and properly tackled. Therefore, it is considered essential to establish a set of effective methodology to help investigate comprehensively urban health status, and diagnose potential urban disease, underlying risks and root-causes, so that proper measures can be designed and implemented to address these urban health risks in a timely manner, which in turn contributes to guarantee the long-term healthy urban development is on-track.

Previous scholars have devoted efforts upon the diagnosis of urban diseases and the examination of urban sustainability for the pursuit of healthy urban development, where both single aspect-based investigation and comprehensive aspects-based investigation were conducted. The first spectrum of studies has attempted to investigate urban sustainability or healthy performance from a particular aspect. For example, centred with urban water resource, Ladi, Mahmoudpour and Sharifi (2021) adopted water poverty index (WPI) to investigate water resources shortage in Iran; Liao et al. (2020) examined the carrying capacity of urban water resources based on a load-carrier methodology framework. Centred with the aspect of urban transportation resource, Zhao and Hu (2019) applied big data analysis approach in investigating the spatiotemporal patterns of traffic congestion in Beijing and captured four typical traffic congestion patterns.

The second spectrum of extant literature attempts to investigate the holistic urban healthy and sustainability status by introducing comprehensive indicator system. Taking Guangzhou city of South China as a sample to conduct urban physical examination, Zhan et al. (2021) established an examination index system covers the aspects of drainage and waterlogging prevention, traffic safety, social security, public health, disaster prevention and emergency rescue. Moussiopoulos et al. (2010) investigated the regional sustainability performance in Great Thessaloniki area of Greece by adopting a set of indicator system (considering the aspects of socio-economic, land planning, energy, transportation, etc.). Schmidt-Traub et al. (2017) introduced comprehensive index and dashboard to evaluate the gap between the practical development status and sustainable development goals (SDGs) amongst 149 of 193 United Nations membership states. Chen et al. (2022) investigated the urban diseases performance in Wuhan of China by simultaneously considering objective indicators-based performance and residents' subjective satisfaction survey results. Practical-wise, with the emerging urban diseases amidst the rapid urbanisation process, the state of some large developing countries have recognised the importance of urban physical examination and have started to devote efforts upon urban physical examination, amongst which China is a typical case. Since 2019, the department of housing and urban-rural construction of PRC has selected a series of pilot cities to conduct urban physical examination, with the first batch of 11 pilot cites including Shenyang, Nanjing and Xiamen.

It can be found that existing studies centred with urban physical examination are overwhelmingly based upon individual cases, whilst no generic and guiding methodology is available for urban physical examination and health diagnosis of different cities across different regions. There is currently no referable guidance upon how to scientifically adopt indicator system and set indicator benchmark to precisely examine the healthy status of urban development at certain time point. Nevertheless, such dynamic evidence-based examination is essential for urban governors to understand genuinely urban health status, identify effectively potential diseases and craft proper interventions for shaping long-term healthy development of their cities.

To fill inherent limitation of extant literature, this study aims to develop an effective guiding methodology for urban physical examination, which can be applied as a generic approach to different countries and regions. The guiding methodology developed in this research will first provide a holistic and comprehensive indicator checklist to measure urban healthy performance, where both tangible (such as urban form and land utilisation) and intangible (social welfare and economic performance) aspects are incorporated to ensure the city function across economic, social and environmental pillars can be well-examined. On top of the measuring indicator itself, the guiding methodology further provides instructions upon how to set the benchmark of each measuring indicator and how to scientifically examine a city's health status in referring to these indicator benchmarks under a specific urban context. This guiding methodology for urban physical examination can help urban governors and decision-makers dynamically examine their cities' health status, and identify underlying weak aspects or potential urban diseases embedded in its urban development trajectory. The mega city of Chongqing in Southwest China will be adopted as the exemplified case to demonstrate the effectiveness of the established guiding methodology of urban physical examination.

2. Research roadmap

To achieve above research aim, the research roadmap of this study is designed (see Fig. 1). Five research procedures across theoretical and empirical studies will be conducted. Theoretically, this research aims to establish an effective and generic guiding methodology for urban physical examination that can be practically applied to examine cities' health status. For this, three research procedures will be conducted, namely, 1) to comprehend the system component and functional composition of healthy cities from the joint perspective of living organism and sustainable development, 2) to construct the guiding indicator checklist of urban physical examination, 3) to establish the benchmark principles for the urban physical examination indicators. Empirically, taking Chongqing, a Municipality in Southwest China, as an empirical case, urban physical examination will be conducted via applying the established guiding methodology; and targeted "treatment" will be tailored in referring to the urban physical examination results as well as the diagnosed urban diseases.

The reminders of this paper are thus arranged as follows. Section 3 develops a generic and comprehensive indicator checklist for urban physical examination. Section 4 presents the guiding approach for indicator benchmark setting and indicator benchmark-based examination upon urban health status. Section 5 exemplifies the applicability and validity of the established guiding methodology via case study of Chongqing Municipality. Section 6 discusses the findings and policy implications synthesised from empirical study, followed by the conclusion and future research agenda set out in Section 7.

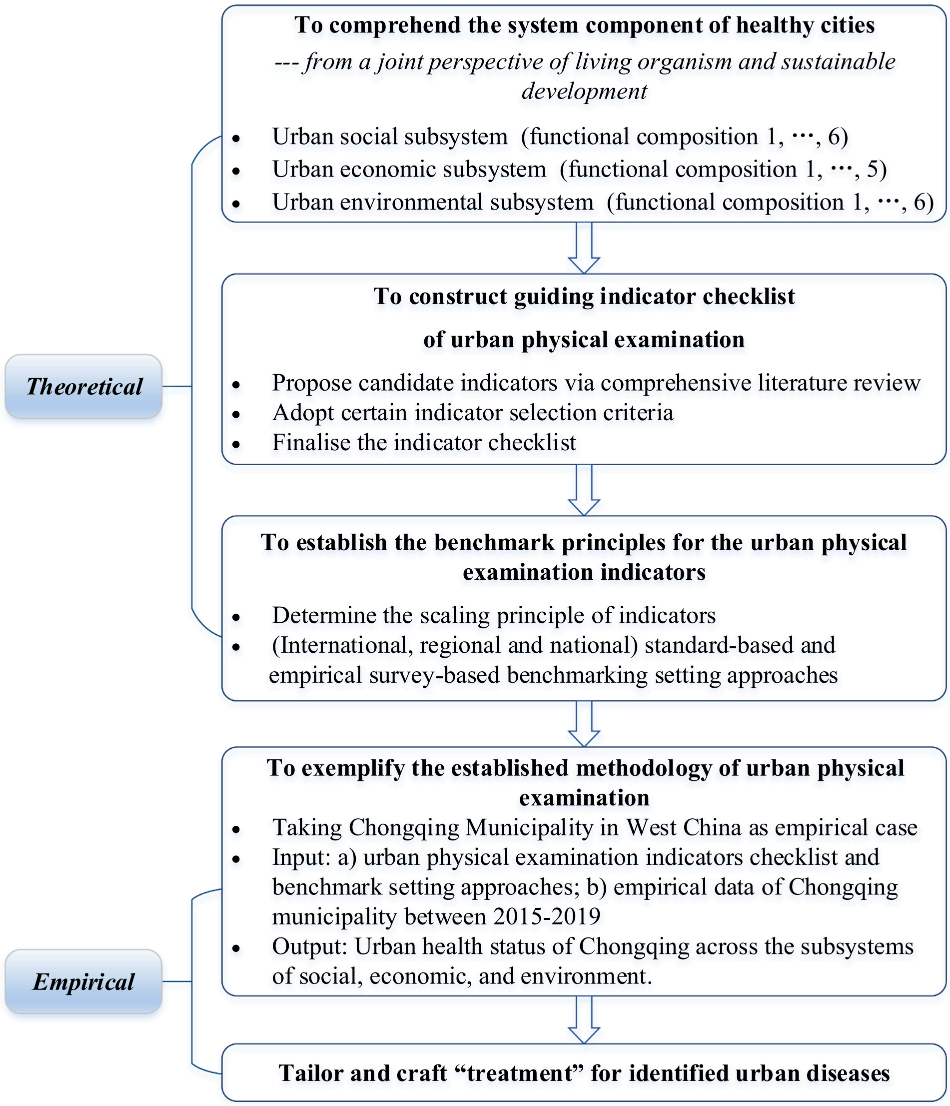

Fig. 1. Research roadmap (*Source: authors*).

3. Establishment of indicator checklist for urban physical examination

3.1. System component of a healthy city

Cities, like organic life forms, are composed of different functional sub-systems, including for example, transportation, housing, industrial, telecommunication, energy, ecological, and sanitation subsystems. These subsystems work jointly to maintain and support the benign operation of cities towards healthy and sustainable. The sub-systems of a city should have self-adaption ability to carry out metabolism, growth and development (Jiang & Liu, 2015; Zhang, He & Chen, 2021). If any sub-system loses self-adaptation ability and encounter the status of disorder, the health condition of urban organism as a whole will be risky and urban sustainability in the long-run would be sabotaged. Therefore, to maintain the city's benign operation and sustainable development, it is necessary to conduct regular monitoring and physical examination upon these sub-systems so that "urban diseases" can be identified timely and potential risks can be treated accordingly.

This study conceptualises the urban system as a "living organism" just like human body, and the subsystem of this "urban living organism" needs to cooperate concertedly with each other to jointly realise the overarching functions underpinning the mission of sustainable urban development. These functions manifest upon the three pillars of social, economic, and environmental (Ren et al., 2021), namely, a) social sustainability: *meeting and satisfying urban residents' needs*, b) economic sustainability: *enabling and stimulating economic growth*, c) environmental sustainability: *providing a livable and sustainable living environment*. Based upon above discussion, the conceptualisation of a healthy city can be depicted as shown in Fig. 2.

The urban diseases undermining a city's health status also present explicitly in the above three aspects of social, economic and environmental sustainability:

Social sustainability is overwhelmingly regarded as an indispensable aspect enabling sustainable urban development (Shen et al., 2011). Contemporarily, with the continuous influx of residential population, urban society is facing greater challenges and encountering emerging urban problems that would hinder cities' sustainable development (Ren et al., 2018). These urban problems under social aspects include for example, urban poverty (Silvestre & Tirca, 2019), extreme hunger (Holden et al., 2008), and social injustice (Hall et al., 2012). Furthermore, these social problems not only hinder the social sustainability of the urban world but also trigger negative effect upon urban economic activities and environmental state (Silvestre & Tirca, 2019), as only

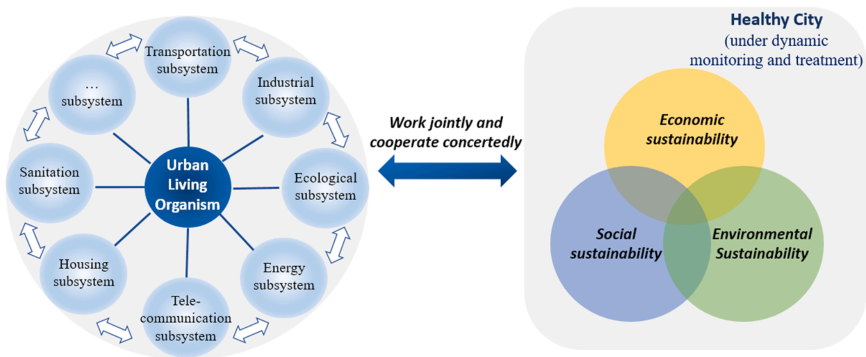

Fig. 2. Conceptualising healthy city: cooperation of sub-systems and gearing towards sustainable urban development.
(Source: Corresponding author)

when people's basic needs are met will they devote efforts to actively address other economic and environmental issues (Valiance, Perkins & Dixon, 2011). Therefore, it is necessary to dynamically diagnosis city healthy status via the lens of social sustainability performance and identify potential risks and underlying problems, so that proper measures can be taken to tackle these social risks timely and guarantee the city's benign and healthy performance of social aspect.

The primary task for maintaining the healthy development of a city is to support and ***sustain urban economic growth***, which is appreciated as the major objective for the advancement of human society (Ren et al., 2021; Wang et al., 2020b). The healthy and sustainable development of urban economy can not only guarantee the long-term improvement of urban living standards, also provide a solid material and capital foundation for pursuing social fairness, justice and environmental protection (Mori & Yamashita, 2015). Therefore, it is essential to conduct scientific physical examination upon the healthy status of urban economy, so that any underlying problems can be identified as early as possible and corresponding measures can be formulated to tackle the problems and ensure the long-term growth of urban economy.

Furthermore, the principle of sustainable development requires a synergetic process that strikes for a coordinated and concerted development amongst economic, social, and environmental dimensions in the long run, and the activities of human being should not only meet the needs of current generation, but address the importance to protect the ***resources and environment*** so that future generations can rely and develop (Ren et al., 2021). In line with the rapid economic development and urban sprawl, the resources and environment of cities are facing the risks of over-utilisation and deterioration, therefore the concerted coexistence between urban social, economic and environmental made-ups becomes challenging (Liu et al., 2020). On the other hand, the sustainable development principle has been increasingly widely-accepted across different countries and regions. Particularly, the covid-19 pandemic makes urban residents to put forward higher requirements and expectations upon their living environment. In a nutshell, the environmental dimension is the key to ensure the healthy and benign development of an urban living organism. Therefore, dynamic monitoring and timely treatment of urban environmental problems are the prerequisite of sustainable and healthy urban development.

Based upon the above discussion, the healthy status of a city can only be achieved under the conditions that all sub-system of an urban organism work and cooperate in a joint and concerted manner to ensure urban social, economic and environmental sustainability. Therefore, the guiding methodology for urban physical examination would be proposed by investigating the performance status across urban social, economic and environmental facets.

3.2. Functional composition of a healthy city

According to Section 2.1, to conduct urban physical examination, urban functional performances across the three aspects of social, economic and environmental needs to be examined and investigated. Furthermore, as commented by Zhang, He and Chen (2021), in conducting human body inspection, it is essential to construct corresponding evaluation indicators according to the functional characteristics of different body systems. Similar principle also applies for conducting urban physical examination. This section therefore aims to investigate the functions taken by urban social, economic, and environmental compositions in supporting the benign operation and sustainable development of cities, and propose a set of comprehensive indicator checklist for monitoring the multifaceted healthy status of a city.

3.2.1. Functional composition of urban social aspect

Due to its diversity, extensiveness and subjectivity, the definition of urban social sustainability can be sophisticated. Given the fact that urban social aspect is mainly formed through human activities, Holden, Linnerud and Banister (2017) argues that social justice and democratic participation are key factors for achieving social sustainability, as these two factors can effectively reflect the extent of public participation in social development. Furthermore, previous studies have presented various viewpoints upon the functions of urban social system, typical ones include community stability; sense of belongings; safety and security; gender equality; residents' living standards; medical, culture and education service provision (Dempsey et al., 2011; He et al., 2018; Holden et al., 2008; Tan & Lu, 2015; Zhu, Shen & Ren, 2022).

Based on the arguments from existing literature, this study conceptualise the key functions of urban social system into six components, including *decent living standard, infrastructure delivery, education services, cultural conditions, medical services*, and *social security*. These six functional compositions are considered as the prerequisites for achieving urban social sustainability. The comprehension upon key functions of urban social system provides a theoretical basis for establishing indicator to monitor and investigate the health status of urban social aspect.

3.2.2. Functional composition of urban economic aspect

Existing literature has argued that the shaping of urban economic sustainability is a dynamic process, which involves the three key facets of economic aggregation, economic increment and economic quality, which reflects respectively the scale of economy, growth trend of economy and the economic efficiencies of a city (Tang et al., 2019; Zhang et al., 2016).

Other scholars commented that the healthy and benign development of urban economy relies not only upon the increase in the total economic scale, also the advancement of urban economic structure as well as the sufficiency of development potential (Li et al., 2009; Shen & Zhou, 2014; Yang, Yang & Wang, 2020). In fact, rational industrial structure and development potential of urban economy are crucial for the long-term economic growth of the cities. Also, given the fact that cities need to continuously exchange capital, labour forces, material, energy, and information with the external world to maintain economic growth (Chi & Yang, 2009; Ren et al., 2018), the openness degree of urban economy is also regarded as the important lens for monitoring a city's health status of economic aspect. To sum up, cities with rational industrial structure, adequate development potential and sound degree of economic openness, are considered healthier in terms of economic performance.

On top of the arguments from previous studies, to ensure the proposal of functional components for urban physical examination is generic and guidable, this study conceptualises the key functions for maintaining urban economic sustainability into five components of *economic increment, economic quality, economic structure, economic openness*, and *development potential*. These components provide a basis for establishing the specific monitoring indicators for investigating the health status of urban economy in next Section.

3.2.3. Functional composition of urban environmental aspect

Urban environmental sustainability is another key pillar for shaping a healthy city. Focusing upon the key functions to maintain the sustainable development of urban environment, both academia and practices have proposed various elements to measure the status of urban environment. For example, Zhang, He and Web (2000) included the dimensions of air pollution, water pollution, water resources, fixed waste pollution, mineral resources, land resources, forestry and fishery resources to establish the indicators to examine environmental sustainability in China. Phillis, Kouikoglou and Verdugo (2017) argues the status of air quality, water quality and landscape quality is the key for ensuring urban environmental sustainability.

In addition, in line with urban socio-economic activities, anthropogenic noise has become a major challenge sabotaging urban acoustic environment across the globe. In fact, existing literature has incorporate noise environment as an important facet in measuring the regional environmental quality as well as ensuring regional environmental sustainability (Zhao, 2003; Radford, Kerridge & Simpson, 2014). Furthermore, artificial lighting appears to become another major concern impacting the urban life quality and sabotaging urban eco-environment (Boyes et al., 2021), therefore the control upon luminous environment is also regarded as the key facet in this study for ensuring urban environment sustainability.

Therefore, this study conceptualise the key functions of urban environmental aspect into six components of *water quality, energy consumption, atmospheric environment, landscape environment, acoustic environment*, and *luminous environment*. These established environmental functions provide a sound foundation for indicator checklist construction to examine the health status of urban environmental aspect.

3.3. Indicator checklist for urban physical examination

Based upon above analysis of functional components across urban social, economic and environmental aspects underpinning a healthy city, this section aims to establish the guiding indicator checklist for urban physical examination, namely, monitoring the health status of a city. The procedures of indicator checklist establishment include comprehensive literature review for proposing candidate indicators, adoption of indicator selection criteria, and invited expert verification for finalising the indicator checklist.

First, in responding to the functional components established in Section 2.2, various high-quality academic works published in reputational international journals within the latest two decades are retrieved as supporting references (see Table 1). These supporting references are helpful to sort out candidate indicators to measure the 17 functional components across urban social, economic and environmental aspects.

Furthermore, "generic" and "guidable" are two key criteria adopted for candidate indicator filtering, which are to ensure that the indicator checklist established in this study can be applied by different cities across different development contexts and support comparative analysis between cities. Besides the two key criteria of "generic" and "guidable", nine specific indicator selection requirements are employed to ensure the applicability of the city physical examination indicators, namely, communicability, rationality, relevance, number limitation, data availability, representativeness, completeness, feasibility, and measurability. These nine indicator selection requirements have been widely adopted for indicator selection and establishment in the research spectrum of sustainable urban development (see for example, Wang et al., 2020a; Hák, Janouškov & Moldan, 2016).

Additionally, five experts are invited to verify the scientific creditability of the indicator checklist. These five experts have been rooted in the research area and the practices of sustainable and healthy city, and they are from universities, research institutes, and governmental departments, thus can provide valuable insights upon the planning, development and governance of healthy cities to ensure the applicability of the guiding indicator checklist. The profile of these invited experts are summarised in Table 2.

Consequently, the indicator checklist for urban physical examination is finalised as shown in Table 3.

Table 1
Functional component and supporting references to select candidate indicators for urban physical examination.

Urban health aspect	Functional composition	Supporting references for candidate indicators selection
Social aspect	• Decent living standard • Infrastructure delivery • Educational services • Cultural conditions • Medical services • Social security	Yang, Yang and Wang (2020); Tang et al. (2019) He et al. (2018); Dempsey et al. (2011); Phillis, Kouikoglou and Verdugo (2017); Zhang et al. (2016) Tan and Lu (2015); Shen and Zhou (2014); Shen et al. (2011); Li et al. (2009)
Economic aspect	• Economic increment • Economic quality • Economic structure • Economic openness • Development potential	Yang, Yang and Wang (2020); Tang et al. (2019); Phillis, Kouikoglou and Verdugo (2017); Zhang et al. (2016); Tan and Lu (2015); Shen and Zhou (2014); Shen et al. (2011); Li et al. (2009)
Environmental aspect	• Water quality • Energy consumption • Atmospheric Environment • Landscape environment • Acoustic environment • Luminous environment	Yang, Yang and Wang (2020); Tang et al. (2019); He et al. (2018); Phillis, Kouikoglou and Verdugo (2017); Zhang et al. (2016); Tan and Lu (2015); Shen and Zhou (2014); Shen et al. (2011); Li et al. (2009); Ferguson, Brown and Deletic (2013).

Table 2
Profile of invited experts for indicator checklist verification.

Expert code	Research/practice expertise	Institute
Expert-A	Sustainable urban development	University
Expert-B	Healthy cities	University
Expert-C	Sustainable urban-rural development	Research Institute
Expert-D	Urban planning and resource management	Research Institute
Expert-E	Urban planning and management	Government Bureau/ Department

Table 3
A guiding indicators checklist for urban physical examination.

Aspect	Indicator code	Indicator	Indicator unit
Social (*So*)	So-1	Engel's coefficient	%
	So-2	Proportion of people guaranteed by pension insurance	%
	So-3	Unemployment rate	%
	So-4	Gas coverage rate	%
	So-5	Electricity coverage rate	%
	So-6	Water coverage rate	%
	So-7	Internet coverage rate	%
	So-8	Traffic congestion index	–
	So-9	Per capita fiscal input for education	US dollar
	So-10	Number of collections in public libraries per 10,000 population	Unit
	So-11	Number of beds in hospitals per 10,000 population	Bed
	So-12	Number of criminal cases per 10,000 population	Unit
Economic (*Ec*)	Ec-1	GDP growth rate	%
	Ec-2	Growth rate of investment in fixed assets	%
	Ec-3	GDP per capita	US dollar/ person
	Ec-4	GDP density	One million US dollar/km^2
	Ec-5	Disposable income per capita	US dollar/ person
	Ec-6	Government debt ratio	%
	Ec-7	Inflation rate	%
	Ec-8	Rationalisation of industrial structure	–
	Ec-9	Upgrade of industrial structure	–
	Ec-10	Trade openness	%
	Ec-11	R&D investment proportion	%
Environmental (*En*)	En-1	Quality of drinking water	%
	En-2	Sewage treatment rate	%
	En-3	Proportion of clean energy consumption	%
	En-4	$PM_{2.5}$ concentration level	ug/m^3
	En-5	PM_{10} concentration level	ug/m^3
	En-6	SO_2 concentration level	ug/m^3
	En-7	NO_2 concentration level	ug/m^3
	En-8	O_3 concentration control	ug/m^3
	En-9	CO concentration control	mg/m^3
	En-10	Green coverage rate	%
	En-11	Treatment rate of household waste	%
	En-12	Treatment rate of general solid waste	%
	En-13	Noise pollution control	Db
	En-14	Light pollution control	Grade

Note: (1) Ec-6 (Government debt ratio) is equal to the ratio of debt balance at the end of the year to the GDP of the year; (2) Ec-8 (Rationalisation of industrial structure) is expressed using the inverse of the Theil index, which is derived from Gan, Zheng and Yu (2011); (3) Ec-9 (Upgrade of industrial structure) is equal to the ratio of the value added of the tertiary industry divided by the value added of the secondary industry; (4) Trade openness is equal to the ratio of total import and export divided by regional GDP; (5) R&D investment intensity is equal to the ratio of R&D expenditure to regional GDP; (6) En-4, En-5, En-6, En-7 refer to the annual average of $PM_{2.5}$, PM_{10}, SO_2, NO_2 concentration.

4. Indicator benchmark setting for urban physical examination

Following the establishment of indicator checklist for urban physical examination, the approach of indicator benchmarks setting will be introduced in this section. With benchmark setting method, the indicator checklist can be adopted to different cities in examining the conditions of urban functional components and diagnose dynamically city healthy status across the three aspects of social, economic, and environmental.

Many international organisations, for example, United Nations, International Organization for Standardization (ISO), International Telecommunication Union (ITU) and Standard Electrotechnical Committee (IEC) have provided international standards of some key indicators manifesting urban development conditions, so that the performances between countries and regions can be compared. For example, "Engel coefficient" has been an international standard set by the Food and Agricultural Organisation of the United Nations. Countries worldwide also appreciate the positive role that indicator benchmarks or standards play in stimulating state development and enhancing national competitiveness, where various indicator standards have been introduced by different countries with incorporating their local context (Li, 1982; Blind & Mangelsdorf, 2016).

As stated previously, this study aims to propose the benchmark setting approach for the indicator checklist of urban physical examination (Table 3), so that both the indicator checklist and benchmark setting approach can be applied to different countries and regions in monitoring city's dynamic health conditions and unravelling potential risks of diseases. For this, three scenarios may occur for indicator benchmark setting:

- One is that the specific indicator has certain international standards published by authoritative international organisations (such as the United Nations) or inter-governmental organisations (such as the European Union). Thus, the international standard will be adopted as references for setting the indicator benchmark.
- The second scenario is that the specific urban physical examination indicator does not have available international standards, while some regions or countries have set out their standard. Thus, the suitable national or regional standard will be adopted as the references for setting the indicator benchmarks, to help monitor city health status under the context of this referred country or region.
- The third situation is that the specific urban physical examination indicator neither has international standards nor be addressed by individual countries about its standards. Under such case, given the consideration that urban development is a systematic process shaped by the governance mode and socio-economic conditions where each country has its own specificity, empirical survey-based benchmark setting approach will be adopted to determine the benchmark of this specific indicator, namely, the performances of certain indicator between different cities in the target country will be adopted as references for setting the benchmarks of this particular indicator.

Above three scenarios for indicator benchmark setting provides two approaches for the benchmark setting upon urban physical examination indicators, namely, *standard-based indicator benchmark setting*, and *empirical survey-based indicator benchmark setting*. Furthermore, proper scaling method is needed to delineate the city health status into different categories, so that dynamic track and comparison can be conducted between different time durations, and also between different cities under the context of specific country. The details of scaling principle, and the two indicator benchmark setting approaches will be presented in below sections.

4.1. Scaling principle of indicator benchmark setting for urban physical examination

This study aims to adopt the indicator checklist of urban physical examination to monitor the health status of a concerned city. For each monitoring indicator, a four-scale measurement[2] will be set to delineate different healthy status of a particular urban functional facet represented by this indicator:

- *Very-healthy (VH)*: The city is appreciated very healthy in terms of the facet represented by the certain physical examination indicator; and dynamic monitoring and continuous health maintaining is recommended.
- *Healthy (H)*: The city is considered healthy in terms of the facet represented by the physical examination indicator; and dynamic monitoring, continuous health maintaining and essential health promotion is needed.
- *Risky (R)*: The city is diagnosed encountering certain risks in terms of the facet monitored by the specific physical examination indicator; thus proper treatment measures should be tailored and implemented to help improve urban health status in the particular aspect.
- *Non-healthy (NH)*: The city is diagnosed encountering severe underlying urban diseases in terms of the facet monitored by the specific physical examination indicator; thus tailored treatment measures and intervention approaches should be taken in a timely manner to effectively address the diseases and improve urban health status of this particular aspect.

This four-scale indicator-based measurement principle for urban physical examination, and the relationship between indicator performance and actions need to be taken are further presented graphically in Fig. 3.

Following the scaling principle of urban physical examination indicators, the indicator benchmark setting approaches can also settle down. As stated previously, for those indicators having international standards published by authoritative international organisations, and those having regional or national standards, the international standards and suitable regional standards will be adopted as the references for setting indicator benchmarks, namely, following the approach of standard-based indicator benchmark setting. For those urban physical examination indicators do not have any international or regional standards, empirical survey-based benchmark setting approach will be adopted to determine the indicator benchmarks.

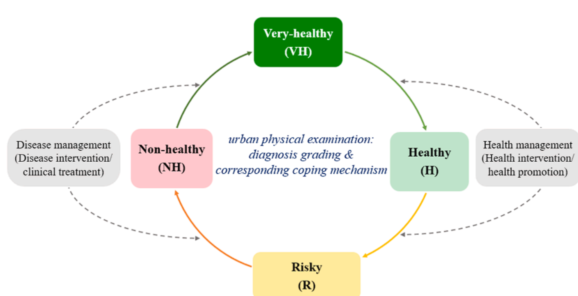

Fig. 3. Scaling principle of urban physical examination: diagnosis grading and corresponding coping mechanism.
(Source: Authors)

[2] The principle of the quartile method refers to the average division of a well-ordered data sample into four parts, and the values at the positions of three segmentation points are respectively recorded as the upper quartile, the median, and the lower quartile. The quartile does not require the feature data to conform to the normal distribution and will not be affected by extreme values, which is considered suitable for the hierarchical analysis of the urban health performance between multiple cities (Montalto et al., 2023; Yigitcanlar & Kamruzzaman, 2018)

4.2. Standard-based benchmark setting

For each urban physical examination indicator listed in Table 3, careful scrutinisation will be conducted upon following the hierarchical process of international standards, regional standards, and national standards introduced by authoritative intergovernmental organisation, governmental bodies and academic institutions to check whether relevant, established, and suitable standards are available to be adopted as references for indicator benchmark setting in this study. In addition, for some indicators with professional specificity, industry-authoritative standards introduced by classical literature and professional industrial reports will also be scrutinised, and be adopted as referee criteria for indicator benchmark setting if available and suitable. A note here is that if an indicator has both benchmark references from international standards and national standards, the international benchmark would be adopted as the benchmark setting references.

With the references from existing standards from international, regional, national or industrial, bear the four-scale measurement principle in mind, each urban physical examination indicator can be benchmarked into four categories of *very healthy* (VH), *healthy* (H), *risky* (R) and *non-healthy* (NH). For example, the urban physical examination indicator So-1 (Engel's coefficient) has the international standard set by the Food and Agricultural Organisation of the United Nations, thus 4 categories of health status can be divided, namely, VH [0–30), H [30–50), R [50–60), NH [60–100).

It is worth noting that for some indicators, according to the existing standards, there may be the case that only two categories of health status can be divided, namely Very-healthy (VH) and Non-healthy (NH). For example, according to the existing standards of various countries, the performance of indicator En-11 (Treatment rate of household waste) can only be considered healthy when the treatment rate reaches 100%, thus the two categorical benchmark setting of En-11 is VH=100%, NH<100%.

4.3. Empirical survey-based benchmark setting

However, it is found that the standards of the majority of urban physical examination indicators are not available via international, regional, national standards. On the other hand, it is considered that urban development is a systematic process which is deeply shaped and influenced by the governance mode and socio-economic conditions that the city rooted in, for which each country has its own specificity and "one size fits all" answer upon indicator standards is impractical. Thus, empirical survey-based benchmark setting approach is proposed by this study to determine the four-scale benchmarks of those indicator who do not have "off the shelf" standards. That is, the performances of the specific indicator between different cities in the concerned country will be adopted as references for setting the indicator benchmark. The selection of sample cities adopts the principle of key city designation and PPS (Probability Proportionate to Size Sampling). The key cities need to endow the same administrative level, similar cultural background and technological standards as the target city where urban physical examination would be conducted. On the other hand, the number of sample cities should be more than 30, as the larger the number of sample cities, the more reliable the results of quartile method.

Based upon the empirical survey, the quartile method will be used to generate five delineation values (maximum, minimum, median, upper quartile, lower quartiles), thus the four-scale indicator measurement can be obtained. Therefore, the practical survey-based indicator benchmarks setting is shown in Table 4.

4.4. Guideline for indicator benchmark setting

In line with the scale-principle of indicator measurement, and the standard-based and empirical survey-based indicator benchmark setting approaches, centred with each indicator of urban physical examination,

Table 4
Practical survey-based indicator benchmark setting for urban physical examination.

Interquartile range	Health status of urban functional component monitored by the indicator performance (*positive indicators*)	Health status of urban functional component monitored by the indicator performance (*negative indicators*)
A4 (maximum - upper quartile)	Very-healthy (VH)	Non-healthy (NH)
A3 (upper quartile - median)	Healthy (H)	Risky (R)
A2 (median - lower quartiles)	Risky (R)	Healthy (H)
A1 (lower quartiles - minimum)	Non-healthy (NH)	Very-healthy (VH)

Note: The positive indicators refer to the indicators where the indicator value is larger, the healthier the city status represented by the indicator; whilst the negative indicators refer to the indicators where the indicator value is smaller, the healthier the city status represented by the indicator.

a set of guideline for indicator benchmark setting can be generated and summarised as shown in Table 5. For each urban physical examination indicator, a tailored benchmark setting method is articulated, ranging from international, regional, national and industrial standard-based, and practical survey-based.

5. Empirical case study of urban physical examination

China, being as the largest developing countries worldwide, has been experiencing an unparalleled urbanisation programme since its open-up and reform in the 1980s (Shen et al., 2018). However, the rapid speed and massive scale of urbanisation development in China has also triggered plenty of challenges in terms of the urban environment and wellbeing, where the conflicts between healthy, sustainable development and urban growth have become a popular topic recently in the arena of both academic debates and policy-making (Ren et al., 2018; Fan & Fang, 2020).

The Municipality of Chongqing, located in mountainous region of Southwest China (Fig. 4), presenting fragile ecological environment and relatively lagging economic foundation and owing both fast-growing metropolitan area and lagged behind rural areas, is under rapid rural-to-urban transition. The Municipality, carrying 32.1 million population of urban and rural entities, is more predominantly facing the pressures of receiving migrants, tackling urban environmental burdens and guaranteeing social wellbeing (Liu, Shen, Ren, & Zhou, 2023). Therefore, Chongqing is considered as a typical case area for exemplifying the validness of the guiding methodology upon urban physical examination.

5.1. Indicator benchmark setting for urban physical examination of chongqing municipality

According to the urban physical examination guidelines established in Section 3, the prerequisite for urban physical examination is to set up the indicator benchmarks by following the four-scale principle and benchmark setting approaches. As stated in Section 3, for those monitoring indicators with international, regional and national standards, the standards will be adopted as references for setting the indicator benchmarks in conducting urban physical examination in Chongqing. For urban physical examination indicators do not have “out of the shelf” standards, practical survey-based approach will be adopted to help settle down the four-scale benchmarks of monitoring indicators in delineating the health status of urban functional components. In the case of urban

Table 5
Indicator benchmarking setting guideline for urban physical examination.

Indicator	Benchmark setting approach (Four scale principle)	Indicator attribute
So-1 *Engel's coefficient*	International Standard (Food and Agriculture Organisation of the United Nations)	–
So-2 *Proportion of people guaranteed by pension insurance*	Practical survey based quartile method	+
So-3 *Unemployment rate*	Practical survey based quartile method	–
So-4 *Gas coverage rate*	Practical survey based quartile method	+
So-5 *Electricity coverage rate*	Practical survey based quartile method	+
So-6 *Water coverage rate*	International Standard (SDGs 6)	+
So-7 *Internet coverage rate*	Practical survey based quartile method	+
So-8 *Traffic congestion index*	Industry standard	–
So-9 *Per capita fiscal input for education*	National standard	+
So-10 *Number of collections in public libraries per 10,000 population*	Practical survey based quartile method	+
So-11 *Number of beds in hospitals per 10,000 population*	Practical survey based quartile method	+
So-12 *Number of criminal cases per 10,000 population*	Practical survey based quartile method	–
Ec-1 *GDP growth rate*	Government working report/ National standard	+
Ec-2 *Growth rate of investment in fixed assets*	Practical survey based quartile method	+
Ec-3 *GDP per capita*	Practical survey based quartile method	+
Ec-4 *GDP density*	Practical survey based quartile method	+
Ec-5 *Disposable income per capita*	Practical survey based quartile method	+
Ec-6 *Government debt ratio*	International standard (Treaty of Maastricht)	–
Ec-7 *Inflation rate*	International standard (Treaty of Maastricht)	–
Ec-8 *Rationalisation of industrial structure*	Practical survey based quartile method	+
Ec-9 *Upgrade of industrial structure*	Practical survey based quartile method	+
Ec-10 *Trade openness*	Practical survey based quartile method	+
Ec-11 *R&D investment proportion*	Government working report/ National standard	+
En-1 *Quality of drinking water*	National standard	+
En-2 *Sewage treatment rate*	Practical survey based quartile method	+
En-3 *Proportion of clean energy consumption*	National standard	+
En-4 $PM_{2.5}$ *concentration level*	National standard	–
En-5 PM_{10} *concentration level*	National standard	–
En-6 SO_2 *concentration level*	National standard	–
En-7 NO_2 *concentration level*	National standard	–
En-8 O_3 *concentration control*	National standard	–
En-9 *CO concentration control*	National standard	–
En-10 *Green coverage rate*	National standard	+
En-11 *Treatment rate of household waste*	National standard	+
En-12 *Treatment rate of general solid waste*	Practical survey based quartile method	+
En-13 *Noise pollution control*	National standard	–
En-14 *Light pollution control*	International standard (The Bortle scale)	–

Note: 1) The criteria for Ec-6 and Ec-7 come from the Treaty of Maastricht (also known as the EU Treaty) The Treaty requires inflation to be under 5%, fiscal deficits not to exceed 3% of GNP, and public debt not to exceed 60% of GNP. 2) The criteria for So-6 is derived from the Sustainable Development Goals of United Nations (SDGs6 - Clean Drinking Water). 3) For indicator attribute, “+” represents positive indicator, where a larger indicator value represents a healthier status; "-" represents negative indicator, where a smaller indicator performance represents a healthier status.4).

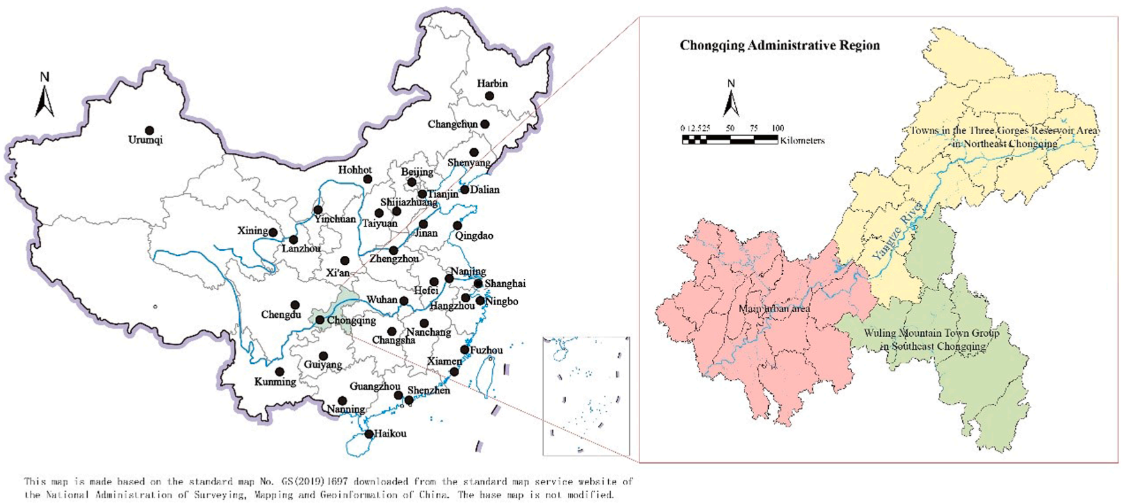

Fig. 4. Chongqing Municipality in Southwest China as empirical case study area. (Source: Authors)

physical examination in Chongqing, sample cities need to be selected as sample (counterpart) cities to help delineate the indicator benchmarks. The selection of sample cities follows the principle of key city designation described in Section 4.3. In reference to Chongqing's administrative rank, the cities of Beijing, Tianjin and Shanghai are selected as sample cities- as they are all municipalities directly under the governance of central government. Furthermore, in order to ensure that the size of sample cities reaches a certain scale, namely, more than 30, PPS sampling is conducted. In this regard, to ensure the spatial balance and representativeness, 32 large cities were sampled from provincial capitals and regional socio-economic centers in China. Thus 35 Chinese major cities are selected as counterparts to help determining the indicator benchmarks (see the note of Table 6). Specifically, the performance of specific indicators between these 35 cities will be adopted as references for setting the four-scale indicator benchmarks to conduct urban physical examination of Chongqing. Also, in this empirical case study, a five-year period (2015–2019) based urban health monitoring and examination would be conducted, so that the indicator benchmarks would be set annually.

Consequently, the indicator benchmark setting approach and results for urban physical examination in Chongqing are shown in Table 6 and Table 7 respectively.

By comparing the actual (practical) value of each urban physical examination indicators performed in Chongqing with the indicator benchmark setting presented in Table 6, the urban health status of Chongqing during 2015–2019 can be diagnosed and delineated into different levels, as depicted in Fig. 5. By further tracking the dynamic changes of Chongqing's urban health status across each facet of urban functional composition manifested by the specific UPE indicators, the evolution of urban healthy status can be captured, marked as "gradually improving (rising, ↑)", "remaining unchanged (stable, –)", and "becoming worse (falling, ↓)" in Fig. 5.

According to Fig. 5, it can be seen that under urban social system, the performances of Engel's coefficient (*So-1*), per capita fiscal input for education (*So-9*) and the number of collections in public libraries (*So-10*) are generally good, delineating as the status of very healthy (VH) and healthy (H) across the study period. This indicates that the urban development in Chongqing has achieved and maintained a relatively long-term healthy state in terms of residents' living standards, education and cultural services. However, Fig. 5 further tells that the performance of gas coverage (*So-4*), water coverage (*So-6*), internet coverage (*So-7*) and the number of hospital beds (*So-11*) is poor during the urban health diagnosis period. This unravels that the "hard" infrastructure (such as gas, water and internet) and "soft" infrastructure (such as medical services)[3] delivery in Chongqing has been under the status of non-healthy (NH) and appeals for enhancement and improvement. In addition, urban employment (manifesting by the performance of *So-3*) has shown an improving trend, whilst the city's health status at the facet of urban traffic system is worsening, evident by the declining performance of "Traffic congestion index" (*So-8*).

Chongqing's urban economy is diagnosed presenting different healthy status across different functional compositions. In terms of economic increment, the performance of GDP growth rate (*Ec-1*) maintained at very healthy status (VH) over the urban health examination period, whilst the growth rate of fixed asset investment (*Ec-2*) gradually declined from healthy status (H) to risky status (R). For urban economy quality, the UPE indicators of GDP per capita (*Ec-3*), GDP intensity (*Ec-4*) and per capita disposable income (*Ec-5*) overwhelmingly present non-healthy status (NH) over the diagnosis period. Whilst the government debt rate (*Ec-6*) and inflation rate (*Ec-7*) consistently performed well and kept the healthy status (H) in the long run. In terms of the economic structure, the rationalisation of industrial structure (*Ec-8*) presented entrenched non-healthy status (NH), and the health status of upgrade of industrial structure (*Ec-9*) declined from risky (R) to non-healthy (NH). Furthermore, the economic openness of Chongqing has presented a deterioration trend, with the performance of "Trade openness (*Ec*-10)" declining from healthy status (H) to risky status (R) over the diagnosis period. Lastly, monitored via the performance of R&D investment intensity (*Ec-11*), the development potential of Chongqing's urban economy has presented an upward trend, improving from non-healthy status (NH) to very healthy (VH).

The healthy status of urban environmental aspect in Chongqing is considered relatively stable amidst the diagnosis period, though both healthy and non-healthy urban functional components co-exist. Most of UPE indicators performed and maintained healthy status (VH or H) during the diagnosis period, including the quality of drinking water (*En-1*), sewage treatment rate (*En-2*), SO_2 concentration level (*En-6*), CO concentration control (*En-9*), green coverage rate (*En-10*) and noise

[3] The definition of "hard" and "soft" infrastructures can be referred to Wang et al. (2020a).

Table 6
Indicators benchmark setting approach for urban physical examination in Chongqing.

Indicator code	Benchmark setting sources of Chongqing
So-1	International Standard (Food and Agriculture Organization of the United Nations)
So-2	Practical survey-based Standard (survey data of 35 major Chinese cities)
So-3	Practical survey-based Standard (survey data of 35 major Chinese cities)
So-4	Practical survey-based Standard (survey data of 35 major Chinese cities)
So-5	Practical survey-based Standard (survey data of 35 major Chinese cities)
So-6	International and National Standard (SDGs 6 & “12th Five-Year Plan” and 2020 long-term goals for the transformation and construction of urban water supply facilities issued by Chinese central government)
So-7	Practical survey-based Standard (survey data of 35 major Chinese cities)
So-8	Industry standard (Baidu map traffic travel big data platform)
So-9	National standard (National civilised city evaluation system of China)
So-10	Practical survey-based Standard (survey data of 35 major Chinese cities)
So-11	Practical survey-based Standard (survey data of 35 major Chinese cities)
So-12	Practical survey-based Standard (survey data of 35 major Chinese cities)
Ec-1	National Standard (Government Working Report: the 13th Five-Year Plan for Chongqing’s National Economic and Social Development)
Ec-2	Practical survey-based Standard (survey data of 35 major Chinese cities)
Ec-3	Practical survey-based Standard (survey data of 35 major Chinese cities)
Ec-4	Practical survey-based Standard (survey data of 35 major Chinese cities)
Ec-5	Practical survey-based Standard (survey data of 35 major Chinese cities)
Ec-6	International Standard (Treaty of Maastricht)
Ec-7	International Standard (Treaty of Maastricht)
Ec-8	Practical survey-based Standard (survey data of 35 major Chinese cities)
Ec-9	Practical survey-based Standard (survey data of 35 major Chinese cities)
Ec-10	Practical survey-based Standard (survey data of 35 major Chinese cities)
Ec-11	National Standard (Government Working Report: the 13th Five-Year Plan for Chongqing’s National Economic and Social Development)
En-1	International Standard (SDGs 6)
En-2	Practical survey-based Standard (survey data of 35 major Chinese cities)
En-3	National standard (“Building on Past Achievements and Launching a New Journey for Global Climate Actions”–Statement by PRC President Xi at the Climate Ambition Summit)
En-4	National Standard (“Ambient air quality standard” [GB3095–2012])
En-5	National Standard (“Ambient air quality standard” [GB3095–2012])
En-6	National Standard (“Ambient air quality standard” [GB3095–2012])
En-7	National Standard (“Ambient air quality standard” [GB3095–2012])
En-8	National Standard (“Ambient air quality standard” [GB3095–2012])
En-9	National Standard (“Ambient air quality standard” [GB3095–2012])
En-10	National Standard (“Urban landscaping evaluation standard” [GB/T 50,563–2010])
En-11	National Standard (The 13th Five-Year Plan for National Construction of Harmless treatment facilities for Urban Household Garbage)
En-12	Practical survey-based Standard (survey data of 35 major Chinese cities)
En-13	National Standard (Standard of environmental noise of urban area)
En-14	International Standard (The Bortle scale)

Note: The 35 major cities in China as the sample city of Chongqing for indicator benchmark setting include: Beijing, Shanghai, Tianjin, Chongqing, Guangzhou, Wuhan, Harbin, Shenyang, Chengdu, Nanjing, Xi’an, Changchun, Jinan, Hangzhou, Dalian, Qingdao, Shenzhen, Xiamen, Ningbo, Shijiazhuang, Taiyuan, Hefei, Nanchang, Fuzhou, Zhengzhou, Changsha, Haikou, Guiyang, Kunming, Lanzhou, Nanning, Yinchuan, Xining, Hohhot, Urumqi.

pollution control (*En-13*). However, the annual average PM 2.5 concentration level (*En-4*) and the treatment rate of general solid waste (*En-12*) has been stuck at non-healthy (NH) status for a long term, and urgent actions are appealed for tackling these urban environmental diseases. Besides, the O_3 concentration level (*En-8*) in Chongqing has been evolved and presented unstable healthy status, which needs to pay particular attention to prevent deterioration. Furthermore, Chongqing has also achieved certain improvements upon urban environmental condition, evident by the improving trajectory of several UPE indicators, such as annual average PM10 concentration (*En-5*), NO_2 concentration (*En-7*) and the treatment rate of household waste (*En-11*), which has risen from the status of non-healthy (NH) to very healthy (VH).

6. Tailoring “treatment” for tackling urban diseases identified from empirical study

On top of the results of urban physical examination in Chongqing, this section aims to propose “treatment” to help tackle the identified urban diseases under three aspects of social, economic and environmental. The proposal of tailored “treatment” further demonstrates the validness of the guiding methodology for urban physical examination.

6.1. Urban social aspect

Under urban social aspect, according to the urban health examination results in Section 5.2, it can be seen that the provision of infrastructure (particularly gas, water and internet) and medical services performed weakly from 2015 to 2019, consistently showing the status of non-healthy. This finding is echoed by the study of Chen et al. (2022) that the phenomenon of insufficient coverage of water and gas in Chongqing is prominent, presenting significant gap from cities such as Beijing and Shanghai. As the only municipality directly under the governance of central government in the middle-western region of China, Chongqing has become the most populous city in the country. Therefore, for the Chongqing Municipal Government, providing sufficient medical services is extremely challenging under such huge medical demand (Liu et al., 2022).

To help tackle the identified urban diseases of social aspect, following measures are proposed: First of all, social capitals can be more actively absorbed to broaden the financial channels to enhance the planning, construction and delivery of urban infrastructures in Chongqing. For example, preferential policies such as tax and fee reductions can be used to attract more social-capital investment in the delivery of infrastructure. Secondly, multiple policy instruments should be implemented to attract more medical professionals, for example, to establish the talent attraction system and improve follow-up training programs, also more advanced medical techniques can be introduced to improve the capability of medical services.

In addition, as mentioned in Section 5.2, the health status of urban traffic system in Chongqing has been deteriorating from risky (R) to non-healthy (NH) over the diagnosis period. The construction of transportation system in Chongqing is deeply shaped by its geographical conditions. In fact, given the terrain of Chongqing is overwhelmingly mountainous, the traffic network in the city are mostly built on mountains; also the geographical restriction has led to a situation that the construction cost of traffic system in Chongqing is much higher than that of other cities. Furthermore, with the continuous increase of car ownership, the transportation system in the city is facing huge challenges with the traffic congestion becoming a prominent problem (Wang et al., 2019; Wei et al., 2022). In fact, the 2019 China Urban Traffic Report released by Baidu Maps stating that Chongqing is one the most congested city in China in the year.

To tackle the urban diseases of traffic congestion, the Municipality government of Chongqing is recommended to devote more resources upon the improvement of urban transportation facilities particularly enhancing urban trunk road network to alleviate traffic congestion.

Table 7
Indicator benchmark setting for urban physical examination in Chongqing (2015–2019).

Indicator	2015	2016	2017	2018	2019
So-1 *Engel's coefficient*	VH: [0–30); H: [30–50); R: [50–60); NH: [60–100)				
So-2 *Proportion of people guaranteed by pension insurance*	VH:>41.62; H:31.04–41.62; R:22.75–31.04; NH:<22.75	VH:>43.41; H:34.99–43.41; R:23.88–34.99; NH:<23.88	VH:>45.75; H:37.09–45.75; R:27.38–37.09; NH:<27.38	VH:>48.78; H:38.10–48.78; R:28.90–38.10; NH:<28.90	VH:>=51.24; H:43.01–51.24; R:31.18–43.01; NH:<31.18
So-3 *Unemployment rate*	VH: <2.11; H:2.11–2.98; R:2.98–3.45; NH: >3.45	VH: <2.37; H:2.37–3.03; R:3.03–3.48; NH: >3.48	VH: <2.35; H:2.35–3.00; R:3.00–3.39; NH: >3.39	VH: <2.22; H:2.22–2.94; R:2.94–3.31; NH: >3.31	VH: <2.16; H:2.16–2.70; R:2.70–3.24; NH: >3.24
So-4 *Gas coverage rate*	VH:100.00; H:99.53–100.00; R:97.97–99.53; NH:<97.97	VH:>99.96; H:99.42–99.96; R:96.22–99.42; NH:<96.22	VH:>100.00; H:99.03–100.00; R:97.34–99.03; NH:<97.34	VH:>100.00; H:98.90–100.00; R:97.00–98.90; NH:<97.00	VH:>100.00; H:99.29–100.00; R:98.04–99.29; NH:<98.04
So-5 *Electricity coverage rate*	!				
So-6 *Water coverage rate*	VH:=100 NH:<100				
So-7 *Internet coverage rate*	VH:>143.56; H:121.07–143.56; R:99.42–121.07; NH:<99.42	VH:>142.24; H:129.99–142.24; R:110.03–129.99; NH:<110.03	VH:>142.16; H:133.93–142.16; R:112.14–133.93; NH:<112.14	VH:>141.83; H:134.08–141.83; R:113.25–134.08; NH:<113.25	VH:>140.83; H:131.69–140.83; R:114.11–131.69; NH:<114.11
So-8 *Traffic congestion index*	VH: [1.00~1.50); H: [1.50~1.80); R: [1.80~2.00); NH: [2.00~)				
So-9 *Per capita fiscal input for education*	VH:>=60.88 NH:<60.88				
So-10 *Number of collections in public libraries per 10,000 population*	VH:>37.41; H:34.55–37.41; R:28.80–34.55; NH:<28.80	VH:>39.23; H:35.03–39.23; R:28.83–35.03; NH:<28.83	VH:>39.83; H:35.52–39.83; R:30.95–35.52; NH:<30.95	VH:>40.69; H:36.80–40.69; R:32.41–36.80; NH:<32.42	VH:>41.90; H:37.19–41.90; R:32.92–37.19; NH:<32.92
So-11 *Number of beds in hospitals per 10,000 population*	VH:>63.87; H:54.83–63.87; R:45.28–54.83; NH:<45.28	VH:>67.69; H:57.54–67.69; R:49.00–57.54; NH:<49.00	VH:>73.07; H:59.31–73.07; R:49.81–59.31; NH:<49.81	VH:>74.93; H:63.34–74.93; R:52.69–63.34; NH:<52.69	VH:>76.47; H:68.00–76.47; R:55.71–68.00; NH:<55.71
So-12 *Number of criminal cases per 10,000 population*	VH: <20.24; H:20.24–69.81; R:69.81–91.18; NH: >91.18	VH: <29.29; H:29.29–62.07; R:62.07–86.00; NH: >86.00	VH: <27.35; H:27.35–61.59; R:61.59–70.10; NH: >70.10	VH: <23.05; H:23.05–47.81; R:47.81–65.05; NH: >65.05	VH: <25.20; H:25.20–42.70; ,R:42.70–64.02; NH: >64.02
Ec-1 *GDP growth rate*	VH:>6% NH:<6%				
Ec-2 *Growth rate of investment in fixed assets*	VH: >16.3 H: 12–16.3 R: 10.1–12 NH: <10.1	VH: >13.65 H: 10.5–13.65 R: 5.65–10.5 NH: <5.62	VH: >12.6 H: 9.5–12.6 R: 5.7–9.5 NH: <5.7	VH: >10.9 H: 9.4–10.9 R: 5.95–9.4 NH: <5.95	VH: >10.15 H: 8–10.15 R: 2.3–8 NH: <2.3
Ec-3 *GDP per capita*	VH: >16,692 H: 12,183–16,692 R: 10,154–12,183 NH: <10,154	VH: >16,720 H: 12,284–16,720 R: 10,137–12,284 NH: <10,137	VH: >18,665 H: 14,933–18,665 R: 11,788–14,933 NH: <11,788	VH: >19,725 H: 14,480–19,725 R: 11,699–14,480 NH: <11,699	VH: >20,484 H: 14,495–20,484 R: 11,629–14,495 NH: <11,629
Ec-4 *GDP density*	VH: >1449 H: 892–1449 R: 369–892 NH: <369	VH: >1467 H: 814–1467 R: 375–814 NH: <375	VH: >1065 H: 709–1065 R: 316–709 NH: <316	VH: >1697 H: 944–1697 R: 412–944 NH: <412	VH: >1570 H: 1014–1570 R: 388–1014 NH: <388
Ec-5 *Disposable income per capita*	VH:>6448 H:5451–6448 R:4672–5451 NH:<4672	VH:>6541 H:5531–6541 R:4655–5531 NH:<4655	VH:>6970 H:5893–6970 R:4927–5893 NH:<4927	VH:>7677 H:6496–7677 R:5419–6496 NH:<5419	VH:>7950 H:6685–7950 R:5619–6685 NH:<5619
Ec-6 *Government debt ratio*	VH:<60% NH:>60%				
Ec-7 *Inflation rate*	VH:<5% NH:>5%				
Ec-8 *Rationalisation of industrial structure*	VH: >24.34 H: 13.56–24.34 R: 7.62–13.56 NH: <7.62	VH: >24.61 H: 12.40–24.61 R: 7.90–12.40 NH: <7.90	VH: >73.04 H: 33.99–73.04 R: 15.40–33.99 NH: <15.40	VH: >31.37 H: 13.69–31.37 R: 8.80–13.69 NH: <8.80	VH: >32.40 H: 15.30–32.40 R: 8.34–15.30 NH: <8.34
Ec-9 *Upgrade of industrial structure*	VH: >1.62 H: 1.26–1.62 R: 1.01–1.26 NH: <1.01	VH: >1.74 H: 1.43–1.74 R: 1.09–1.43 NH: <1.09	VH: >1.90 H: 1.57–1.90 R: 1.40–1.57 NH: <1.40	VH: >1.88 H: 1.48–1.88 R: 1.28–1.48 NH: <1.28	VH: >2.16 H: 1.79–2.16 R: 1.50–1.79 NH: <1.50
Ec-10 *Trade openness*	VH:>43.29 H:22.41–43.29	VH:>42.14 H:20.81–42.14	VH:>52.58 H:26.83–52.58	VH:>45.61 H:28.05–45.61	VH:>45.61 H:28.05–45.61

(*continued on next page*)

Table 7 (*continued*)

Indicator	2015	2016	2017	2018	2019
	R:13.61–22.41 NH:<13.61	R:11.9–20.81 NH:<11.9	R:15.74–26.83 NH:<15.47	R:15.94–28.05 NH:<15.94	R:15.94–28.05 NH:<2.66
Ec-11 *R&D investment proportion*		VH:>2.2% NH:<2.2%			
En-1 *Quality of drinking water*	VH:=100% NH:<100%				
En-2 *Sewage treatment rate*	VH:>95.065% H:92.65%−95.065% R:89.85%−92.65% NH:<89.85%				
En-3 *Proportion of clean energy consumption*	VH:≥25% NH:<25%				
En-4 $PM_{2.5}$ *concentration level*	VH:≤35ug/m^3 NH:>35ug/m^3				
En-5 PM_{10} *concentration level*	VH:≤70ug/m^3 NH:>70ug/m^3				
En-6 SO_2 *concentration level*	VH:≤60ug/m^3 NH:>60ug/m^3				
En-7 NO_2 *concentration level*	VH:≤40ug/m^3 NH:>40ug/m^3				
En-8 O_3 *concentration control*	VH:≤160ug/m^3 NH:>160ug/m^3				
En-9 *CO concentration control*	VH:≤4 mg/m^3 NH:>4 mg/m^3				
En-10 *Green coverage rate*	VH:≥40% NH:<40%				
En-11 *Treatment rate of household waste*	VH:=100% NH:<100%				
En-12 *Treatment rate of general solid waste*	VH:>97.96% H:93.76%−97.96% R:86.2%−93.76% NH:<86.2%				
En-13 *Noise pollution control*	VH:≤70db NH:>70db				
En-14 *Light pollution control*	!				

Note: (1) "!" means the empirical data for this urban physical examination indicator is not available. (2) Combining SDGs 6 – "Clean Drinking Water" and China's water supply target mentioned in the national policy documents, this study considers that the quantity and quality of drinking water supply should be ensured, so the watershed of indicator benchmark for So-6 and En-1 are both set at 100% (VH:=100%; NH:<100%).5.2 Urban physical examination result in Chongqing.

Also, the Municipality government of Chongqing is recommended to encourage the free airing of views and obtain existing traffic issues from multiple channels, in order to solve them in a targeted and timely manner. Simultaneously, measures such as optimising traffic light systems over peak hours, developing three-dimensional traffic system as well as promoting urban public and green transportation should also be actively explored to jointly tackle urban traffic diseases in Chongqing.

6.2. Urban economic aspect

It can be seen from the urban health examination results (Section 4.2) that the potential diseases of urban economic system mainly manifest upon the compositions of economic quality, economic structure, and economic openness. In light of economic quality, urban physical examination (UPE) indicators "GDP per capita (*Ec-3*)" and "per capita disposable income (*Ec-5*)" have all presented non-healthy status (NH) over the diagnosis period, and such non-healthy status may be caused by the significant income gaps between different social stratifications in Chongqing. As a large Municipality featured with "big city, big countryside, big mountainous area, big reservoir area", the income inequality in the municipality is critical given the large population of rural villagers. This finding is consistent with the study of Ye et al. (2017), pointing out that Chongqing has a prominent phenomenon of regional income inequality, resulting to a lower per capita GDP and per capita disposable income than the national average. Also, the UPE indicator "GDP intensity (*Ec-4*)" performed non-healthy status in Chongqing, whilst this UPE indicator performs healthy status in all the other three municipalities of Beijing, Shanghai and Tianjin. The unhealthy performance of "GDP intensity" in Chongqing maybe due to two reasons. Firstly, the regional territory of Chongqing is too vast and there are many administrative divisions in the municipality, and many industrial infrastructures could be constructed repeatedly in different districts of Chongqing, which caused the waste of land resources and hinder the generation of agglomeration benefits for regional economic development, so that the land utilisation effectiveness has been poor. Secondly, the development of Chongqing is highly dependant on land finance (Liu et al., 2018). The municipal government auctions a large amount of land annually, but the development of these land tend to fail in producing the expected economic benefits, which further resulted in poor land use efficiency. From the perspective of economic structure, Chongqing, as a typical industrial city, has been relying upon the development of secondary industries such as automobile and chemical, whilst the advanced tertiary industries such as finance and tech-novation has been presenting a stagnated development trend. Although in recent years, the municipal government has continuously put forward various strategies to promote the transformation and upgrading of industrial structure, Chongqing's economic structure are still in an unhealthy status in referring to our diagnostic results. Furthermore, the declining trend of "Trade Openness (*Ec-10*)" may be caused by the adjustment of economic development strategy in Chongqing, transforming from investment and export-relied to an economic strategy emphasising more upon the consumption sector.

To tackle the above urban diseases of economic aspect, local government is recommended to take the following measures. First, to enhance social benefits of low-income groups, reduce unemployment via providing more job opportunities to further improve per capita income. Secondly, future decision-making upon the planning and layout of economic activities can be further crafted to help promote agglomeration benefits for regional economy. Also, it is suggested to exploit local comparative advantages to determine the development direction of each

UPE Indicator	2015	2016	2017	2018	2019	Evolving trend (Rising ↑, Stable —, Falling ↓)
So-1	33.6	32.7	32.1	31.5	31.2	—
So-2	28.15	31.24	32.17	33.89	36.1	—
So-3	3.6	3.7	3.4	3.3	2.6	↑
So-4	94.64	96.1	96.4	97.09	97.36	—
So-5	!	!	!	!	!	
So-6	96.55	97.13	98.05	98.17	97.89	—
So-7	75.85	83.85	92.08	92.28	96.55	—
So-8	!	!	1.95	1.89	2.16	↓
So-9	1777.67	1886.82	2036.64	2195.49	2331.17	—
So-10	39.41	40.38	40.74	40.78	41.22	—
So-11	41.1	44.69	48.96	52.28	54.77	—
So-12	62.07	54.95	43.15	40.69	42.01	—
Ec-1	11	10.7	9.3	6	6.3	—
Ec-2	17.1	12.1	9.5	7	5.7	↓
Ec-3	52321	57690	60254	63896	68235	↓
Ec-4	19	21	22	23	26	—
Ec-5	27239	29610	32193	34889	37979	—
Ec-6	21.5	21.6	21.2	25.2	26.4	—
Ec-7	1.3	1.8	1	2	2.7	—
Ec-8	6.5	5.7	6.7	5.9	5.7	—
Ec-9	1.1	1.08	1.1	1.3	1.3	↓
Ec-10	29.4	23.9	23.8	28.1	27.3	↓
Ec-11	1.6	1.8	1.9	2.2	2.2	↑
En-1	100	100	100	100	100	—
En-2	93.5	95.43	94.72	95.04	97	—
En-3	!	!	!	!	!	
En-4	57	54	45	40	38	—
En-5	87	77	72	64	60	↑
En-6	16	13	12	9	7	—
En-7	45	46	46	44	40	↑
En-8	127	141	163	166	157	↑
En-9	1.5	1.4	1.4	1.3	1.2	—
En-10	40.32	40.75	40	40.35	!	—
En-11	98.85	99.98	99.4	100	100	↑
En-12	84.45	76.9	70	60.98	75	—
En-13	67.3	67.1	66.7	67.1	65.6	—
En-14	!	!	!	!	!	

Legend: Very-healthy (VH); Healthy (H); Risky (R); Non-healthy (NH); Lack of data (!)

Fig. 5. Urban physical examination results of Chongqing (2015–2019).

region, so that to avoid vicious competition between regions and enhance the land ustlisation efficiency. Simultaneously, the municipality should control the speed of urban land sprawl, whilst focus upon improving the economic intensity of land utilisation, and to gradually decouple the local development with "land finance". Economic structure-wise, the non-healthy status of urban industrial structure in Chongqing may be caused by the mismatch between labour forces distribution and sectoral industrial development. Local government is suggested to actively expand the proportion of the tertiary industry and tackle the hidden risks of urban diseases caused by the low-end industrial structure. For example, to cultivate more senior human capital, to increase investment in digital and green industries, and to promote the transformation of traditional automobile industry to new energy vehicles. Additionally, being as one of the recent "Wanghong" city in China, Chongqing endows rich tourism resources, local government is suggested to give full play to the driving effect of tourism resources upon the service industry, so as to make the service industry prosper. Furthermore, to boost towards healthy status of economic openness, local government is suggested to guide regional economic actors to actively participate in the national and international trade as well as to expand the economic volume of export and import activities. For example, as an important node city of the "Belt and Road Initiative" and the initiative city of the "Chongqing-Xinjiang-European International Railway", the municipality should give full play to its transportation advantages in logistics, to strengthen its trade links with other countries internationally, and to further improve trade openness.

6.3. Urban environment aspect

The health status of urban environment in Chongqing is considered jointly shaped by its geographical and nature conditions, economic activities, and policy manipulation. Being as a mountainous city with undulating topography and winding rivers in the upper reaches of the Yangtze River, the Municipality of Chongqing has advantaged endowment for developing urban green spaces (Liu et al., 2022). Also, given its geographical location, the water quality in Chongqing is significantly important to the water safety of the lower reaches of the Yangtze River, where most large-cities and intensified economic activities in the country are located. Due to both natural condition and policy emphasis, the quality of drinking water and wastewater treatment rate in Chongqing have performed very healthy (VH) status. This finding of urban health examination is aligned with previous studies such as Feng et al. (2020), pointing out that the antibiotic concentration in the drinking water sources in Chongqing is significantly lower than the other cities in China. On the other hand, the awareness of environment protection in Chongqing is relatively advanced. For example, the Municipal government of Chongqing has promulgated the *Measures for the Prevention and Control of Environmental Noise Pollution in Chongqing* in 2013, and the "Measures" have been revised several times to effectively tackle the problems of urban noise. Therefore, the noise pollution control in Chongqing has been performing a very healthy status. However, Chongqing has been one of the largest car and motorcycle production centers in China, also its terrain condition is not conducive to air diffusion (Liu et al., 2017), the two factors of which have led to the relatively severe air pollution in Chongqing, manifesting with the non-healthy status of UPE indicators "PM 2.5 concentration level (*En-4*)". This urban health diagnosis results upon Chongqing's air pollution condition is consistent with the study by Lu et al. (2021). Therefore, the Municipal government of Chongqing should further devote efforts to improve the air condition via more effective prevention and control actions. Furthermore, the issue of waste treatment in Chongqing should be emphased: although the treatment capacity of household waste has been improving over the diagnosis period, the performance of general solid waste treatment has been stuck in the non-healthy (NH) status, particularly comparing with other counterpart cities such as Tianjin, Shanghai, Ningbo and Fuzhou who present the state of very health (VH) or health (H) in terms of general solid waste treatment.

To tackle this identified urban disease, the industrial transformation and advancement should be enhanced to promote the technical level of economic activities, and reduce industrial waste as well as enhance the waste treatment capability in Chongqing (Guo & Leng, 2016). Specifically, finer source separation and recycling systems should be introduced in industrial activities, and more efficient recycling technologies should be developed, and key industrial solid waste reduction paths should be further explored to improve the waste treatment ability (Wang et al., 2021).

7. Conclusion

Rapid urbanisation has brought rampant urban sprawl and various urban diseases are emerging, and this is particularly the case of cities in the Global South. Both policy-makers and urban planners are committed to addressing these urban diseases and improving urban functions. Therefore, it is very important to adopt a scientific approach to understand the health status of cities and diagnose the underlying problems of urban development, so that effective policy measures can be crafted and taken to help tackle these diseases. Standing from the viewpoint of sustainable urban development and regarding the complicated urban system as a living organism, this study proposes a guiding methodology for urban physical examination, which provides a set of indicator checklist, a toolkit of indicator benchmark setting approaches, and the specific principle for conducting urban physical examination via the indicator benchmarks. By adopting the indicator checklist and benchmark setting approaches, different cities can investigate scientifically and thoroughly the healthy status of their urban development. So that underlying urban diseases can be identified in a timely manner and targeted policy instruments and actions can be tailored as "treatment" to help address these diseases over urban social, economic and environmental aspects. The applicability and validness of the proposed guiding methodology have been demonstrated via the empirical study of Chongqing Municipality in the West China. Urban healthy status over social, economic and environmental facets of Chongqing has been investigated, and the potential urban diseases across various functional compositions have been identified, based upon which targeted treatments have been tailored to help tackle these urban diseases and improve urban health status.

The indicator checklist of city physical examination provides a comprehensive set of indicators across the aspects of economic, social and environmental. However, due to certain limitations of local statistics ability and governance capability between different urban contexts, it may appear the situation that empirical data for some of the indicators are not available in certain cities when conducting the urban physical examination. For example, the indicator of *En-14* (light pollution control) is not available in the empirical case study of Chongqing, however, the indicator *En-14* itself is considered essential to delineate the health status of urban environmental aspect. From this narrative, the indicator checklist and benchmark setting approaches proposed in this study *de facto* take a guiding role for city governors to establish sufficient dataset of urban indicators and to employ the indicator checklist and benchmarks in understanding dynamically its urban health status.

Future research works can adopt the guiding methodology to conduct urban physical examination in different cities internationally, and comparative analysis can be conducted to unravel the healthy status performances and evolutions between different cities. By this, underlying urban diseases can be identified, root causes can be exploited and helpful treatment can be proposed by absorbing the lessons and experiences generated from different cities across the international community.

CRediT authorship contribution statement

Hongman He: Conceptualization, Methodology, Formal analysis, Project administration, Validation, Writing – original draft. **Yitian Ren:** Conceptualization, Methodology, Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. **Liyin Shen:** Conceptualization, Methodology, Writing – review & editing. **Jun Xiao:** Investigation, Formal analysis, Data curation, Methodology, Writing – original draft. **Yueyan Lai:** Investigation, Formal analysis, Data curation, Methodology, Writing – original draft. **Yi Yang:** Investigation, Formal analysis, Data curation, Methodology, Writing – original draft. **Lingyu Zhang:** Investigation, Formal analysis, Data curation, Methodology, Writing – original draft.

Declaration of Competing Interest

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

Data availability

Data will be made available on request.

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