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Regeneration towards suitability: A decision-making framework for determining urban regeneration mode and strategies

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ABSTRACT

Urban regeneration has become a popular research topic globally against the critical challenges that cities face with the decay of urban function, urban fabric, and residents living condition. However, it is the proper decision-making on urban regeneration mode and strategies to bring the long-term effectiveness of urban regeneration, no matter how much efforts and resources are devoted. This study introduces a "two-step" decision-making framework for determining the suitable urban regeneration mode and strategies. The decision-making variables are mobilised to delineate the status-quo decay of the local territory across the facets of sustainable performance and physical conditions, thus the most suitable regeneration mode can be designed (step 1). On top of the regeneration mode design, the most suitable urban regeneration strategies can be further tailored by considering the regeneration constraint factors including the requests for historical and cultural conservation, government financial capacity and previous regeneration experiences (step 2). The proposed decision-making framework is proven effective via the case study of nine districts of Chongqing municipality in China. The framework is instrumental for assisting urban governors to identify the most critical issues that need to be addressed, and to tailor suitable mode and strategies for implementing urban regeneration programs in order to tackle the decay challenges and revitalise their urban territory. Via enabling the effective integration between the resources within a city and rationalising the investment allocation, the introduced decision-making framework is effective for the overall planning and (re)development at city level.

1. Introduction

Urban regeneration can be seen as a "metabolic" process of reusing resources and rebuilding the urban environment (Zheng et al., 2016). In addition to improving buildings' physical conditions and urban living environment, urban regeneration also contributes to enhancing the function of a city and helping tackle the urban challenges such as congested traffic, inadequate public space, and insufficient urban infrastructure delivery (Couch, 1990; Lai et al., 2014; Zielenbach, 2000). Appreciated in other research works, urban regeneration is proven effective in benefiting urban socio-economic development by upgrading industries, creating job opportunities, enhancing social networks, and promoting the active participation of urban residents (Chan & Yung, 2004; dos Santos Figueiredo et al., 2022; Hulsbergen, 2004). It can be seen that the "metabolic" process of urban regeneration provides a comprehensive and diverse approach to solve wide range of urban problems, aiming at continuous improvement of urban areas across the multiple aspects of economic, social, cultural and physical environment (Roberts et al., 2000).

As highlighted by UN-Habitat in *Transforming our world: the 2030 Agenda for Sustainable Development*, it is an indispensable requirement for sustainable development to make cities and communities inclusive, safe, resilient and sustainable. This blueprint can only be achieved via strengthening urban planning and management. Urban regeneration initiative has been popular worldwide in the last few decades, particularly in those large developing countries, such as China. Nevertheless, urban regeneration is a complicated and systematic process, which requires the trade-off between multiple objectives and the needs imposed by various stakeholders including the state, public and private sector. The implementation of urban regeneration also needs to take into account the socio-economic status and physical conditions of local context (Bromley et al., 2005). Therefore, the decision-making upon urban

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regeneration mode and strategies is complicated and yet essential to determine the suitability of urban regeneration programs to sustainable urban development.

The existing practice of urban regeneration in China reveals various problems such as blind large-scale demolition and redevelopment (Fig. 1), "cities in similar layout", and "superficial renewal". These problems occur overwhelmingly in contemporary Chinese cities (Liu et al., 2014; Xu et al., 2019; Zhou et al., 2017). For instance, the study by Zhang and Zeng (2016) shows that there were at least 460 million m^2 of buildings demolished in China between 2011 and 2015. Previous studies suggest that the average service lifespan of the demolished buildings in China is only 34 years, which is much shorter than the designed lifespan and the international average level (CABR, 2014; Zhao, 2014). The blind demolitions of exiting urban entities have brought the ramifications of urban culture fading-out, resources waste, aggravation of environmental pollution, and emergence of social conflict and instability. Consequently, the outcomes of these demolition oriented urban regeneration programs are largely disappointed with poor suitability towards sustainable urban development although massive human, material and financial resources have been invested.

These urban regeneration problems suggest that the existing methodology applied in the decision-making stage are of shortcomings (Nestico & Sica, 2017). In echoing this, Zhou et al. (2021) commented that the urban regeneration practice in China could be more effective if proper decision-making can be made particularly at the stage when regeneration plans are produced. It is therefore considered essential to employ a proper decision-making method for enabling the suitability and quality of urban regeneration. Only proper decision-making can produce adequate urban regeneration programs, and in turn urban regeneration practices can be harnessed towards better suitability to support achieving sustainable urban development.

Against this background, this paper aims to establish a proper decision-making framework to help produce suitable mode and strategies to improve the quality of urban regeneration. The novelty and originality of the decision making framework can be highlighted as follows. We conceptualise and argue that the suitability of urban regeneration practices lies in the comprehensive consideration and trade-off of the facets across sustainable performance, physical conditions, and constraint factors of a concerned urban territory. Building upon this theoretical stone, standing at regional scale, we first mobilise a set of critical indicators to delineate the status-quo decay of urban sustainability (social, economic, environmental) and physical conditions (building, land use pattern, facilities), so that the most suitable regeneration mode can be designed in referring to the local reality. On top of the regeneration mode, tailored urban regeneration strategies are further proposed, which is determined by considering the historical and cultural conservation, government financial capacity and previous regeneration experiences in the local urban area. The decision-making framework enables the effective integration of resources within a city and the rational allocation of investment and efforts in urban regeneration programs, which will allow the outcome of the regeneration programs more suitable towards sustainable development. We exemplify the validness of the decision making framework via the case study in nine districts within the core urban area of Chongqing Municipality in West China, where rich empirical regeneration evidences and experiences are presented and discussed.

2. Literature review

Existing literature has devoted good efforts in the discipline of urban regeneration. The critical review in this section will focus upon the decision making of urban regeneration strategies and the regeneration contents reported in the existing literature.

2.1. Urban regeneration strategies

Urban regeneration is a process in which urban environments are rebuilt and some local resources are reused, and it provides a new opportunity of rethinking the use of spaces (Evans & Jones, 2008). The concept of urban regeneration also refers to a comprehensive integration of vision and action aimed at resolving the multi-faceted problems of those deprived urban areas to improve their economic, physical, social, and environmental conditions (Ercan, 2011).

Some studies tend to explore strategies of urban regeneration by establishing various frameworks and methodologies (Zheng et al., 2016). Others focus on analysing the implementation of different urban regeneration strategies, so that relevant experiences and lessons can be drawn to help explore appropriate pathways for future regeneration programs (Hemphill et al., 2004; Schulze Bäing & Wong, 2012). By building a decision matrix with the two dimensions of sustainability and physical conditions, Zheng et al. (2016) proposed four modes of urban regeneration, namely, redevelopment, conservation, revitalisation and rehabilitation. Manupati et al. (2018) introduced the conception of smart city oriented urban regeneration and argued that the urban

Fig. 1. Example of blind large-scale demolition in urban regeneration practices.
(*Source*: *Photo from Visual China Group, 2017*)

regeneration strategies should base upon a set of criteria across economic conditions, infrastructure and utilities provision. By referring to the experiences gained from previous urban regeneration practices, Zhou et al. (2021) constructed an experience mining system of urban regeneration through establishing case experience dataset and text mining approach, and their study categorises the modes of urban regeneration by development pattern (conservation, renovation and redevelopment) and resettlement pattern (on-site and off-site).

However, the existing urban regeneration decision-making framework reported by previous studies presents limitations in designing regeneration modes and strategies. On one hand, the strategies and methods proposed in existing literature tend to be generic, which have limitation in providing *place-based* guidance for implementation. For example, many studies promote improving infrastructure conditions as an important and generic strategy but they do not describe how the local territorial conditions are taken into account (Mateo & Cunat, 2016; Tin & Lee, 2017). On the other hand, the various regeneration models and strategies proposed in existing studies are based upon what needs to be renewed, but the suitability of these strategies from the perspective of sustainable development is to large extent overlooked. The variables considered in decision-making process do not include the multifaceted suitability and constraints presented in local territory. However, it is important that the implementation of urban regeneration should be in conformity with the local context and be flexible to adapt to different scenarios of local territorial development (Bromley et al., 2005). An adaptive decision-making framework with incorporating local characteristics is therefore urgently needed for designing urban regeneration modes and strategies particularly in those developing countries where urban transition is rapidly evolving, so that the outcome of regeneration can contribute to sustainable urban development.

2.2. Urban regeneration contents

A large number of studies have been carried out in examining urban regeneration contents and elements such as land resource, infrastructure delivery, etc, and these studies are overwhelmingly based at individual project or neighborhood level. For example, Riera Pérez and Rey, (2013) investigated the regeneration project of Fleurettes neighborhood, located near the train station in Lausanne, Switzerland, through comparing three possible development scenarios using the tool of "SméO" by applying multiple criteria. Williams and Dair (2007) referred to a number of cases of brownfield redevelopment projects and proposed a framework for assessing the sustainable redevelopment of brownfield sites. Huang et al. (2020) proposed a matrix decision-making framework for studying urban regeneration projects at community level in Chongqing municipality in China and validated the framework with eight case communities in the city. In referring to, Liu et al. (2019) simulated the dynamic trends in land use change by referring to the scenarios of future urban regeneration in the city Chongqing in China. Brown and Barber (2012) assessed the effectiveness of the provision of social infrastructure in Lancaster in UK, and argued that residents' equitable access is the key prerequisite for delivering benefits through social infrastructure provision amid urban regeneration programs. Langston et al. (2008) introduced an adaptive reuse potential model to help decision-makers to identify the existing buildings with high adaptive-reuse potential in the highly-urbanised city of Hong Kong.

It appears that the urban regeneration decision-making methods reported in existing studies tend to focus on and based at micro-scale (such as neighbourhood or project level), and the decision indicators tend to concern individual elements (such as land, infrastructure, and buildings). Nevertheless, although urban regeneration programmes are implemented through individual projects and specific elements within an urban system, it would be difficult to achieve the overarching sustainable development aim by solely addressing the individual projects and specific urban elements at micro level. The micro-perspective may not be adaptive to different regeneration scenarios and not suitable for the promotion of regeneration programmes at city-level. Instead, an overarching decision-making methodology upon the urban regeneration orientation, modes and strategies at regional level is essential.

The above discussions demonstrate that existing literature presents inherent limitations in providing regeneration decision-making guideline for ensuring that the suitability of urban regeneration can be gained. Therefore, in line with the critical review of existing literature, this paper aims to fill the gaps by establishing the theoretical understanding upon the suitability of urban regeneration, and developing a "two-step" urban regeneration decision-making framework to help determine the suitable regeneration mode and strategies at the regional scale, whilst the local territorial context of both conditions and constraints are fully incorporated. Healey (2020) also pointed out that the necessity to develop strategic plan for implementing regeneration programmes at the regional level in order to address the interconnected problems faced by decay urban areas. The implementation of urban regeneration programmes at regional scale (such as the scale at the level of urban district) emphasises the consideration for the overall challenges encountered by the local territory and the available resources (i.e. financial) that can be mobilised. As the result, the resource allocation and utilisation efficiency across the regional context can be improved.

3. Research roadmap

This study aims to propose a novel "two-step" decision-making framework to help enhance the suitability of urban regeneration rooted in a defined area. To achieve the research aim, the details of research procedures are designed by a research roadmap, as shown in Fig. 2.

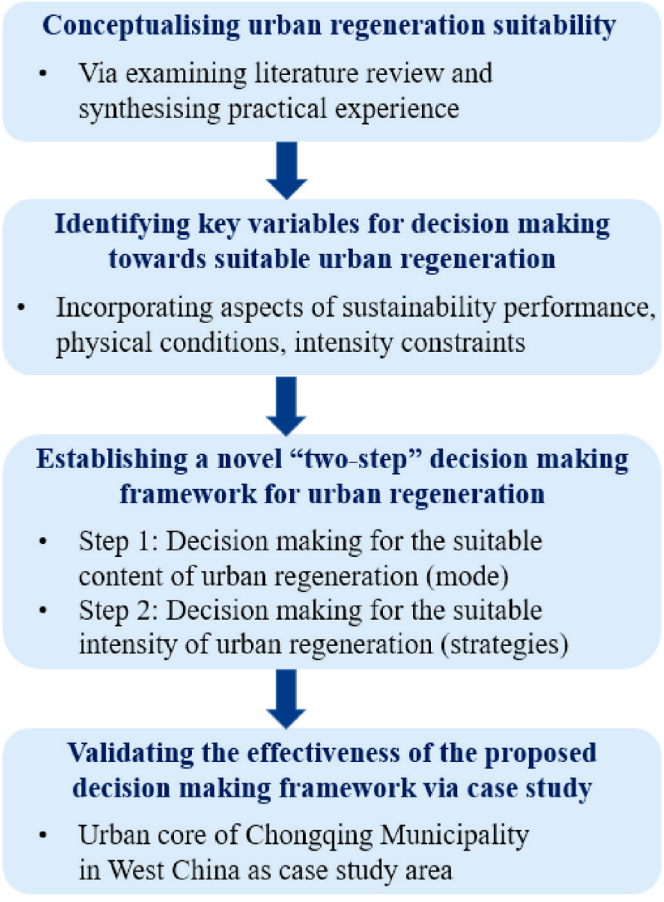

Fig. 2. Research roadmap.
(*Source*: *Authors, 2022*)

Firstly, the connotation of urban regeneration suitability will be comprehended by reviewing both the existing literature in the field and practical experiences in China. Secondly, the variables for decision-making on urban regeneration will be identified and synthesised, which should allow for incorporating local territorial context and assessing the local conditions for practicing regeneration programs. Thirdly, a novel "two-step" decision-making framework will be established for producing suitable urban regeneration modes and strategies by considering both the content and intensity of local context. Finally, the applicability and validness of the proposed novel decision-making framework will be exemplified through the case study in Chongqing Municipality of Southwest China.

4. Conceptualisation of urban regeneration suitability

4.1. Theoretical-based exploration

A proper definition upon the connotation of urban regeneration suitability is critical for decision-making. The suitability of urban regeneration can only be gained by correctly understanding the territorial context and identifying what aspects and contents that need to be regenerated for the aim of sustainable urban development.

For this, the principle of sustainable development is instrumental to help understand the conception and implication of regeneration suitability. The pursuit of sustainable urban development is a complicated process which requires multidimensional efforts. Contemporary academia has reached a consensus that there are three crucial pillars underpinning the objective of sustainable development, namely, social, economic and environmental (Lorr, 2012; Ren et al., 2021; Weingaertner & Barber, 2010). UN-Habitat Agenda 2030 for Sustainable Development, particularly the Goal 11 of "Sustainable cities and communities" highlights the importance for making cities and human settlements inclusive, safe, resilient and sustainable. It is therefore important that the principle of sustainable development is corresponded and embedded into the suitability of urban regeneration contents in a local context (Alker & McDonald, 2003). In fact, urban regeneration is a comprehensive approach to contribute to sustainable development through urban land redevelopment and resources reutilisation. It is an instrument for optimising physical conditions and functional spaces of cities and enhancing the functioning of an urban organism by improving its social, economic and environmental performances (Korkmaz & Balaban, 2020). Urban regeneration is thus the key pathway to achieving sustainable development, and *in-versa*, sustainable development is a target traction for promoting urban regeneration practices. Therefore, the principle of sustainable urban development is employed to help understand the suitability of urban regeneration modes and strategies.

Furthermore, the decay and deterioration of urban physical living conditions (such as building conditions, utilities conditions) are the root reasons for implementing urban regeneration (Tin & Lee, 2017; Wang et al., 2014). Given the fact that different areas within a city may suffer from different degree of decay in terms of urban physical living conditions, the decision-making upon urban regeneration should be targeted and tailored to appropriately address the challenges faced by the specific urban area, for which a *place-based* approach should be adopted (Donaldson & Du Plessis, 2013). Therefore, the local territory's physical conditions must be considered for comprehending the regeneration needs and contents, which will ensure that regeneration suitability can be guaranteed.

In addition, other researchers pointed out that the regeneration intensity should also be incorporated for appreciating regeneration suitability (Wang et al., 2022). Regeneration intensity is determined by various factors such as the historical and cultural conservation needs and the financial capability of local urban context. Wu (1999) proposed the theory of organic renewal in examining the regeneration intensity of Beijing's historic and cultural conservation area. They argued that the regeneration of historic and cultural conservation areas should respect inherent urban fabric, and that small-scale and incremental regeneration strategy should be adopted, so that the overall environment improvement and the sustainable development of historic urban area can be achieved. Instead of the aggressive and blind large-scale demolition and reconstruction, organic urban renewal emphasises the importance of obeying the local condition in determining the mode and strategies of urban regeneration, so that the suitability of urban regeneration can be better approached.

To sum up, the regeneration content (including both sustainable performance and physical conditions) and intensity are considered the decisive aspects in determining the direction, mode and strategies of urban regeneration activities. Therefore, a *place-based* principle should be applied in shaping better suitability of urban regeneration programs.

4.2. Experience-based exploration

In addition to the theoretical-based exploration by digesting the relevant literature, comprehending the connotation of urban regeneration suitability also needs to be informed by the practical experience. As the largest developing country, China has experienced over sixty years of urban regeneration practice and has accumulated extensive experiences in implementing urban regeneration across different development stages (Yang & Chen, 2020). The urban regeneration practices in China distinguish significantly from the rest of world. Firstly, the state-led approach is a common regeneration mode in China due to the top-down planning regime (Zhou et al., 2021). In this mode, the government has strong administrative power and plays an omnipotent role in processing urban regeneration affairs, such as leveraging and cooperating with private sectors to achieve the objective of urban renewal and land acquisition by compulsory measures (Zhang et al., 2019). Secondly, given the unprecedented fast urbanisation development and the increasing demands of urban housing since the open-up in the 1980s, many cities in China have implemented redevelopment programmes from old obsolete properties and buildings (Wong et al., 2021). Large-scale demolition, some being blind, has been carried out amidst the Chinese urban regeneration practices in the past four decades.

Contemporarily, China is dedicated to transit from quantity-oriented urban regeneration pattern to quality-oriented regeneration (Sun & Cui, 2018), for which the suitability of urban regeneration programs is emphasised (Guo et al., 2018). In 2021, 21 cities or districts within different cities in China have been designated by the central government as the first batch of quality-oriented urban regeneration pilot areas (Ministry of Housing and Urban-Rural Development of the PRC, 2021). In particular, those mega cities have been the major arena where urban regeneration programs are implemented at mass scale. Considering the difference in geographical feature, socio-economic development level, historic and cultural conservation needs and the maturity of urban regeneration practices, the four Chinese megacities of Beijing, Chongqing, Shanghai and Shenzhen are selected as sample cities in this section to derive urban regeneration practical experiences, for facilitating the comprehension of urban regeneration suitability. Fig. 3 shows the four sample cities' geographical location, population size, their key issues, the challenges of urban regeneration, and the typical urban landscape after regeneration. Table 1 summarises the urban regeneration practices in these four megacities. It can be seen that the regeneration policies in these four mega Chinese cities all clearly define what content needs to be regenerated in line with sustainable urban development objective and place-based principle. They adopt different regeneration modes (such as conservation, rehabilitation and reconstruction) with incorporating the local conditions.

The above discussion about the conceptualisation of urban regeneration suitability from the perspectives of both theoretical and practical context demonstrate that the regeneration suitability relies upon the two aspects of content and intensity, as shown graphically in Fig. 4.

In the conceptualisation framework of Fig. 4, the content aspect

Fig. 3. Locations and representative descriptions of the four megacities.
(*Source*: *Authors, 2022*)

refers to the sustainable performance (economic, social and environmental development) and the local physical conditions (building conditions, land-use pattern and utilities status). Content aspect emphasises upon what needs to be improved and regenerated in the local urban context. The intensity aspect refers to the suitable regeneration intensity (regeneration scale, resources input, and demolition and re-construction degree) given the historic and cultural conservation needs and other restrictive capabilities of local urban context. For example, large-scale redevelopment is considered as a high-intensity regeneration strategy to deal with severe urban decay, the implementation of which should be supported by strong financial and governance capability. Detailed illustrations of different levels of urban regeneration intensity are presented in later Section 6.2.

Building upon the conceptualisation of urban regeneration suitability, the next section will present the two-step decision-making framework for determining regeneration mode and strategies.

5. Two-step urban regeneration decision-making framework

Previous studies have introduced various decision-making tools for helping decide urban regeneration pathways and strategies, such as indicator-based evaluation, decision-making matrix, multi-criteria comparison of potential schemes, as well as scenario simulation, as summarised in Table 2. However, as discussed in literature review section, those existing decision-making methods tend to focus on micro-scale (such as neighborhood or project level) and to take into account specific elements (such as land, infrastructure, and buildings). They are of limitations for ensuring the suitability of urban regeneration. In line with this, a "two-step" decision-making framework is proposed in this study for enhancing urban regeneration suitability via investigating both regeneration content and intensity.

5.1. Decision-making variables

As discussed in previous section, the decision-making framework to be proposed towards better urban regeneration suitability needs to consider both regeneration content and intensity. Therefore, the decision-making variables should reflect the implication of these two aspects.

5.1.1. Decision-making variables for determining the regeneration content

Previous sections have argued that the status quo of sustainable performance and the physical conditions of a concerned urban area are the key factors for determining regeneration content to ensure the suitability of regeneration. The sustainable performance of an urban area can be assessed from social, economic, and environmental dimensions; the physical conditions of the urban area refer to building conditions, land use pattern, and facilities status. By reviewing the existing literature and having the advices from experts in the field, the decision-making variables for measuring urban regeneration contents are proposed, as shown in Table 3.

5.1.2. Decision-making variables for determining the regeneration intensity

Urban regeneration is a complicated and systematic practice constrained by various factors in a given local territory context. This study introduces the constraint variables in facilitating the determination of urban regeneration intensity. The constraint variables cover three dimensions, namely, historical and cultural conservation, financial capacity and urban regeneration experience, as elaborated in Table 4.

Firstly, the conservation requirement for historical and cultural elements is an important intensity constraint factor in implementing urban regeneration, highlighted in the policy frameworks in the four sample cities (Table 1). Secondly, financial support capability from local

Table 1
Practical experience of urban regeneration in four selected megacities in China.

City	Regeneration content and goals	Regeneration modes and strategies	Policy references (Year)
Beijing	· Urban spatial structure and function layout · Industrial upgrading · Human living environment and safety conditions · Public facilities and infrastructure · Historical and cultural preservation · Green and low-carbon development-goal · Sustainable urban development-goal	· Reconstruction · Partial rebuilding, alteration or expansion · Improvement of infrastructure and functional facilities · Conservation and rehabilitation · Business replacement	1. Guiding Opinions of Beijing Municipal People's Government on the Implementation of Urban Regeneration Action[a] (2021) 2. Beijing Urban Regeneration Action Plan (2021–2025)[b] (2021)
Chongqing	· Urban function and structure · Industrial upgrading · Municipal and public facilities · Human living and ecological environment · Urban traffic · Historical and cultural preservation · Green and low-carbon development-goal · Disaster prevention and mitigation	· Reconstruction · Renovation and upgrading · Conservation and rehabilitation	1. Technical Guidelines for Urban Regeneration in Chongqing[c] (2022) 2. Urban regeneration plan for the central city of Chongqing[d] (2021)
Shanghai	· Urban spatial structure and function layout · Public facilities and infrastructure · Human living and ecological environment · Historical and cultural preservation	· Reconstruction · Partial rebuilding, alteration or expansion · Conservation and rehabilitation	1. Shanghai Urban Regeneration Regulations[e] (2021)
Shenzhen	· Public facilities · Urban function and layout · Human living environment · Energy saving reconstruction · Historical and cultural preservation	· Reconstruction · Comprehensive improvement (Maintaining the existing building pattern intact, one or more measures such as rehabilitation, addition, alteration, extension, partial deconstruction or change of function)	1. Shenzhen Special Economic Zone Urban Regeneration Regulations[f]

[a] Available at: http://www.gov.cn/xinwen/202109/01/content_5634665.htm.
[b] Available at: http://www.gov.cn/xinwen/202106/10/content_5616717.htm.
[c] Available at: http://zfcxjw.cq.gov.cn/zwxx_166/gsgg/202203/t20220330_10570445.html.
[d] Available at: http://ghzrzyj.cq.gov.cn/ztlm_186/ghgb/zxgh/202109/t20210917_9730811.html.
[e] Available at: https://ghzyj.sh.gov.cn/gzdt/20210831/fc38143f1b5b4f67a810ff01bfc4deab.html.
[f] Available at: https:http://www.sz.gov.cn/szcsgxtdz/gkmlpt/content/8/8614/post_8614017.html#19169 (*in Chinese*).

government is important in influencing and shaping the intensity of regeneration programs. In fact, urban regeneration programmes in China are to large extent driven and shaped by the local government, and their intensity is restricted by the financial and governance capability of local state (Yi et al., 2017). Finally, the previous regeneration experience gained will affect the ability and effectiveness of conducting new urban regeneration projects. Therefore, these three group of factors are the determinants to the regeneration intensity.

In employing the above regeneration decision-making variables under the two aspects of content and intensity, each variable needs to be standardised to eliminate the influences of different variable units. The Min-Max standardisation method is used in this study to standardise the original variable data, detailed calculation process is shown as follows:

Negative variable:

$$x_{ij}^{*} = \frac{\max\{x_{ij}\} - x_{ij}}{\max\{x_{ij}\} - \min\{x_{ij}\}} \quad (1)$$

$$(i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n)\ \#$$

Positive variable:

$$x_{ij}^{*} = \frac{x_{ij} - \min\{x_{ij}\}}{\max\{x_{ij}\} - \min\{x_{ij}\}} \quad (2)$$

$$(i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n)\ \#$$

where x_{ij}^{*} is the standardised value of the variable i for an empirical object (concerned urban area) j; $\max\{x_{ij}\}$ and $\min\{x_{ij}\}$ are the maximum and minimum values of the variable i among all empirical objects; m is the number of variables; n is the number of empirical objects in the scope of the study.

On top of the variable standardisation, the entropy weight method will be employed to calculate the weighting value of each decision-making variable. After the standardisation and the calculation of weighting value for each variable, the overall performance of "sustainable performance decay", "physical conditions decay" and "regeneration constraints" can be obtained by summing up the product of each variable value and the variable weighting value. For instance, the aspect value of "sustainable performance decay" can be calculated via formula (3):

$$X_s = \sum_{i=1}^{k} w_{Si} \cdot x_{Si}^{*} \quad (i = 1, 2, \ldots, k)\ \# \quad (3)$$

Where X_s is decay value of sustainable performance aspect; w_{Si} is the weighting value of each variable under sustainable performance aspect;

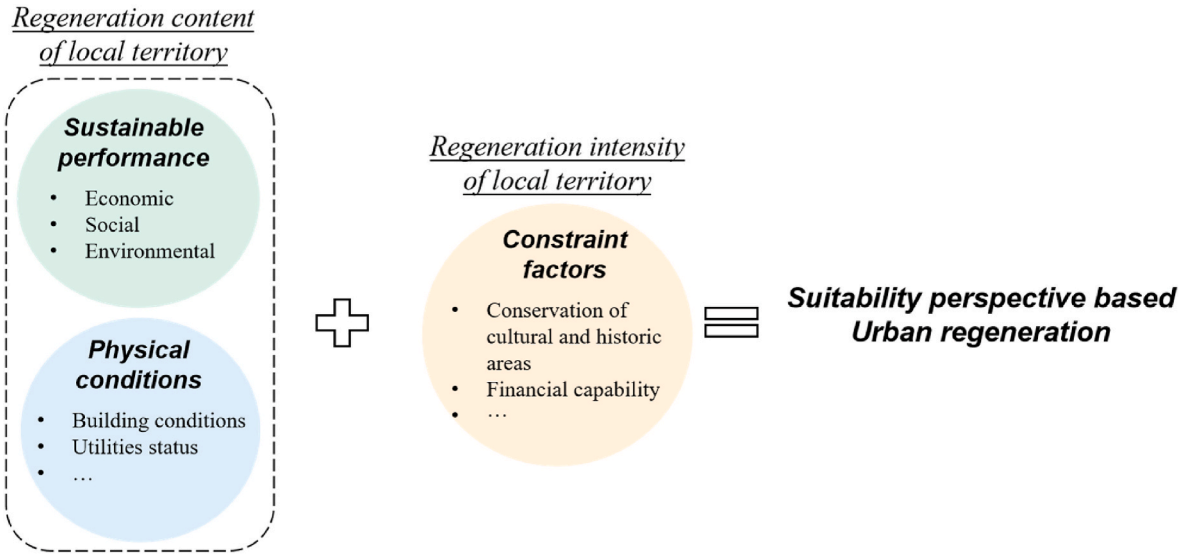

Fig. 4. Conceptualisation of urban regeneration suitability.
(*Source*: *Authors, 2022*)

Table 2
Typical decision-making tools of urban regeneration in existing literature.

Decision context	Methods and tools	Authors (Year)
· Urban regeneration for regional economic transformation	The Index of Multiple Deprivation	Greig et al. (2010)
· Sustainability assessment and renewal of old industrial areas	Evaluation based on indicator system	Yang (2017)
· Sustainable urban renewal at neighborhood level	A decision matrix based on local status and residents' perception	Huang et al. (2020)
· The adaptive reuse of historic buildings	Fuzzy Delphi method + Multi-criteria decision-making	Chen et al. (2018)
· Urban renewal simulation with land use	Cellular Automata model	Liu et al. (2019)
· Smart city oriented urban regeneration	Multi-criteria decision-making + Analytic Network Process	Manupati et al. (2018)
· Stakeholder participation in urban renewal process	A GIS-based decision support system	Omidipoor et al. (2019)
· Rules of regeneration projects modes	An experience-based mining system	Zhou et al. (2021)

x^*_{Si} is the standardised value of each variable under sustainable performance aspect; k is the total number of variables under sustainable performance aspect.

5.2. *"Two-step" decision-making framework for determining suitable urban regeneration mode and strategies*

5.2.1. *Step1 Decision-making on urban regeneration mode*

In referring to the decay values of sustainable performance and physical conditions calculated in Section 5.1, a quadrant map showing the decay level of the concerned urban space and environment is introduced to help decision-makers understand the regeneration content, as shown in Fig. 5, from which the suitable regeneration mode can be located.

Quadrant 1 (Q1) refers that both sustainable performance and physical conditions in the concerned local urban area perform well, indicating that there is no significant need for further improvement. Thus the urban area located in Q1 is recommended to adopt a *Conservation mode* oriented regeneration practices.

Quadrant 2 (Q2) refers that the local area endows high sustainable performance whilst significant decay of physical conditions, so that the emphasis should be given to improve the physical conditions. Hence urban area located in Q2 is recommended to adopt the mode of *improving the physical conditions* in practicing urban regeneration programs.

Quadrant 3 (Q3) presents a contrary situation to that of Q2, and urban area located in this quadrant is recommended to adopt the mode of *improving sustainable performance* in implementing regeneration projects.

Quadrant 4 (Q4) refers that the concerned urban area presents both poor sustainable performance and deteriorating physical conditions. It is most suitable for the local governors to adopt the *overall upgrade* mode for implementing regeneration programs.

5.2.2. *Step2 Decision-making on urban regeneration strategies*

The above Step1 decision-making helps select one regeneration mode from the three regeneration modes, namely, *improving the physical conditions mode*, *improving sustainable performance mode*, *overall upgrade mode* to tackle poor performance (sustainability or physical conditions). Given the satisfactory sustainable performance and physical conditions presented by the mode of *Conservation*, there is no need to further calculate its intensity index.

In the Step 2 decision-making, the regeneration intensity will be determined to facilitate producing proper regeneration strategies in referring to each regeneration mode. The suitability of regeneration intensity depends upon the combination of decay degree and constraint variables of local context defined in Section 5.1. In other words, the suitable intensity of urban regeneration is determined jointly by considering three parameters, namely, the current urban sustainable performance, physical conditions and the constraint factors defined in Table 4. The method for producing the value of current urban sustainable performance and physical conditions has been discussed in step 1 decision making. The value of the constraint factors' effects can be obtained by introducing a constraint coefficient:

$$c = \sum_{i=1}^{r} w_{Ci} \cdot x^*_{Ci} \ \ (i = 1\ ,\ 2\ ,\ \ldots\ ,\ r)\ \ (0 \le C \le 1)\# \tag{4}$$

Where c is the value of constraint coefficient; x^*_{Ci} is the standardised value of each regeneration constraint variable i; w_{Ci} is the weighting value of each constraint variable determined by the entropy weight

Table 3
Variables on determining the urban regeneration content.

Aspect	Dimension	Variables	Supporting references	Variable attribute
(S) Sustainable performance	(S_{soc}) Social dimension	(S_1) Natural growth rate of population	Hutchins and Sutherland (2008)	–
		(S_2) Population density	Boggia and Cortina (2010); Lee and Huang (2007)	–
		(S_3) Urbanisation rate	Shen et al. (2011)	–
		(S_4) Population age diversity	Zheng et al. (2016)	–
	(S_{eco}) Economic dimension	(S_5) GDP per capita	Tang et al. (2019)	–
		(S_6) Disposable income per capita	Lee and Huang (2007); Tan et al. (2018)	–
		(S_7) Per capita total retail sales of consumer goods	Ren et al. (2018)	–
		(S_8) Proportion of secondary and tertiary industries	Ren et al. (2018)	–
		(S_9) GDP growth rate	Tang et al. (2019)	–
	(S_{env}) Environmental dimension	(S_{10}) Greenery coverage rate in built-up areas	Liu et al. (2020); Tan et al. (2018)	–
		(S_{11}) Harmless disposal rate of domestic waste	Liao et al. (2020); Jiao et al. (2016)	–
		(S_{12}) Proportion of air quality equal to and better than level II (%)	Pires et al. (2014); Li et al. (2009); Tang et al. (2019)	–
(P) Physical conditions	(P_b) Building conditions	(P_1) Building age	Huang et al. (2020); Zheng et al. (2016)	+
		(P_2) Building density	Huang et al. (2020); Zheng et al. (2016)	+
		(P_3) Plot ratio	Yang (2017)	+
	(P_l) Land use pattern	(P_4) GDP per construction site	Experts' suggestion	–
		(P_5) Land use mix	Huang et al. (2020); Zheng et al. (2016)	–
	(P_f) Facilities status	(P_6) Public library holdings per capita	Tan et al. (2018)	–
		(P_7) Number of primary and secondary schools per 10^4 people	Jiao et al. (2016)	–
		(P_8) Number of health care facilities per 10^4 people	Shen et al. (2011)	–
		(P_9) Per capita park and green space	Tan et al. (2018)	–
		(P_{10}) Density of public transport stations	Huang et al. (2020)	–
		(P_{11}) Road network density	Moussiopoulos et al. (2010); Huang et al. (2020)	–

Note: The variable system responds to the decay degree upon sustainable performance and physical conditions of the concerned urban areas. For the variable attribute, "+" refers to the positive variable, "-" refers to the negative variable. Positive variable in this study indicates that the higher the variable's score, the greater decay degree and greater regeneration potential; negative variable indicates that the higher the variable's score, the less decay degree and less regeneration potential.

Table 4
Variables determining the urban regeneration intensity.

Aspect	Dimension	Variables (supporting reference)	Variable attribute
(C) Regeneration constraints	(C_h) Historical and cultural conservation	(C_1) Historical and cultural heritage density (Wang et al., 2016; Zhou et al., 2017)	–
	(C_f) Government financial capacity	(C_2) General government budget revenue (Manupati et al., 2018)	+
	(C_e) Urban regeneration experience	(C_3) Number of urban regeneration projects undertaken (Zhou et al., 2021)	+

Note: For the variable attribute, "+" refers to the positive variable, "-" refers to the negative variable. Positive constraint variable indicates that the higher the variable's value, the higher the urban regeneration intensity can be; the negative constraint variable indicates that the higher the variable's value, the lower the urban regeneration intensity can be.

method; r is the number of constraints variables listed in Table 4. This method for calculating the constraint coefficient has been widely adopted in the academia and the practice of spatial territorial planning, see for example (Tang & Sun, 2012).

Consequently, the suitable urban regeneration intensity can be determined by considering jointly the decay level of local sustainable performance, physical conditions, and constraint coefficient:

$$I = c \bullet (X_S + X_P) \ \# \tag{5}$$

Where I is the value of regeneration intensity; c is the value of the regeneration constraint coefficient; X_s is the value of sustainable performance decay; X_P is the value of physical conditions decay (Tang & Sun, 2012).

By further applying ArcGIS software, the regeneration intensity (I) can be classified into three categories via natural breakpoint approach, namely, *high-intensity*, *medium-intensity* and *low-intensity*.

Combining the above classified three-level of regeneration intensity in correspondence with the three regeneration modes (*improving physical conditions mode*, *improving sustainable performance mode*, *overall upgrade mode*), nine regeneration strategies can be produced. By further adding the *conservation mode*, the "two-step" decision framework produces total

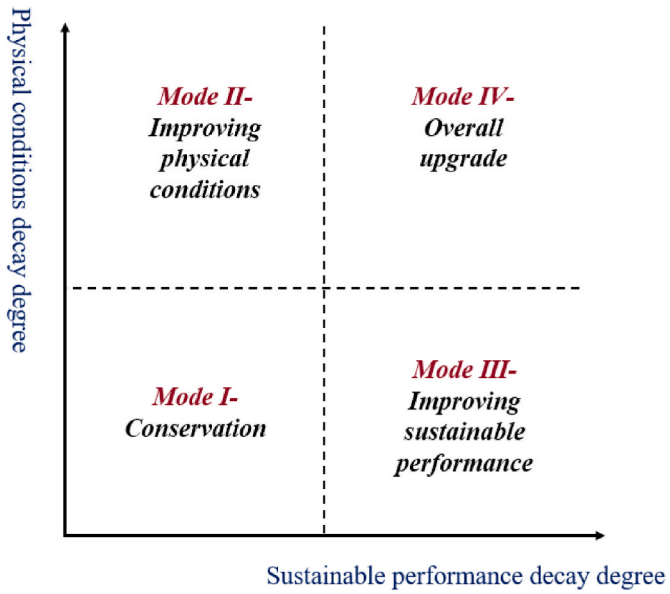

Fig. 5. A quadrant map decision-making matrix for determining the regeneration mode.
(*Source*: *Authors, 2022*)

10 (9 + 1) regeneration strategies for enhancing the suitability of urban regeneration practices, which are listed in Table 5.

6. Case study

This section exemplifies the applicability and validness of the proposed "two-step" urban regeneration decision-making framework via a case study of Chongqing municipality in Southwest China.

6.1. Study area

Chongqing is one of four municipalities under the Chinese Central Government's direct governance. It is the regional economic centre in Southwest China and the largest city in the country in terms of population scale. The city has been undergoing rapid urban construction and socioeconomic development since it was designated as the municipality in 1997. By the end of 2021, the urbanisation rate of Chongqing municipality has reached 70.32% with a total population of 32.12 million. In line with the rapid urban economic growth, various significant urban problems and challenges have emerged in Chongqing in the recent decade. Typical problems include infrastructure deterioration, construction land supply shortages, environmental pollution, building function decay, and the difficulty for transiting industrial sites. It was reported that Chongqing has more than 7394 old neighbourhoods with aging buildings and backward public facilities, covering 102 million square meters, which require regeneration (People's Daily, 2020). Therefore, urban regeneration has been appreciated by Chongqing municipality government as one of the key approaches for urban environment upgrade, urban transition and urban function enhancement (Tang et al., 2020).

The municipality is composed of 26 districts and 12 counties, and its urban core area consists of 9 districts of Yuzhong, Dadukou, Jiangbei, Shapingba, Jiulongpo, Nan'an, Beibei, Yubei, and Banan (see Fig. 6). Endowed with rich historical heritages but the decay of functional facilities, the urban core area of Chongqing is the key arena requesting regeneration, which is selected as the case study area in this research, as shown in Fig. 6.

Table 5
Different strategies for enhancing the suitability of urban regeneration incorporating both regeneration content and intensity (source: authors).

No	Mode and Strategies	Key focus
1	Conservation	Take measures to maintain superb conditions where physical conditions and sustainable performance are satisfactory
2	Improving physical conditions (*High intensity*)	The local urban area's sustainable performance is acceptable whilst encounters significant physical conditions decay. The regeneration practices should mainly focus upon improving physical conditions with a high intensity manner
3	Improving physical conditions (*Medium intensity*)	The local urban area's sustainable performance is acceptable whilst encounters significant physical conditions decay. The regeneration practices should mainly focus upon improving physical conditions with a medium intensity manner
4	Improving physical conditions (*Low intensity*)	The local urban area's sustainable performance is acceptable whilst encounters significant physical conditions decay. The regeneration practices should mainly focus upon improving physical conditions with a low intensity manner
5	Improving sustainable performance (*High intensity*)	The local urban area's physical conditions are acceptable whilst encounters significant decay in terms of sustainable performance. The regeneration practices should mainly focus upon improving sustainable performance with a high intensity manner
6	Improving sustainable performance (*Medium intensity*)	The local urban area's physical conditions are acceptable whilst encounters significant decay in terms of sustainable performance. The regeneration practices should mainly focus upon improving sustainable performance with a medium intensity
7	Improving sustainable performance (*Low intensity*)	The local urban area's physical conditions are acceptable whilst encounters significant decay in terms of sustainable performance. The regeneration practices should mainly focus upon improving sustainable performance with a low intensity
8	Overall upgrade (*High intensity*)	The local urban area encounters decay of both physical conditions and sustainable performance. The regeneration practices should improve the two aspects jointly with a high intensity manner
9	Overall upgrade (*Medium intensity*)	The local urban area encounters decay of both physical conditions and sustainable performance. The regeneration practices should improve the two aspects jointly with a medium intensity
10	Overall upgrade (*Low intensity*)	The local urban area encounters decay of both physical conditions and sustainable performance. The regeneration practices should improve the two aspects jointly with a low intensity

Note: The content in the Table is designed by the authors via combing the three categorical regeneration intensity (*high/medium/low intensity*) on top of the three regeneration modes (*improving physical conditions/improving sustainable performance/overall upgrade*), in addition to the regeneration mode of *conservation*.

6.2. Data collection

In referring to the decision-making variables listed in Tables 3 and 4, the data required include spatial data and non-spatial data. Variables P_2, P_3, P_5, P_9, P_{10}, P_{11} refer to spatial data. Specifically, P_2 (Building density) and P_3 (Plot ratio) are extracted from AutoNavi map via big data mining technique. The variables P_5 (Land use mix) and P_9 (Per capita park and green space) can be obtained via the urban land utilisation map. The variables P_{10} (Density of public transport stations) and P_{11} (Road network density) can be calculated by the POI data and Open Street Map (OSM).

The data for other variables ($S_1 - S_{12}$, P_1, P_4, P_6, P_7, P_8, C_1, C_2) are non-

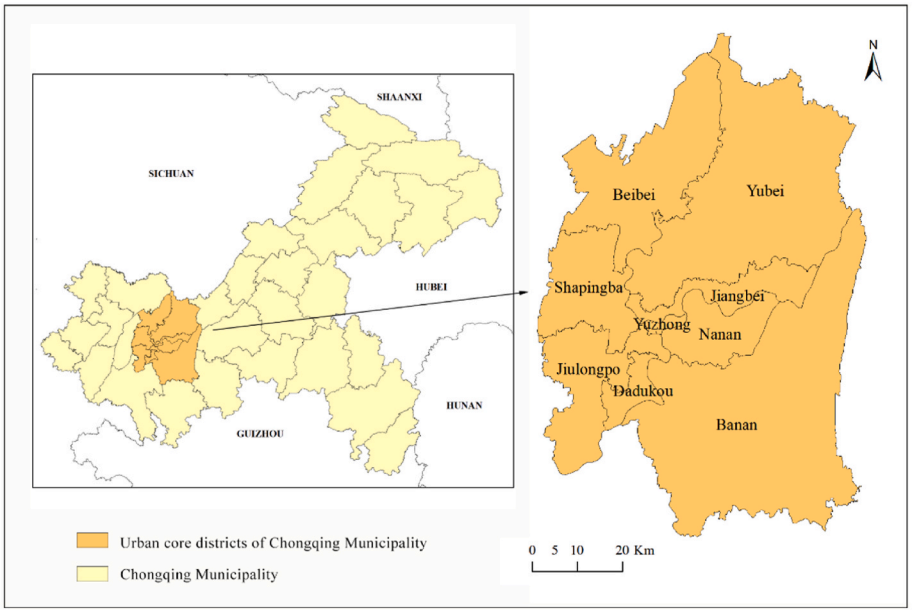

Fig. 6. Urban core area of Chongqing Municipality.
(*Source*: *Authors, 2022*)

spatial data and are collected via statistical books, public websites and web crawling technique. Statistic books include the Chongqing Statistical Yearbook (2020), and the statistical yearbooks and bulletins of the nine surveyed districts. Public websites refer to both government institutes website such as Chongqing Municipal Bureau of Planning and Natural Resources; and the commercial website such as the second-hand housing transaction website "Daojiale". Web crawler technique is used to collect the empirical data of variable C_3 (Number of urban regeneration projects undertaken), which is derived from Chongqing Public Resources Trading Website to understand the local urban regeneration experience. The details of the data sources are listed in the Appendix.

6.3. Analysis results

By applying the empirical data of the nine urban core districts of Chongqing Municipality to Equations (1)–(3), the decay values in terms of sustainable performance and physical conditions can be obtained for each surveyed district. In further referring to Equations (4) and (5), the constraint coefficient of urban regeneration and the suitable regeneration intensity can also be obtained, as shown in Table 6.

Given its satisfactory sustainable performance and physical conditions shown in Table 6, and in referring to the quadrants of Fig. 5, Jiangbei District is recommended to follow the regeneration mode of *Conservation*, therefore there is no need to further calculate constraint coefficient and intensity index for this case district.

In referring to Table 6, Jiangbei District endows the best sustainable performance among the nine surveyed districts, evidenced with the lowest decay value of 0.115, followed by Jiulongpo and Nanan Districts with values of 0.146 and 0.154 respectively. In terms of physical conditions aspect, Dadukou District obtained the lowest decay score, indicating the relatively good physical conditions in the local territory. Yuzhong District is identified endows the worst physical conditions, mainly due to the significant decay and poor building conditions in the local area.

Fig. 7(a)–(f) further presents graphically the decay values of the nine surveyed districts in referring to each variable under the six dimensions across sustainable performance (social, economic, environmental) and physical conditions (building conditions, land use pattern, facilities status).

By precisely investigating the multifaceted sustainable performance and physical conditions of local territory, the status-quo of the nine surveyed districts can be delineated. Thus, the critical challenges in each district can be identified and understood. Based upon this, proper regeneration mode and strategies can be designed for the local urban

Table 6
Decay values of sustainable performance, physical conditions, constraint coefficient and suitable regeneration intensity of the nine surveyed districts in Chongqing.

Aspect and Dimension	Yuzhong	Dadukou	Jiangbei	Shapingba	Jiulongpo	Nanan	Beibei	Yubei	Banan
Sustainable performance decay value	0.165	0.206	0.115	0.214	0.146	0.154	0.269	0.221	0.329
Social dimension	0.092	0.049	0.060	0.038	0.049	0.046	0.122	0.079	0.101
Economic dimension	0.022	0.132	0.032	0.128	0.053	0.090	0.124	0.107	0.201
Environmental dimension	0.051	0.025	0.023	0.048	0.043	0.019	0.023	0.035	0.027
Physical conditions decay value	0.326	0.144	0.187	0.193	0.223	0.201	0.178	0.206	0.169
Building conditions	0.281	0.023	0.045	0.051	0.059	0.051	0.024	0.012	0.008
Land use	0.015	0.024	0.016	0.029	0.022	0.027	0.056	0.051	0.086
Public facilities	0.029	0.097	0.126	0.112	0.142	0.123	0.097	0.143	0.074
Total decay value	0.491	0.351	0.303	0.406	0.369	0.356	0.447	0.427	0.498
Constraint coefficient	0.358	0.209	/	0.749	0.738	0.762	0.386	0.775	0.660
Historical and cultural heritage density	0.00	0.21	/	0.22	0.21	0.21	0.22	0.22	0.22
General government budget revenue	0.21	0.00	/	0.18	0.28	0.34	0.06	0.42	0.30
Number of urban regeneration projects undertaken	0.15	0.00	/	0.35	0.24	0.22	0.11	0.13	0.14
Intensity Index	0.176	0.073	/	0.305	0.272	0.271	0.172	0.331	0.328

Note: the analysis result is based upon the data of 2020.

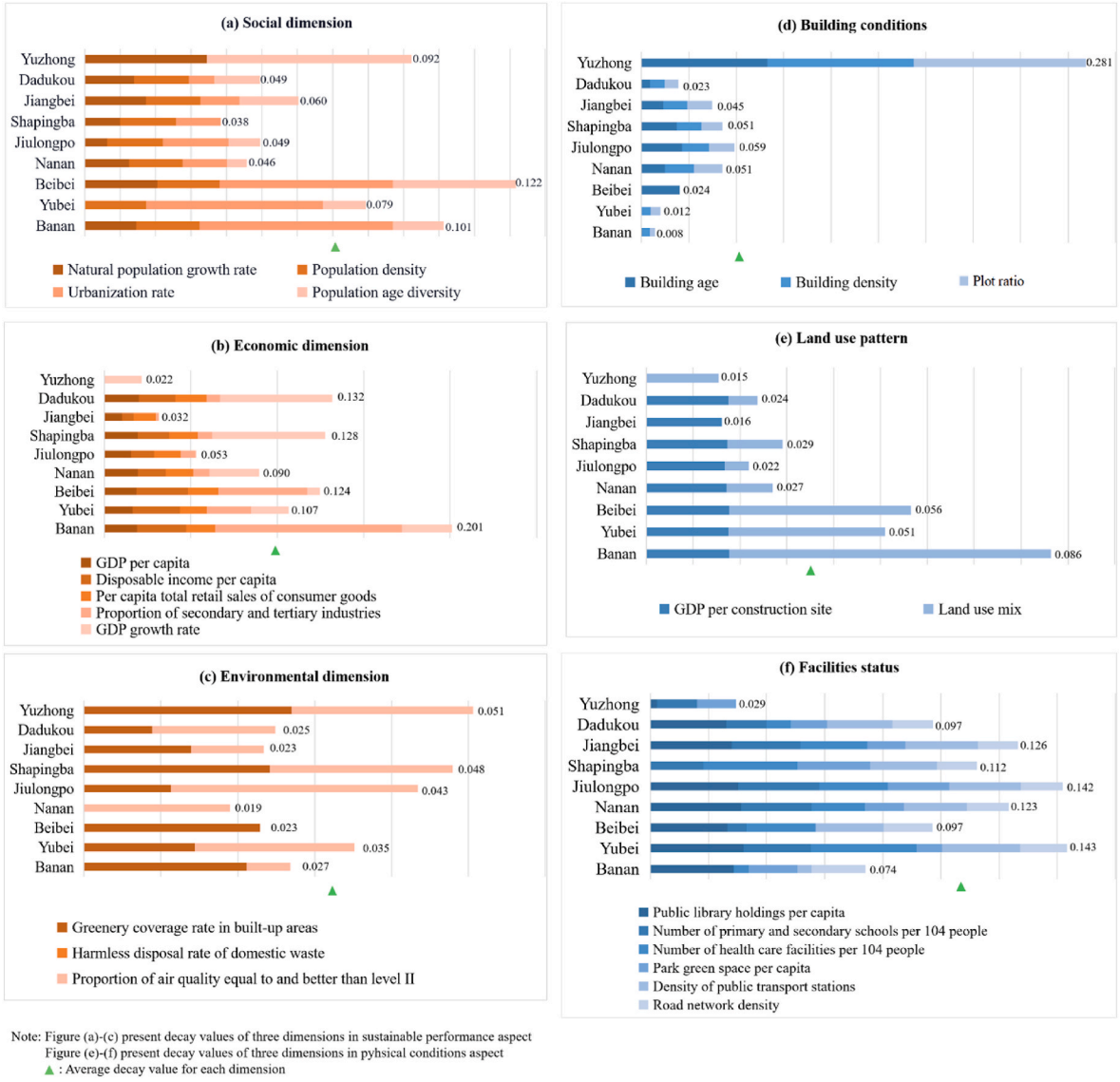

Fig. 7. Decay performance of each decision-making variable under six dimensions.
(*Source: Authors, the analysis result is based upon the research data of 2020*)

area to tackle effectively the challenges and further improve their urban façade and functions.

6.3.1. *Decision-making result for suitable urban regeneration mode*

By applying the decay values of sustainable performance and physical conditions to the decision-making matrix established in Section 5.2, the suitable regeneration mode of each case district can be determined, as shown in Fig. 8.

Jiangbei District presents good performance in both sustainable performance and physical conditions and it is located in the quadrant Q1, so the *conservation mode* is recommended for Jiangbei District in implementing urban regeneration programmes. The districts of Yuzhong, Jiulongpo, Nanan presents poor physical conditions but relatively good sustainable performance and they are located in the quadrant Q2, so that the regeneration mode of *improving physical conditions* is recommended for these three districts. Banan, Beibei, Shapingba and Dadukou Districts are identified with significant decay upon local sustainable performance, and they are all captured in the quadrant Q3. So these four districts are recommended to adopt the mode of *improving sustainable performance* in leveraging urban regeneration as effective approach for local reinvigoration. Yubei District is found encounters critical decay in both physical conditions and sustainable performance and is located in quadrant Q4, so the regeneration mode of *overall upgrade* is considered most suitable for Yubei District.

6.3.2. *Decision-making result for suitable urban regeneration strategies*

Following the decision-making upon the suitable urban regeneration mode in each case district shown in step-one, except Jiangbei District (endows with relatively satisfactory physical conditions and sustainable performance and is recommended to adopt *conservation mode*), all the other eight districts of Yuzhong, Jiulongpo, Nanan, Banan, Beibei, Shapingba, Dadukou, Yubei are identified with comparatively poor performance (either the sustainability or physical conditions) and are recommended with the suitable regeneration mode. On top of the regeneration mode, the second step is to determine the proper intensity for implementing regeneration practices in local territory.

By employing the natural fracture point technique via ArcGIS, the urban regeneration intensity values in Table 6 are classified into three intervals of high intensity, medium intensity and low intensity. The differences between ***low***, ***medium*** and ***high intensity*** of urban regeneration practices are detailed as below:

For urban regeneration practices characterised with ***high-intensity***,

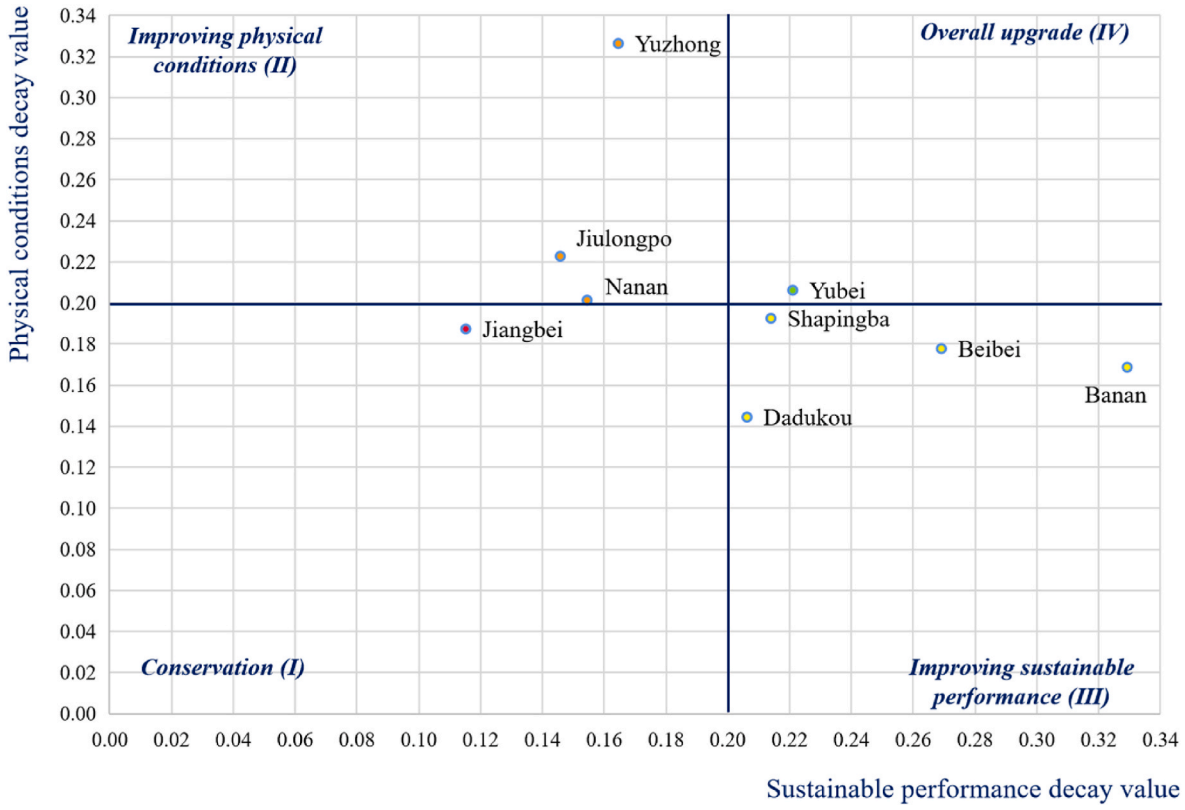

Fig. 8. Decision-making result upon the suitable urban regeneration mode in the surveyed nine districts of Chongqing Municipality. (*Source*: *Authors, 2022*)

strategies such as large scale-based implementation, reasonable demolition and redevelopment, as well as restructuring of land utilisation and spatial layout should be adopted to prevent the severe urban decay and boost urban sustainability. The application of this strategy should be supported by the strong financial and governance capability, as well as relatively low historical and cultural preservation needs of local urban context. For ***medium-intensity*** regeneration practices, approaches such as partial rebuilding, alteration or expansion with business replacement and functional upgrade upon buildings and urban zones should be adopted. For ***low-intensity*** urban regeneration, strategies such as micro-scale, finer-level and progressive based renewal and regeneration should be adopted, given the relatively weak capability of local urban context, local historical preservation needs, or the local area's relatively satisfactory performances of sustainability and physical conditions. Fig. 9 illustrates examples of regeneration practices under three levels of intensity.

Consequently, on top of the suitable regeneration mode investigated in Step 1, by combining the regeneration intensity, the specific regeneration strategies for the eight districts can be designed, as illustrated in Fig. 10.

As shown in Fig. 10, Yuzhong District is recommended to implement the strategy of *Improving physical conditions (Low intensity)* in promoting local urban regeneration practices. Dadukou and Beibei Districts are recommended to adopt the strategy of *Improving sustainable performance (Low intensity)* for enhancing the suitability of urban regeneration programme. Nanan and Jiulongpo Districts are suggested to conduct the strategy of *Improving physical conditions (Medium intensity)* in their local territory. Shapingba and Banan Districts are considered most suitable for the strategy of *Improving sustainable performance (High intensity)* in improving city façade and urban functions. Yubei District is suggested to follow the regeneration strategy of *Overall upgrade (High intensity)* to achieve the overall improvement and reinvigoration of local urban area.

High intensity: redevelopment
(Source: Visual China Group website, year not available)

Medium intensity: partial rebuilding and expansion with business upgrade
(source: Photo taken by authors, 2022)

Low intensity: refurbishment
(source: Jianshu website, 2020)

Fig. 9. Example regeneration practices under three levels of intensity.

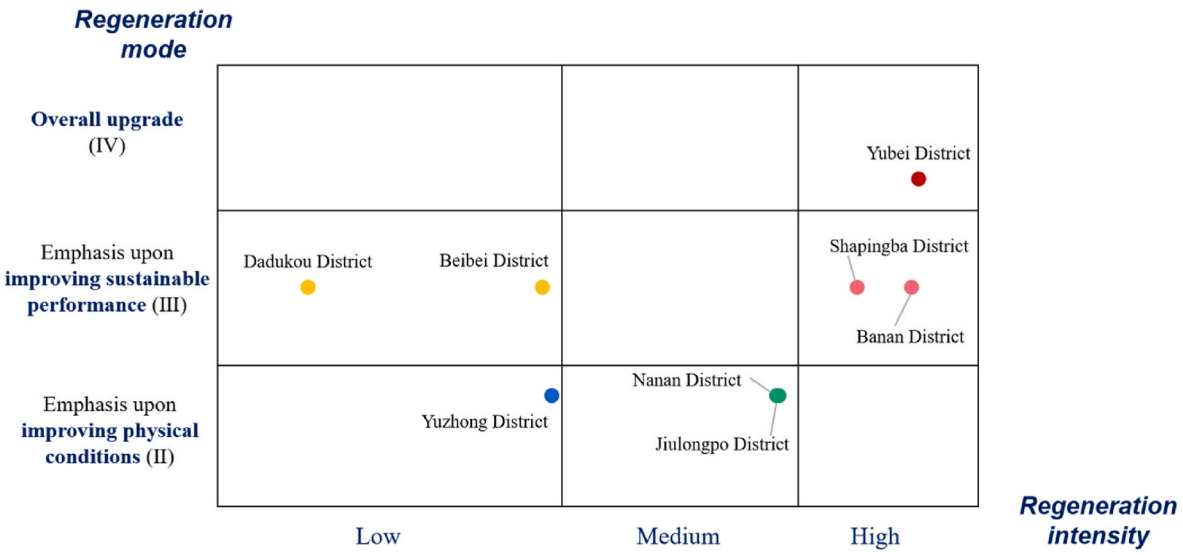

Fig. 10. Decision-making results upon regeneration modes and strategies for the case districts in Chongqing Municipality. (*Source*: *Authors, 2022*)

Finally, Jiangbei District should implement a *Conservation mode* in its urban regeneration practices, given its relatively good performance across the aspects of sustainable performance and physical conditions.

7. Discussions: linking decision-making results with local practices

In applying the "two-step" urban regeneration decision-making framework, suitable regeneration mode and strategies are designed for the nine surveyed districts in Chongqing Municipality in referring to their status quo sustainable performance, physical conditions, as well as the constraint factors. This section aims to conduct in-depth discussion by linking the urban development reality of these nine surveyed districts of Chongqing Municipality, justifying the suitability of designed regeneration mode and strategies in each of the case districts. On top of these, tailored recommendation measures are proposed to facilitate local urban governors to harness urban regeneration practices towards sustainability and suitability.

Jiangbei District is recommended to adopt *conservation mode*, given its relatively satisfactory performance in both sustainable performance and physical conditions facets. Via scrutinizing the detailed decay score of each dimension in Table 6 and Fig. 7, the public facilities condition is the only dimension that Jiangbei District encounters decay challenge. Therefore, Jiangbei District is suggested to enhance the maintenance, deployment and delivery of both existing and newly-added urban public services during local urban regeneration practices.

Yuzhong District is recommended to adopt the *Improving physical conditions (Low intensity) strategy* for local urban regeneration, given local area's significant decay challenges of physical condition as well as the strict constraint factors. According to the dimensional decay values in Table 6 and Fig. 7, Yuzhong District encounters severe building conditions decay in comparing with the other eight districts of urban core area in Chongqing Municipality. Sustainable performance-wise, the District presents unbalanced development status between economic, social and environmental dimensions, with economic dimension presenting lowest decay whilst environmental dimension encountering the most significant decay challenges. In capturing the above challenges of urban development, the decision-makers and urban governors in Yuzhong District is suggested to re-orient its local development direction from solely pursuing economic growth towards a sustainability pathway by particularly addressing the environmental facets and people's living conditions.

In terms of the regeneration intensity, Yuzhong District, as the origin of Chongqing City, endows plenty historical and cultural heritages, therefore low-intensity should be adopted in implementing regeneration programs. In light of this, incremental, small-scale, restoration and conservation-based regeneration strategy (such as alternation and renovation) are recommended to revitalise the dilapidated areas through improving physical conditions and preserve historical landscape and cultural characteristics. In fact, these regeneration strategies have been adopted and proven effective, for example, the 4th Zhongshan Road in Yuzhong District is a renowned street, with 40 historical heritage sites sitting along its 1-km length. By implementing a low-intensity and small-scale based restoration and partial rebuilding strategy, and injecting cultural and creative industries into the reinvigoration of local historic heritages, the Road has preserved its original urban fabric and historical feature of Chongqing, and simultaneously improved the physical conditions and environment (see Figs. 11 and 12). In addition, Yuzhong District's high population density should also be well-considered amidst local urban regeneration practices, for example, proper arrangement upon local residents' compensation and rehousing, and rational time schedule should be particularly addressed.

Nanan District and **Jiulongpo District** are recommended to adopt *Improving physical conditions (Medium intensity)* in implementing urban regeneration practices, given the critical decay challenges of physical conditions as well as medium-level constraint factors. In referring to the dimensional decay scores delineated in Table 6 and Fig. 7, both districts of Nanan and Jiulongpo present severe decay upon facilities status and building conditions. These two Districts are therefore suggested to improve public facilities and building conditions with a medium intensity manner, for example, promoting public transport and road network density, enhancing accessibility to quality public facilities, and implementing refurbishment upon building's façade and functions. In addition, sustainable performance-wise, Jiulongpo District encounters critical decay challenges upon environmental dimension, thus it is suggested to boost local environmental condition particularly by improving the air quality.

Dadukou District and **Beibei District** is recommended to adopt *Improving sustainable performance (Low intensity) strategy*, given their significant decay challenges at sustainable performance aspect, as well as the high-level constraint factors present. Specifically, Dadukou District presents poor performance at economic dimension, with S_5 (GDP per capita) and S_9 (GDP growth rate) ranked bottom among the nine surveyed districts. Beibei District encounters poor performance at socio-

Fig. 11. Regeneration of historical buildings in Yuzhong District: Former Residence of Zhou Enlai (Left) and Zengjiayan Academy (right) on the 4th Zhongshan Road, now regenerated as cultural memorial hall and leisure library.
(*Source: Photo by the authors, 2022*)

Fig. 12. Injecting cultural and creative industries in revitalising historical buildings in Yuzhong District: Zhongshan Cultural Industry Park on the 4th Zhongshan Road.
(*Source: Photo by the authors, 2022*)

economic dimension, evident by the relatively high decay score of socio-economic variables such as S_2 (Population density), S_3 (Urbanisation rate), S_4 (Population age diversity), S_6 (Disposable income per capita) and S_8 (Proportion of secondary and tertiary industries) in Fig. 7. Therefore, the boosting of economic development should still be set as the priority for Dadukou District and Beibei District, for which urban incremental construction and urban stock regeneration are both important. Also, constrained by the limited government financial capacity and urban regeneration experience, both districts are recommended to follow low intensity manner in implementing urban regeneration projects in their local territory. Under these contexts, Dadukou District and Beibei District are suggested to mobilise market and social forces and multiple financial channels in conducting small-scale and low-intensity urban regeneration programs at first, and later accumulate more financial capability and experiences for conducting further urban regeneration, to continuously reinvigorate building function, upgrade industrial structure, and revitalise socio-economic activities. For instance, in Dadukou District, urban regeneration initiatives by reutilising resources endowed by the old industrial zones are proven helpful for reinvigorating regional socio-economic vitality (Fig. 13).

Banan District is recommended to adopt the strategy of *Improving sustainable performance* (High-intensity) for local urban regeneration practices. For this, the relatively high intensity regeneration approaches like suitable reconstruction, proper optimisation of land use structure, can serve as instruments to help Banan District efficiently address its socio-economic sustainability challenges. **Shapingba District** is also recommended to adopt the strategy of *Improving sustainable performance* (*High-intensity*) for addressing its critical decay upon environmental dimension. As a relatively old district with lagged-behind urban planning landscape, the regeneration practices in Shapingba District are suggested to particularly address air quality issue and improve urban green space coverage, so that a better living environment can be provided to local urban residents.

Yubei District is recommended to adopt *Overall upgrade (High intensity) strategy*, as suggested early in previous section. This case district

Fig. 13. Old industry factories in Dadukou District, now regenerated as the Chongqing Industrial Museum to develop urban tourism. (*Source: Photo from the museum's official website*[7]*, 2022*)[7] http://www.2019cqim.com/

has massive needs and greet potential for improving both sustainable performance and physical conditions. As a relatively newly-developed urban district, Yubei endows stronger financial capability for implementing urban regeneration programmes, and is simultaneously less-restricted by historical and cultural heritages. Therefore, relatively high regeneration intensity can be injected to leverage the overall upgrade in the local territory.

It can be seen from the empirical practices in the nine case districts in Chongqing that the suitability of urban regeneration is a trade-off between the regeneration needs and regeneration constraints of local urban area. For example, Yuzhong District, which endows with strong capability to tackle urban deterioration but is restricted by the conservation of historical heritages, so that the strategies of refined, low-intensity, preservation-oriented regeneration are considered suitable. Dadukou District, restricted by relatively weak local governance capability, however, adopted the urban regeneration strategies of small-scale alternation to support its industrial upgrading, later on can accumulate more financial capability and regeneration experiences to further revitalise regional socio-economic activities. Yuzhong and Dadukou Districts are both considered have produced suitable regeneration outcomes as the two districts understand rightly their urban problems, historical preservation needs, and local capability of financial resources and regeneration experiences. In comparison, Yubei District endows massive regeneration needs and strong financial and governance capability, whilst it has only implemented limited scale of regeneration projects. According to official information released from District government website, the current urban regeneration projects in Yubei District mainly focus on the aspects of roadway renovation, housing maintenance and other low-intensity regeneration programmes. However, higher-intensity regeneration approaches such as reasonable reconstruction, land-use adjustment, and proper optimisation of urban layout, can serve as instruments to help efficiently address its physical conditions decay and socio-economic sustainability challenges. Following the case study discussions, a comprehensive comparison of the current situation, regeneration strategies by the introduced framework, and local regeneration practices in reality among the nine districts is summarised in Table 7.

8. Conclusion and future research avenue

In contemporary era, cities are under the ongoing rapid urbanisation and the influx of massive immigrants, and are increasingly facing with the scarcity of land resources and a set of urban problems associated with urban decay. Urban regeneration initiatives hold great promise for improving urban function and people's living conditions, thus are regarded as important instruments for urban governors to drive cities' transition towards health and sustainability. However, no matter how plenty efforts and resources are devoted, the effectiveness of urban regeneration programs lies in the decision-making that can generate suitable urban regeneration mode and strategies. The suitability of the regeneration mode and strategies can only be guaranteed if they well incorporate with the status-quo of local urban territory. The current decision-making of urban redevelopment is essential as it would impact not only the current but also future generations. In line with this, the introduction of "two-step" decision-making framework in this study provides valuable guidance as it considers the suitability as top priority from both regeneration content and regeneration intensity. The variables incorporated in the process of decision-making across three aspects of sustainable performance, physical condition, and constraint factors, which can reflect the status-quo conditions of local territory.

Table 7
Comprehensive summary upon the current situation, proposed, and adopted urban regeneration practices among the 9 surveyed districts in Chongqing.

Surveyed District	Sustainability performance & local physical condition	Proposed regeneration decision-making strategies in this research	Currently adopted regeneration strategies in reality[a]
Jiangbei	Good sustainable performance and physical conditions	Conservation	Medium number of regeneration projects, including housing refurbishment, infrastructure improvements (roads, underground pipe network) and old neighborhoods renovation
Yuzhong	Poor socio-environmental sustainability; significant decay of building conditions	Improving physical conditions (*Low intensity*)	Medium number of regeneration projects, mostly low-intensity environmental restoration and landscape improvement, old neighborhoods renovation, and conservation and upgrading of historic and cultural districts
Nanan	Relatively good sustainable performance; significant decay of facilities	Improving physical conditions (*Medium intensity*)	Medium number of regeneration projects, including infrastructure and public service facility improvements (schools, roads and underground pipe network) and old neighborhoods renovation
Jiulongpo	Poor environmental sustainability; significant decay of facilities and buildings	Improving physical conditions (*Medium intensity*)	Medium number of regeneration projects, including old neighborhoods renovation and infrastructure improvements (roads, underground pipe network)
Dadukou	Poor economic sustainability; significant decay of facilities	Improving sustainable performance (*Low intensity*)	Small number of regeneration projects like public service facility renovation (schools, nursing homes) and old neighborhoods renovation
Beibei	Poor socio-economic sustainability; land use problems in physical conditions	Improving sustainable performance (*Low intensity*)	Small number of regeneration projects like infrastructure and public service facility renovation (roads and schools)
Banan	Poor socio-economic sustainability; land use problems in physical conditions	Improving sustainable performance (*High intensity*)	Medium number of regeneration projects, including old neighborhoods renovation, infrastructure improvements (roads, underground pipe network) and cultural and tourism-oriented upgrading and renovation
Shapingba	Poor economic and environmental sustainability; significant decay of facilities	Improving sustainable performance (*High intensity*)	Large number of regeneration projects including infrastructure and public service facility improvements, environmental restoration and landscape improvement, and old neighborhoods renovation
Yubei	Overall sustainable performance decay; land use and facilities problems in physical conditions	Overall upgrade (*High intensity*)	Medium number of regeneration projects, mostly low-intensity road renovation and housing maintenance

[a] The urban regeneration strategies in reality are synthesised based on the bidding announcements of urban regeneration projects issued by Chongqing Public Resources Trading Centre up to December 2021 (Available at: https://www.cqggzy.com/).

Thus the outcomes of the two-step decision making framework can ensure both the mode and strategies of regeneration programmes most suitable for the mission of sustainable urban development.

The applicability and validness of the proposed decision-making framework are proven effective via a case study which involves nine districts of the urban core area in Chongqing municipality, Southwest China. The case study delineates the decay status in terms of sustainable performance and physical conditions, and the constraint degree of urban regeneration in the case districts. As a result, the most critical issues for implementing regeneration programmes in each case district are identified, so that the suitable regeneration mode and strategies are generated. The case study results can facilitate local decision-makers to better harness regeneration programs through tackling the most critical issues in their urban context. The various urban regeneration practices reviewed and discussed in empirical case studies of the nine urban districts in Chongqing Municipality also provide valuable and heuristic references that can be adapted to further urban context in the other regions. Furthermore, the decision-making model established in this research can also be generated to other cities and districts in China and other regions in the developing countries to help different cities to scientifically identify their most critical urban problems, their rational regeneration intensity and then implement suitable urban regeneration strategies to improve urban functions and images.

The "two-step" decision-making framework is an instrumental tool for selecting the most suitable urban regeneration mode and strategies. Future research can further develop the following aspects to enrich this research domain and contribute to promote the suitability of urban regeneration practices. For example, a dynamic monitoring mechanism can be implemented to ensure the regeneration strategies in an urban context can be adjusted timely to better meet the evolving urban (re) development demands. Also, local residents' perception can be incorporated into the design of decision-making process in future research, to better facilitate the pursuit that cities are built and developed for people (Zhu, Shen and Ren, 2022). Big-data based analysis approaches can also be injected into future research to precisely identify the local status and critical issues to ensure urban regeneration strategies can cope with local genuine realities and needs.

Author credit statement

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Declaration of competing interest

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

Appendix. Data sources and measurement of urban regeneration decision-making variables

Aspect	Dimension	Variables	Data source	Measurement
(S) Sustainable performance	(S_{soc}) Social dimension	(S_1) Natural growth rate of population	Statistical Yearbook	
		(S_2) Population density	Statistical Yearbook	
		(S_3) Urbanisation rate	Statistical Yearbook	
		(S_4) Population age diversity	Statistical Yearbook	Shannon's Diversity Index
	(S_{eco}) Economic dimension	(S_5) GDP per capita	Statistical Yearbook	
		(S_6) Disposable income per capita	Statistical Yearbook	
		(S_7) Per capita total retail sales of consumer goods	Statistical Yearbook	
		(S_8) Proportion of secondary and tertiary industries	Statistical Yearbook	
		(S_9) GDP growth rate	Statistical Yearbook	
	(S_{env}) Environmental dimension	(S_{10}) Greenery coverage rate in built-up areas	Statistical Bulletin	
		(S_{11}) Harmless disposal rate of domestic waste	Statistical Yearbook; Statistical Bulletin	
		(S_{12}) Proportion of air quality equal to and better than level II (%)	Statistical Yearbook; Statistical Bulletin	
(P) Physical conditions	(P_b) Building conditions	(P_1) Building age	Commercial website: https://cq.daojiale.com/	Number of second houses over twenty years old/Number of all second houses
		(P_2) Building density	Spatial analysis in GIS	
		(P_3) Plot ratio	Spatial analysis in GIS	
	(P_l) Land use pattern	(P_4) GDP per construction site	Statistical Yearbook; Statistical Bulletin	
		(P_5) Land use mix	Spatial analysis in GIS	Shannon's Diversity Index
	(P_f) Facilities status	(P_6) Public library holdings per capita	Statistical Yearbook; Statistical Bulletin	
		(P_7) Number of primary and secondary schools per 10^4 people	Statistical Yearbook	
		(P_8) Number of health care facilities per 10^4 people	Statistical Yearbook	
		(P_9) Park green space per capita	Spatial analysis in GIS	
		(P_{10}) Density of public transport stations	Spatial analysis in GIS	
		(P_{11}) Road network density	Spatial analysis in GIS	
(C) Regeneration constraints	(C_h) Historical and Cultural Conservation	(C_1) Historical and cultural heritage density	Government documents	
	(C_f) Government financial capacity	(C_2) General government budget revenue	Statistical Yearbook	
	(C_e) Urban regeneration experience	(C_3) Number of urban regeneration projects undertaken	Web crawler technique	

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