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Green Remediation and Transformation Planning Path for Inefficient Industrial & Productive Land with Environmental Constraints in Shanghai

Xueke Zang[1,a], Zhenxue Dai[2,b], Yi Li[2,c,*]

[1]Shanghai Yaxin Urban Construction Co., Ltd, Shanghai, 200436, China
[2]College of Construction Engineering, Jilin University, Changchun, 130026, China
[a]zangxueke@sgeeg.com, [b]dxz@jlu.edu.cn, [c]Liy24@mails.jlu.edu.cn
[*]Corresponding author

Abstract: *The transformation of inefficient industrial & productive land (IIPL) in urban centers and surrounding areas is a crucial component of stock planning and urban renewal in megacities. From the perspective of environmental risk, both national and local governments have gradually established and refined a 'full life-cycle' environmental management process. Through a review and analysis of current research, this study summarizes the current status of soil environmental quality in a central urban area of Shanghai, reveals its relationship with historical land use, and establishes a risk assessment model for the soil environmental quality of IIPR in the central urban area. According to different risk levels and the current status of IIPR in central urban areas, a technical framework has been formulated for land planning and banking. For high-risk land parcels that require urgent treatment, a green governance strategy has been proposed such as the 'environmental remediation+' model. This approach integrates remediation with development needs, minimizing redundant excavation and backfilling, thereby reducing costs. A tailored remediation plan, 'One Parcel, One Policy' was introduced to ensure rational planning and efficient reuse of land, promoting urban renewal and the resource-efficient utilization. The results of this study provide significant insights for soil environmental management in megacities.*

Keywords: *Inefficient Industrial & Productive Land(IIPR); Pollution Prevention and Control Planning; Risk Classification; Environmental Remediation+; Green Governance Strategy*

1. Introduction

1.1 Research Background

In recent years, the development and construction of many cities in China have been significantly influenced by shifts in national land policies. These policy changes often reflect underlying issues in land resource management[1]. While urbanization in China has been advancing rapidly, land resources face challenges such as disordered urban spatial structures, imbalanced land-use distribution, low spatial utilization efficiency, vacant buildings, and aging infrastructure[2-4]. The traditional model of expanding new construction land is no longer suitable for the urbanization paradigm of the new era.

As a megacity with a permanent population exceeding ten million in China, Shanghai is currently experiencing significant pressure on land supply and demand. The city's quotas for new construction land have been progressively tightened, shifting the primary land supply from the expansion of new construction land to the revitalization and utilization of existing land stock. Stock development has become an inevitable strategy for cities to alleviate land resource constraints and meet the increasingly stringent national regulations on urban construction land[5]. The renewal of IIPR constitutes a critical component of stock development[6-7]. However, certain land parcels, due to the lack of adequate environmental awareness during their historical development and utilization, often face certain pollution and associated risk issues.

According to the Provisions on Soil Pollution Investigation, Risk Assessment, Risk Control, Remediation, and Effectiveness Evaluation for Construction Land in Shanghai (Document No. 4 [2021] issued by the Shanghai Municipal Bureau of Ecology and Environment), the principle of 'the polluter is responsible for remediation, and the user is accountable' stipulates that land use right holders (including land reserve institutions) or soil pollution responsible parties must organize and complete soil pollution

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investigations, risk assessments, risk control, remediation, and effectiveness evaluations before any changes in land use purpose, or before the land is reserved, transferred, recovered, renewed, or allocated. The relevant reports must be submitted to the ecological and environmental authorities of the area where the land parcel is located. However, China's current approach to soil pollution prevention and control remains largely reactive, addressing issues as they emerge. There is a lack of a comprehensive, lifecycle-based approach and refined management strategies focused on land use[8].

In summary, to align with the overall trend for IIPR in the era of stock planning—specifically, optimizing land utilization structure (by curbing inefficient scale), upgrading quality, and enhancing comprehensive efficiency. it is essential to strengthen environmental risk management in the reuse of IIPR in urban renewal[9]. This is vital for improving the efficiency of high-quality transformation and utilization of the large-scale IIPR awaiting transformation in Shanghai. By reviewing and drawing lessons from the mature brownfield reuse management systems of developed countries, and comparing the current state of environmental management in the transformation and development of IIPR in domestic central urban areas, the study of land environmental risk classification methods has become a key step. This will provide essential management recommendations for planners and land managers.

1.2 Objectives and Significance

To proactively respond to the demands of high-quality urban development, it is essential to systematically survey the basic information and soil quality conditions of industrial land parcels in the central urban area designated for transformation. This investigation will provide a clear understanding of how the current soil environmental quality influences the land transfer process and informs planning for land reutilization.

From the perspective of land renewal and utilization needs, understanding the current status of industrial land in the central urban area is crucial for project stakeholders to establish a classification-based management system for industrial land and implement phased remediation[10]. This will provide technical support for the rational use of industrial land and offer renewal and transformation planning recommendations for the entire district’s industrial land. From an institutional innovation standpoint, this approach holds significant practical importance for the innovation-driven, stock revitalization-based, and sustainable development path focused on intrinsic growth.

2. Current Study Status

In response to the current issues, the Guiding Opinions on Building a Modern Environmental Governance System, issued by the Central Committee of the Communist Party of China and the State Council in March 2020, encourage the adoption of the 'environmental remediation + development' model for industrial land.

Beijing’s Green Heart Forest Park implemented a three-tiered remediation approach for its core ecological conservation area based on the severity of pre-existing soil pollution. The primary ecological remediation zone (heavily polluted areas) adopts soft isolation, minimal disturbance, and natural self-remediation. The secondary ecological remediation zone (lightly polluted areas) allows limited public access while incorporating plant-based buffer zones. The tertiary ecological remediation zone (lightly polluted areas) undergoes topographical mounding, followed by soil covering and greening, before being opened to the public. Through refined management, scientific assessment, and eco-friendly remediation methods[11], the park has become a successful model for the green transformation of IIPR in China.

Guangzhou and Shenzhen have issued relevant policy documents. Specifically, Guangzhou has proposed two approaches: "early land transfer and "early construction," both aiming to reduce time constraints in the environmental management process for parcels designated for development. For contaminated parcels requiring urgent development, the remediation timeline is determined by either setting a fixed schedule for remediation projects or integrating remediation work into the construction process, thereby clarifying the land transfer schedule[12].

While Shenzhen also suggests synchronizing design and construction where remediation and development can be effectively coordinated, it does not impose a specific time limit. Instead, its primary focus is on the integration of urban planning and environmental management. Regardless of whether the "environmental remediation + development" or "environmental remediation + planning and design" model is adopted, both emphasize the role of environmental management in land use planning. Moreover, Shenzhen has taken a more proactive approach than Guangzhou in environmental risk prevention by

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requiring preventive environmental monitoring and risk control for parcels that are temporarily unsuitable for remediation and development.

In 2023, the Ministry of Natural Resources officially issued the "Notice on Implementing Pilot Projects for the Redevelopment of Inefficient Land." The notice highlights widespread issues related to stock construction land in both urban and rural areas, such as urban villages and outdated industrial zones. These issues are characterized by scattered layouts, inefficient land use practices, and suboptimal land allocation. From a macro-level decision-making perspective, in order to effectively implement a comprehensive conservation strategy and actively and steadily advance the redevelopment of urban villages in megacities, the focus should be placed on revitalizing and effectively utilizing stock land. This approach aims to enhance land use efficiency and, in turn, promote high-quality development in both urban and rural areas.

In addition, this study selects the United States, the United Kingdom, and Germany—three early-industrialized and highly developed nations—as research subjects. It focuses on comparing their industrial land planning concepts, the content and depth of environmental quality survey data, and the role of this data in decision-making regarding the reutilization of industrial land. The comparison aims to highlight the differences between China and these developed countries in the environmental management of industrial land reuse.

Through a comprehensive comparison, the results indicate that industrial land renewal is regarded as a key component of the revitalization of aging urban areas during a certain stage of urbanization, both in China and in countries such as the United States, the United Kingdom, and Germany[13]. In both China and the UK, land renewal emphasizes the implementation of higher-level policies; however, China focuses more on land use allocation, whereas the UK places greater emphasis on the overall functional requirements of the area[14]. The United States prioritizes balancing multiple stakeholder interests, while Germany, while coordinating with various parties, places more importance on the environmental quality characteristics of the land itself[15-16].

These conceptual differences have led to a more proactive and detailed approach to environmental pollution risk management, as well as data collection and analysis, in these countries compared to China[17]. In the UK and the US, this is primarily reflected in the establishment of conceptual models at the early stages of soil pollution investigations, which are used to assess the environmental risks of land parcels under different scenarios. Germany’s approach is characterized by its long-term soil monitoring database, which enables precise identification of the soil environmental quality characteristics of parcels, thereby supporting land use decisions[18]. In contrast, China’s current survey methods and requirements are more standardized, with evaluation methods and models tending to simplify scenarios and parameters. This often results in insufficient consideration of complex situations, leading to conservative assessment outcomes.

As evident from the above, conducting soil contamination assessments prior to the planning stage allows for a more proactive approach in environmental management during industrial land renewal. On one hand, it aids in redevelopment planning and mitigates environmental risks; on the other hand, it supports scientific spatial planning and ensures the orderly scheduling of implementation phases. Additionally, it reduces uncertainties associated with emergency remediation measures triggered by adverse environmental quality assessment results.

3. Methodological framework

The study employs policy-institutional analysis and case study methods, supplemented by quantitative data analysis, to address issues related to the environmental governance mechanisms of inefficient industrial land transformation, the effectiveness of policy tools, and the practical impacts of different green governance pathways. The policy-institutional analysis component involves an examination of national and local policy frameworks governing industrial land redevelopment and soil pollution control, focusing on policy objectives and instruments aimed at regulating environmental risks, the institutional arrangements for full-life-cycle management, and the rights and responsibilities of relevant stakeholders (governments, landowners, developers). The case study method is used to investigate specific practices in a central urban district of Shanghai, analyzing the current status of soil pollution, risk assessment processes, and the implementation effects of transformation strategies. Quantitative data analysis serves to process and interpret statistical information, such as land use type proportions, to verify the correlation between historical land use and environmental risks.

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The analytical strategy is based on a systematic review of policy documents, academic literature, and empirical data from the case study area. The analyzed materials include national and local regulatory texts (such as Shanghai's "14th Five-Year Plan for Soil and Groundwater Pollution Prevention and Control"), field survey data (soil monitoring reports, land use surveys) and case study reports. The temporal scope of the sources primarily covers the past five years (since 2019) to reflect the latest policy developments and research progress, with some key historical documents beyond this period also included for contextual analysis. The selection criteria for materials prioritize relevance to the research topic, scientific rigor, and the presence of original data or in-depth analysis. For data analysis, qualitative content analysis is applied to policy texts and case descriptions, with elements of latent analysis aimed at identifying core themes such as "risk grading logic" and "green governance pathways." Quantitative analysis is used to process statistical data on land use types and pollution rates, employing descriptive statistics to reveal distribution patterns and correlation trends.

The categories for analysis are defined a priori based on the research framework, including " inefficient industrial & productive land," "environmental risk assessment," "policy tools," "remediation technologies," and "governance effects." These categories are refined and supplemented during the analysis process to adapt flexibly to the empirical materials, ensuring comprehensive coverage of the multifaceted dynamics in environmental governance of industrial land transformation.

4. Soil Pollution Prevention and Control Pathways in an Urban Central District of Shanghai

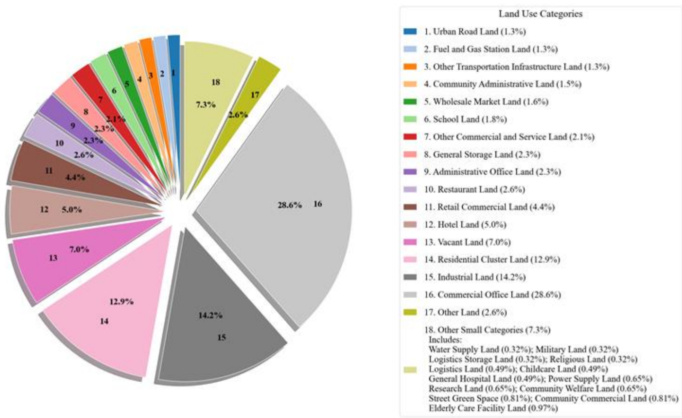
4.1 Current Status and Challenges of IIPR

A central district in Shanghai historically focused on industries such as manufacturing, machinery, and textiles, leading to significant soil environmental issues and a substantial presence of IIPR. This inefficient land primarily includes idle, abandoned, or undeveloped industrial sites. In recent years, multiple site environmental investigations have shown that industrial enterprises were predominantly concentrated in the northern part of the central district. As a result of past industrial activities, many parcels in this area have been classified as "brownfields," posing varying degrees of environmental risk[19-22].

4.2 Analysis of Underutilized Industrial Land Conditions

From the perspective of land classification, IIPR is primarily composed of industrial land, accounting for 86%, while storage land makes up the remaining 14%. These parcels are mainly concentrated in the core areas of old industrial zones.

According to the Third National Land Survey, IIPR spans 45 different land-use types, including business office land, industrial land, residential clusters, and idle land. Among these, business office land holds the largest share at 28.6%, indicating a growing trend in recent years toward improving land-use efficiency, with a significant portion of former industrial land being repurposed for commercial office use. The distribution of various land-use types for IIPR under the Third National Land Survey is shown in Figure 1.



Note: The types with only one land parcel total 16, and are categorized as 'Others'.
(a) the use of IIPR parcels.

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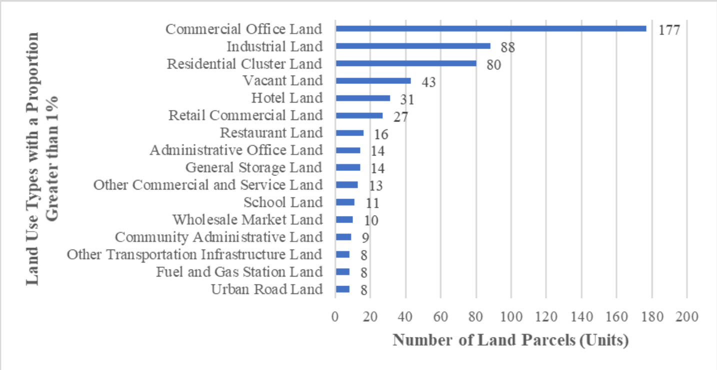

Note: Only land use types with a proportion greater than 1% in Figure (a) are listed in this chart.
(b) the use of IIPR parcels greater than 1%.

Fig.1 Use of low-efficiency industrial land under the third national land resource survey.

From the perspective of land ownership, the current ownership structure is relatively complex, encompassing municipal state-owned enterprises, district-level state-owned enterprises, and private entities. These varied ownership structures lead to significant differences in their willingness to engage in land renewal.

In terms of current land use planning, the central district has adopted a policy for areas with concentrated industrial land and a high proportion of inefficient industrial parcels. This policy involves delineating integrated transformation zones based on natural boundaries such as roads and rivers. By incorporating survey results on property owners' renewal intentions, a development mechanism has been established, comprising "joint transformation, independent renewal, government acquisition and storage, and preservation." This approach follows a "one parcel, one policy" strategy for resource planning, development mechanisms, and implementation strategies.

In summary, the compilation of data on inefficient industrial parcels has facilitated a preliminary understanding of the historical context, current conditions, and future planning of the survey area. In terms of land parcel distribution, the central and southern regions are characterized by dispersed parcels with a low proportion of industrial sites, whereas the northern region contains a higher concentration of large, contiguous heavy industrial parcels. To ensure that the environmental quality of these parcels is suitable for safe utilization and to facilitate the land transfer process, the environmental survey results will be systematically analyzed to develop a risk-level classification model for these sites.

4.3 Development of an Environmental Quality Risk Assessment Model for IIPR

Based on the compilation and summary of data such as collected historical images and the Third National Land Survey, it is known that IIPR has a wide variety of historical uses, including residential land, commercial office land, storage land, and productive industrial land (involving both "15 categories" and non-"15 categories"). Among them, the "15 categories" are divided into 12 categories of key industries and 3 categories of specific projects in accordance with the Catalog of Key Industries for Environmental Impact Assessment of Construction Projects in Shanghai (2021 Edition) issued by the Shanghai Municipal Bureau of Ecology and Environment. The 12 categories of key industries include petrochemical, pharmaceutical, and chemical fiber industries; non-metallic mineral products, ferrous metal, and non-ferrous metal industries; environmental infrastructure industry; transportation, pipeline transportation, and warehousing industry; marine engineering; and nuclear and radiation-related industries, etc. The 3 categories of specific projects involve individual projects with high-pollution processes and large scales, construction projects within the city's ecological protection red line, and construction projects listed in the national and municipal high-energy-consumption and high-emission lists. To explore the intrinsic relationship between different historical uses of the plots and pollution situations, the plots are classified by industry category, and finally divided into four types of land use: "15 categories", non-"15 categories", "automobile repair and storage industries", and "residential, commercial office, schools, etc.".

Through data analysis, it was found that of the 33 industrial parcels classified under the "15 categories," 32 exhibited soil or groundwater contamination exceeding regulatory limits, while only one met land use requirements, resulting in an exceedance rate of 97%. Among the 25 non-"15 categories" industrial parcels, two were found to have soil and groundwater test results exceeding the standards, with

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an exceedance rate of 13%. Of the 43 parcels related to auto repair and storage, two exceeded soil and groundwater environmental quality standards, leading to an exceedance rate of 5%. Historical analysis indicates that these parcels were previously used as coal storage sites. Inadequate seepage prevention or incomplete coal slag removal likely resulted in excessive polycyclic aromatic hydrocarbons (PAHs) in the surface soil. In contrast, all 38 parcels designated for residential, business office, and school use met soil and water quality standards, with no exceedances (0%). A summary of exceedance rates for different land use types in the investigated parcels is provided in Table 1.

Table 1: Summary of exceeding standards for various land types in the investigated land parcels.

Historical Land Use	Total Number of Land Parcels	Number of Exceedance Land Parcels	Exceedance Rate of Land Parcels
Land Involving ‘15 Categories’ of Industrial Land Use	33	32	97%
Non-‘15 Categories’ of Industrial Land Use	25	2	13%
Land Parcels with Simple Uses	43	2	5%
Land Parcels for Residential, Commercial Office and School	38	0	0%

A correlation analysis between the historical land use and contamination exceedance of the investigated parcels indicates that in subsequent soil contamination assessments, exceedance rates were 97% for parcels formerly used for "15 categories" industrial activities, 13% for non-"15 categories" industrial activities, 5% for auto repair and storage sites, and 0% for residential, business office, and school land. These findings suggest a clear correlation between historical land use and contamination exceedance, with higher pollution risk levels in historical land use corresponding to greater probabilities of exceedance.

Based on an analysis of typical cases and existing environmental quality data from central urban areas, the potential contamination risks of IIPR with different historical uses were classified. A risk-level assessment model for the environmental quality of IIPR parcels in central urban areas was developed, categorizing the risk levels as follows:

(1) Risk Level I: Parcels with a historical land use limited to residential, school, or business office functions, without involvement in storage or industrial production.

(2) Risk Level II: Parcels historically used for storage (excluding hazardous material storage), auto repair, or other non-industrial production activities.

(3) Risk Level III: Parcels with a history of industrial production activities but not associated with the "15 categories" of industrial enterprises.

(4) Risk Level IV: Parcels historically used for industrial production activities and classified under the "15 categories" of industrial enterprises.

Based on the historical land use of inefficient industrial parcels in the central urban area, classifications were made according to potential contamination risks. Differentiated recommendations for planning and government acquisition were proposed accordingly (Figure 2):

(1) For parcels with Risk Level I, they can be designated as Category I construction land and safely utilized. According to regulations, with sufficient data, the land can be acquired following the completion of the first-phase soil contamination investigation, allowing for a more rapid land transfer process.

(2) For parcels with Risk Level II, they can be designated as either Category I or Category II construction land. Upon completing the initial soil contamination investigation, if classified as Category II construction land, the likelihood of contamination exceedances is low, facilitating a swift land transfer. If classified as Category I construction land, minor contamination exceedances in soil or groundwater may occur, but severe contamination is unlikely, ensuring a relatively smooth land transfer process.

(3) For parcels with Risk Level III, it is advisable to prioritize their designation as Category II construction land. Minor contamination exceedances in soil or groundwater may occur, but severe contamination is unlikely, facilitating a relatively smooth land transfer process.

(4) For parcels with Risk Level IV, to ensure the safe utilization of the land, it is recommended to designate them as Category II construction land. Contamination exceedances in soil or groundwater are likely, with a possibility of severe pollution. Remediation efforts will require significant costs and time, leading to a prolonged land transfer process.

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For higher-risk parcels, it is recommended that the detailed control plan incorporate risk levels and be adjusted based on actual needs to ensure both land safety and resource utilization. A comprehensive approach should consider factors such as planning design, development timelines, and detailed regulations. This integration of remediation with planning will minimize remediation workload while laying a foundation for future development.

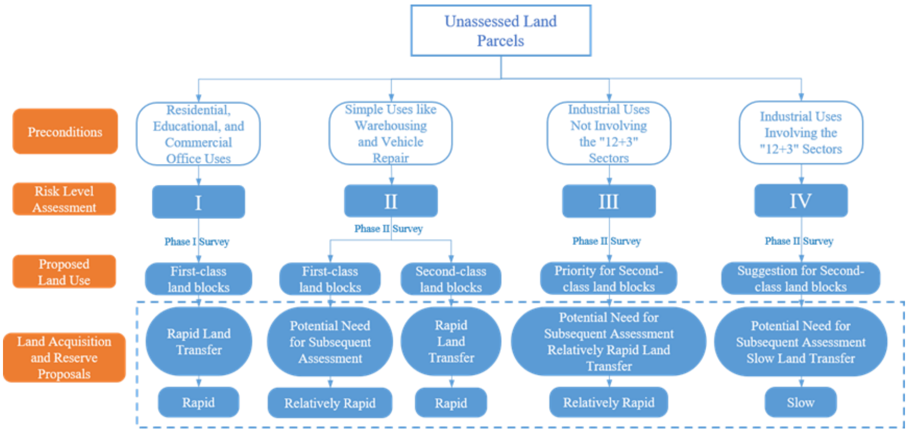

Fig.2 Technical roadmap for planning and storage suggestions for inefficient land parcels.

4.4 Suggestions for Transition Planning and Green Remediation of IIPR

Soil and groundwater pollution in central urban areas is characterized by significant contamination depth, complex pollutants, combined soil-water pollution, and high contaminant mobility. For sites with particularly complex pollution—especially those involving deep contamination and groundwater pollution that require a two-year monitoring cycle for IIPR—it is recommended to adopt the new "Environmental Remediation+" approach[23].

The 14th Five-Year Plan for Soil and Groundwater Pollution Prevention in Shanghai proposes that "pilot areas should explore the establishment of centralized soil disposal facilities and the 'Environmental Remediation + Development' model to mitigate conflicts between remediation cycles and development schedules, promote the resource-efficient utilization of soil, and support urban renewal and transformation." This policy framework establishes the feasibility of implementing the "Environmental Remediation+" approach in Shanghai.

In planning and design, the central urban area's high utilization of underground space adds a unique characteristic. The "Environmental Remediation+" model's core lies in integrating remediation efforts with development needs. This means that during the soil and groundwater remediation construction phase, underground engineering can also be considered simultaneously. Excavation only needs to be done once—once the remediation is complete, the land with excavation pits can be handed over to developers without the need for repeated excavation and refilling, thus avoiding the waste of financial and time resources.

Additionally, in the context of urban renewal and the efficient management of IIPR, planning should play a leading and coordinating role. Using the "Comprehensive Environmental Quality Map for IIPR" as a diagnostic tool, a "One Site, One Strategy" approach should be implemented for targeted actions. A holistic solution integrating "planning and design + environmental assessment + green remediation" should be developed for environmentally constrained IIPR (as shown in Figure 3), ensuring its rational planning and efficient reutilization.

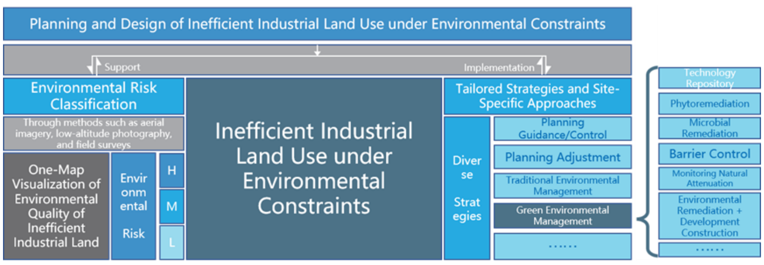

Fig.3 Roadmap for planning and design of IIPR with environmental constraints.

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5. Conclusions

Against the backdrop of urban renewal and the need to transform IIPL, this study focused on a central urban district of Shanghai, exploring the planning and green governance pathways for such land from an environmental constraint perspective.

Through sorting out related cases and policies, and analyzing the current situation of IIPL in the study area—including its types, historical uses, property rights, and spatial distribution—the study found a correlation between historical land use and soil environmental quality: plots with historical use in "15 categories" of industries had a high pollution exceedance rate (97%), while those used for residential, commercial office, or educational purposes showed no exceedance. Based on this correlation, a four-level risk assessment model for soil environmental quality of IIPL was constructed, dividing plots into four risk levels according to their historical uses. Correspondingly, differentiated technical routes for planning and land acquisition were formulated: for example, plots with lower risk levels could be planned as first-class construction land with faster circulation, while those with higher risk levels were more suitable for second-class construction land with slower circulation. In view of the characteristics of soil and groundwater pollution in the central urban area—such as deep pollution, complex pollutants, and combined soil and water pollution—the study proposed the "environmental remediation+" model for high-risk plots, which integrates pollution remediation with development and construction to reduce costs and time waste.

This study provides a reference for the environmental risk management and transformation planning of IIPL in central urban areas. To further enhance this approach, future research will incorporate additional case studies, broaden industry coverage, conduct deeper investigations into pollution sources, and refine risk classification methodologies. Expediting the formulation of detailed operational guidelines will facilitate a more diversified and precise approach to soil pollution control in the central urban areas.

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