

UNIVERSIDAD POLITÉCNICA DE MADRID

Escuela Técnica Superior de Arquitectura



**Research on ecological restoration of mine
wasteland to a healthy area
Xishan District of Taiyuan City case study**

DOCTORAL THESIS

Submitted for the degree of Doctor by:

Zhizhong Hong

Master of Engineering in Urban Planning

Madrid, 2024



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Doctoral Degree in "Sustainability and Urban Regeneration"

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Under the supervision of:

Dr. ESTER HIGUERAS GARCIA

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Title: Research on ecological restoration of mine wasteland to a healthy area Xishan District
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Abstract

In the 21st century, with the development of industrialization and urbanization, some large-scale mine wastelands located in peri-urban areas have become increasingly close to the center of urban areas and have a closer relation to the daily lives of urban and rural residents. In General, mining operations hurt the environment during mining activities and after mine closures, leading to problems such as surface damage, soil erosion, geological subsidence, and loss of biodiversity. However, the global healthy city movement has put forward higher requirements for the urban environment. How to carry out ecological restoration and reuse of polluted mining areas has become an issue of increasing concern to everyone. Many studies have studied the policies, methods, and measures of ecological restoration and reuse of mining areas. However, there are few studies about the healthy benefits of ecological restoration and transformation reuse in mining areas. From the perspective of a healthy city, this research takes the Xishan area in Taiyuan City, Shanxi Province, China, as a study case. The ecological restoration benefits on environmental health were quantified, and the reuse benefits on health, well-being, and services were analyzed. The specific content and innovation points are as follows:

First, comprehensive ecological restoration and management policies and measures that address the ecological environment and their implementation effects in the Xishan area were examined through on-site surveys and by collecting and comparing environmental data before and after mining industrial ecological management. The study shows that systematic ecological restoration, targeting all the main ecological elements, enabled significant improvements in the ecological environment of the atmosphere, water, soil, vegetation, biodiversity, etc..

Second, the regeneration and reuse construction methods of mining areas to meet the health needs of residents and the demands of healthy city construction and sustainable development have been studied through on-site surveys, construction data collection, and an open-ended web-based questionnaire focused on researching the perceived health needs of urban and rural residents in Taiyuan City concerning the main elements that determine health. The study shows that comprehensive reuse methods in such areas could better meet the health needs of residents. Furthermore, governments, enterprises, communities, and other stakeholders should consider the specific needs of residents in terms of health safety, health equity, health quality, and healthy low-carbon industries. The study also shows that a complete understanding of the health needs of residents holds excellent practical significance for improving the healthy environment and service supply construction and for promoting the development of regional healthy city construction.

In sum, this study shows that the healthy ecological restoration and management approach in mining areas could enhance the health benefits in the mining and

surrounding areas and was conducive to promoting the relevant city to meet the healthy city standards. This can provide more healthy facilities, spaces, and services for urban and rural residents and benefit urban constructions to meet the healthy city comprehensive standards. It can also constitute an effective means of transforming traditional mining cities into healthy and sustainable cities.

Resumen

En el siglo XXI, con el desarrollo de la industrialización y la urbanización, algunos p~~á~~amos mineros a gran escala ubicados en ~~á~~reas periurbanas se han acercado cada vez más al centro de las ~~á~~reas urbanas y tienen una relación más estrecha con la vida cotidiana de los residentes urbanos y rurales. En general, las operaciones mineras dañan el medio ambiente durante las actividades mineras y después del cierre de minas, lo que genera problemas como daños a la superficie, erosión del suelo, hundimiento geológico y p~~é~~rdida de biodiversidad. Sin embargo, el movimiento global de ciudades saludables ha planteado mayores requisitos para el entorno urbano. Cómo llevar a cabo la restauración ecológica y la reutilización de ~~á~~reas mineras contaminadas se ha convertido en una cuestión q ue preocupa cada vez más a todos. Muchos estudios han estudiado las polícas, m~~é~~odos y medidas de restauración ecológica y reutilización de ~~á~~reas mineras. Sin embargo, existen pocos estudios sobre los beneficios saludables de la restauración ecológica y la reutilización de la transformación en zonas mineras. Desde la perspectiva de una ciudad saludable, esta investigación toma como caso de estudio el ~~á~~rea de Xishan en la ciudad de Taiyuan, provincia de Shanxi, China. Se cuantificaron los beneficios de la restauración ecológica sobre la salud ambiental y se analizaron los beneficios de la reutilización sobre la salud, el bienestar y los servicios. Los contenidos esp~~e~~cíficos y los puntos de innovación son los siguientes:

En primer lugar, se examinaron polí cas y medidas integrales de restauración y gestión ecológica que abordan el entorno ecológico y sus efectos de implementación en el ~~á~~rea de Xishan mediante estudios in situ y recopilando y comparando datos ambientales antes y después de la gestión ecológic a industrial minera. El estudio muestra que la restauración ecológica sistemática, dirigida a todos los elementos ecológicos principales, permitió mejoras significativas en el entorno ecológico de la atmósfera, el agua, el suelo, la vegetación, la biodiver sidad, etc.

En segundo lugar, se han estudiado los m~~é~~odos de construcción de regeneración y reutilización de ~~á~~reas mineras para satisfacer las necesidades de salud de los residentes y las demandas de una construcción urbana saludable y un desarrollo soste nible a trav és de encuestas in situ, recopilación de datos de construcción y un cuestionario abierto basado en la web. Se centró en investigar las necesidades de salud percibidas por los residentes urbanos y rurales de la ciudad de Taiyuan en relación con los principales elementos que determinan la salud. El estudio muestra que los m~~é~~odos de reutilización integral en dichas ~~á~~reas podían satisfacer mejor las necesidades de salud de los residentes. Además, los gobiernos, las empresas, las comunidades y otra s partes interesadas deben considerar las necesidades esp~~e~~cíficas de los residentes en téminos de seguridad sanitaria, equidad sanitaria, calidad de la salud e industrias saludables con bajas emisiones de carbono. El estudio también muestra que una compre nsió n completa de las necesidades de salud de los residentes tiene una excelente importancia práctica

para mejorar el medio ambiente saludable y la construcción de suministro de servicios y para promover el desarrollo de la construcción de ciudades regionales saludables.

En resumen, este estudio muestra que el enfoque de gestión y restauración ecológica saludable en áreas mineras podrá mejorar los beneficios para la salud en la minería y las áreas circundantes y fue conducente a promover que la ciudad relevante cumpliera con los estándares de ciudad saludable. Esto puede proporcionar instalaciones, espacios y servicios más saludables para los residentes urbanos y rurales y beneficiar a las construcciones urbanas para que cumplan con los estándares integrales. También puede constituir un medio eficaz para transformar las ciudades mineras tradicionales en ciudades saludables y sostenibles.

Abbreviations and Acronyms

WHO	World Health Organization
AML	Abandoned Mine Lands
MSL	Mine-scarred Lands
GI	Green Infrastructure
UGS	Urban Green Spaces
RBC	Resource-based City
MRC	Mineral resource-based city
HIA	Health Impact Assessment
HP	Health Perception
HL	Health Literacy
HUP	Healthy urban planning
SDH	Social determinants of health
VKT	Vehicle Kilometres Travelled
QOL	Quality of Life
SDGs	Sustainable Development Goals
UN	United Nations
EU	European Union
EC	European Commission
US EPA	U.S. Environmental Protection Agency
EUNIS	European Environment Agency
APHA	American Public Health Association
ERDF	European Regional Development Fund
ESF	European Social Fund

Part 1 Introduction

1 Chapter1 Introduction

Human development and utilization of minerals can be traced back to ancient times. From the Stone Age to the Bronze Age, the Iron Age, the Steam Age, the Electric Age, the Atomic Age, and the Information Age, every scientific and technological change and civilization leap is inextricably linked to the excavation and utilization of minerals.

At the same time, the advancement of science and technology is accompanied by the development of cities. After the Industrial Revolution, the world entered a stage of rapid urbanization. From 1800 to the present, the world population has increased by six times, of which the world's urban population has increased by nearly 60 times (David Satterthwaite, 2007). With the advancement of global urbanization, human consumption of natural resources and energy in the past 100 years has reached an unprecedented level in human history, resulting in the deterioration of the global environment. The environmental problems of cities are no longer related to the city itself but involve the entire region, cross-border, and even international ecological degradation and improvement.

In the 20th century, concepts such as sustainable development, circular economy, ecological city, and healthy city have been gradually formed, which have gained worldwide consensus and have been practiced at various levels, such as regional development, urban planning, construction, and building construction. As the site and city of mining development and operation, how to realize its sustainable and healthy development has become an issue of increasing concern to all walks of life.

This chapter briefly introduces the background and question basis of the topic, presenting the reasons leading to the applicability and interest of this investigation. And the research questions, objectives, hypotheses, and explanations of the research methods and research framework are introduced.

1.1 Research Background

1.1.1 Statement of Problems

■ Global Mining Development and Pollution

A mine is “an excavation made in the earth to extract minerals.” Mining is “the activity, occupation, and industry concerned with the extraction of minerals” (Howard L Hartman & Jan M Mutmanský, 2002). Common natural minerals include metals, coal,

clay, gemstones, stone, potash, gravel, etc. In a broad sense, mining includes extracting non-renewable resources such as oil, natural gas, etc.

Human beings have a long history of mining minerals. Since the Paleolithic age, humans have mined stone, clay, and some metals. The oldest known mine in the archaeological record is the Ngweny hematite mine in Eswatini, which is 43,000 years old. Ancient Egyptians, Greeks, and Romans could already mine granite, sandstone, limestone, gypsum, malachite, gold, silver, copper, and other metal minerals. The mining industry in early medieval Europe mainly focused on mining precious metals such as copper and iron. In the 17th century, with the application of technologies such as water mills and gunpowder to mineral mining, the mining industry became more efficient and prosperous. In the middle of the 18th century, the Industrial Revolution first occurred in central England, where the rich shallow coal mines and iron ore were essential resources for the development of industrialization (CE Gregory, 2021; Martin Lynch, 2002).

With the Industrial Revolution and the development of mining technology, the mining industry in many European countries flourished. In the 19th century, the mining industry had been promoted and developed globally. The Americas and Oceania set off a "mining fever." One of the driving factors. In the 21st century, the technology of the global mining industry has become increasingly mature and modernized. The types of minerals have become increasingly affluent, and the global mining industry of large multinational companies has emerged. The global mining market grew from USD 2,022.6 billion in 2022 to USD 2,145.15 billion in 2023 at a compound annual growth rate (CAGR) of 6.1%. Asia Pacific was the largest mining market region in 2022, North America is the second largest, and the mining market covers Western Europe, Eastern Europe, South America, the Middle East, and Africa (R. Anthony Hodge et al., 2022).

Mining operations hurt the environment, both during mining activities and after mine closures. Mining may lead to problems such as surface damage, soil erosion, geological subsidence, and biodiversity loss. Chemical substances emitted during mining may pollute the atmosphere, soil, groundwater, and surface water and increase carbon emissions. Most countries have passed regulations to reduce impacts, such as requiring ecological restoration of mines. With the United Nations' "carbon neutrality" and other goals, building a low-carbon society has become an internationally recognized development goal (Edwin Woerdman et al., 2021). Traditional mining methods, the mining industry, and even mining cities face significant challenges nowadays. Therefore, reducing the environmental pollution and health risks brought by the mining industry and carrying out ecological restoration and reuse of mines have become important issues facing the sustainable development of the global mining industry and mining cities. (R. Anthony Hodge et al., 2022)

■ Healthy City Development and Environmental Health

The Toronto Healthy Cities Project has been operated since the early 1980s, and the work by Duhl and colleagues inspired the development of Healthy City Program of World Health Organization (WHO). Motivated further by the Ottawa Charter on Health

Promotion to create supportive environments, strengthen community actions, develop personal skills, reorient health services, and build healthy public policies to promote population health, the Healthy Cities movement has gained an international foothold since its inception in 1986. By World Health Day 1996, which adopted the theme "Healthy Cities for a Better Life," some 3000 cities worldwide were linked to the international Healthy Cities network in some way or another (Marina Kenzer, 1999).

In 2000, WHO announced the launch of the National Health Promotion Plan at the Mexico City Conference, requiring global health policies and projects to put health first, strive to narrow the equity gap, and promote health promotion in developing countries, marking a new stage of international cooperation in health promotion. Since then, the results of the conferences involving many countries, such as the "Bangkok Charter," "Nairobi Initiative," "Helsinki Declaration," and "Shanghai Consensus," have all made health promotion the top priority. At this stage, international cooperation in healthy city construction and research is constantly emerging, and countries have accumulated rich theoretical and practical experience (Evelyn De Leeuw & Jean Simos, 2017).

In the 21st century, more than half of the world's population lives in urban areas. During this time, urbanization should also be beneficial for health. Economic and industrial development accelerates urbanization and creates opportunities for better housing and living conditions, access to safe water and good sanitation, efficient waste management systems, more employment opportunities, and access to health and community services and recreational facilities, just a few potential benefits of urbanization. However, unplanned and uncontrolled urbanization that occurs too rapidly can strain services, damage the environment and health, and exacerbate poverty and inequality. Urban environmental problems such as environmental pollution, ecological damage, and improper construction have seriously threatened urban residents' physical and mental health. Protecting people's health in the process of economic development and urbanization is an urgent concern for global urban development (Christopher Auffrey, 2024; Evelyn De Leeuw & Jean Simos, 2017; Abbas Ziafati Bafarasat & Ayyoob Sharifi, 2024).

■ Transformation and Regeneration of Mining Cities

The industrial revolution that started in the middle and late 18th century resulted in the emergence of a large number of resource-based cities in some countries. The rise of a large number of resource-based cities has contributed greatly to the realization of industrialization in Western countries. However, since the 1950s and 1960s, due to the depletion of mineral resource reserves due to long-term mining, resource-based cities gradually began to face the problems of resource depletion and damage to existing resource industries. The issue of urban transformation has become increasingly prominent.

As the resource exploitation of traditional mining cities enters the decline stage, the transformation of resource-based cities is an inevitable problem. Theories such as sustainable development, circular economy, ecological city, and healthy city provide a theoretical basis for transforming and developing such cities and adjusting industrial

structure in the new era. In the process of urban transformation and development, industrial regeneration, development of alternative industries, improvement of the ecological environment of the original mining city, and improvement of the health and welfare of urban residents are the paths many mining cities adopt (Cristina Martinez-Fernandez et al., 2012; Xiangyan Qian et al., 2021).

1.1.2 Justification of the Research

■ Exploring the Paths of Ecological Restoration to Improve the Ecological Environment and Healthy Quality of Mine Wasteland Areas

From the beginning of the 20th century, many countries began to work on the ecological restoration of abandoned mines. At first, the ecological restoration theory of abandoned mines mainly came from the development of restoration ecology. The concept of ecological restoration usually refers to the practice of renewing and returning a degraded, damaged or destroyed ecosystem to its original (prior to disturbance) condition (Nimisha Tripathi et al., 2016). The research on the ecological restoration of abandoned mines has gradually expanded to land reclamation, vegetation restoration, solid waste reuse, acid mine drainage, heavy metal removal, industrial heritage reuse, traditional industry transformation, and so on. Regarding the construction of laws and policies, developed countries such as Britain, the United States, and Australia have formulated relevant laws and regulations, as well as governance measures, for the ecological restoration of mine wasteland and have achieved good results (JA Cooke & MS Johnson, 2002; Markus Gastauer et al., 2018).

Many researchers have studied the policies, methods, and measures of ecological restoration of mine abandoned land. However, from the perspective of a healthy city, few studies have focused on improving the environmental health quality and health services of the areas where the mine abandonment sites are located (Wenxin Mao et al., 2021).

■ Contributing to Better Health Well-being and Services through Mine Wasteland Areas Reuse Construction

In the 21st century, with the rapidly growing urbanization process, some mine wastelands that were initially far away from built-up areas have gradually become peri-urban sites close to or even adjacent to built-up areas due to the continuing expansion of many urban built-up areas. Due to the large area involved in such abandoned mine land, the area often includes towns, villages, and industrial and mining construction components (Min Zhang et al., 2019). With the continuous growth of the population and the scale of construction land in the peri-urban area of cities (Douglas Webster, 2002), regional functions are continuously enhanced (Thomas Sieverts, 2003).

The restoration and construction of large-scale abandoned mines are increasingly closely related to the lives of urban and rural residents and have received increasing

attention from all walks of life with regard to, for example, ecological restoration, reuse construction (Suiling Wang & Catherine N Mulligan, 2009), landscape restoration (Sabine Tischew & Antje Lorenz, 2005), residents' health (P Coelho et al., 2007; Jianhua Wu et al., 2019), public participation (Xiuli Wang et al., 2023; Xiaolu Wu et al., 2021) and other aspects that have been studied to some extent.

The goal of mine wasteland revitalization has not only been limited to pollution control and ecological environment restoration itself. How to properly use the destroyed land and highly changed the landscape, how to restore the productivity of land, protect the history of the mining area, promote economic development, coordinate the contradiction between mining and land use, and adapt to the development goals of mining area and city have become the focus of attention of all parties, and continue to apply, summarize and promote in practice all over the world.

However, at present, there are not many studies on promoting better health, well-being, and services in the region through the reuse and construction of the mine wasteland area for citizens and visitors.

1.2 Research questions, objective and hypothesis

1.2.1 Research questions

The main research questions of this study revolve around the ecological restoration and reuse of mining areas and health, primarily based on the main case study. The main research questions carried out are as follows:

- How can we achieve healthier ecological and environmental benefits and services in mining areas through healthy and sustainable mine ecological restoration and management methods with practical implications for the mining industry and environmental policy?
- How can urban and rural residents achieve healthier well-being and social benefits in mining areas through healthy and sustainable mine reuse construction methods?

1.2.2 Objective

This research will study the ecological restoration and healthier transformation benefits of urban and regional mine wasteland restoration. The main objectives of the research carried out include the following points.

- Objective 1: Quantify the ecological restoration benefits on air, water, soil, and the ecological services of the healthy mine wasteland restoration to people.
- Objective 2: Analyze the healthier benefits of the reuse of the restored mine wasteland to inhabitants, such as less respiratory diseases, a more active lifestyle, and well-being.
- Objective 3: The definition and conceptualization of important terms regarding

urban health, which should be considered by practitioners when restoring degraded areas in general.

- Objective 4: Collecting good practices and possibilities to restore abandoned mine areas with ecological and social benefits. This is carried out through a bibliographical review and includes real cases worldwide.
- Objective 5: To develop a qualitative and quantitative approach able to measure the health benefits of the reuse of mine wastelands (which is applied to a concrete case study). This procedure (adequately justified and described) may be used for the analysis of other case studies.
- Objective 6: To explore citizens' opinions of and perceptions about these types of actions (in the case study of analysis).

1.2.3 Hypothesis

Carrying out the ecological restoration and reuse development of mine wasteland with the concept of a healthy city can provide more than twice the ecological and healthier benefits for the territory of the previous situation.

■ The Hypothesis of Ecological Restoration of Abandoned Mine Land Based on the Perspective of Healthy City

Referring to the standards and requirements of a healthy city for the ecological environment, the comprehensive restoration of the complex ecosystem of all elements such as mountains, water bodies, soil, vegetation, and atmosphere on the abandoned mine land can promote the re-naturalization of the site ecosystem and reduce the impact of pollutants on the ecological environment. The mutual transmission of elements promotes the overall improvement and stability of the ecological functions and quality of ecological elements and helps the ecological restoration of the site to meet the relevant environmental quality standards of a healthy city. The environmental quality and ecological service functions of the site will be comprehensively improved, and compared with before the ecological restoration, it can produce more than twice the ecological and environmental health benefits. Specifically include:

The hypothesis on the improvement of site environmental quality and health benefits: The ecological restoration of mine wasteland in accordance with the ecological environment quality standard of a healthy city will significantly improve the air, water, soil, and other healthy environmental quality of the site. In this paper, through the collection and analysis of environmental quality data before and after the ecological restoration of the study case and the comparison of health benefits assessment, it is confirmed that the restored site can produce more than twice the ecological environmental health benefits. For example, reduce the health risks of residents by more than two times due to exposure to air and water pollutants.

The hypothesis on improving the health benefits of site ecological service functions: Referring to the requirements of healthy cities for urban ecosystems, ecological

restoration of mine wasteland will significantly enhance the health benefits of site ecological service functions. This paper intends to collect and judge the site's main ecological service function elements before and after the ecological restoration and evaluate and prove that the restored site can produce more than twice the health benefits of ecological services. If the ecological service function of the site vegetation is restored, it can produce more than twice the health benefits.

■ The Hypothesis of Mine Abandoned Land Reuse Construction Based on the Perspective of Healthy City

By the construction standards for healthy cities, this study adopts a health-centric approach to guide the economic and industrial development of mining areas and the reuse constructions. These measures aim to significantly enhance the functionality of these areas, potentially generating more than double the health service benefits compared to their pre-transformation state.

The hypothesis on improving the health benefits of the site economy industry: Regarding the demands of healthy cities for the development of urban economic sectors, selecting regional healthy industries and guiding economic development will significantly improve the health benefits of regional economic industries. This paper intends to collect and judge the regional healthy economic industry development data before and after the reuse construction and prove that the regional economic industry can produce more than twice the health benefits compared to their pre-transformation state through healthy construction.

The hypothesis on improving the health benefits of site life service functions: Referring to the requirements of healthy cities for the construction of physical space such as land use, transportation systems, green infrastructure, and public service facilities, the reuse construction will significantly improve the health benefits of site life service functions and better meet the health requirements of urban and rural areas. This paper intends to collect and judge the construction data of site living service facilities before and after reuse and conduct a questionnaire survey on the health needs of local residents to prove that through healthy construction and transformation, regional life service functions can produce more than twice the health benefits.

The hypothesis on improving the health benefits of site life service functions: As referring to the requirements of healthy cities for the construction of physical environments such as land use, transportation systems, green infrastructure, and public service facilities, this study concerns that the reuse construction will significantly improve the health benefits of site life service functions and better meet the health requirements of urban and rural areas. This study intends to collect and judge the construction data of site living service facilities before and after the reuse construction and conduct a questionnaire survey on the health needs of residents to conduct an approach that through healthy construction and transformation, regional life service functions can produce more than twice the health benefits.

2 Chapter2 Methodology

2.1 Research methodology

This study is interdisciplinary research that mainly focuses on the regeneration of mining areas from a healthy city perspective, combining environmental ecology, mineral science, healthy city, and urban planning, and attaches great importance to the conceptualization, association, and integration of multi-disciplinary research theories, policies, guidance, strategies, measures and technologies, and followed by quantitative and qualitative analyses of the chosen cases. The thesis is divided into three parts: the fundamental research, method and empirical research, and the main case study, expecting to explore the successful path of healthy ecological restoration and transformation in mining areas.

2.1.1 Fundamental research

The first part is the basic research, including research background and problems, research purpose and significance, conceptualization, research methods and technical routes, theoretical basis, and literature review.

Conduct a review of the basic concepts of health, medicine, sociology, and psychology principles and summarize the urban environmental conditions required for physical, psychological, and social adaptation to health.

A literature review is conducted on the basic concepts, goals and visions, standards and specifications, fundamental theories, development history, and global successful construction cases of healthy cities and their planning and construction, and the basic requirements, models, methods, and paths of healthy city planning and construction are summarized.

Conduct comparative studies on health-related urban planning theories such as eco-city, resilient city, smart city, smart growth, urban renewal, and sustainable development, sort out the health concepts in related theories, and summarize the models and methods of healthy urban planning.

Conduct a comprehensive study on the construction requirements and models of the elements of a healthy city, such as the ecological environment, land use, road traffic, and public service facilities, and analyze the impact and role of urban physical space elements on public health of citizens, and how to pass healthy cities construction and development, improving the public health level of citizens, and promoting the development of urban public health.

2.1.2 Strategies, measures and practical research

The second part is the study of policy strategies, restoration measures, technical supports, and regeneration practical research. Based on the perspective of the healthy city, systematic research is conducted on the ecological restoration and reuse planning and construction in the mining areas. It includes a review study on the main distribution, types, and hazards of mining areas worldwide, a collection and summarization of relevant public policies, laws, regulations, indicators of ecological environment, planning and construction index data, and scientific and technical support in mining areas.

This study selected representative cases of ecological restoration and reuse construction in mining areas, summarized and analyzed their models, and evaluated the different health benefits they can produce. By inductively summarizing the best models and methods for ecological restoration and reuse construction in mining areas according to the standards for healthy cities, this research aims to identify optimal practices. Additionally, the role of mining area regeneration in promoting urban public health during the renewal and redevelopment of traditional mining cities is thoroughly examined.

2.1.3 Main case study

The third part is the main case study, taking Xishan, Taiyuan City, Shanxi Province, China as an example. The main research contents include research on ecological restoration and the health benefits of the main case and research on the health benefits of reuse construction through data collection, quantitative and qualitative analyses, and in addition, on-site surveys on the public health perception of urban and rural residents are carried out and treated with the statistical program SPSS.

Our research focuses on the ecological restoration and its health benefits of the primary case study. We have collected and organized environmental quality data from the site before and after the ecological restoration, including air, water, and soil metrics. Using relevant WHO environmental and pollutant indicators, we conduct a comparative evaluation and analysis of the site's environmental and health conditions pre- and post-restoration. Additionally, we have collected data on the ecological services provided by elements such as forests, farmland, and grasslands within the site before and after the restoration and evaluated and analyzed the improved health benefits resulting from the restoration of the ecological environment.

This research also examines the health benefits associated with the reuse construction of the primary case study. We have collected and compared data on healthy economic industries in the region before and after the reuse construction, conducting a comparative evaluation and analysis of related health economic benefits. Additionally, we have gathered construction data on land use, transportation, public health services, leisure and tourism facilities, and other public services in pre- and post-reuse construction areas. This comprehensive research also includes a health benefits

assessment and a health demand questionnaire from residents, which help to evaluate the health benefit improvement of the mine area reuse constructions.

2.2 Research methods

The research methods for this paper include literature collection and analysis, a comparative study of representative cases, official social and economic data, public network data, environmental governance data collection and analysis, questionnaire surveys, and mathematical statistics. Additionally, this study analyzes the health effects of ecological restoration and reuse construction in post-mining areas based on health impact assessments (HIA).

This study collects relevant theoretical literature on mine wasteland ecological restoration, reuse, and mining city urban transformation in theories, legislation, policies, measures, and cases. It collects and analyzes healthy city policies and urban planning theories, methods, and measures. The theoretical study also covers the relative urban planning concepts and ideas such as urban landscape ecology, sustainable development, resilient cities, smart growth, and green infrastructure. The aim is to summarize and analyze the frontier theories in these areas.

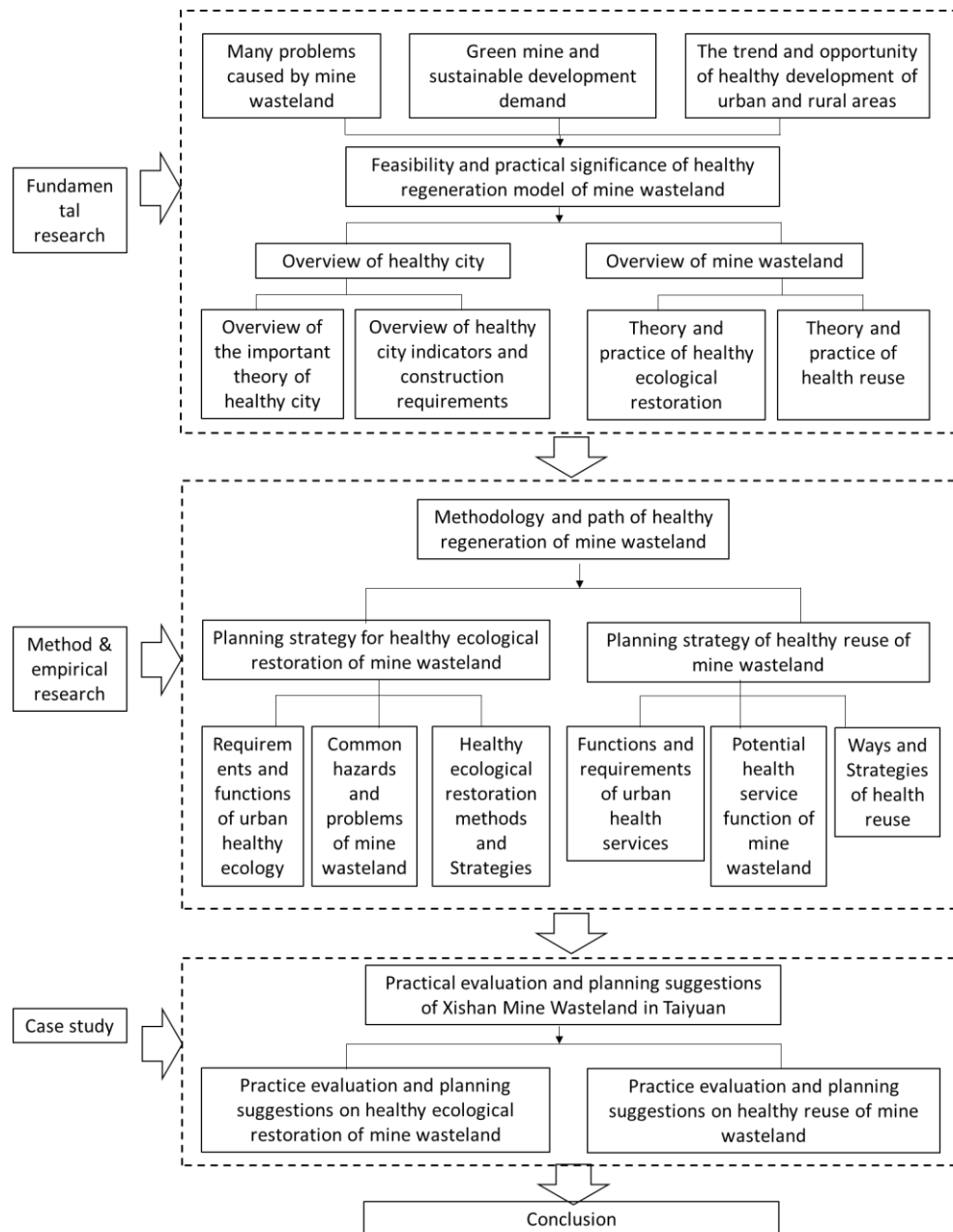
The presentative post-mining city and area case study collects successful ecological restoration and reuse cases of post-mining areas and cities worldwide from a healthy city perspective. These cases are compared and evaluated based on their public health benefits, ecological restoration and reuse measures and policies, practical outcomes, urban planning methods, and strategies related to healthy urban planning.

The primary case study collects mining city urban transformation data, such as the official public data on the ecological environment, socio-economy, and healthy urban construction. The environmental data of the post-mining areas, including air, water, soil ecological quality, and land use changes before and after the mine restoration and reuse construction, are collected through official social and economic data channels and online data sources. Additional critical environmental data, such as remote sensing images, enterprise information, ecological restoration technologies used in the mining areas, and social, economic, and urban construction data, are also collected, analyzed, and evaluated. According to the World Health Organization (WHO) and China's national regulations on physical environmental pollution-related indicators, this study compares and analyzes the health effects of the relevant environmental pollution data before and after ecological treatment. And the results are evaluated based on health impact assessments (HIA) as well.

For the main study case, on-site interviews and an internet questionnaire survey are conducted to gather public health perceptions from urban and rural residents. Advanced mathematical statistics are performed using SPSS software to compare and analyze the collected data on the health services benefits and well-being of residents related to the ecological restoration and reuse of mine wastelands.

Finally, the benefits and effects of ecological restoration and reuse measures and policies are analyzed, assessed, and summarized from the healthy city perspective.

2.3 Research ideas and framework



3 Chapter3 Healthy City and its Construction and Development

Health is one of the primary goals pursued by human beings for survival and development, and it is an everlasting subject of human society. Since the emergence of cities in human civilization, the requirements of human culture for a healthy urban environment and healthy urban planning and construction have shown an increasing trend. With the development of the Industrial Revolution, human civilization has gradually entered modern society, and the wave of global urbanization and industrialization has led to the destruction and deterioration of the urban environment. However, at the same time, the growing urban economic level, science and technology, and successful planning and construction experience have also created good opportunities for promoting high-quality, sustainable, and healthy urbanization in the new era. Among them, the research on the theory and practice of healthy city planning and construction is one of the critical research fields of urbanization in the new era.

Since this research is aimed at the healthy ecological restoration and reuse of large-scale urban mine wastelands, which cover a large area and even include multiple towns and villages, the research on such mine wastelands should focus on Relevant research and theory at the urban scale.

This chapter summarizes the definition of health and human society's basic needs for health. It also summarizes a literature review on the planning theory and practice of healthy cities, including the basic concepts, components, construction measures, public policies, development paths, successful experiences of healthy cities, and the benefits of healthy city construction for human development.

3.1 Basic Concept Analysis

This chapter concerns the basic concepts of health, public health, health needs, healthy city, health impact assessment, and health perception.

3.1.1 Health, Public Health and Health Needs

(1) Health

■ WHO definition

Definition of health from WHO Constitution (1948): The widely accepted definition of health is that given by the World Health Organization (WHO) constitution, which states: "Health is a state of complete physical, mental and social well-being, not merely the absence of disease or infirmity" (WHO, 1948).

This statement has been amplified by "the ability to lead a socially and economically productive life". (Halldan Mahler, 1981)

Three important points can be drawn from the WHO definition(John R Kemm & Ann

Close, 1995):

- There is a lot more to being healthy than just being in good physical shape. We also have to think of mental and social functions.
- The absence of disease and infirmity is a necessary feature of health.
- Health requires the presence of various features which are referred to as positive health.

Operational definition of health (1957) : To enable direct measurement, the WHO study group has provided the operational definition as “a condition or quality of the human organism expressing the adequate functioning of the organism in a given condition, genetic or environmental” in a broad sense, and “no obvious evidence of disease, organs of the body are functioning adequately in themselves and in relation to one another implying a kind of equilibrium or homeostasis.” in a narrow sense (World Health Organization, 1957).

■ Changing conceptions of health

Understanding the evolving concepts of health is crucial for all communities around the world. In some ancient cultures, such as the ancient Indians, Greeks, and Chinese, health meant equilibrium and harmony, and disease was attributed to disturbances in bodily equilibrium. The concept of health has evolved with the continuous changing of the world over the centuries. In the 20th century, with the development of modern medicine and public health, health has gradually become a fundamental human right, and it is essential to the satisfaction of basic human needs. Some of the changing concepts of health are given below (John Everett Park, 1970).

The biomedical concept, which defines health as the "absence of disease" based on the "germ theory of disease," has been a subject of intense critique. This narrow view of health, which disregards the influence of environmental, social, psychological, and cultural factors, challenges us to think critically about our understanding of health (Paul I Ahmed et al., 1979).

Ecological Concept: health is a dynamic equilibrium between man and his environment, and disease is a maladjustment of the human organism to the environment (RenéJules Dubos, 1980) .

Psychosocial Concept: health is not only a biomedical phenomenon but also one that is influenced by social, psychological, cultural, economic, and political factors of the people concerned. By that means, health is both a biological and social phenomenon (World Health Organization, 1987).

Holistic concept: health is an integrated or multidimensional process involving the well-being of the whole person in the context of his environment, and all sectors of society have an effect on health, in particular, agriculture, animal husbandry, food, industry, education, housing, public works, communications, and other sectors (Jake Epp, 1986; World Health Organization, 2003).

Dynamic concept: "To reach a state of complete physical, mental and social well-being, an individual or group must be able to identify and to realize aspirations, to satisfy needs, and to change or cope with the environment." WHO provides a dynamic

concept in the Ottawa Charter (1986) that health is "seen as a resource for everyday life, not the objective of living. Health is a positive concept emphasizing social and personal resources and physical capacities". This concept is used for health promotion. (World Health Organization, 1986)

Positive concept: Positive physical health includes various aspects of fitness, such as strength, stamina, suppleness, and speed. Positive mental health includes happiness, self-esteem, solving problems, adapting to mental stresses, etc. Positive social health comprises, for example, having a role in society and being able to form social links (John R Kemm & Ann Close, 1995).

The concepts of health have changed and developed over time. They gradually moved from "the absence of disease" to broader factors, such as physiological, psychological, social, economic, and environmental factors. Their implications changed from narrow and essential to broad, positive, and dynamic. Health is also a fundamental human right and the essence of productive life. (John Everett Park, 1970)

(2) Public Health

■ Definitions of public health

In 1920, "public health" was defined by C.E.A. Winslow, a leading figure in the history of public health, as "the science and the art of preventing disease, prolonging life, and promoting physical health and efficiency through organized community efforts for the sanitation of the environment, the control of communicable infections, the education of the individual in principles of personal hygiene, the organization of medical and nursing services for the early diagnosis and preventive treatment of disease, and the development of the social machinery which will ensure every individual in the community a standard of living adequate for the maintenance of health." (C-EA Winslow, 1920) This definition was later accepted by the World Health Organization in 1952 (Donald Acheson, 1988).

Nowadays, The American Public Health Association (APHA) defines public health as "the practice of preventing disease and promoting good health within groups of people, from small communities to entire countries." APHA further states it includes health professionals from many fields working together with the common purpose of protecting the health of the population (American Public Health Association, 2008).

■ Health Promotion

According to WHO: "Health promotion is the process of enabling people to increase control over, and to improve their health." (World Health Organization, 1986)

Therefore, health promotion is not just the health sector's responsibility; it goes beyond healthy lifestyles to well-being. The fundamental conditions and resources for health are peace, shelter, education, food, income, a stable ecosystem, sustainable resources, social justice, and equity (World Health Organization, 1986, 2021a). "It

moves beyond a focus on individual behavior towards a wide range of social and environmental interventions." "This is accomplished by building healthy public policies, creating supportive environments, and strengthening community action and personal skills." The emphasis of health promotion is on: "Strengthening health promotion capacity (financing and infrastructure); promoting urban health (including healthy cities and health equity through Urban HEART); Building other healthy settings (including schools and workplaces) and healthy islands; and developing health literacy." (WHO, 2023b)

In essence, health promotion encompasses all activities aimed at preventing disease and promoting well-being in the community. These activities include making the environment safe, individual protection, health education, facilitating healthy choices, protection against anti-health factors, and early detection of health problems when they are still reversible. (John R Kemm & Ann Close, 1995)

3.1.2 Healthy city

(1) Definitions of Healthy City

The World Health Organization (WHO) defines "A healthy city is one that continually creates and improves its physical and social environments and expands the community resources that enable people to mutually support each other in performing all the functions of life and developing to their maximum potential" (WHO, 2023d).

"A healthy city is one that puts health, social well-being, equity and sustainable development at the center of local policies, strategies and programs based on core values of the right to health and well-being, peace, social justice, gender equality, solidarity, social inclusion and sustainable development and guided by the principles of health for all, universal health coverage, intersectoral governance for health, health-in-all-policies, community participation, social cohesion and innovation". (World Health Organization, 2020a)

A Healthy City commits to achieving better physical and social environments. Any city can start the process of becoming a Healthy City if it is committed to developing and maintaining physical and social environments that support and promote better health and quality of life for residents. Building health considerations into urban development and management is crucial for Healthy Cities (Abbas Ziafati Bafarasat & Ayyoob Sharifi, 2024).

Key features of a Healthy Cities project include high political commitment, intersectoral collaboration, community participation, integration of activities in elemental settings, development of a city health profile and a local action plan, periodic monitoring and evaluation, participatory research and analyses, information sharing, involvement of the media, incorporation of views from all groups within the community, mechanisms for sustainability, linkage with community development and human development, and national and international networking (World Health Organization, 2000).

(2) Relative Terms of Healthy City

■ Environmental Health

Definition from the UK Government: Those aspects of human health, including quality of life that are determined by physical, biological, social and psychosocial factors in the environment. It also refers to the theory and practice of assessing, correcting, controlling and preventing those factors in the environment that can potentially affect adversely the health of present and future generations (Department of the Environment and the Department of Health, 1996).

■ Urban health

According to descriptions of WHO: “Two thirds of the population of the European Region live in towns and cities. Urban areas are often unhealthy places to live, characterized by heavy traffic, pollution, noise, violence and social isolation for elderly people and young families. People in towns and cities experience increased rates of non communicable disease, injuries, and alcohol and substance abuse, with the poor typically exposed to the worst environments. However, there are ways to tackle these challenges”.

“Where people live affects their health and chances of leading flourishing lives. Communities and neighborhoods that ensure access to basic goods, that are socially cohesive, that are designed to promote good physical and psychological wellbeing, and that are protective of the natural environment are essential for health equity.” (WHO, 2023c)

3.1.3 Health impact assessment (HIA)

A widely accepted definition of Health Impact Assessment (HIA) is published in the Gothenburg Consensus Paper as “a combination of procedures, methods, and tools by which a policy, a program or project may be judged as to its potential effects on the health of a population and the distribution of effects within the population” (WHO European Centre for Health Policy, 1999). And HIA is described by World Health Organization (WHO) as “a practical approach used to judge the potential health effects of a policy, program or project on a population, particularly on vulnerable or disadvantaged groups” (WHO, 2023a). Other definitions of HIA are shown below (Table 1).

Table 1 Definitions of HIA

Year	Author/ Publisher	Definitions
1998	Scott Samuel	“Health impact assessment is the estimation of the effects of a specified action on the health of a defined population” (Alex Scott-Samuel, 1998).
1999	Scottish Office	“Health impact assessment is a method of evaluating the likely effects of policies, initiatives and activities on health at a population level and helping to develop recommendations to maximize health gain and minimize health risks. It offers a framework within which to consider, and influence the broad determinants of health”(Scottish Office Department of Health, 1999).
2000	Karen Lock	“Health impact assessment is a multidisciplinary process within which a range of evidence about the health effects of a proposal is considered in a structured framework.” “A health impact assessment is based on a broad model of health which proposes that economic, political, social, psychological, and environmental factors determine population health.”(Karen Lock, 2000)
2006	Ministry of Social Affairs and Health, Finland	“Health impact assessment is an approach, which supports policy-makers by predicting the consequences and clarifying the various trade-offs that have to be made.”(John Kemm, 2006)
2009	IFC	“An HIA is a combination of procedures, methods, and tools to assess the potential health impacts of a project on nearby populations, and to recommend mitigation measures. HIA addresses both negative and positive aspects of health. HIA will also try to identify benefits to health that may be enhanced.”(IFC (International Finance Corporation), 2009)
2011	National Research Council (U.S.)	“HIA is a systematic process that uses an array of data sources and analytic methods and considers input from stakeholders to determine the potential effects of a proposed policy, plan, program, or project on the health of a population and the distribution of those effects within the population. HIA provides recommendations on monitoring and managing those effects.”(National Research Council, 2011)
2011	Rajiv Bhatia	“Health impact assessment, or HIA, is a structured decision support practice to characterize the anticipated health effects, both adverse and beneficial, of societal decisions. Decisions subject to HIA may include projects, plans, programs, and policies undertaken by government or the private sector.”(Rajiv Bhatia, 2011)
2012	John Kemm	“HIA has two essential features: It seeks to predict the future consequences for health of possible decisions”; “It seeks to inform decision making” (John Kemm, 2012).
2013	British Medical Associatio n (BMA)	Health impact assessment is “a methodology which enables the identification, prediction and evaluation of the likely changes in health risk, both positive and negative, (single or Collective), of a policy, program plan or development action on a defined population. These changes may be direct and immediate or indirect and delayed.”(British Medical Association, 2013).
2013	Martin Birley	“Health impact assessment (HIA) is an instrument for preparing justified recommendations for the management of the future health impacts of proposals. The proposals may be policies, plans, programs or projects. HIA is primarily used before the proposal is activated and examines both positive and negative consequences. The intention of HIA is to make recommendations supported by evidence that modify the proposal in order to safeguard and enhance population health.” (Martin Birley, 2013)
2021	IAIA	“Health impact assessment (HIA) is a process which systematically judges the potential, and sometimes unintended, effects of a project, program, plan, policy, or strategy on the health of a population and the distribution of those effects within the population.” (Mirko & Viliani Winkler, Francesca & Knoblauch, Astrid & Cave, Ben & Divall, Mark & Ramesh, Geetha & Harris-Roxas, Ben & Furu, Peter., 2021)

Source: Author’s own complication

Although there are many definitions of HIA, several vital features corresponding to healthy city areas among most of those definitions are as follows (Catherine L Ross et al., 2014):

- The primary purpose of HIA is to inform decision-making.
- HIA is to judge the potential health effects and distribute the health of a population.

The main purpose of HIA is to inform decision-making and present information during the decision-making process. Informing a decision is one key feature that distinguishes HIA from academic health research (Catherine L Ross et al., 2014). It draws on cost–benefit analysis, ecology, biological sciences, epidemiology, toxicology, risk assessment, and increasingly sociological disciplines (Jürg Utzinger, 2004) .

HIA is to judge the potential health effects and distribute the health of a population. Health impacts include changes in biomedical health outcomes (such as injury and disease rates), mental well-being, and health determinants. The HIA will identify potential positive or beneficial health benefits stemming from the policies and possible negative or adverse effects (Catherine L Ross et al., 2014).

3.1.4 Health Perception

(1) Health Perception

Health perception (HP) refers to the perception of a person's health in general, either by the person or, in the case of proxy response, by the person responding (Arnout De Bruin, 1996). HP concerns an individual's personal beliefs and statements regarding their health status. It is a subjective term and a strong indicator that reflects an individual's physical, mental, and social well-being state of an individual (Teresa S. Souto et al., 2018). HP affects the health-seeking behaviors and health responsibility of individuals (Dorota Kaleta et al., 2009). HP is also associated with health literacy (HL), as it is known to increase as HL increases (Say Şahin Deniz et al., 2018).

Health literacy: the concept of health literacy (HL) is closely linked to conventional literacy and requires knowledge, motivation and competence needed to access, understand, evaluate and use the necessary health information in order for individuals to make health decisions in their daily lives, enhance and maintain their quality of life and to prevent disease (Kristine Sørensen et al., 2012) .

Health needs: Health needs are comprehensive and encompass various aspects of health. A simple explanation of "health needs" is people's desire to maintain health (Lijana Zaletel-Kragelj et al., 2008). Health needs refer not only to what people can benefit from the healthcare system but also to broader social and environmental factors such as ecology, housing, food, exercise, education, employment, etc. (John Wright et al., 1998).

Psychological comfort: The Oxford English Dictionary (1989) defines comfort related to psychological area as relief or support in psychological distress or affliction. Comfort corresponds to everything contributing to the well-being and convenience of

the material aspects of life. It describes some well-being experienced by the individual and an item of furniture satisfying objective evaluation criteria can be used with pleasure (Claude Pineau, 2008).

Bioclimatic comfort: People are relaxed (satisfied or well-off) in what is described as comfortable climatic conditions (Mehmet Cetin et al., 2018). Bio comfort is limiting values in which people feel comfortable in environmental conditions such as wind, humidity, temperature, and precipitation (Fatih Adiguzel et al., 2020; Mehmet Cetin, 2019).

(2) Equity of health perception

Health perception and bioclimatic comfort varies based on personal characteristics like gender and age (Michelle Rutty & Daniel Scott, 2015). For example, women showed a stronger adverse reaction to high wind speed than men (Henrique Andrade et al., 2011; Sandra Oliveira & Henrique Andrade, 2007). A difference in thermal comfort was indicated between genders (Nobuko Hashiguchi et al., 2010). Mental comfort perception is different between males and females (MHF). Ellaway and Macintyre (2001) found a stronger association between perceptions of neighborhood social cohesion and mental health in men than in women, whereas local neighborhood problems (ranging from lack of facilities to physical features such as fumes) were more strongly related to physical health amongst women than amongst men (Anne Ellaway et al., 2001).

3.2 Theoretical Framework: Healthy Urban Planning

3.2.1 A Brief History of Healthy Urban Planning

Throughout history, many ancient societies realized there were connections between health and environmental sanitation, personal hygiene, prevention, and nutrition. For instance, the ancient Chinese, Egyptian, Indian, Greek, and Roman societies all in some ways provided sanitary amenities and took measures to improve the physical environment (sanitation), control transmissible disease, and provide drinking water, sewerage, and drainage systems (George Rosen, 2015; Theodore H Tulchinsky & Elena A Varavikova, 2014).

In the 19th century, the Industrial Revolution promoted the rapid development of industrialization and urbanization and brought a series of urban environmental pollution and public health problems. Modern urban planning has a profound origin in public health, while public health was primarily a matter of sanitary legislation and sanitary reforms aimed at controlling man's physical environment. The concept of a healthy city originated from the public health problems that broke out in Britain in the 19th century; the UK government strengthened urban public health management through legislation and other means. For instance, In the 1830s, the outbreak of cholera in Britain prompted parliament in 1848 to promulgate the world's first modern "Public Health Act". The bill focuses on constructing public facilities and improving the physical environment,

linking public health with the built environment, and has become the pioneer of modern urban planning practice. (John Everett Park, 1970)

T. Moore proposed "Utopia" in the 16th century, and C. Fourier proposed phalanstère, which was the grass-roots organizational unit of the ideal society in the 19th century. Owen bought a textile mill in New Lanark. He established the "New Harmonious Commune" in 1800, which improved the original industrial environment and built good public service facilities and a landscape environment.

These utopian socialists viewed the city from a broader perspective, linking the whole social and economic system together and combining urban construction with social transformation. To promote the combination of urban and rural areas, the scale of cities should not be too large and should be as close to the countryside as possible. They also proposed building various new public buildings and facilities in cities. All these measures contribute to the improvement of the living and health standards of the residents. In 1875, Sir Benjamin Ward Richardson proposed an ideal model of a healthy city. In *Hygeia, a City of Health*, he foresaw a town of one hundred thousand people at a density of five houses per acre. The construction goal of the city is to minimize the death rate. Its core concepts include orderly urban layout, appropriate construction intensity, numerous park greening, good environmental sanitation, complete medical care, and public welfare (Benjamin Ward Richardson, 2021).

In 1882, Arturo Soria y Mata put forward the theory of linear city, taking traffic factors as the primary organizational factors of urban planning, which has profoundly influenced modern urban planning. The theory proposed arranging the city along the traffic trunk line, connecting the city with the countryside, facilitating the residents' access to nature and maintenance of a healthy urban environment, and preventing the massive concentration due to the expansion of the urban scale, which leads to the deterioration of the urban environment (Diana Velez, 1983).

In 1870, at the American Social Science Association meeting in Boston, landscape planner elder Olmsted presented a paper entitled "Public Parks and the Descriptive of Towns." He linked the concepts of park, park road, and residential district together and proposed that a well-managed central park of a city can become a center for urban development. Traffic trunks can connect it with urban built-up and planned areas. These paths will eventually go to the well-planned residential area Olmsted calls "the open town suburb." These measures were conducive to forming a complete park system and a healthy urban environment (Frederick Law Olmsted, 2016). Howard put forward the "garden city" theory in 1898, which established the symbiosis of rural and urban at the regional level and created a healthy living environment through reasonable control of population scale, industrial allocation, facility layout, green space organization, etc (Ebenezer Howard, 2013; Ebenezer Howard et al., 2013).

In the 20th century, with the development of pioneering epidemiological studies, devising forms of preventive medicine, and community health promotion, public health has achieved dramatic expansions. Almost all industrialized countries established systems of ensuring access to care for their whole population as essential for the health of both the individual and the collective (Theodore H Tulchinsky & Elena A Varavikova,

2014).

After World War II, with the population's and economy's rapid growth, energy consumption and environmental pollution became increasingly severe. Social contradictions gradually intensified, and public health faced significant challenges. In the 1960s, experts in the planning field began to reflect on the health problems under the modern urban planning model.

Building a healthy city is a global action strategy advocated in the 1980s in the face of the challenges of urbanization to human health (Public Health Advisory Committee, 2008), and the "new public health movement," "Ottawa Charter" and "health for all" have had a wide range of influences. 1984, the "healthy city" concept was first proposed at an international conference in Toronto, Canada. In 1986, the WHO Regional Office for Europe decided to launch the urban health promotion program and implement the regional "Healthy Cities Project" (HCP). Toronto, Canada, first responded by formulating healthy city planning, corresponding health management regulations, taking anti-pollution measures, and organizing all citizens to participate in urban health construction, achieving gratifying results. Subsequently, the active, healthy city movement was introduced from Canada to the United States and Europe and then set off an upsurge in Japan, Singapore, New Zealand, Australia, and other countries, gradually forming an international movement of cities worldwide (World Health Organization, 2000).

In the 21st century, research on health and safety in urban and rural ecosystems (Sotiris Vardoulakis et al., 2020) has garnered significant attention, reflecting the growing awareness of these issues across all sectors of society. Similarly, studies on health equity for the population (Ann Rowe et al., 2001), improving the quality of health services (John Øvretveit, 2004), and low-carbon development of community health (Martin Hensher & Forbes McGain, 2020) have also received widespread attention, contributing to a more comprehensive understanding of these crucial areas.

3.2.2 Goals and Requirements of Healthy City

(1) The Vision and Goals of Healthy City

WHO Healthy City project is a long-term sustainable development project. The central vision of a healthy city is encouraging the participation of all communities in the pursuit of peace and prosperity, tackling inequalities, and promoting good governance and leadership for health and well-being (WHO, 2018). The goal of a healthy city is to put health issues on the agenda of urban decision-makers and urge local governments to formulate corresponding health plans to improve residents' health status (World Health Organization, 1988). With the development of "sustainable development" (SD), the goals of SD, such as good health and well-being (Goal 3), gender quality (Goal 5), clean water and sanitation (Goal 6), decent work and economic growth (Goal 8), reduced inequality (Goal 10), sustainable cities and communities (Goal 11), climate action (Goal 13), life on Land (Goal 15), are closely related to the

goal and principles of a healthy city and profoundly influence each other (United Nations, 2015).

■ The Vision of Healthy City (WHO)

● The Vision of Healthy City (WHO)

- People: A healthy city takes a human approach to development, prioritizing investment in people and ensuring access for all to common goods and services.
- Participation: A healthy city leads by example ensuring community participation in decisions that affect where and how people live, their common goods and services.
- Prosperity: A healthy city strives for enhanced community prosperity and strengthened assets through values-based governance of common goods and services.
- Planet: A healthy city ensures that the health and well-being of both the people and the planet are at the heart of all the city's internal and external policies.
- Place: A healthy city creates an accessible social, physical and cultural environment that facilitates the pursuit of health and well-being.
- Peace: A healthy city leads by example by promoting and keeping peace in all its actions, policies and systems. This includes: institutions, governance systems and architecture that prioritize social justice and inclusive participation, the promotion of cultural norms of inclusion and equity, a non-exploitative egalitarian approach, formal governance and societal norms that tackle corruption, discrimination and all forms of violence.

Source: World Health Organization (WHO, 2018)

● Vision of Healthy Cities in the Western Pacific Region

- Building cities and communities of peace.
- Where all citizens live in harmony.
- Committed to sustainable development, respectful of diversity.
- Reaching for the highest possible quality of life and equitable.
- Distribution of health.
- By promoting and protecting health in all settings.

Source: World Health Organization Western Pacific Region (World Health Organization, 2015)

■ The Goal of Healthy City

● The Goal of Healthy City (WHO)

Every healthy city should strive to achieve the following goals: “creating a supportive environment conducive to health, stabilizing a sustainable ecosystem,

meeting the basic health needs of residents, building a diversified, dynamic and innovative urban economy, and providing high-quality and accessible public health and sanitation services etc.” (World Health Organization, 1988).

● **Strategic Goals of the WHO European Healthy Cities Network**

- To promote action to put health high on the social and political agenda of cities
- To promote policies and action for health and sustainable development at the local level emphasizing addressing the determinants of health, equity in health and the principles of the European policies Health for All and Health 2020
- To promote intersectoral and participatory governance for health, health and equity in all local policies and integrated planning for health
- To generate policy and practice expertise, good evidence, knowledge and methods that can be used to promote health in all cities in the European Region
- To promote solidarity, cooperation and working links between European cities and networks of local authorities and partnerships with agencies concerned with urban issues
- To increase the accessibility of the WHO European Network to all Member States in the European Region.

Source: World Health Organization Regional Office for Europe.(World Health Organization, 2019)

● **Goals to the 21st Century context (WHO)**

In translating Healthy Cities to the 21st century context, the main goals of the initiative are extensive and can be articulated as follows:

- Promoting health and equity in all local policies impacting social determinants of health (SDH) and fully aligning with the Sustainable Development Goals (SDGs).
- Creating environments that support health, well-being, healthy choices and healthy lifestyles.
- Providing UHC, and social services that are accessible and sensitive to the needs of all citizens.
- Investing in health promotion and health literacy.
- Investing in a healthy start in life for children, and providing support to disadvantaged groups such as migrants, the unemployed, and people living in poverty.
- Strengthening disease prevention programmes, with special focus on obesity, smoking, unhealthy nutrition and active living.
- Promoting healthy urban planning and design.
- Investing in green policies, clean air and water, as well as child- and age-friendly city environments, and addressing climate change-related issues such as by lowering emissions and identifying climate-resilient pathways.

- Supporting community empowerment, participation and resilience, and promoting social integration, peace, inclusion and community-based initiatives.
- Strengthening the city's public health services and capacity to respond to public health emergencies.

Source: World Health Organization (World Health Organization, 2020a).

(2) The Principles and Indicators of Healthy City

■ The Principles of Healthy City (Place & Neighborhood)

In the early days of healthy city movement, WHO listed a series of basic characteristics of healthy city (place & neighborhood) as a supplement to the concept of healthy city and a guide for healthy city movement. Among them, the more important principles of a healthy city include: Characteristics of a Healthy City (1997), Principles for Developing a Healthy Cities Project (1996), etc. Those principles are changing over time. The 11 characteristics of a healthy city more focus on the construction of healthy physical environments, socio-economic environment, providing good health care services, and improving the health status of residents (Europe World Health Organization. Regional Office for, 1997). With the development of healthy city project, the principles of equity, intersectoral action, community participation, and peace are further emphasized (Europe World Health Organization. Regional Office for, 1996). For building a healthy neighborhood, the principles are further refined into diversity, green, all travel modes, all-age learning, multiple opportunities, and aesthetically-attraction etc., to make the healthy city principles more operable in neighborhood scale (Hugh Barton et al., 2021). With the development of “sustainable development” (SD), the principles of healthy city combine the ideas of SD a lot, such as “built for health and well-being”, “collaboration for equity and opportunity”, “seek balance and harmony” (UNU–IIGH, 2015).

■ Main Indicators of Healthy City

“A health indicator is a characteristic of an individual, population, or environment which is subject to measurement (directly or indirectly) and can be used to describe one or more aspects of the health of an individual or population (quality, quantity, and time)”(Don Nutbeam & Ilona Kickbusch, 1998).

A framework of indicators for healthy cities was proposed and formally confirmed at the annual conference in Stockholm in 1990. Forty-seven cities submitted information on at least some of the 53 agreed indicators. These indicators were later revised to a set of indicators comprising 31 items instead of the previous 53. They consist of four groups as follows (Premila Webster & Denise Sanderson, 2013):

- **Health**
 - Mortality

- Main causes of death
- Low birth weight.
- **Health services**
 - City health education programs
 - Immunization rates
 - Inhabitants per primary health care practitioner
 - Inhabitants per nurse
 - Percentage of population covered by health insurance
 - Availability of services in foreign languages
 - Health debates in city council.
- **Environmental indicators**
 - Air pollution
 - Water quality
 - Sewage treatment
 - Household waste collection
 - Household waste treatment
 - Green space
 - Derelict industrial sites
 - Sport and leisure facilities
 - Pedestrianization
 - Cycle routes
 - Public transport access
 - Public transport range
 - Living space.
- **Socio-economic indicators**
 - Percentage of population in inadequate housing
 - Homelessness
 - Unemployment
 - Poverty
 - Availability of child care
 - Age of mothers at time of birth
 - Abortion rate
 - Employment of disabled people.

There are many studies on indicators of healthy cities, some of the indicators of healthy city are listed as below (Table 2):

Table 2 Healthy city indicators

No	Author	Study method	Main result
1	WHO (1992)	A feasibility survey in which a questionnaire consisting of tentative indicators was developed by a working group. The questionnaire was sent to 47 Healthy City Coordinators in WHO European Network for collection and submission of data.	53 indicators from four categories of health, health services, environment, and social and economic conditions were developed. The indicators were intended to reflect three global health promotion agreements: the Health For All (60% of the indicators), the Ottawa Charter (20% of the indicators), and the 11 Healthy City Objectives (20% of the indicators).
2	Webster and Price (1996)	Multi-disciplinary group analysis of the 53 indicators of WHO (1992).	A revision of the 53 indicators of WHO (1992) was recommended because: (a) some indicators, like a few indicators that reflected the Ottawa Charter, did not have quantitative data or were not measurable at the city level; (b) some indicators, like several indicators that reflected Health For All, involved different interpretations; and (c) sources of data for indicators were too wide.
3	WHO (1998)	Integrative review of reports and analyses about the 53 indicators of WHO (1992).	32 indicators were developed from the 53 indicators of WHO (1992).
4	National Institute of Public Health (2001)	Expert analysis of the 32 indicators of WHO (1998)	There was enough city level data available in WHO European Healthy Cities Network for 31 out of the 32 indicators of WHO (1998). The one indicator with insufficient data was on the 'percentage of disabled persons employed'.
5	Takano and Nakamura (2001)	Review of Japan's indicator archives	71 indicators from three categories of healthcare, residential environment, and socioeconomic status.
6	Nakamura (2003)	Scoping review	341 comprehensive indicators from 12 categories: population health; urban infrastructure; environmental quality; housing, living environment and sanitation; community action and activities; lifestyles and preventative activities; healthcare, welfare and environmental health services; education and empowerment; employment and industry; income and family living expenses; local economy; and demographics.
7	Pineo et al. (2018)	(1) Review of indicators from peer-reviewed literature, (2) filtering indicators based on international data availability, (3) stakeholder workshops to validate remaining indicators	58 indicators from 10 categories of air quality, food access, green infrastructure, housing and buildings, leisure and recreation, noise pollution, resilience, safety and security, transport, utilities and services.

8	Li et al. (2020)	(1) Review of indicators from Chinese government documents, (2) focus group discussions and personal interviews with senior staff of healthy city-related work for suggestions of including/excluding indicators.	5 first-level indicators, 21 second-level indicators, 73 third-level indicators, and 3 characteristic indicators. These indicators are from five categories of environment, society, health services, healthy people, and health behaviors.
9	Giles-Corti et al. (2020)	Integrating Indicators of SDGs and the New Urban Agenda in desk research	43 indicators from six categories, including urban system policies and government investment, urban and transport planning and design interventions, daily living outcomes, risk exposures, intermediary outcomes, and injury and disease outcomes
10	Luo et al. (2022)	(1) Systematic literature review, (2) a combined questionnaire and interview with relevant professionals to validate the indicators	37 indicators from six categories of urban form and transportation, health-friendly service, environmental quality and governance, community and facility, green and open space, and ecological construction and biodiversity.

Source: A set of 99 healthy city indicators for application in urban planning and design (Abbas Ziafati Bafarasat et al., 2023)

3.2.3 The determinants of planning a healthy city

The most world-widely used model of the main determinants of population health is “The Rainbow Model” (“Dahlgren and Whitehead model”) (Göran Dahlgren & Margaret Whitehead, 2021). It is also called the “Health Map”(Fig. 1) (made by Barton and Grant (Hugh Barton & Marcus Grant, 2006), developed from a concept by Dahlgren G. and Whitehead M.), which shows the relationship between health and the physical, social, and economic environment (Dahlgren Göran & Margaret Whitehead, 1991; Margaret Whitehead & Göran Dahlgren, 1991) .



Fig. 1 The health map: The determinants of health and well-being in our cities

Source: Barton, Hugh Grant, Marcus (Hugh Barton & Marcus Grant, 2013)

Comprehensive urban environments have long been recognized as important determinants of health, and this map is widely used in the field of urban planning. (Hugh Barton & Marcus Grant, 2013). In the map, people (Age, Sex, Hereditary Factors) are at the center of planetary health in the global context. “In six concentric arcs, from individual lifestyle to the natural urban environment, it captures urban components of the determinants of health. The three outer arcs are rendered in a darker color to highlight the core locus of operation for those actors who intervene directly in the built environment.” (Marcus Grant, 2018) The health map is a systemic tool. For planning a healthy city, each of the arcs can be translated into specific and measurable objectives (Table 3), reflecting determinants related to the environment of a healthy city and the core principles of the WHO strategy for health for all, such as equity, community participation, and intersectoral cooperation. (Hugh Barton & Marcus Grant, 2013; Hugh Barton & Catherine Tsourou, 2000; Marcus Grant, 2018).

Table 3 Linking the health map to urban planning objectives

Arcs	Contents	The Objective for Health Urban Planning
People	Age, Sex & Hereditary Factors	• providing for the needs of all groups in the population • reducing health inequalities • involving people in supporting a healthier local environment
Lifestyle	Diet, Physical Activity, Work-life balance,	• promoting active travel • promoting physically active recreation • facilitating healthy food choices
Community	Social Capital, Networks	• facilitating social networks, social cohesion and inclusion • supporting a sense of local pride and cultural identity • promoting a safe environment
Local Economy	Incomes, Innovation, Markets, Investment	• promoting accessible job opportunities for all sections of the population • encouraging a resilient and buoyant local economy
Activities	Activity System (Working, Shopping, Living, Playing, Learning) and Movement	• ensuring retail, educational, leisure, cultural and health facilities are located to be accessible to all • providing good quality facilities, responsive to local needs
Built Environment	Adapted Spaces (Building, Places) and Channels (Streets, Routes)	• ensuring good quality, variety and supply of housing • promoting a green urban environment supporting mental well-being and contact with nature • planning an aesthetically rewarding environment, with acceptable noise levels
Natural Environmental	Local Natural Environmental Capital (Air, Water, Land, Soils, Natural habitats, Trees)	• promoting good air quality • ensuring security and quality of water supply and sanitation • ensuring soil conservation and quality • reducing risk of environmental disaster
Global Ecosystem	Climate stability, Biodiversity	• reducing transport and building-related greenhouse gas emissions • improving city and city-region support for global biodiversity

Sources: Adapted from *Planning for Healthy Cities* (Marcus Grant, 2018).

3.3 Healthy urban Planning

Healthy urban planning (HUP) promotes healthy, prosperous places to live and work. HUP focuses on the positive effects that urban planning can have on human health, well-being, and quality of life and reflects WHO's broad definition of health. Urban problems are complex because of the interrelated nature of the components of cities. Planning practices and processes need to be adapted to this concept to reflect a new awareness and to integrate health, environmental, urban spatial and facilities, economic and social concerns, and sustainability issues. Healthy urban planning is one of the three core themes in Phase IV of the WHO European Healthy Cities Network (Hugh Barton et al., 2003; Hugh Barton & Catherine Tsourou, 2013).

3.3.1 Healthy Urban Ecosystem

(1) The Concept of Healthy Urban Ecosystem

Urban ecology, in the narrower sense, is the sub-discipline of ecology that deals with urban biocoenoses, biotopes, and ecosystems, their organisms and site conditions, and the structure, function, and history of urban ecosystems (H Sukopp & R Wittig, 1998). The urban ecosystem includes air, water, soil, habitat, plants, wildlife, human-building structures, and climate (Richard TT Forman, 2014). Those factors are deeply related to human health.

A poor, polluted urban ecological environment will have adverse effects on human health, while a clean, excellent urban ecological environment will have positive effects on human physical and mental health. Formulating effective urban planning strategies has a positive impact on controlling and improving the urban ecological environment.

(2) Urban Atmosphere Environment

Urban atmosphere (air) is a component of the Earth's atmosphere; dry air contains 78.08% nitrogen, 20.95% oxygen, 0.93% argon, 0.04% carbon dioxide, and small amounts of other gases. Human survival is inseparable from air; adults need about 10-15 m³ of air daily. The Earth's atmosphere can be divided into the troposphere, stratosphere, mesosphere, thermosphere, and exosphere. Among them, the most closely related to urban activities is the troposphere, which has the characteristics that the temperature usually decreases with the increase of altitude, the air convection is intense up and down, and the weather phenomena are complex and changeable (Herman Koren & Michael S Bisesi, 2019).

■ Unhealthy Urban Atmosphere Environment and Their Causes

The main health risk in the atmosphere of urban environments is air pollution. Air pollution is the result of harmful substances being discharged into the air at a rate that exceeds the ability of natural processes in the atmosphere to transform, deposit, or dilute them. It has the characteristics of easy diffusion and wide range, and even leads to large-scale pollution. The migration and diffusion of pollutants in the atmosphere are mainly affected by meteorological conditions such as wind direction, wind speed, airflow temperature distribution, atmospheric stability, and terrain conditions. For example, due to reasons such as the urban "heat island effect", the diffusion and dilution of air pollutants are hindered, thereby exacerbating the problem of air pollution in some urban areas.

The main sources of pollutants in the atmosphere include fossil fuel combustion, emissions from industrial enterprises, emissions from transportation, and emissions from agriculture. The main pollutants include aerosol pollutants: dust, smoke, haze, smog, etc.; gaseous pollutants mainly include carbon oxides (CO, CO₂, etc.), nitrogen-containing compounds (NO, NO₂, etc.), sulfur-containing Compounds (SO₂, SO₃, H₂S, etc.), hydrocarbons (alkanes, alkenes, aromatics, etc.), halogen compounds,

photochemical smog, etc.

Harmful substances in the atmosphere mainly enter the human body through the respiratory tract, and a small amount enters the human body through the skin and digestive tract. Atmospheric pollutants entering the human body will cause discomfort in the sense organs and physiological functions of the human body. For example, SO₂ may cause bronchial disease, affect human metabolism, cause some degree of liver damage and may even lead to cancer (Herman Koren & Michael S Bisesi, 2019; Annalee Yassi et al., 2001).

■ Criteria and Urban Planning Strategies for A Healthy Urban Atmosphere Environment

Since 1987, WHO has regularly published air quality guidelines based on health risk assessments. 2021 saw the publication of the WHO global air quality guidelines, which are intended to guide the implementation of new AQG levels and present good practice statements to support the management of the six major air pollutants present in the atmosphere (PM_{2.5}, PM₁₀, O₃, NO₂, SO₂ and CO) (World Health Organization, 2021c). In addition, many countries have detailed regulations for the indicators of pollutants in the atmosphere. The main countermeasures for the prevention and control of air pollution in the field of urban planning are a collective effort. They include:

- Optimizing the urban industrial structure and layout can significantly reduce air pollution. Which involves adjusting and optimizing the regional industrial structure, promoting an advanced industrial structure that combines economic, social, and environmental benefits, and eliminating industrial enterprises with severe pollution.
- Reasonably plan the spatial structure of local cities, adapt measures to local conditions, scientifically group commercial, industrial, and residential functions in some cities, and reduce the impact of industrial air pollution emissions on residents' daily lives. For example, industrial projects with air pollution emissions should be located in a location conducive to the diffusion and dilution of pollutants, such as the downwind of the city's dominant direction. Adopt a circular industrial layout to form an industrial chain of efficient recycling of resources and reduce waste gas emissions. The industrial land with polluting emissions can be effectively isolated by planning and constructing urban green spaces and other measures.
- Actively promote green transportation methods, such as trains, buses, and other public transportation, bicycle and walking transportation, etc. Limit the excessive use of private cars. Restrict trucks, agricultural vehicles, and other vehicles with large emissions from traveling on specific routes.
- Improve local energy plans, such as developing centralized gas and heat supply in cities and reforming rural energy structures. Support and encourage the use of clean energy, such as supporting the development of energy-efficient buildings and communities and promoting the use of clean energy (biogas, solar energy, etc.) in rural areas.

- Increase urban and rural green planting and encourage the planting of green plants that can purify air pollution. (Hugh Barton & Catherine Tsourou, 2000; World Health Organization, 2022a).

(3) Urban Water Environment

The survival and development of human beings and cities hinge on the availability of sufficient and clean water. In urban areas, water resources are utilized for a variety of purposes, including domestic needs (drinking, entertainment), production (industrial, agricultural, hydropower, and shipping), and ecological conservation (forests, lakes, and rivers). (MO Gessner et al., 2014; Arjen Y Hoekstra et al., 2018)

Natural water resources in the urban environment are mainly composed of precipitation, surface water, and groundwater. Among them, precipitation refers to the water vapor condensed in the atmosphere that falls to the earth's surface in different ways and can be divided into liquid, solid, and mixed precipitation. Surface water refers to the liquid water above the earth's surface, most of which is produced by the surface runoff of precipitation, meltwater, and spring water, mainly including rivers, lakes, and wetlands on land. Groundwater refers to the water stored in cracks in rocks and soil voids below the ground. The water cycle refers to the various forms of water in nature, under the action of solar radiation, the earth's gravity, etc., through the evaporation of water, water vapor transportation, condensation and fall, infiltration, runoff, and other links, the continuous cycle of movement. (Jiri Marsalek et al., 2008; V Grace Mitchell et al., 2001)

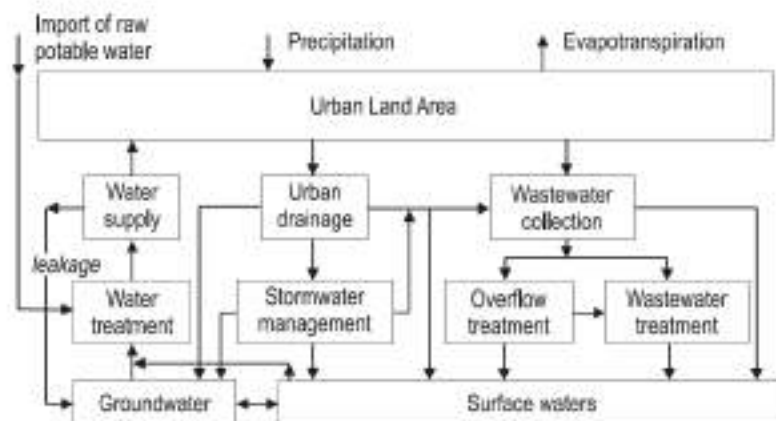


Fig. 2 Urban water cycle – main components and pathways

Source: from Jiri Marsalek et al. (Jiri Marsalek et al., 2008)

However, this cycle is significantly modified by urbanization's environmental impacts and the need to provide water services to the urban population, including water supply, drainage, wastewater collection and management, and beneficial uses of receiving waters. The resulting "urban" hydrological cycle is called urban water cycle (UWC) (Fig.2) (MO Gessner et al., 2014; Jiri Marsalek et al., 2008).

■ Unhealthy Urban Water Environment and Their Causes

Water bodies in nature have the function of self-purification. However, when a certain amount of sewage, waste water, waste and other pollutants enter the water area and exceed the self-purification and pollution-holding capacity of the water body, the physical and chemical properties and biological community groups of the water body and its sediment will undergo adverse changes. Ecosystem and water body functions are destroyed, causing water quality to deteriorate, endangering human health, and destroying the ecological environment. This phenomenon is water pollution.(Janet G Hering et al., 2013)

In the urban environment, the main causes of water pollution include industrial wastewater, domestic sewage discharge, and agricultural production pollution, etc. Water body pollutants mainly include: physical pollutants, such as suspended solids, thermal pollution, radioactive substances, etc.; chemical pollutants, including organic (carbohydrates, proteins, fats, organic chlorine compounds, polycyclic aromatic compounds, etc.) and inorganic (Acids, alkalis, general inorganic salts, heavy metals, etc.) compounds; bacteria and microbial pollutants, mainly refer to various bacteria, viruses, parasites and other pathogenic bacteria contained in water (P.W. Purdom, 2013).

Water pollutants can enter the human body through drinking water or the food chain, threatening human health. Among them, heavy metal pollutants such as cadmium can cause kidney and bone lesions, lead can cause anemia and human kidney and brain damage, and hexavalent chromium can cause skin ulcers and even induce cancer. Organ chlorine pesticides can cause harm to the endocrine, immune and reproductive functions of the human body. Most fused aromatic hydrocarbons are carcinogenic. Cyanide can cause human respiratory failure to suffocate and die. Typhoid fever, cholera, dysentery, gastroenteritis, infectious hepatitis, etc., can all be transmitted through water contaminated by germs (H. Koren & M.S. Bisesi, 2016).

■ Criteria and Urban Planning Strategies for Healthy Urban Water Environment

WHO has published relevant standards for drinking water and recreational water. The Guidelines for Drinking-water Quality (GDWQ) covers a broad range of chemicals, pathogenic bacteria, viruses and parasites, radioactive substances, and aspects of taste, odor, and appearance that can affect drinking-water quality, and providing health-based targets for over 200 parameters (World Health Organization, 2022b; WHO, 2011a). And the *Guidelines on recreational water quality. Volume 1: Coastal and fresh waters* (World Health Organization, 2021b) and *Guidelines for safe recreational water environments. Volume 2: Swimming pools and similar environments* (Sanitation Water & World Health Organization, 2006). These guidelines focus on water quality-related health hazards for the general population engaging in recreational water use involving contact with water and beach sand. WHO also published some guidelines for protecting and managing water quality (World Health Organization, 2018a, 2018b; Oliver Schmoll et al., 2006). Many countries have detailed regulations for the indicators of different

water quality.

The main measures for the prevention and control of water pollution in the field of urban planning include:

- Through urban and rural planning and management and control measures, strengthen the protection and management of the ecological environment in areas where urban and rural surface water and groundwater sources are located.
- Formulate and strengthen the standards and guidelines for water pollution prevention and control that urban and rural construction and development projects must meet. Strictly control the water pollution caused by urban and rural planning and construction (industrial and agricultural, transportation, living) projects.
- Ensure the flood control safety of urban and rural construction. Strengthen the construction of urban and rural flood control projects.
- Strengthen the municipal infrastructure construction of urban and rural water supply and drainage, ensure the supply of clean drinking water and industrial and agricultural water sources that meet relevant city standards, and strengthen the discharge control, collection, and reuse of urban and rural production and domestic sewage.

Key measures to control urban runoff pollution include optimal use of stormwater, promoting safe on-site water collection, purification, infiltration back into the ground, or replenishing surface water, reducing urban hard ground, increasing urban green land, etc.. And the main measures to control non-point source pollution in rural areas include guiding farmers to rationally use pesticides, intercepting agricultural sewage, and rationally disposing of livestock and poultry manure.(Hugh Barton & Catherine Tsourou, 2000; World Health Organization, 2018a; Oliver Schmoll et al., 2006)

(4) Urban Soil Environment

Soil is a layer of loose material on the earth's surface. It is composed of minerals formed by the weathering of rocks, animals, and plants, organic matter produced by the decomposition of microbial residues, soil organisms, water, air, and oxidized humus. The soil belongs to the land and is an important natural resource on the earth's surface. It is the earth's surface foundation for the growth of natural vegetation and crops and the land surface foundation for urban and rural construction. (Peter Bullock & Peter J Gregory, 2009)

■ Unhealthy Urban Soil Environment and Their Causes

Soil pollution means that the pollutants produced by human activities enter the soil, the quantity and speed of which exceed the capacity of the soil and the speed of purification, thus changing the nature, composition and properties of the soil, resulting in the natural dysfunction of the soil and the quality of the soil. Deterioration affects the growth and development of crops, and causes direct harm to organisms and humans through the food chain.

In the urban environment, the leading causes of soil pollution include water pollution, mainly due to industrial and agricultural production, and urban and rural domestic sewage discharge, which is the pollution formed by the accumulation of pollutants in the soil. Atmospheric pollution: pollutants such as sulfur dioxide, nitrogen oxides, and particulate matter in the atmosphere fall to the ground through precipitation, causing soil acidification, heavy metals, toxic and harmful substances in the soil exceeding the standard, and other pollution. Solid waste pollution: Industrial and mining waste, sludge, and urban waste are piled up to occupy cultivated land, and through atmospheric diffusion or precipitation leaching, the soil in the surrounding area is polluted by heavy metals, oils, pathogenic bacteria, and toxic and harmful organic substances. Agricultural pollution mainly refers to the pollution caused by chemical fertilizers, pesticides, urban waste composting, sludge, etc., in agricultural production, including organic chlorides, nitrogen, phosphorus, other compounds, and various heavy metal pollution. (Kuldip Kumar & Lakhwinder S Hundal, 2016; Gang Li et al., 2018)

Soil pollution will cause pollutants to accumulate in plant (crop) objects and be enriched to the human body through the food chain, endangering human health. Pollutants (heavy metals, etc.) in topsoil easily enter the atmosphere and water bodies under the action of wind force and water force, respectively, leading to air pollution and water body pollution. Soil pollutants include inorganic pollutants, such as heavy metals (mercury, tin, lead, chromium, copper, zinc, nickel, etc.), metalloids (arsenic, selenium, etc.), and other poisons. Organic pollutants mainly refer to agriculture and chemical fertilizers (compounds such as organic chlorides, nitrogen, phosphorus, etc.), which can easily cause damage to human internal organs, poisoning, and even cancer. Pathogenic bacteria pollutants, such as leptospirosis and anthrax through the skin and mucous membranes, intestinal infectious diseases and parasitic diseases through the mouth, and soil contaminated by pathogens can spread typhoid, paratyphoid, dysentery, hepatitis, and other contagious diseases. In addition, soil contaminated by organic waste is a breeding ground for vector organisms such as mosquitoes, flies, and rodents, so soil contaminated by organic waste is considered a hazardous substance epidemiologically. (Herman Koren & Michael S Bisesi, 2019; Gang Li et al., 2018; P.W. Purdom, 2013)

■ Criteria and Urban Planning Strategies for Healthy Urban Soil Environment

WHO has formulated standards for indicators of heavy metal content in soil (World Health Organization (WHO), 1996). Many countries have formulated soil environmental quality standards according to their situations. For example, the soil screening values (SSLs) and ecological soil screening values (Eco-SSLs) formulated by the United States Environmental Protection Agency (EPA) (US EPA, 2018), according to the exposure scenarios of the population under residential, commercial/industrial, construction and other land use modes. Criteria of different countries include the Soil Quality Guidance Values (SGVs) formulated and revised by the British Environmental Agency, the Soil Intervention Values (IVs) of the Netherlands, Australia's Soil investigation values (SILs), etc.. (Else K Bünemann et al.,

2018; Sigbert Huber et al., 2008)

The main countermeasures for soil environmental protection in the field of urban planning include:

- Control pollution sources: strengthen the prevention and control of air and water pollution, and the treatment and disposal of solid waste.
- Increase the environmental carrying capacity of the soil: increase surface greening, improve soil water storage capacity, prevent and control soil erosion, improve soil structure, increase soil organic matter, and prevent land ecological degradation.
- Optimize agricultural production methods: promote organic farming, control the use of chemical pesticides, rationally apply chemical fertilizers, and strengthen the monitoring and management of sewage irrigation areas.
- Encourage urban and rural green development and construction: Strengthen the construction and protection of urban and rural green infrastructure, and use recycled and renewable materials as much as possible in the construction process.
- Support brownfield restoration and development: Strengthen soil environmental restoration and various forms of reuse measures for abandoned land such as mining, industry, and transportation in urban and rural areas. (Hugh Barton & Catherine Tsourou, 2000; Herman Koren & Michael S Bisesi, 2019; Kuldip Kumar & Lakhwinder S Hundal, 2016)

(5) Urban Habitat and Biodiversity

■ Concept and Principles

● The Concept of Urban Habitat and Biodiversity

• Urban Habitat

In general, “habitat” refers to “the type of environment in which a specific organism lives” (Peter Collin, 2010). EUNIS defines a “habitat” as: “a place where plants or animals normally live, characterized primarily by its physical features (topography, plant or animal physiognomy, soil characteristics, climate, water quality, etc.) and secondarily by the species of plants and animals that live there”. However, not all habitats are “biotopes”, which means “areas with particular environmental conditions that are sufficiently uniform to support a characteristic assemblage of organisms” (Cynthia E Davies et al., 2004). The term “urban habitat” is used here referring to the physical, chemical and biological components of a defined geographical area (Ian Douglas et al., 2010).

• Urban Vegetation

The term of vegetation means, “All the plants that cover an area and form plant formations and communities.”(J. Breuste et al., 2021).

• Urban Biodiversity

Cities often have unique habitats whose characteristics and structures result from

urban use (type, intensity, and frequency of use and management). Land use determines the structures and processes of the urban habitat. They are complex ecosystems with unique ecological characteristics, often influenced by anthropogenic factors. The diversity and smallness of the structures created by use are characteristic. Cities are, therefore, also rich in species, often including a high proportion of non-native species and different habitats. Cities are, therefore, usually characterized by a high level of species diversity, for which humans are the decisive factor. Urban habitats development should consider providing diverse biotopes for flora and fauna, which is conducive to regional flora and fauna conservation and biodiversity. (F.R. Adler & C.J. Tanner, 2013; H. Sukopp, 1998).

● Classification of urban habitats

Urban habitats could be generally classified in terms of two broad categories: vestiges of the natural world and the artificial wild (David Goode, 1986), as the urban areas harbor diverse nature ranging from “semi-natural habitats to wastelands, parks and other highly human-influenced biotopes with their associated species assemblages.” (Ian Douglas et al., 2010)

The broadest classification in the EUNIS system comprises the level 1 units:

- A Marine habitats
- B Coastal habitats
- C Inland surface waters
- D Mires, bogs, fens
- E Grasslands and lands dominated by forbs, mosses or lichens
- F Heathland, scrub and tundra
- G Woodland, forest and other wooded land
- H Inland vegetated or sparsely vegetated habitats
- I Regularly or recently cultivated agricultural, horticultural and domestic habitats
- J Constructed, industrial and other artificial habitats.

Each category has further subdivisions (level 2, level 3). For example, Category J has the following level 2 units, such as the building of cities, towns, and villages; low-density buildings; extractive industrial sites; transport networks and other constructed hard-surfaced areas; highly artificial waters and associated structures; and waste deposits (Cynthia E Davies et al., 2004).

■ Healthy Effect of Urban Habitat and Biodiversity

Favorable urban habitats and biodiversity environments can significantly contribute to public health activities. Urban greenery can improve health, well-being, and aspects of behavior and cognition, along with extending social networks. A deteriorating, dangerous, or unpleasant outdoor environment with little access to green open space results in poor mental well-being and further reduces physical activity. Visiting or even viewing nature might give the mind a rest, leading to improved mental health and

reduced stress. Animals and caves, for example, are intrinsically fascinating to people and help restore the mind by attracting involuntary attention. People reported more reflection and a sense of identity from spending time in places with higher plant species richness and more of a sense of continuity with the past with higher bird species richness. However, broader health effects have not been established. Paradoxically, the sense of well-being can be lower with high plant species richness, and few people could identify 12 common urban species. (F.R. Adler & C.J. Tanner, 2013)

■ Unhealthy Urban Habitat Environment and Their Causes

Urban space consists of a habitat mosaic of high heterogeneity (building structures, uses, and unused spaces). And urban habitat conditions are directly dependent on urban structure and land use. There is a general consensus that the transformation of habitats into other land uses (including urban development), and the additional loss of habitat due to fragmentation, have devastating effects on indigenous plant diversity (Robert DeCandido, 2004; Anibal Pauchard et al., 2006; Nicholas SG Williams et al., 2009). Landscape transformation in terms of land-use and land cover changes from natural to urban land not only drives biodiversity changes but also aspects such as climate change on local (urban heat island) and regional (Nancy B Grimm et al., 2008). Anthropogenic disturbances are an inevitable part of urban ecosystems, as was mentioned earlier. Some of the most obvious types of disturbance regimes in urban areas include trampling of vegetation and soil compaction (Rachel Hill & Catherine Pickering, 2009; Pariente Sarah & Helena M Zhevelev, 2007), soil pollution (Luis Madrid et al., 2004), alien plant invasions (Montserrat Vilà & In é Ibáñez, 2011), and mowing, cutting of managed landscapes (Jan P Bakker, 1989). The reasons for the species richness and attractiveness of cities as habitats are: urban landscape rich in structure, protected and safe habitat (J.H. Reichholf, 2007).

The natural distribution of plants on urban sites is linked to the habitat requirements of the plants and the existing site characteristics. The locations of the city are usually less favorable for plants in comparison with surrounding areas: The chemical environment of the soil, air (gases, dust etc.) is usually less favorable; the enjoyment of light is reduced at many locations; the water balance is usually in imbalance; higher temperatures cause water losses, soils are often reduced in their water storage capacity (low soil moisture content due to soil compaction); soil sealing and compaction impede the colonization by plants (H. Sukopp, 1998). Compared with plants, animal species show a more high plasticity in morphological, physiological, and ecological adaptability. However, urbanization induces reduced movement in animals of escape distances and the propensity to migrate. For animals, the urban physical environment brings a constant stream of disturbances, and they must learn to filter or ignore them to feed and reproduce successfully. (J. Breuste et al., 2021)

■ Urban Planning Strategies for Healthy Urban Habitat and Biodiversity

Urban form and land-use planning adopt a model (patch–corridor–matrix) consistent

with landscape ecology to build a comprehensive network of urban habitats that benefit healthy urban habitat and biodiversity, providing a network for effective species movement across an urban area and preventing habitat fragmentation. For example, plant species richness typically correlates with habitat size within urban areas, commonly increasing plant diversity with increased habitat areas. And the construction of urban ecological corridors is conducive to the migration of animals and plants. (Zev Naveh & Arthur S Lieberman, 2013; Monica G Turner et al., 2001; Monica Goigel Turner, 1989)

Planning should safeguard urban forests, mountains, rivers, lakes, wetlands, green spaces, and parks. Significant natural and semi-natural habitats remain sources of species, especially natives that readily move across the area, mainly using the vegetation network. Regions with a broader array of habitats, such as mountains, tend to have higher biodiversity even in the face of stress.

Brownfields, such as abandoned factories, transportation facilities, mining wastelands, and landfills, should be encouraged to be ecologically restored and reused.

Planning can ensure that recycled and renewable materials are used whenever possible during urban construction. (Hugh Barton & Catherine Tsourou, 2000)

3.3.2 Healthy Economy

(1) Introduction

Rapid urbanization began during the Industrial Revolution in the nineteenth century. The production of goods was both labor and capital-intensive, growth in a competitive economy required the generation of new ideas to spur innovation, and transportation costs were high, all of which necessitated agglomerations with high population densities. Individuals flocked to cities, motivated by the promise of upward mobility. Rapid population growth, along with limited living standards and inadequate infrastructure, created public health risks within cities. (Sandro Galea et al., 2019)

In the 21st century, urbanization has enabled societies to achieve rapid growth by capturing economies of scale and by allowing efficient coordination of the production and delivery of goods and services (Paul Krugman, 1992). Economic and technological improvements have generally improved public health, but they also exacerbate crowded urban environments, ecological deterioration, increased pollution, and inequalities in both economic and health outcomes across and within cities. In the new era, urban public health is still facing challenges. (Dora L Costa, 2015; Anthony J McMichael, 2000).

(2) Urban Economy and its impact on Public Health

■ Urban Economy and Health Related Quality of Life

The World Health Organization defines quality of life (QOL) as "an individual's

perception of their position in life in the context of the culture and value systems in which they live and about their goals, expectations, standards, and concerns." Standard indicators of the quality of life include wealth, employment, the environment, physical and mental health, education, recreation and leisure time, social belonging, religious beliefs, safety, security, and freedom. Health-related QOL (HRQOL) evaluates QOL and its relationship with health.

At the broadest level, economic growth is associated with better quality of life (Angus Deaton, 2013). According to some research, rising quality of life is associated with greater access to nutrition, and improvements in education and housing play a dominant role in improving population health (Dora L Costa, 2015; Thomas McKeown, 1976). The congruent patterns in cities' economic fortunes and life expectancy are consistent with well-known relationships between quality of life and health (Dora L Costa, 2015). The relationship between urban economic conditions and public health is becoming more robust.(Sandro Galea et al., 2019).

■ Urban Economy and Healthy Urban Ecological Environment

Economic development has brought about rapid industrialization and urbanization. In many cities, the rapid development of industry has led to the production of large amounts of waste gas, wastewater, and solid waste due to lax controls, which have damaged the urban ecological environment and posed a severe threat to public health. The extensive use of fossil fuels in industrial production, transportation, and other fields has caused severe air pollution, greenhouse effect, and other adverse consequences.

However, the development of the urban economy can also increase investment in urban construction, such as increasing investment in municipal infrastructure such as urban water supply and drainage, sanitation, clean energy, and green infrastructure construction, thereby improving the urban ecological environment, which can improve the health of the population. For example, explicit investments in public health infrastructure, such as municipal water disinfection and sewage, appear to have dramatically reduced mortality. These investments were motivated in part by a growing recognition that the private sector had limited capacity and incentive to provide these services at scale and realized due to innovations in municipal financing. (David Cutler & Grant Miller, 2005) Therefore, balancing economic development and environmental protection is crucial to public health.

■ Urban Economy and Mental Health

Overall, the economically disadvantaged may face more negative stimuli and experience more stress, uncertainty, social isolation, and even violence and crime, all of which increase the risk of mental illness. Poverty, marginalization, violence, complex emergencies, and human rights violations threaten human development and sustainable economic development. Generally, the development of the urban economy, the increase in financial income, and the improvement of the quality of life and social services can promote the mental health of the public.

However, the very forces in cities that spur human capital accumulation and economic growth may also generate conflict and instability, leading to increased psychological stress, nervousness, and even depression in populations, which can, in turn, further influence health (Edward L Glaeser et al., 2009).

Therefore, in urban development, it is of great significance to increase the construction of public mental health-related facilities and projects and provide better public mental health services to improve the public's mental health.

■ Urban Economy and Health Equity

Urban health inequality is related to differences in economic development levels among cities. These differences are reflected in the construction of healthy cities in terms of urban healthy environments, public health services, and residents' health levels. In urban areas, it is also reflected in the inequalities in physical and mental health and urban health benefits obtained among urban residents (or groups) of different economic income levels.

The development of the urban economy generally has a positive impact on reducing urban health inequalities. A robust economic foundation enables cities to construct superior public health facilities, deliver higher-quality public health services, and foster a healthier public environment. Additionally, it allows for the provision of more targeted health benefits to specific segments of the urban population, such as individuals with disabilities, low-income groups, the elderly, women, and children. Consequently, the overall health welfare of all urban residents is enhanced.

Technological advancements and globalization, however, have also contributed to economic inequality, which can exacerbate disparities in health outcomes. Research in the United States indicates significant economic inequality across cities, with the average GDP per capita being nearly twice as high in the wealthiest cities compared to the poorest ones. These economic disparities are paralleled by variations in health outcomes, which have been widening over time (Jacob Bor et al., 2017; Edward L Glaeser et al., 2009; David Hollanders, 2015). The increase in inequality and concentrated poverty has led to urban squalor and disease outbreaks (Simon Szreter, 1997). Moreover, the rising health risks in urban environments disproportionately affect the poor, as wealthier individuals are often able to relocate to safer areas, despite increasing living costs (Sandro Galea et al., 2019).

Therefore, urban economic development must pay more attention to issues such as eliminating health inequities and promoting fair and equitable development of urban public health.

■ Urban Economy and Health Investment and Industry

Health is a central input in economic development and poverty reduction. Health is the basis for job productivity. It enhances the capacity to learn at school. In economic terms, health and education are the cornerstones of human capital and form the basis of an individual's economic productivity. As with economic well-being of households,

good population health is a critical input to poverty reduction, economic growth and development of whole societies. Countries with the weakest conditions of health and education have a much harder time achieving sustained growth than countries with better conditions of health and education. Globally, increased investment in health would save 8 million lives a year and generate \$360 billion annually within 15 years (World Health Organization, 2002).

The vigorous development of a healthy economy can stimulate the growth of new urban industries, optimize the urban industrial structure, and contribute to the sustainable growth of the urban economy. As the social economy continues to develop, the pursuit and demand for physical and mental health are increasingly significant, creating a substantial market demand. This presents a significant opportunity. Developing a healthy economy can accelerate the release of consumer demand, create employment, promote the integration of industrial structures, transform economic development modes, and improve the quality and efficiency of economic growth. (Liqiong Luo, 2022; P.A. Morgon, 2016)

(3) Urban Planning Strategies for Healthy Urban Economy and Sustainable Development

■ Improve the Quality of Life Through Economic Development

The primary economic strategies enhancing the quality of life encompass promoting full employment, augmenting the income levels of urban residents, providing a diverse range of economic industries and employment opportunities etc. Additionally, significant emphasis is placed on improving urban living conditions through substantial investments in urban infrastructure. This includes developing medical and health service facilities, the ecological environment, sports, leisure, tourism, and municipal infrastructures. Furthermore, promoting health-related industries, such as medical care, food services, and elderly care, is critical for creating high-quality urban living environments. (Richard A Easterlin & Laura Angelescu, 2011; Martha Nussbaum & Amartya Sen, 1993)

A crucial aspect of urban economic development is the attention given to citizens' mental health. Investments in and constructing projects and facilities to enhance mental health can improve residents' satisfaction and happiness. Such initiatives are integral to fostering a holistic and thriving urban environment. (Debasish Basu, 2004; Heinz Katschnig & Monika Krautgartner, 2002)

■ Shaping Sustainable Urban Economic, and Industrial Development Model

Actively promoting the green and low-carbon development of urban industries is essential. It is imperative to oppose high energy consumption and high pollution economic and industrial development models. While advancing the urban economy,

efforts must be directed towards fostering green, low-carbon, and intelligent urban industrial development through technological innovation and industrial upgrading, thereby establishing a sustainable urban economic and industrial structure. (Cathryn Tonne et al., 2021)

Encouraging and supporting the development of urban green industries is crucial. This includes energy-saving and environmental protection industries, such as water-saving technologies and environmental protection equipment manufacturing. The green transformation of traditional industries should be promoted, integrating the concept of green development into industry, agriculture, and service sectors. This involves advancing green industrial development, continually building a green manufacturing system, enhancing green factories, green parks, and green supply chains, and establishing a green industrial supply chain. Furthermore, promoting the development of a circular economy and cleaner production is essential. Transforming agricultural production methods, vigorously promoting green agricultural production and management models, and developing an agricultural circular economy are also critical to improving the green standards of the service industry. (Xiaoyu He & Bo Li, 2023; Cathryn Tonne et al., 2021)

Promoting the green and low-carbon development of the energy industry is another vital component. This includes the vigorous development of renewable energy sources such as solar, wind, hydropower, and bio-energy; enhancing the clean and efficient use of fossil fuels; and transforming and upgrading traditional energy production methods, including the establishment of green mines. (Kok Sin Woon et al., 2023)

Additionally, encouraging and supporting the transformation and upgrading of urban old industrial sectors is necessary. This involves gradually transforming and upgrading heavily polluting industrial and mining enterprises within urban areas. Strengthening the ecological restoration, transformation, and reuse of urban brownfields, including abandoned mines and factories, is also essential. (Ray Hudson et al., 1992; KAREL Skokan, 2009; Michael Steiner, 1999)

■ Promotion of Urban Health-related Industry

Promoting the development of the aforementioned health-related industries, such as urban medical medicine, rehabilitation and health care, health management, healthy food, sports and fitness, health care and elderly care, and health and leisure, not only contributes to the overall health of the population but also drives economic growth and enhances social welfare. The primary urban health-related industries include various components, as follows : (Charles E Phelps, 2017; Rexford E Santerre & Stephen P Neun, 2012)

The healthcare and pharmaceutical industry encompasses medical services, pharmaceuticals, medical device research and development (R&D), manufacturing of medical devices, and other high-tech industries. Additionally, it includes high-end service industries where medical science is the primary means. This sector focuses on enhancing the quality of medical services and fostering innovation to meet the growing health needs of the population. (Sherman Folland et al., 2024)

The rehabilitation and healthcare industry includes rehabilitation treatment, family health care, elderly rehabilitation, sports rehabilitation, and other health service sectors. It also comprises the manufacturing industry dedicated to producing rehabilitation and healthcare products. This industry aims to provide comprehensive rehabilitation and healthcare services to individuals across all age groups, thereby improving overall health standards.

The health management industry covers family health management, elderly health management, health check-ups, and related services. By offering systematic and personalized health management services, this industry helps individuals and families achieve comprehensive health monitoring and management, enhancing quality of life and health outcomes.

The healthy food industry includes organic food production, healthy catering, and the production and services of health and nutrition foods. This sector is committed to providing high-quality, nutritionally balanced foods, promoting healthy eating habits, and fostering a culture of nutrition and wellness.

The sports and fitness industry encompasses leisure sports, physical fitness activities, sports training services, and the manufacturing of sports and fitness equipment and leisure sports goods. This industry promotes public health and physical well-being through diverse sports and fitness activities and high-quality equipment.

The elderly care industry includes various health care and elderly care services, the development of health care parks, and the construction of elderly care communities (e.g., elderly apartments). This industry is dedicated to providing professional and considerate health care and elderly services, creating a comfortable and convenient living environment for the elderly.

The health leisure and tourism industry encompasses cultural leisure, tourism, social activities, entertainment, and other services primarily focusing on health. By promoting health-themed leisure and tourism activities, this sector enhances the quality of life and promotes physical and mental well-being. (Jinhee Kim et al., 2022)

■ Reducing Health Inequities Caused by Poverty

To enhance the overall health status of urban populations, robust health systems that provide comprehensive coverage for all urban residents are essential. This strategy focuses on improving the health and nutritional status of the poor and vulnerable groups and aims to prevent "disease-induced poverty", aligning with the principles of the World Bank Health, Nutrition, and Population Strategy (2007). (Rifat Atun et al., 2008; Banque Mondiale, 2007)

A critical approach involves reducing inequalities in the determinants of health status and healthcare utilization. This can be achieved by enhancing equity in health service coverage and situating healthcare services closer to disadvantaged populations. Promoting cross-sectoral collaboration among cities to implement "Health in All Policies" is vital for advancing urban health equity. The formulation of health policies and plans must fully consider the actual needs of the poor and vulnerable groups within society. (T. Ståhl, Wismar, M., Ollila, E., Lahtinen, E., & Leppo, K., 2006)

Furthermore, constructing a robust urban health security system is crucial to assist the poor and vulnerable in obtaining reasonable financial protection for healthcare. Expanding access to health services for the entire population can be facilitated through private sector involvement or public-private partnerships. These initiatives collectively aim to create an inclusive health system that supports the well-being of all urban residents, particularly those most in need. (Darrin Hodgetts & Otilie Stolte, 2017; Adam Wagstaff, 2002)

3.3.3 Healthy Urban Physical Spaces and Facilities

This section includes urban physical spaces and facilities, including urban forms, land use, transportation, and public service facilities. These are important parts of urban physical space, and their planning and construction models and development strategies are of great significance to the construction and development of healthy cities.

(1) Healthy Urban Form and land use

“Urban form” is used to describe a city's physical characteristics. It refers to the size, shape, and configuration of an urban area or its parts. It could be categorized as five broad and interrelated elements.(Jelena Živković, 2019) Which include density, land use, transport infrastructure, housing/building type, and layout (Nicola Dempsey et al., 2010).

“Land use” is the term used to describe the human use of land. It represents the economic and cultural activities (e.g., agricultural, residential, industrial, mining, and recreational uses) that are practiced at a given place (United States Environmental Protection Agency, 2022). Although different countries and regions have different classification methods, the main land use classifications in urban areas usually include agricultural, woodland, unimproved grassland and heathland, water and wetland, rock and coastal land, minerals and landfill, recreation, parkland, transport, residential, community buildings, industrial, commercial, vacant land and buildings, defense land and buildings, etc. (A. Di Gregorio et al., 2005; Andrew R Harrison, 2006).

■ Unhealthy Urban Form and land use and Their Causes

There are many ways of unhealthy urban forms and land use methods, mainly including disorderly sprawl of cities, unreasonable urban spatial structure, imperfect protection of urban ecological system and ecological environment.

Disorderly urban sprawl is defined as “the spreading of urban developments (such as houses and shopping centers) on undeveloped land near a city.” Which has been described as “a form of urbanization distinguished by leapfrog patterns of development, commercial strips, low density, separated land uses, automobile dominance, and a minimum of public open space.” The disorderly sprawl and expansion of cities will occupy a large number of urban development forms in the suburbs that originally belonged to agricultural production and ecological natural space, resulting in land loss, a reduction in biodiversity, losing of farmland and local food production; in addition,

the sprawl will increase the demand for using cars to travel, resulting in increased vehicle emissions. Exacerbating air and water pollution and other problems. (Marco Garrido-Cumbrera et al., 2018; Dario Genovese et al., 2023)

Unreasonable urban spatial planning and construction structure is, such as the excessive concentration of urban industrial and mining enterprises, which may easily cause serious pollution in some urban areas. The utilization efficiency of urban space is not high. For example, there are large-scale abandoned industrial and mining sites in the city, inefficiently used transportation and storage land, etc., and may cause regional environmental pollution, security, and other problems. Such areas need to be updated and developed to improve the intensive utilization efficiency of construction.

Imperfect protection of urban ecological system and ecological environment, such as a lack of urban green open space and insufficient protection of urban blue (water) space, may affect the urban atmosphere and water quality, cause urban residents lacking outdoor space for healthy activities, and it is easy to cause problems such as the urban heat island effects. (Augustinus EM de Hollander & Brigit AM Staatsen, 2003; A Prüss - Ustün et al., 2017)

■ Urban Planning Strategies for Healthy Urban Form and land use

In the field of sustainable urban development research, there are still disputes about whether to choose a decentralized or compact urban form. The consensus within European Union countries favors the idea of urban compactness and hinterland restraint put forward by the 1990 *Green Paper on the Urban Environment*. The idea of compactness has fairly obvious health and sustainability benefits compared with a dispersed pattern - at least in theory.

In general, integration, regeneration, and centralization can be healthy urban form planning concepts. Policy-makers usually consider four urban form strategies: urban regeneration, compact growth, focused decentralization, and linear concentration. (Hugh Barton & Catherine Tsourou, 2000)

The healthy reasons of these urban forms include: trip lengths being shorter (than a dispersed pattern) and there being more opportunities for exercise through walking and cycling; car dependence is lower, reducing levels of air pollution; a wide choice of facilities is within easy walking distance promoting greater access to and choice of food; land values can be sufficient to encourage urban regeneration and regeneration, which can help foster pride and a sense of community; the vitality and viability of the city center is bolstered, improving the economy and providing more employment opportunities; buildings and materials are reused, reducing energy and resource consumption; and access to rural open space is improved, providing opportunities for increased recreational activity (Hugh Barton & Catherine Tsourou, 2000; Tao Yang & Bill Hillier, 2007) (Table 4).

Table 4 Healthy Urban Form and Benefits

Urban Form Strategies	Definition	Suitable Place	Healthy Benefits
Urban regeneration (Peter Roberts & Hugh Sykes, 1999)	Accommodating most new development within the existing urban area, by reusing and recycling buildings and brownfield sites	Economic restructuring is occurring or where current gross urban density is low, and towns, cities, and rural areas that are dying through experiencing economic and social decline and a consequent loss of population	Improve environment quality and reduce pollution causing disease. Increases physical and social activities, and decreases ailments associated with inactivity.
Compact growth (Gabriel Ahlfeldt et al., 2018)	Release land close to the city with good access to urban facilities by foot, bicycle, and public transport. Development on green-field sites is not seen as an alternative to regeneration but as a supplement.	The urban area has insufficient capacity to accommodate the growth predicted. Cities that are growing more rapidly but are still relatively small.	Improve environment quality and reduce pollution causing disease. Increases physical and social activities, and decreases ailments associated with inactivity.
Focused decentralization (Aaron Schneider, 2003)	Deflect some of the growth potentials into suburban towns or free-standing commuter towns with the aim of making these more self-sufficient in jobs and services, effectively counter-magnets to the main city.	Highly urbanized regions with clusters of closely linked cities.	Improve environment quality and reduce pollution causing disease.
Linear concentration (Takatoshi Tabuchi, 1986)	Treat the city region as a social and economic entity	Growth along broad public transport corridors linking the dominant city and counter-magnet centers.	Improve environment quality and reduce pollution causing disease.

Source: Healthy urban planning: a WHO guide to planning for people (Hugh Barton & Catherine Tsourou, 2000)

Incorporating health strategies into urban land use planning involves considering factors such as land use density, mixed use, impervious surfaces, green spaces, accessibility, and non-motorized vehicle accessibility. Specific strategies are outlined in Table 5 and include the following (Table 5):

Appropriate Construction Density and Mixed Use: Implementing optimal construction density and mixed-use development can enhance land use efficiency, foster industrial agglomeration and diversification, and improve community safety. These strategies also have health benefits, including reducing car dependency, improving air and water quality, increasing opportunities for walking, promoting regional economic prosperity, and enhancing community awareness and a sense of security.

Controlling Land Use with Pollution Risks: This involves rational planning and layout of industrial enterprises with polluting emissions, establishing safety isolation and protection zones, and strengthening environmental protection measures. Additionally, it supports the ecological restoration and redevelopment of brownfields to mitigate health risks.

Protection and Utilization of Natural Resources and the Environment: Strategies include limiting the unregulated occupation of urban construction land, protecting natural resources such as forests, farmland, water bodies, and grasslands, and increasing urban open spaces. These strategies have significant health benefits, including improvements to the urban ecological environment, increased opportunities for outdoor activities, and the provision of locally sourced healthy food.

Improving Diverse Accessibility of Urban Facilities: Enhancing the accessibility of multiple modes of transportation, such as public transit, walking, and cycling, can reduce traffic accidents, air pollution, and CO₂ emissions. This also promotes healthy mobility and increases equitable access to urban services, particularly for people with disabilities.

For example, the Copenhagen metropolitan area has avoided urban sprawl and overly dense urbanization that lowers the quality of life through its modular urban development of the “Five-Finger Plan.” The plan was drafted in 1947, and it proposed carrying out urban expansion along commuter rail lines radiating from the dense urban texture of central Copenhagen (palm) to the surroundings. Most public buildings and high-density residential zones are concentrated around rail stations, while residential neighborhoods exhibit moderate density. The areas between the five corridors (fingers) serve as green wedges. In these areas, the construction of neighborhoods and shopping malls is prohibited. However, fingers are modular and consist of sub-modules or joints. This means that fingers can be extended or shortened by new neighborhoods, and new fingers can be added (Abbas Ziafati Bafarasat & Ayyoob Sharifi, 2024).

Table 5 Healthy Land-use and Benefits

Factors	Definition	Healthy Urban Planning Strategies	Healthy Benefits
Density	Number of people, jobs or housing units in an area	Appropriately improve urban density can properly concentrate urban functions, improve the efficiency of land use, and reduce the demand for vehicle traffic.	Improve environment quality and reduce pollution causing disease.
Mix	Whether different land use types (commercial, residential, etc.) are located together	Mix of residential and commercial development, mixed uses of the built environment for long term flexibility. Improve neighborhood safety, accessibility, and equity.	Improve environment quality and reduce pollution causing disease. Improve physical and social activities, mental health.
Layout	Control land use with pollution risks	Rational planning and layout of land used by industrial enterprises with polluting emissions in the city, safety isolation and protection. Encourage the ecological restoration and reuse development of brownfields.	Prevent health risks by industrial and brownfields pollution
Impervious surface	Land covered by buildings and pavement, also called footprint	Adopt a low-impact development model to increase groundwater recharge, reduce storm water management costs, and reduce urban water pollution.	Improve water quality and reduce pollution causing disease.
Green space	Portion of land devoted to gardens, parks, farms, woodlands, etc.	Preserve natural beauty, forests, parks, rivers, and environmentally critical areas. Farmland preservation around each urban area, provision for community gardens and farmers markets.	Increase physical, social activities and decrease ailments associated with inactivity. Improve environment quality and reduce pollution causing disease. Provide enhanced nutritional value food by local farmland.
Accessibility	Ability to reach desired activities and destinations	Shopping, restaurants, libraries, post offices, and other daily destinations within walking or biking distance of homes or offices.	Increases physical and social activities, and decreases ailments associated with inactivity.
No motorized accessibility	Diversified transportation options and quality of walking and cycling conditions	Vehicular traffic and parking control. Diversified transportation options including public transportation, bicycles, walking, etc. open to all sectors of the population - especially people who do not use cars - for access to employment, education, health, shopping, and leisure activities.	Increases physical activity and decreases ailments associated with inactivity. More energy efficient transportation options improve air quality and helps decrease respiratory problems.

Source: Author edits. (LF Fallon & J Neistadt, 2006; Todd Litman, 1995; Kim Perrotta, 2011)

(2) Healthy Transportation

The term “transportation” means of “conveyance or travel from one place to another. Conveyance of passengers or freight” (Merriam-Webster, 2004).

Urban transportation usually consists of private transportation and public transportation. Public transportation means “Movement of people by means of public conveyance, such as bus, tram, railway, and taxicab”. Private transportation means “Movement of individuals by any means of personal conveyance, especially by private motor vehicles”. (Klaus-Jürgen Evert, 2010) .

Health impacts of transport are largely related to road safety, vehicle emissions, noise, and physical activity (Eiichi Taniguchi et al., 2013).

The Third Ministerial Conference on Environment and Health was held in London in June 1999 and attended by ministers of environment, health and transport from 54 countries. The Conference noted the potential of integrated strategies to reduce car use while promoting bicycling, walking and public transport, and a Charter on Transport, Environment and Health was adopted. This emphasized the key strategic role of land-use policies and urban and regional planning in promoting healthy transport.(Hugh Barton & Catherine Tsourou, 2000)

■ Health Impacts of Transportation

With the continuous growth of urban construction areas and urban population, the use of various means of transportation, such as trains, automobiles, motorcycles, and bicycles. The impact of urban traffic on the health of urban residents is becoming more and more significant.(Amir Samimi & Abolfazl Kouros Mohammadian, 2010)

Vehicle emissions: transport-related air pollutants that affect health include: particulate matter, oxides of nitrogen, ozone, carbon monoxide and benzene. They increase the risk of a number of important health problems, including cardiovascular and respiratory disease, cancer and adverse birth outcomes, and are associated with higher death rates in populations exposed.

Traffic accidents and injuries: the burden of road traffic injuries is growing along with increased motorization. The main factors affecting road traffic safety include vehicle kilometers traveled, vehicle speed, and traffic behavior management (such as prohibiting drivers from using alcohol), etc.

Lack of physical activity: extensive use of private cars greatly reduces opportunities for people to walk or use bicycles (active transport) in their daily lives. And significantly reduce people's opportunities for daily physical activity. Because of lack of activities, it is easy to cause a decrease in human physical fitness and cognitive ability and increase the probability of obesity, cardiovascular and other diseases.

Noise: road traffic is the source of noise in most urban communities. Noise exposure will have adverse effects on human mental health, such as irritability, sleep disorders, psychological stress, etc., and can induce cardiovascular and other diseases. (WHO, 2011b)

Mental health: Traffic congestion, traffic accidents, improper planning and construction of transportation facilities (such as railway stations, parking lots, etc.), overuse, obsolescence, and other problems can easily cause psychological phenomena such as anxiety, increased stress, and even depression.

Disease transmission: If not correctly managed, public transportation facilities can increase the chances of spreading infectious diseases. For example, studies have shown that the chances of spreading COVID-19 are significantly growing in closed public transport facilities. (Hugh Barton & Catherine Tsourou, 2000)

■ Urban Planning Strategies for Healthy Urban Transportation

Studies have shown that increase land use density and diversity can increase proximity of destinations, reducing need for car travel and reducing vehicle kilometers travelled (VKT), improves access by walking, cycling and rapid transit/public transport. Measures such as supporting and encouraging the development of urban public transport systems, restricting the use of private cars and motorcycles, and encouraging the use of clean energy vehicles can reduce car dependence and reduce urban air pollution and carbon dioxide emissions. (Mark J Nieuwenhuijsen, 2016)

Strengthening urban traffic management and improving the level of intelligence in urban traffic use and management can reduce traffic accidents, traffic congestion, traffic noise, and the spread of traffic-related diseases. Studies show that public transportation, especially rail transit and buses, is often the mode of transportation with the lowest incidence of traffic accidents. Increasing the proportion of walking and cycling in urban transport can reduce the per capita risk of injury for its users and can reduce the risk of transmission of diseases through traffic exposure. (Jeffrey Tumlin, 2011)

The development of urban active transport (walking and cycling) is one of the most effective ways to promote physical activity among people. Improving walking and cycling accessibility can promote healthy exercise and local community awareness, and can increase equity in access to services for people with disabilities. (Gregory W Heath et al., 2006)

Good planning and construction of transportation facilities (roads, transportation stations, protective green spaces, etc.) is an effective means to reduce traffic noise and reduce mental health problems (Table 6). (Hugh Barton & Catherine Tsourou, 2000)

Table 6 Healthy Urban Transportation and Benefits

Healthy Planning Strategies	Urban Key Pathways	Healthy Benefits
Land use systems that increase density and diversity of uses	Increases proximity of destinations, reducing need for car travel and reducing VKT, improves access by walking, cycling and rapid transit/public transport.	Increase physical, social activities and decrease ailments associated with inactivity. Improve environment quality and reduce pollution causing disease.
Investment in and provision of transport network space for pedestrian and cycle infrastructure	Improve access by walking and cycling; Encourage shift from car use to walking and cycling, reducing VKT.	Increase physical, social activities and decrease ailments associated with inactivity. Improve environment quality and reduce pollution causing disease.
Investment in and provision of transport network space for rapid transit/public transport infrastructure	Improve access by rapid transit/public transport; Encourage shift from car use to rapid transit/public transport, reducing VKT	Increase physical, social activities and decrease ailments associated with inactivity. Improve environment quality and reduce pollution causing disease. Reduce the chance of traffic accidents.
Engineering and speed reduction measures to moderate the leading hazards of motorized transport	Reducing speed improves safety of walking and cycling, Increasing separation of vehicles from walkers and cyclists improves safety of walking and cycling; Encourages walking and cycling by reducing safety barriers; Technological improvements reduce production of hazards per vehicle (greenhouse gases, pollutants, noise);	Increase physical, social activities and decrease ailments associated with inactivity. Reduce the chance of traffic accidents. Reduce mental health problems.
Good planning, construction and management of transportation facilities	Encourage public transportation development and use; reduce traffic accidents, injuries and noise; reduce the risk of transmission of diseases through traffic exposure.	Reduce the chance of traffic accidents. Reduce mental health problems.

Notes: VK7: vehicle kilometers travelled

Source: *Urban transport and health* (WHO, 2011b)

(3) Healthy Public Service Facilities

Social determinants of health, are “the conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life” (Angela Donkin et al., 2018; Frank Pega et al., 2017). Social determinants of health are reflected in urban public services (facilities) including: access to medical and health care services, education and vocational training, commercial services and healthy food, services for the elderly, leisure and tourism, social interaction and support, etc.

■ Health Impacts of Public Service Facilities

Excellent, systematic urban public service facilities can greatly support urban residents in practicing healthy behaviors and lifestyles. Among them, establishing a sound urban medical care service system guarantees urban residents' physical and mental health. Integrating the concept of health into the construction of education and vocational training facilities can improve the overall health level of children and adolescents, help to lay a solid foundation for the health of the whole people, and improve people's health literacy through the education and publicity of educational institutions, and popularize various fields of health knowledge. Establishing an urban commercial service system with a high level of health services will help provide multiple commodities and material conditions for people's daily healthy lives. The establishment of a healthy elderly service system will help to improve the health level of the elderly, improve the quality of life of older people, create an elderly-friendly city, and improve the health equity of the city. The perfection and improvement of the leisure and tourism facility system can provide rich social interaction activities and space, improve the happiness and mental health of urban residents, and promote the development of the urban healthy economy. The construction of community activities and cultural facility systems can increase the diversity of social interactions and service levels and improve urban health equity. (Shihang Fu et al., 2021)

■ Urban Planning Strategies for Healthy Public Service Facilities

In urban planning, the main planning measures for building a healthy public service facility system include:

The planning and construction of urban public service facility systems should be divided into levels and levels, fully considering the different needs of different scopes and different service groups. And pay attention to the accessibility of diversified transportation modes in the planning, and increase the accessibility and convenience of public transportation, walking, bicycle and other transportation methods.

Integrate the concept of health into the planning and construction of urban public service facilities. The planning and construction of relevant facilities should fully consider the support and services for residents' daily health behaviors and healthy lifestyles. Support the construction of child-friendly cities and age-friendly cities.

Supports a mix of compatible, synergistic land uses, which may include medical, commercial, retail, residential, senior care, education, sports, and cultural, recreational and natural spaces within one geographic area or across multiple geographic areas. Promote the diversification and concentration of regional industries, promote the economic prosperity of settlements, increase the scope of employment opportunities, and create urban areas and the resources needed to provide services.(Table 7) (Stefano Capolongo et al., 2018; Jason Corburn, 2009; Colorado Department of Public Health and Environment, 2023)

Table 7 Healthy Urban Public Service Facilities and Benefits

Factors	Components	Healthy Urban Planning Strategies	Healthy Benefits
Medical and health service facilities	Hospitals & Clinics Rehabilitation Services Women's Medical Service Children's Medical Service Mental Health Services Medical Examination Institution	Provide medical service facilities that can serve for residents of different regions and demands, Improving the accessibility of using multiple modes of transportation, Increased service equity	Access to healthcare, primary care, health literacy
Education and training facilities	Early Childhood Education Primary, Middle and High School University Language and Literacy	Making every school a health-promoting school, Improving the accessibility of using multiple modes of transportation	Increase child care, Access to health literacy, Increase social interaction opportunities
Commercial facilities	Store Shopping center Supermarket Food Market	Support the healthy lifestyles (food, necessary etc.), Improving the accessibility of using multiple modes of transportation	Support healthy material life (healthy food etc.), Increase social interaction opportunities
Aged care facilities	Elderly Health Care Service Center Apartments for the Elderly	Provide diversify facilities for different demands, Improving the accessibility of using multiple modes of transportation	Increase aged care, Increase social interaction opportunities
Leisure and tourism facilities	Restaurant Bars Recreation center/ park	Provide diversify facilities for different demands, Improving the accessibility of using multiple modes of transportation	Increase happiness and mental health, Increase social interaction opportunities
Sport and fitness facilities	Sport field/ park Stadium Gym	Provide diversify facilities for different demands, Improving the accessibility of using multiple modes of transportation	Increase physical activity opportunities, Increase social interaction opportunities
Social interaction and support	Community Center Cultural Activity Center Social Assistance Organization/ Agency Place of Worship	Provide diversify facilities for different demands, Improving the accessibility of using multiple modes of transportation	Increase social cohesion, identity, Increase social interaction opportunities

Source: Author's own complication (A. Bonner, 2017; Colorado Department of Public Health and Environment, 2023)

3.3.4 Healthy Green and Blue Infrastructure

(1) Green Infrastructure and Parks

■ The concept of green infrastructure and healthy parks

Green Infrastructure (GI): “a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services’ in both rural and urban settings” (European Union 2013) (Anastasia Chatzimontori et al., 2020; European Union, 2000). More specifically GI, being a spatial structure providing benefits from nature to people, aims to enhance nature’s ability to deliver multiple valuable ecosystem goods and services, such as clean air or water.” (Europäische Kommission DG ENV - Generaldirektion Umwelt, 2013)

Healthy parks: As health is “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”, the assessment of accessible and attractive green spaces is an integral part of the quality of urban life (Ann Van Herzele & Torsten Wiedemann, 2003). When parks were first designed in the nineteenth century, city officials had a strong belief in the possible health advantages that would result from open space (Gianluca Grilli et al., 2020). Urban green spaces provide both physical and psychological benefits (Alex YH Lo & Chi Yung Jim, 2012) that contribute to improving citizens’ well-being (Cristiano Adinolfi et al., 2014), such as physical, mental, spiritual, social, and environmental contributions, through ecosystem services, and settings for community engagement (Cecily Maller et al., 2009). Recreational green spaces enable interactions between humans and the natural environment, being one of the key facilities in modern cities due to the benefits provided, such as stress relief and aesthetic appreciation (Liisa Tyrvänen et al., 2007).

■ The health effects of green infrastructure and healthy parks

Healthy perception of green infrastructure is a subjective perception. The overall quality of life perceived by citizens is positively correlated with urban greenness (Vincenzo Giannico et al., 2021).

However, not all urban green spaces have the same characteristics, nor are their health and well-being benefits perceived in the same way by the population, affecting their frequency of use. It is therefore important to evaluate the population’s perceptions of the characteristics of these spaces, since it may help to identify facilitators and barriers related to using green spaces. (Sabina Caula et al., 2009) People’s perception of environmental conditions also depends on non-climatic factors such as clothing type, coping ability, age, gender, physical appearance, subcutaneous fat, fitness, diet, and skin color. (Noë Djongyang et al., 2010; Joost Van Hoof & Jan LM Hensen, 2007)

Regulating ecosystem services should be planned with a focus on residents’ aesthetic and recreational needs (Gyula Kothencz et al., 2017). The young residents’ perception of green space components for health promotion had a greater effect on their

willingness to use parks and to promote health, while it was less influential with respect to their actual park use behavior (Chongxian Chen et al., 2020). Visual and auditory sensation were found to be linked with mental restoration directly and indirectly, while the tactile sensation was only associated with mental restoration indirectly; and health-related behaviors and emotional responses mediated the relations between the three sensations and mental restoration significantly (Chongxian Chen et al., 2020).

Contemporary ecological models of health have evolved to prominently feature the natural environment as fundamental to the ecosystem services that support human life and health (Christopher Coutts et al., 2014). Larger green infrastructure has been associated with reduced temperatures (Farshid Aram et al., 2019), air pollution (VM Jayasooriya et al., 2017), and crimes and violence (Blair Alexandra Burley, 2018; Mardelle Shepley et al., 2019), but less so with health, although some data suggest that it may be beneficial for health such as good health, mortality etc. (Mark J Nieuwenhuijsen, 2021). Responsible actions to deploy GI are urgently needed at present impacted by increasing anthropic climate change, accelerated transformation of the urban/peri-urban landscape, and their related risks (Marta Chãer et al., 2020). In fact, greening cities is a concept that has gained increasing relevance in the last decades (CY Jim & PY Tan, 2017) and more studies that experimentally demonstrate its effectiveness allow promotion of the implementation of greenery systems among city planning and governments providing measurable wellness benefits (Marta Chãer et al., 2020). GI can alleviate air pollution to a certain extent. Creating “green oases”, i.e., slowly ventilated areas containing or surrounded by GI but with no internal anthropogenic pollutant sources, will always lead to an improvement in air quality (C. Nick Hewitt et al., 2020). Planting that changes the local distribution of pollution relative to people, to reduce the concentrations of pollutants where most people, and/or people of highest vulnerability, are most exposed (Helen Pearce et al., 2021). Urban green spaces (UGS) can help to moderate the urban heat island effect (Ranhao Sun & Liding Chen, 2017), have cooling and energy saving effect (Xiyan Xu et al., 2017). And large urban parks located in the core of the populated cities in providing thermal comfort for citizens from both physiological and psychological perspectives (Farshid Aram et al., 2020). The green environment of slow transport systems, which primarily uses landscape plants and is largely concerned with roadside green space, aims to moderate the tension caused by traffic noise and is concerned with increasing the probability of walking trips so as to improve the popularity of Green Transportation (Kinjal J Shah et al., 2021; Shanyong Wang et al., 2020). A GI system that supports health simply by being present in one’s environment (e.g., water quality, climate regulation) can also bring with it co-benefits from the health behaviors that occur when accessing it (e.g., physical activity, social interactions) (Christopher Coutts & Micah Hahn, 2015). People can easily choose to view nature, be in the presence of nearby nature, or active participation and involvement with nature according to their convenience or physical ability in everyday life to enhance their psychological health (Ke-Tsung Han, 2021). And both blue and green urban settings were found to be restorative and therefore provide psychological health benefits to citizens (Mikel

Subiza-Pérez et al., 2020) .

■ Urban Planning Strategies for The Constructuion of Healthy Green Infrastructure

Developing healthy green infrastructure (GI) in urban areas involves several key measures. The primary one is creating a comprehensive healthy urban park and green space system. This system should be designed with full consideration of its health benefits, including the regulation of urban microclimates, adaptation to global climate change, enhancement of urban health activities, improvement of public service provision, and beautification of the urban landscape. (Mare Lõmus & John Balbus, 2015)

One critical measure is the conservation of forests, mountains, rivers, parks, and other natural features within urban areas. These natural habitats support wildlife and enhance biodiversity, contributing significantly to ecological balance and environmental sustainability. Additionally, constructing green corridors and ensuring connectivity between parks, rivers, and other natural features can establish an interconnected green network throughout the city. This network is essential for increasing tree canopy coverage, improving air quality, and mitigating urban heat island effects. (Judy Bush et al., 2021; Attila Tóth et al., 2015)

Moreover, identifying and repurposing underutilized lands, such as brownfields, idle lands, and abandoned properties, is crucial. These areas can be transformed into parks, community gardens, and urban forests, especially in neighborhoods with limited green space. This strategy not only revitalizes neglected areas but also provides accessible green spaces for recreation and relaxation, particularly in proximity to residential communities, schools, and business districts. (PA Cook et al., 2020; Mare Lõmus & John Balbus, 2015; Konstantinos Tzoulas et al., 2007)

One successful example of healthy green infrastructure is London's Green Belt, established in the mid-20th century. It is integral to the city's urban planning and provides numerous health benefits to its residents. Green belts are designated areas of protected open land surrounding the city to curb urban sprawl and preserve natural landscapes. And they serve as crucial lungs for the city. They will improve air quality by filtering pollutants and providing a buffer against noise pollution. Woodlands are set for creation in the Green Belt to ensure that they provide a contrasting natural experience. These green spaces promote physical activity, offering residents opportunities for walking, cycling, and recreational activities, which contribute to lower obesity rates and improved cardiovascular health. Moreover, the green belts support mental well-being by providing serene environments that reduce stress and promote relaxation. The access to nature within these belts enhances the overall quality of life for Londoners, supporting both physical and mental health. Public transport to the Green Belt is improved to better serve social and mental health purposes. It is seamlessly connected between its modes and with footpaths, bike share docking stations, and car/taxi pick-up and set-down points. (Vanessa Miriam Carlow & Yeon

Wah Hong; Alan Mace et al., 2016)

(2) Blue Infrastructure

■ The concept of blue infrastructure

Urban blue infrastructure refers to the area composed of various water bodies in the city. The combination design of blue space and green space can complement each other. Because human beings have psychological needs such as natural hydrophilicity. Urban water space can satisfy human beings to use water bodies for leisure and entertainment, rest and relaxation, enjoy the coolness and reduce heat and other activities. The urban blue infrastructure has a variety of health service functions. (Zahra Ghofrani et al., 2017; Clara J Veerkamp et al., 2021)

■ Urban planning strategies for the construction of healthy blue infrastructure

Healthy blue infrastructure, encompassing urban water systems such as rivers, lakes, canals, and stormwater management facilities, is paramount in fostering sustainable and resilient cities. Effective strategies for developing urban blue infrastructure can facilitate water recycling, enhance water quality, manage stormwater, and promote public health and ecological balance.

Restoring and protecting urban water bodies, including rivers, streams, lakes, canals, reservoirs, wetlands, etc., is essential for constructing an urban blue infrastructure system. Urban water body protection strategies include protecting the areas of water bodies, enhancing the water cycling natural functions, removing or retrofitting concrete channels to restore natural flow patterns, rehabilitating riparian buffers with native vegetation to improve water quality and habitat, and protecting existing wetlands and restoring degraded ones allow natural stormwater, flood control, and wastewater treatment. (Robert M Hughes et al., 2014; Siddhartha Koduru & Swati Dutta, 2013)

Integrating water features into urban spaces can enhance their healthiness and attractiveness. This includes developing public waterfronts with parks, promenades, and recreational facilities, ensuring these developments incorporate sustainable design principles to protect water quality. Establishing blue-green corridors that connect water bodies with green spaces can offer ecological and recreational benefits. Creating continuous corridors that link rivers, lakes, and wetlands with parks and urban forests can support wildlife movement and provide community amenities. (Joost Buurman & Rita Padawangi, 2018; Ratko Ristić et al., 2013; Carlos Smaniotto Costa et al., 2015)

Developing integrated strategies for water resource management is essential. This involves creating and implementing city-wide water management plans that address water supply, quality, and stormwater management, ensuring coordination among various government agencies. Integrating water management into urban planning and design can be achieved by adopting water-sensitive urban design (WSUD) principles

in planning regulations and building codes.(Tong Wong & Malcolm L Eadie, 2000) Implementing sustainable water management practices, such as incorporating green roofs and walls that utilize building surfaces for vegetation, can significantly aid in stormwater management and improve building insulation. The use of permeable materials in sidewalks, streets, and parking lots, alongside the design of rain gardens in residential and commercial areas, can reduce runoff and enhance water quality by capturing and filtering stormwater.(Richard Ashley et al., 2013; Alan Hoban, 2019; Sara Dorothy Lloyd et al., 2002; Tony HF Wong, 2006)

■ Naturalization and restoration for unhealthy urban blue infrastructure

In some past urban constructions, improper development of water space damaged natural water bodies. Therefore, in recent years, water protection, ecological restoration, and redevelopment have become common urban construction behaviors for healthy cities.

Stream naturalization seeks to establish sustainable, morphologically and hydraulically varied yet dynamically stable fluvial systems capable of supporting healthy, biologically diverse aquatic ecosystems (Rebecca J Wade et al., 2002). Renaturalization objectives also include recovering the critical function of the river as an ecological corridor and enhancing the landscape and social value of the river within its urban context (Mañ Dáz -Redondo et al., 2018). Naturalization seeks to establish morphologically and hydraulically varied but dynamically stable fluvial systems capable of supporting healthy, genetically diverse aquatic ecosystems. River stream restoration includes re-meandering rivers and reducing their canalization, which can facilitate the creation of a more balanced floodplain and re-establishing natural reed beds. This habitat confers multiple benefits, including improved flood protection, increased biodiversity, and wastewater management (Robin James Patrick Holmes, 2019; Joachim Pander & Juergen Geist, 2013; John Wiley & Sons, 2008). Green infrastructure as both urban infrastructure and infrastructure to the biosphere is essential for the continued provision of this health-sustaining and promoting ecosystem services(Christopher Coutts et al., 2014).

For example, the plan for the renaturalization of the river Manzanares as it passes through the city of Madrid is an excellent example of how a local initiative can contribute to preserving and improving biodiversity within an urban space, even though this is a densely populated area that has suffered intense human intervention. (Pedro Molina-Holgado et al., 2020). River restoration is used to describe a variety of modifications of river channels and adjacent riparian zones and floodplains, as well as of the water, sediment, and solute inputs to rivers (Sean J Bennett et al., 2011). Cheonggyecheon is an urban stream in downtown Seoul, South Korea, restoration solves the problem of environmental pollution, such as air pollution caused by the divergence of sewage gas (SL Kyung & L Zeng, 2007). After two years of repair and maintenance, in addition to BOD and total nitrogen, all water quality indexes can meet the first-class standard of surface water in Korea (Lin Qi Cao Xiangsheng, Meng Xuezheng, Zhang Jie, 2007; Zhiliang Ding et al., 2022). Since the restoration, the

number of annual and biennial herbs has continuously increased and stabilized after several years (H.-J. Kim, & Lee, K.-H. , 2012; B. H. Koo, 2013). In many respects, the most significant benefits to restoring local urban creeks are probably the social benefits accruing through community building and public environmental education.

4 Chapter4 Mining City Transformation from the Perspective of Healthy City

In the 21st century, with the rapid development of the world economy and science and technology, the global consumption of mineral resources has shown an upward trend, and the number and scale of global mining areas have increased unprecedentedly.

According to the International Organizing Committee for the World Mining Congresses, the total mining production in 2022, is 19.1 billion metric tons. Total mineral production in 2022 was 7509 billion USD, of which the mineral fuels were 6050 billion USD, accounting for approximately 80% of the total. The global top country in mineral production in 2022 was China, and the total mineral production of China was 1438 billion USD in 2022 (M. Schatz C. Reichl, 2024). With the production methods, such as automation, digitalization, and artificial intelligence technologies improvement, the global mining industry will once again leap forward. However, the contradiction between mining industry development, environmental protection, and human health has also face new challenges. And due to deindustrialization, economic recession, globalization, and climate change policies, some formerly prosperous mining cities are now facing urban decline and a decrease in the mining industry, especially in the North America, West Europe, and some Asian countries.



Fig. 3 Map of active metal and energy minerals mining sites

Source: SNL Metals & Mining Database, 2017.

This chapter focuses on summarizing the concept, theories, and urban development practices of mining cities, discussing the basic history, research achievements, global successful practice cases, and development strategies of mining cities, and analyzing their relationship with public health.

4.1 Conceptual Framework

4.1.1 Mine, Mineral, Mining, Mining city, Resource-based city

(1) Mine

According to merriam-webster dictionary mine is “a pit or excavation in the earth from which mineral substances are taken, an ore deposit”¹. Generally it refers to an opening or excavation in the ground for the purpose of extracting minerals; a pit or excavation from which ores or other mineral substances are taken by digging; an opening in the ground made for the purpose of taking out minerals, and in case of coal mines, commonly a worked vein; an excavation properly underground for digging out some usual product, such as ore, metal, or coal, including any deposit of any material suitable for excavation and working as a placer mine; collectively, the underground passage and workings and the minerals themselves. And the term “mining district” refers to a section of country usually designated by name, having described or understood boundaries within which minerals are found and worked under rules and regulations prescribed by the miners therein. There is no limit to its territorial extent and its boundaries may be changed if vested rights are not thereby interfered with (Paul W Thrush, 1968).

(2) Mineral

A naturally occurring inorganic element or compound having an orderly internal structure and characteristic chemical composition, crystal form, and physical properties (Paul W Thrush, 1968).

There are about 150 kinds of minerals with application value in the world, of which more than 80 kinds are widely used. With the development of human science and technology and the continuous progress of mineral exploration technology, new minerals are also emerging. Mineral resources can be classified into solid, liquid and gaseous states according to their existing forms. According to its mineral composition, it can be divided into three categories of minerals: energy, metal and non-metal.

Energy minerals: mainly include oil, natural gas, coal, peat, uranium, etc., which are the main source of energy for people to obtain from the earth.

Metal minerals: refers to minerals that can be used to extract metal raw materials for industry, generally divided into non-ferrous metal ores, ferrous metal ores, precious metal ores, rare metal ores, etc.

Non-metallic minerals: Refers to rock or mineral aggregates that can extract non-metallic elements, compounds, and can be directly used, mainly including diamond, graphite, asbestos, mica, silicon dioxide, etc (V.C. Sinha et al., 2022).

¹ <https://www.merriam-webster.com/dictionary/mine>

(3) Mining

The science, technique, and business of mineral discovery and exploitation. Strictly, the word connotes underground work directed to severance and treatment of ore or associated rock. Practically, it includes opencast work, quarrying, alluvial dredging, and combined operations, including surface and underground attack and ore treatment (Paul W Thrush, 1968).

(4) Mining city

Mineral industry is an industry for the exploitation of minerals from soil deposits by underground excavations or open workings, employing adequate plants and equipment. (Concept URL: <http://www.eionet.europa.eu/gemet/concept/5268>).

The concept of "mining city" is a component, complex concept that includes three main content characteristics: 1) It is a city which economic specialization is based on the extraction and processing of metal ores; 2) mining city necessarily has a special architectural and planning structure based on the mandatory presence of rivers as a mechanical force for mining activities; 3) mining cities did not initially have the status of an urban settlement, they had the status of a settlement near factories and were called factories (Elena Dvoryadkina & Elvin Jalilov, 2020).

(5) Resource-based city

A resource-based city (RBC) is a kind of city that has risen or developed while dependent on the exploitation and processing of one or more local natural resources (e.g., minerals, oil, forests, etc.), where this resource-based industry plays a leading role in the entire urban economy (Fei Fan & Xuerong Zhang, 2021; Dong-Hyeon Kim & Shu-Chin Lin, 2017; Huijuan Li et al., 2013; Cristina Martinez-Fernandez et al., 2012; Chang Yu et al., 2016).

Mineral resource-based city (MRC) refers to the type of city in which the mining and processing of natural resources, such as minerals (coal, metallurgy, and oil), in the region are the leading industries (Jingyuan Yang et al., 2023).

4.1.2 Urban Regeneration and Transformation

(1) Urban regeneration

Urban regeneration is an elastic concept, and it has changed gradually with the times and is used interchangeably with other similar or complementary concepts such as reconstruction, revitalization, renewal, and redevelopment in some situations (Peter Roberts & Hugh Sykes, 1999; Andrew Tallon, 2020).

Urban Reconstruction: development and construction activities aimed at restoring urban operations at the original site or new site due to urban damage caused by natural and man-made disasters such as earthquakes, tsunamis, fires, and wars, or other non-

disaster reasons such as disrepair of buildings (Denis Bocquet, 2021; Jeffry M Diefendorf, 1989; SKAT IFRC, 2012).

Urban Revitalisation: it is a form of action, combining respect for the past and local traditions with solving local problems of inhabitants (Małgorzata Wilczkiewicz & Magdalena Wilkosz-Mamcarczyk, 2015), which refers to a rebirth or revival in the conditions and character of a place that has endured a period of decline (Carl Grodach, 2015).

Urban Renewal: urban renewal is defined as the process of slum clearance and physical redevelopment that takes account of other elements such as heritage preservation (Chris Couch et al., 2011; Helen Wei Zheng et al., 2014). Urban renewal and urban regeneration are sometimes used as synonyms. Urban regeneration processes have often aimed to counteract urban decay, in contrast to urban renewal, which is geared mainly towards fostering new urban development (Giulia Marra et al., 2016).

Urban Redevelopment: urban redevelopment means demolition and reconstruction or substantial renovation of existing buildings or infrastructure within urban infill areas or existing urban service areas (Barry Hersh, 2016; Florida Statutes, 2018).

Urban Regeneration: urban regeneration refers to the necessary and planned reconstruction of the urban areas that are no longer suitable for the social life of modern cities (Peter Roberts & Hugh Sykes, 1999). As defined by Lichfield, urban regeneration is a “Comprehensive and integrated vision and action which leads to the resolution of urban problems and which seeks to bring about a lasting improvement in the economic, physical, social and environmental condition of an area that has been subject to change or offers opportunities for improvement” (Dalia Lichfield, 1992). In UK, urban regeneration refers to the state or local community is seeking to bring back investment, employment and consumption and enhance the quality of life within an urban area (Chris Couch, 1990). And Claudio and Nikos describes urban regeneration as, “a way of addressing issues of decline, social exclusion and a host of other public policy objectives through private-led property development operations, which are expected to provide the spaces, the public goods and the kind of built environment that will turn those policy objectives into reality” (Claudio de Magalhães & Nikos Karadimitriou, 2018). UN-Habitat in the report of the work day “Urban Regeneration” concerns that urban regeneration “consists of the remodeling of consolidated urban areas in the city center and is used as a mechanism to reverse a process of economic, demographic and social decline through an intervention that in many cases is marked by strong public action” (CENTRO CULTURAL FERNANDO LÁZARO CARRETER, 2016). There are three distinctive features of contemporary urban regeneration: It is intended to change the nature of a place and in the process to involve the community and other actors with a stake in its future. It embraces multiple objectives and actives that cut across the main functional responsibilities of central government, depending on the area’s particular problems and potential. It usually involves some form of partnership working amongst different stakeholders, although the form of partnership can vary (Table 8) (Nick Buck et al., 2017; Andrew Tallon, 2020; Ivan Turok, 1992).

Table 8 The evolution of urban regeneration

Period Policy Type	Reconstruction	Revitalisation	Renewal	Redevelopment	Regeneration
Major strategy and orientation	Reconstruction and extension of older areas of towns and cities often based on a 'masterplan' suburban growth.	Continuation of 1950s theme; suburban and peripheral growth; some early attempts at rehabilitation.	Focus on insitu renewal and neighbourhood schemes; still development at periphery.	Many major schemes of development and redevelopment; flagship projects; out of town projects.	Move towards a more comprehensive form of policy and practice, more emphasis on integrated treatments.
Key actors and stakeholders	National and local government; private sector developers and contractors.	Move towards a greater balance between public and private sectors.	Growing role of private sector and decentralisation in local government.	Emphasis on private sector and special agencies; growth of partnerships.	Partnership the dominant approach.
Spatial level of activity	Emphasis on local and site levels	Regional level of activity emerged	Regional and local levels initially; later more local emphasis.	In early 1980s focus on site; later emphasis on local level.	Reintroduction of strategic perspective; growth of regional activity.
Economic focus	Public sector with some private sector involvement	Continuing from 1950s with growing influence of private investment.	Resource constraints in public sector and growth of private investment.	Private sector dominant with selective public funds.	Greater balance between public, private and voluntary funding.
Social content	Improvement of housing and living standards.	Social and welfare improvement.	Community-based action and greater empowerment.	Community self-help with very selective state support	Emphasis on the role of community.
Physical emphasis	Replacement of inner areas and peripheral development.	Some continuation from 1950s with parallel rehabilitation of existing areas.	More extensive renewal of older urban areas.	Major schemes of replacement and new development; 'flagship schemes'	More modest than 1980s; heritage and retention.
Environmental approach	Landscaping and some greening	Selective improvements	Environmental improvement with some innovations	Growth of concern for wider approach to environment	Introduction of broader idea of environmental sustainability.

Sources: from Stohr (Walter Stohr, 1989) and Lichfield (Dalia Lichfield, 1992).

(2) Urban Transformation

The term “transformation” means a complete change in the appearance or character of something, especially that thing is improved (Cambridge University Press, 2024). According to Akkar, “Urban Transformation” refers to the sum of the comprehensive and integrated approaches, strategies and actions implemented to improve the economic,

social, physical and environmental conditions of urban space that experienced collapse and degradation (Akkar, 2006). And it is broadly described as, a process in which a city gradually integrates into the world's urban system through the continuous optimization of its development factors, involving economic, social, resource, and environmental systems (Katharina Hdscher & Niki Frantzeskaki, 2021; Elina Mikelson et al., 2021; Tayfun Salihoğlu et al., 2021).

Urban transformation includes types such as urban development, urban regeneration, and heritage preservation. Urban development-based urban transformation focuses on urban improvement and upgrading, such as intelligent, healthy, sustainable, and innovative urban development. Regeneration-based urban transformation focuses on urban regeneration as well as reconstruction, redevelopment, renewal, revitalization, rehabilitation, and land-use change as methods. Heritage conservation-based urban transformation: which focuses on historic preservation and urban conservation as well as urban restoration, restitution, renaissance and reuse as methods in the process (Table 9) (Nuran Zeren Güleroy & Ebru Güler, 2011) .

Table 9 Urban regeneration and urban transformation

Key element	Urban regeneration	Urban transformation
Scale	Specific, and smaller urban areas	Broader, and can involve citywide and regional agglomeration urban areas
Objective	Renewal, reconstruction, revitalization, redevelopment of the function, facilities, economic vitality, models, and aesthetics in urban areas	Comprehensive improvement and upgrading of the structures, function, systems, models, appearance, and competitiveness in urban and regional areas
Approach	Emphasize revitalizing and improving existing urban areas	Remodeling, improving existing urban areas. Creating new structure and systems.

Sources: Author's own complication

4.2 An Introduction of Mining Cities

4.2.1 A Brief History of Global Mining Cities Development

Starting from about 3000 BC, the Mesopotamian Valley, the Indus Valley, Egypt, and China entered the Bronze Age one after another. Bronzeware had become the main product of production and life in society at that time, which led to a significant increase in the demand for copper and tin ores, ushering in the first peak period of mining activities in human history. Archaeological data show that at that time, there were some mining settlements whose main functions were ore mining, smelting, and copperware manufacturing, such as Hallstatt in Austria (salt), Kition in Cyprus (copper), Rio Tinto in Spain (copper), Kültepe in Turkey (copper, Tin), Faynan in Jordan (copper), Great Orme in Britain (copper), Laurium in Greece (silver).

These mining settlements are usually arranged based on the distribution of mineral resources. The scale of a single settlement is small and the functions are relatively

simple. During this period, urban areas with metal smelting, processing, and manufacturing as the main functions also appeared in some important cities in some countries. For example, Memphis in Egypt (Copper), and Erlitou in China (Copper) (Vere Gordon Childe, 1963; Peter Darling, 2011; J Arwel Edwards & Joan Carles Llurde i Coit, 1996) . These mining processing areas are usually separated from the city's administrative, religious activities, and residential areas by a certain distance to reduce the impact of noise and exhaust gas from the production and processing process on residents' lives.

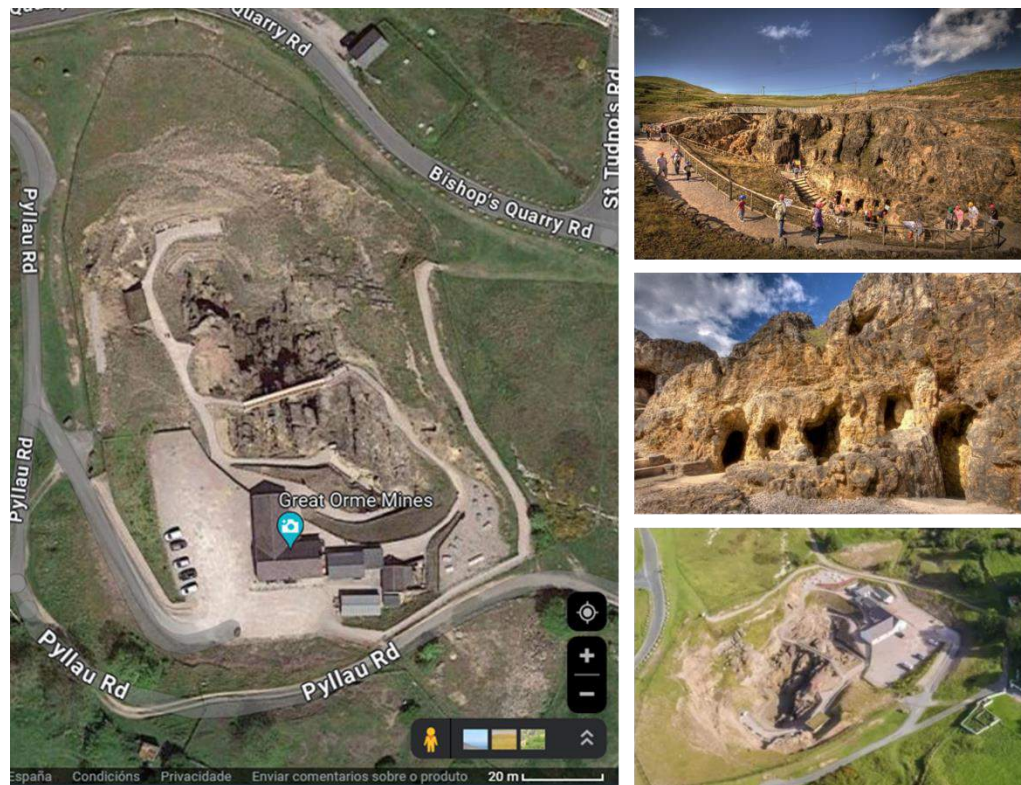


Fig. 4 Great Orme, Britain (Copper)

Source: <https://www.greatormemines.info/>; (Great Orme Mines, 2024)



Fig. 5 Laurium, Greece (Silver)

Source: <https://www.ancient-greece.org/archaeology/lavrion.html>

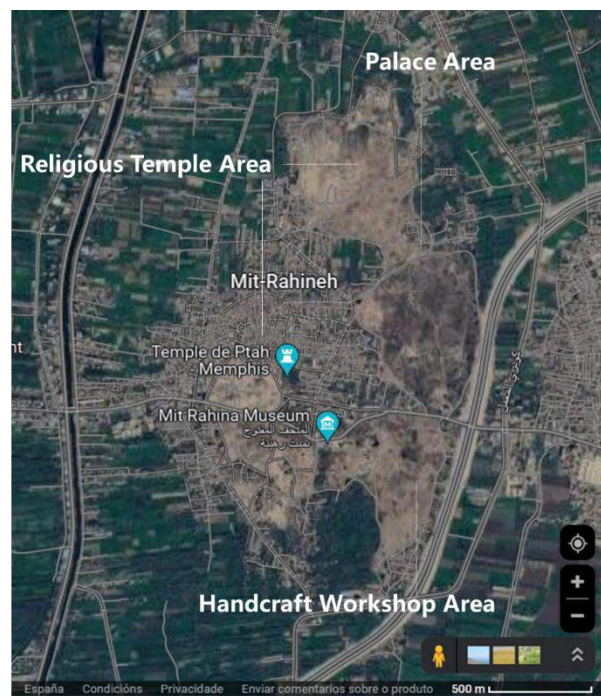


Fig. 6 Memphis Relic Site, Egypt (Copper)

Source: From Google map



Fig. 7 Erlitou Relic Site, China (Copper)

Source: From Google map

Around 1000 BC, humans invented iron smelting technology, and iron ore mining entered an active stage. At the same time, the development and utilization of metals such as gold, silver, copper, and tin also increased, and the scale of mining activities further expanded. With the continuous development of mining, smelting, and handicraft manufacturing, mining has become more closely related to the manufacture of production and living tools, weapons, coins, and fuel, and gradually formed larger-scale

mining towns. Famous mining towns include Timna Valley in Israel (copper), Taveirye in Switzerland (iron), Jebel Barkal in Sudan (iron), and Noricum in Slovenia (iron). With the use of iron tools, social productivity increased significantly, the scale of human cities expanded, and the process of urbanization accelerated. During this period, in some important cities, the areas of metal smelting and manufacturing further expanded, often concentrated on the edge of the city, near the river source, or in certain specific neighborhoods in the market and trade area, and separated from the residential and public building areas. For example, the metal manufacturing workshops in ancient Rome were mainly concentrated in Trastevere near the Tiber River, near Campus Martius near the market, near the Subura district, and in the Esquiline Hill neighborhood on the edge of the city (Olivia F Robinson, 2003).

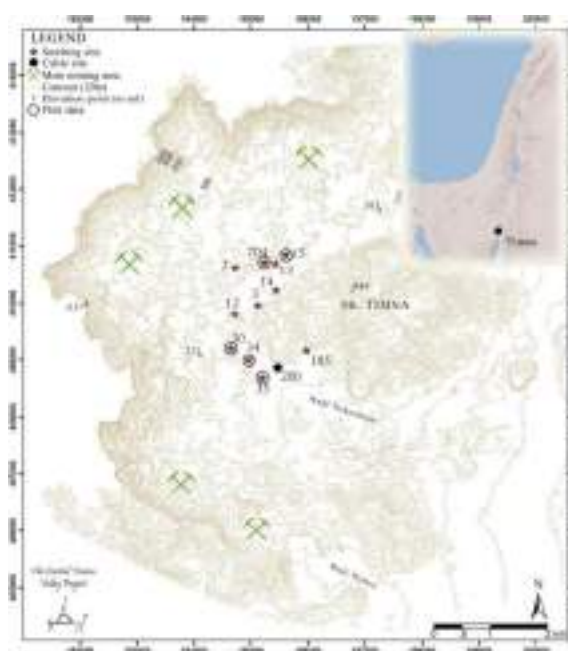


Fig. 8 The Timna copper mining and smelting complex dated to the Late Bronze and early Iron Ages (thirteenth–ninth century BC)

Source: from Ron Shimelmitz & Erez Ben-Yosef (Ron Shimelmitz & Erez Ben-Yosef, 2023)

During the 18th and 19th centuries, the Industrial Revolution spurred rapid development in modern industry and mining, leading to the emergence of numerous new industrial cities in countries like Britain, France, Germany, and the United States. Cities such as Newcastle, and Cardiff in Britain; Pittsburgh in the USA; and Essen and the Ruhr area in Germany, along with Lorraine in France, became pivotal pillars of the industrialization process. These cities not only played a crucial role in their respective national economies but also significantly contributed to the global industrial landscape (Robert C Allen, 2017; Jeffrey G Williamson, 2002; Lee T Wyatt III, 2008). After the 19th century, developing countries such as Asia, Latin America, and Africa also began large-scale mining activities, and several important mining cities emerged, such as Belo Horizonte in Brazil (iron), Antofagasta in Chile (copper), Kitwe in Zambia (copper),

Pretoria in South Africa (iron, diamonds), and Anshan in China (steel). These mining cities occupy an important position in the global economy. In the layout of these cities, coal mines, smelters, steel mills, etc. are often located close to mineral burial areas or transportation routes such as railways and rivers to facilitate the transportation of raw materials and industrial products. At this time, to facilitate production and life, many cities have built infrastructure such as transportation and electricity, public service facilities such as commerce and medical care, and large workers' communities, and the scale of cities has expanded rapidly. However, due to pollution emissions from industrial and mining production, these cities often have serious environmental pollution problems.

In the 20th century, with economic globalization and the progress of emerging science and technology, the development of mining cities has undergone new changes. Economic globalization requires that important production factors be optimally allocated in the global market. As a very important production factor, mineral resources have shown multiple choices and mobility in the allocation of mining capital, mining technology and mining service markets. Traditional mining cities attempt to fix these factors in resource-based cities based on mining. This way of solidifying factor allocation will increasingly lack market competitiveness. At the same time, with the construction of urban and rural infrastructure and the development of science and technology, the radiation capacity of cities has been greatly enhanced. A large mining area can obtain support from the financial, information, technical, material and life services of existing cities, and no longer needs to build a new mining city specifically for it. The new technological revolution with information technology as the core has completely changed the technology and equipment level of mining production and greatly improved labor productivity. For example, a mining area with an annual mining output of tens of millions of tons may only require a few thousand employees, and the impact on the urban population and construction layout is very limited. Therefore, mining is no longer a labor-intensive industry, and the urban phenomenon of tens of thousands of miners and hundreds of thousands of mining-related populations in the past will gradually become history. The following are some examples of modern mining areas that have applied advanced production technologies:

Gudai-Darri Mine, Pilbara, Australia: Gudai-Darri Mine is located in the Pilbara region of West Australia, and which operated by Rio Tinto with an annual capacity of 43 million tonnes. This mine supports over 3,000 jobs in the construction and design phases and establishes around 600 jobs for the mine's operation. As West Australia has become more interconnected with the increasingly Northeast Asian core of globalizing capitalism, the Pilbara region has become resource-oriented and prosperous. Gudai-Darri hosts a suite of technological innovations, including autonomous trucks and drills, autonomous trains for long-distance transport which are monitored remotely by operators from our Operations Centre in Perth more than 1,500 kilometers away, and the world's first autonomous water carts for dust suppression. The mine also employs advanced robotics for sampling and heavy mobile equipment handling, and a digital twin of the processing plant for real-time monitoring and training. Additionally, a solar

farm consisting of about 83,000 solar panels with a capacity of up to 34MW, powers a significant portion of the mine's operations, highlighting its commitment to sustainability (Raymond Leung et al., 2023; Rio Tinto, October, 2023).



Fig. 9 Gudai-Darri Mine in Australia

Source: <https://www.mining-technology.com/projects/gudai-darri-iron-ore-project-pilbara-australia/?cf-view>;
<https://www.mining.com/web/in-australias-outback-rio-tinto-prepares-for-a-low-carbon-future/>;
<https://www.dtm.com.au/project/gudai-darri-project-concrete-works-and-underground-services/>



Fig. 10 Map of Gudai-Darri Mine, Pilbara, Australia

Source: From Google map

Venetia Underground Mine, South Africa: This mine, operated by De Beers, has become South Africa's largest producer of diamonds, since 1995, located 37 kilometers from Alldays in the Limpopo province. It transitioned from open-pit to underground operations in 2023, employing approximately 4,300 people, mainly from Musina and Blouberg. The advanced underground operation is set to process up to 7 million metric tons of kimberlite ore annually, yielding approximately 4 million carats of diamonds. By 2027, the Venetia Underground Project (VUG) aims to implement autonomous

mining systems to enhance safety and productivity, including autonomous drilling, rock reinforcement, and loading and hauling equipment, operated independently or remotely from surface control rooms. (Gavin du Venage).



Fig. 11 Google map of Venetia Underground Mine, South Africa

Source: <https://www.google.com/maps>

4.2.2 Ming City Spatial Structure

(1) The Relationship between Mine and City

■ Economic dependence between cities and mines

Level 1: Mining and its related heavy industries are the most important pillar industries of the city.

Level 2: Mining and its related heavy industries are one of the main industries of the city. In addition to mining, the city also has many other economic industries.

Level 3: Mining and its related heavy industries are not the main industries of the city, but only one of its components.

■ Spatial dependence between cities and mines

Level 1: The city and the mining area are highly dependent, and its mining area is mainly located in the urban and suburban areas of the city.

Level 2: The city has a high degree of dependence on the mining area, and its mining area is partly located in the urban and suburban areas, and partly located in other places outside the urban and suburban areas of the city under the jurisdiction of the administrative district.

Level 3: It means that the city has a low degree of dependence on the mining area,

and the mines are scattered in the administrative district under the jurisdiction of the city.

(2) The Spatial Structure of Ming Cities

Combining the research results on the spatial structure of mining cities and the investigation of mining cities, the common spatial structure of mining cities mainly includes five structural types (Charles Press, 1963; Tao Yang & Bill Hillier, 2007) (Table 10).

Table 10 Main types of spatial structure of mining cities

Type	Basic Features	
Centralization (Manuel Wolff, 2018)	Concentrated mass type	The city is in a concentrated cluster. The reasons for this include being in the early stages of development or being a mining city developed from an old city.
	Continuous strip type	The city is in a continuous belt-like pattern. The main reasons for this are the belt-like distribution of mineral resources, traffic conditions, and topographical restrictions (such as river valley topography).
Dispersion (Stephen Belcher et al., 2013)	Dual-city structure	The city has two relatively independent and concentrated urban areas (clusters). The main reasons for this are the distribution of mineral resources, rivers or other terrain (barriers), etc.
	One city, multiple towns	The city is mainly composed of a main urban area and multiple townships, with a certain distance between the main urban area and the townships. The main reasons for its formation include the scattered distribution of mineral resources and the development of mining cities based on the old city.
	Multi-city and multi-town type	The city is composed of multiple urban areas (clusters) of a certain size. Each urban area can have different functional divisions or rely on relatively independent mining areas.

Sources: Author's own compilation.

4.2.3 The Evolution of Mining Cities

The development and evolution of mining cities are affected by many factors, including the abundance of resources, technological level, economic policies, environmental factors, etc. In the 1930s, Innis pointed out the characteristics of resource-based cities, stating that they rose rapidly during resource mining and declined after resource depletion after studying Canadian resource-based cities (Harold Adams Innis, 1929). Canadian scholar Lucas believes that resource-based cities must go through stages such as population influx, stabilization and decline (Rex Lucas, 1971). Generally speaking, the development and evolution of mining cities can follow the following stages:

Initial development stage: When a mineral deposit is discovered, it usually triggers a

resource development boom. At this stage, a large number of mining companies, investors and workers flock to the area, forming a small settlement dominated by the mining industry. These settlements may be simple mining camps or small mining villages. At this time, the mineral deposits in the region have just been developed and the resources are sufficient.

Rapid expansion stage: With the development and utilization of mineral resources, a large number of people poured in, the city began to expand rapidly, and various facilities such as urban road transportation, housing, medical care, and commerce were built and improved. The development of mineral resources shows an upward trend. With the exploration of regional mineral deposits, new buried resources may also be discovered.

Mature and stable stage: With the gradual exploitation of mineral resources and the improvement of urban infrastructure, mining cities have entered a relatively stable development stage, with good urban economic development and stable mineral resource supply.

Resource depletion or transformation development stage: With the gradual depletion of mineral resources, the urban mining economy faces a recession. In this stage, some cities have diversified their economic structures and no longer rely on mining. In other cities, due to the lack of alternative economic industries, urban economic vitality has declined, population loss has intensified, urban infrastructure and social services are under pressure, and they have even become abandoned cities.

4.3 Theories of Mining City Transformation

In 1921, British scholar Aunousseau first proposed the concept of mining towns. Famous scholars, such as Jane Jacobs and L. Mumford, put forward the idea of humanism as an important theoretical basis for urban transformation. (Eric Mumford, 2018; Lewis Mumford, 1961). Urban transformation in mining industry cities is a multifaceted phenomenon influenced by socio-economic, environmental, and political factors. These cities often undergo significant changes as they transition from active mining hubs to post-mining communities. This section aims to synthesize the current knowledge on the urban transformation of mining cities, focusing on the drivers of change, impacts on public health, and strategies for sustainable development.

4.3.1 Historical Context of Mining City Transformation

Mining cities have historically been characterized by rapid growth driven by resource extraction. The economic boom associated with mining activities often leads to rapid urbanization, infrastructural development, and population growth (Bell & York, 2010). However, the depletion of mining resources triggers economic decline, social, physical, and governance challenges in post-mining cities, leading to the need for urban transformation (Shannon Elizabeth Bell & Richard York, 2010).

The early 20th century was the starting point for the transformation of mining cities, which mainly focused on issues such as resource dependence, population characteristics, and urban construction to resolve unstable factors in development.

Moreover, driven by the simultaneous disruptive processes of migration, economic readjustment, and demographic change, many mining cities in Europe and the US have undergone a profound transformation since the end of World War II. Dozens of cities, large and small, such as Newcastle, Britain (coal), Cardiff, Britain (coal), Ruhr, Germany (coal and steel), Lorraine, France (coal and steel), Butte, Montana (copper), Pittsburgh, Pennsylvania (steel), Cleveland, Ohio (steel), Scranton, Pennsylvania (coal), Bisbee, Arizona (copper), Gilman, Colorado (lead and zinc), have experienced this shift. Initially, most of these cities focused on urban reconstruction and the proposal of urban improvement plan in the beginning. However, until the 1980s, this transformation was largely negative for most of these cities, marked by job losses, economic decline, and population decrease. Since the 1990s, however, an increasing number of these post-mining cities have begun to rebuild by discovering new economic roles in the global economy, reconfiguring their physical landscapes, reconstructing their urban infrastructure, and re-emerging as hubs of innovation (Table 11) (Donald K Carter, 2016).

Table 11 Challenges of Mining City Transformation

Dimension	Challenges
Economic	Resource depletion, economic decline, unemployment
Social/ Cultural	Population loss, poverty, crime, reduced quality of life, risks of public health, lack of education, loss of cultural heritage
Physical/ Environmental	Land degradation, environmental pollution, landscape degradation
Governance	Public policy dilemma, community degradation

Sources: Author's own complication.

4.3.2 Dimensions of Mining City Transformation

Urban transformation in mining cities serves multiple purposes, reflecting economic, social and environmental objectives. The main dimensions of urban transformation can be broadly described as economic, social, and cultural, physical and environmental, and governance sectors. As resources deplete, cities need to transition from a mining-based economy to other sectors like tourism, technology, or services. Revitalized urban areas can attract new businesses and investors, fostering economic growth and job creation. Moreover, urban transformation aims to enhance the quality of life by providing better housing, healthcare, education, and recreational facilities. For example, transforming former mining sites into green spaces, parks, or new urban developments helps restore environmental balance, while implementing eco-friendly infrastructure reduces pollution and promotes sustainability. By making the city more attractive, urban transformation can counter the population decline often seen when mining activities decrease, helping the city to thrive and prosper (Table 12) (Carl Grodach, 2015; Andrew Tallon, 2020).

Table 12 Dimensions of Mining City Transformation

Dimension	Concerns
Economic	Job creation, income, employment, skills, employability, development
Social/ Cultural	Quality of life, health, education, crime, housing, quality of public services
Physical/ Environmental	Infrastructure, built and natural environment, transport and communications
Governance	Nature of local decision-making, engagement of local community, involvement of other groups, style of leadership

Sources: from Andrew Tallon (Andrew Tallon, 2020).

4.3.3 Urban Industrial Transformation in Mining City

The early 20th century was the starting point for research related to the mining city industry. Innis developed the staples theory, which argues that the economic development of Canada was heavily influenced by the export of staple products. Innis emphasized how resource dependency impacted Canadian mining cities. He argued that reliance on a single resource for economic growth could lead to economic vulnerability, especially when global demand for that resource declined. This was particularly evident in mining towns where the boom-and-bust cycle of resource extraction led to economic instability (Trevor Barnes, 2005; Harold Adams Innis, 1929, 1999; Melville H Watkins, 1963). Representative studies on the mining city transformation include Corden and Neary's study on the "Dutch Disease" about resource-based cities, which believed that the prosperity of the traded goods sector induced deindustrialization, leading to a decline in the competitiveness of the manufacturing and service industries, losing the ability for sustainable development (W. Max Corden & J. Peter Neary, 1982). Auty proposed the theory of the "resource curse", that is, the richer the natural endowment, the longer the country will tolerate failed macroeconomic policies and rent-seeking behavior, which will have a negative impact on industrialization (Richard Auty, 2002; Richard M Auty, 1994). In the late 20th century, the concept of sustainable development emerged as a crucial ideological foundation for the urban transformation of mining cities, fostering resilient, diversified, and environmentally friendly economic development in former mining regions (Niki Frantzeskaki et al., 2017). Extensive research has also been conducted on issues such as the economic growth drivers, economic structure changes, population and labor market dynamics, community development, and the effects of globalization in mining cities (Steven C Deller & Andrew Schreiber, 2012; Fiona Haslam McKenzie, 2013; Cristina Martinez-Fernandez et al., 2012; Cristina Martinez-Fernandez & Chung-Tong Wu, 2009; Ivan Turok, 2014).

To address the challenges of economic transformation in mining cities, extensive research has been conducted on the factors, models, and methods that influence their economic development. The main factors affecting the transformation of mining cities

include the city's geographical location, policies and management systems, existing economic and industrial foundation, urban investment, education and scientific and technological innovation capabilities, and the natural ecological and construction environment (Donald K Carter, 2016; Xiaojia Guo et al., 2023; Matthew E Kahn & Mac McComas, 2021; Xiangyan Qian et al., 2021; Huiming Zhang et al., 2018). According to the studies of successful urban transformation of mining city cases, the common transformation paths include extensions of industrial chains, industrial substitution patterns, and a comprehensive development model (Donald K Carter, 2016; Matthew E Kahn & Mac McComas, 2021; Qiangyi Li et al., 2021).

4.3.4 Urban Physical Environment Transformation in Mining Cities

The transformation of the urban physical environment in mining cities involves revitalizing and reconfiguring the built environment to adapt to post-mining economic realities and promote sustainable development. This includes brownfield redevelopment, infrastructure upgrades, smart growth, heritage preservation, and resilience development. Brownfield redevelopment involves converting former industrial and mining sites into new uses such as residential areas, parks, commercial spaces, or cultural hubs, often including the remediation of contaminated land and the clearance of blighted buildings. Modernizing urban infrastructure, including roads, bridges, utilities (water, sewer, electricity), and telecommunications, supports new economic activities and improves quality of life. Encouraging mixed-use zoning that integrates residential, commercial, and recreational spaces promotes walkability, reduces urban sprawl, and fosters a sense of community. Urban planning, traditionally focused on growth-related challenges, now addresses the concentration of empty properties in downtown areas by discouraging suburbanization and concentrating projects in city centers, thereby increasing the attractiveness of public spaces. Preserving and repurposing historic buildings and cultural landmarks related to the city's mining heritage helps maintain a sense of identity and history. Creating or expanding green spaces, parks, and recreational areas enhances urban aesthetics, provides leisure opportunities, and promotes environmental sustainability. Developing strategies to mitigate the impacts of climate change and natural disasters, such as flood management systems, green infrastructure, and resilient building design is also crucial (Argonne National Laboratory. Energy et al., 1978; Klaus-Jürgen Evert, 2010; Yuhang Shang et al., 2022; Peter Wirth et al., 2018).

4.3.5 Urban Transformation Policies in Mining Cities

Different countries have formulated different policies for the transformation of mining cities. The main policies formulated by the United States, the European Union, and China are as follows.

The main policies of the United States for the transformation of mining cities mainly include: promoting regional economic diversification and industrial chain extension

through government guidance and market-oriented methods, and reducing dependence on a single industry (such as coal mines). It mainly includes attracting enterprises to settle in and supporting emerging industrial projects by establishing special funds, formulating economic development plans, tax incentive policies, and strengthening regional infrastructure construction. For communities and families affected by the decline of traditional industries, government assistance projects such as vocational skills education and training, employment counseling, financial assistance, and mental health support are provided to help them overcome the difficulties during the economic transformation. Strengthen regional environmental protection and brownfield ecological restoration, promote the recycling plan of the original mining area, minimize the original environmental pollution and create new economic uses. Through close cooperation between the government, communities, enterprises, and non-profit organizations, transformation plans that suit local needs are jointly formulated and implemented to ensure the effectiveness of the plan. Houston and Pittsburgh in the United States are both relatively successful transformation cases under this model.

The main policies of the EU for the transformation of mining cities include using a combination of government and market regulation to promote sustainable development and green economic transformation. It mainly includes promoting the adjustment of economic structure through environmental protection and climate policies, reducing dependence on fossil fuels (such as coal), and increasing the proportion of renewable energy. Through regional policies and funds, such as the European Regional Development Fund (ERDF) and the European Social Fund (ESF), it is used to promote employment, economic diversification, education and training, to support the transformation of mining cities. Support the development of innovation and emerging technology industries, focusing on supporting high-value-added, environmentally friendly high-tech industries such as computers, electronics, biopharmaceuticals, and new energy. Through social inclusion policies and human resource development measures, such as retraining, education, and social security support, help affected local residents transform to new employment areas. Encourage partnerships between governments, social groups, and the private sectors to jointly formulate and implement transformation strategies that suit local needs and conditions. The Ruhr area in Germany and the Lorraine region in France are both relatively successful representatives of this model.

China's main policies for the transformation of mining cities include promoting industrial restructuring and upgrading in mining cities, supporting the development of emerging industries, modern service industries and high-tech industries, and reducing dependence on traditional mining. Encouraging economic diversification through scientific and technological innovation and industrial chain extension. Implementing environmental governance and ecological restoration projects to address environmental issues in mining areas. Policies include land reclamation, pollution control and ecological restoration in abandoned mining areas to improve environmental quality and enhance residents' living standards. Providing vocational training and re-employment support to help miners and affected labor adapt to the new job market. Implementing

vocational skills improvement programs and entrepreneurship support to enhance their employability and competitiveness. Strengthening social security for communities and families affected by the mining recession, providing essential services such as medical care, education, and housing to ensure social stability, unemployment insurance, and minimum living security to ensure residents' basic living needs. Promoting the construction of new urbanization, improving infrastructure and public services, and improving the comprehensive carrying capacity of cities. Enhancing the attractiveness and development potential of cities through the upgrading of infrastructure such as transportation, communications, and energy (Wenting Jiao et al., 2021; He Li et al., 2015).

In 2007, the State Council formulated and issued the "Several Opinions of the State Council on Promoting the Sustainable Development of Resource-Based Cities." In 2013, the State Council issued the "National Sustainable Development Plan for Resource-Based Cities (2013~2020)", which covers 262 resource-based cities in China and proposes to accelerate the transformation and development of resource-based cities across the country. In 2021, the National Development and Reform Commission, the Ministry of Finance, and the Ministry of Natural Resources jointly issued the "14th Five-Year Plan Implementation Plan for Promoting High-Quality Development in Resource-Based Areas" to further strengthen the development guidance for resource-based cities (Yujie Wang et al., 2022; Qian Zhang & Roy Brouwer, 2020).

The policies of major countries and regions in the worldwide have consistently provided encouragement and support for the industrial transformation and upgrading of mining cities. These policies emphasize that ecological restoration and the improvement of the urban environment will enhance regional attractiveness and elevate residents' living standards. Additionally, they offer policy guarantees addressing the livelihood and employment of affected local residents, ensuring a smoother transition during the transformation process.

4.4 Global Practice Cases of Mining City Transformation

4.4.1 Ruhr, Germany

(1) Historical Context of Ruhr

The Ruhr also referred to as Ruhr Valley, which is a polycentric urban area in North Rhine-Westphalia, Germany. With a population density of 2800/km² and a population of over 5 million (2017). The urban landscape of the Ruhr extends from the Lower Rhine Basin east to the Westphalian Plain and south to the hills of the Rhenish Massif. Through the center of the Ruhr runs a segment of the loess belt that extends across Germany from west to east. Since the 19th century, these cities have grown together into a large complex with a vast industrial landscape.



Fig. 12 Map of Ruhr district in Germany

Source: From Google map

There were more than 150 coal mines in 1939, the year of the highest coal production (130 million tons) in the Ruhr District. The coal and steel crisis of the 1960s and 1970s affected the Ruhr economy. In 2005, ThyssenKrupp AG closed the Dortmund works and consolidated all regional steel making in Duisburg, located its new global headquarters in Essen on an old Krupp plant site. However, in 2007, the German government approved phasing out coal mining by 2018. And on December 21, 2018, the Prosper-Haniel coal mine, the last hard coal mine in the Ruhr area, officially closed. This event marked the end of over 150 years of coal mining history in the region (Gert-Jan Hospers, 2004a).

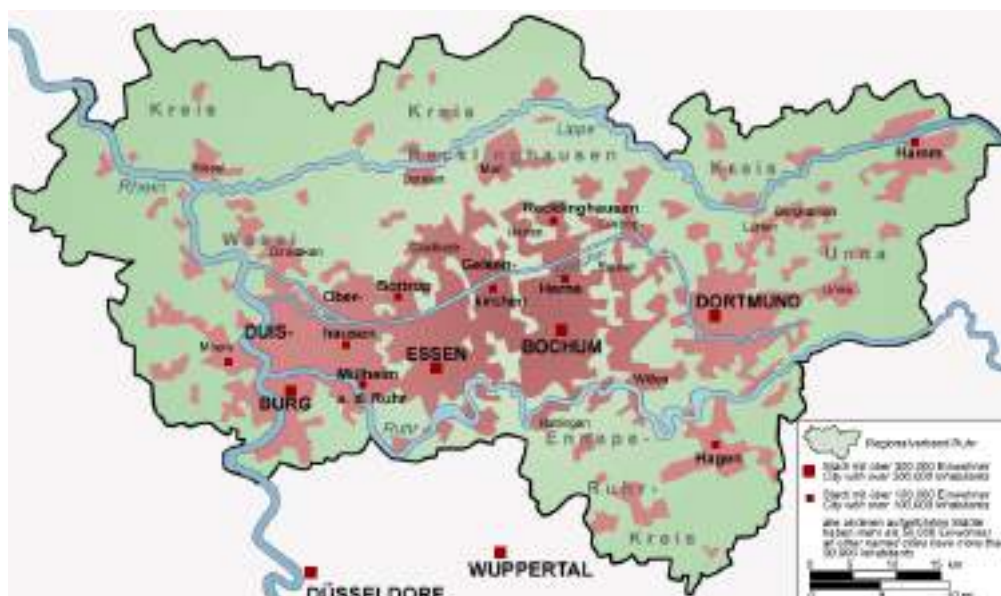


Fig. 13 Map of Ruhr

Source: Threedots (Daniel Ullrich)(https://es.m.wikipedia.org/wiki/Archivo:Ruhr_area-map.png)

(2) Urban Transformation in Ruhr

From the mid-1980s, the structural neo-industrialisation policy had been implemented in the Ruhrgebiet region. The economy is no longer dependent on or dominated by the old industries. The economic strengths of the region are now in the chemicals, logistics, new energy, health care, environment and emerging technology sectors. It should be noted that it is less a regional economy than part of the global economy. Many famous companies such as RWE AG, E.ON Ruhr Regiongas AG, ALDI Süd and ALDI Nord that are based in the Ruhr region sell their knowledge and products worldwide.

Replanting of brownfield land has created new parks and recreation areas. The Emscher Landschaftspark (Emscher Landscape Park) lies along the river Emscher, formerly virtually an open sewer, parts of which have undergone natural restoration. This park connects strips of parkland running from north to south, which were developed through regional planning in the 1920s to form a green belt between the Ruhr cities from east to west.

Since the early 1990s, efforts to restore the Emscher to its natural state have been making headway. Now that coal mining near the route of the river has halted, a large underground pipe is being built along the path of the river. The first stretch of the river to be restored is that in the city of Dortmund. The overall project is headed by the public water board Emschergenossenschaft.

The International Building Exhibition (IBA) Emscher Park was a unique workshop that operated from 1989 to 1999 to capitalize on the industrial heritage of the Ruhr region. It was a state-owned taskforce under the direction of Professor Karl Ganser. The

IBA concentrated on seven activities: Emscher Landscape Park, Redevelopment of the Emscher River system, Recreation at the Rhein-Herne Ship Canal, Industrial monuments and industrial heritage, Working in the park, Urbanism and new housing, New social, cultural, and recreation opportunities.

The open-water sewage system of the early 20th century was called into question at the beginning of the 1980s. More than 400 km of sewer tunnels are necessary before the river Emscher restoration could begin. The largest one next to the river Emscher collects wastewater from the whole Emscher catchment. The circumstances caused by mining subsidence, like the reversal of natural drainage, cannot be eliminated. The channelized rivers in the Emscher catchment can only be restored by removing concrete beds, flattening the river banks, infilling river sediments, provoking a gentle sinuous river course, and establishing plants along the river banks.



Fig. 14 Nettebach after restoration



Fig. 15 Resser Bach after restoration

Fig. 14 Sources: <https://www.eglv.de/medien/nettebach-planung-der-renaturierung-laeuft-bereits-auf-hochturen/>;

Fig. 15 Sources: https://www.lokalkompass.de/gelsenkirchen/c-natur-garten/abwasserfreie-gewaesser-bekommen-neuen-geh-und-radweg-mitte-mai-wird-die-bruecke-an-der-kleiststrasse-an-den-neuen-weg-angeschlossen_a1726321



Fig. 16 Underground canal system in Bach



Fig. 17 The Living Lips program

Fig. 16 Sources: <https://themennetzwerke.de/tagesanzeiger/wasser/ziel-erreicht-leither-bach-ist-abwasserfrei/>

Fig. 17 Sources: <https://www.eglv.de/lippe/lebendige-lippe/>

Especially in the less densely populated areas along some tributaries of the river Emscher, the restoration of a fluvial morphology even comparable to the situation before industrialization is possible. For instance, near the city of Castrop-Rauxel, parts of the Deininghauser Bach are flowing over a wide floodplain with no restrictions due to settlements, traffic routes, or industries nearby. The Deininghauser Bach shows the typical fluvial morphology of a meandering river in a loess-covered area. Bike and hiking trips are available along the rivers (Gert-Jan Hospers, 2004b).



Fig. 18 A bird view of Emscher River

Sources: <https://www.eglv.de/lippe/lebendige-lippe/>



Fig. 19 Emscher River

Sources: <https://www.eglv.de/lippe/lebendige-lippe/>



Fig. 20 Bicycle lane system

Sources: <https://www.komoot.com/es-es/tour/380957923>



Fig. 21 Waterfront slow lane system

Sources: <https://www.eglv.de/gluecksradtour5/>

4.4.2 Newcastle, UK

(1) Historical Context of Newcastle

Newcastle in the UK, not only produced coal but was also a crucial coal transportation port during the 19th century. The city expanded rapidly during the Industrial Revolution, driven by the growth of railways, roads, and port development, which facilitated industrial growth and commerce. The opening of the Newcastle Central Station in 1850 improved transportation and connectivity. Key infrastructural achievements, such as the High-Level Bridge (1849) and the Swing Bridge (1876), improved movement across the River Tyne. The city's need for modernization, expansion of transportation networks, and general urban development drove the

ongoing removal of the medieval structures, reshaping the city. Rapid industrialization necessitated the construction of numerous terraced houses to accommodate the growing working-class population. These houses were often densely packed and lacked modern sanitation, reflecting the social challenges of the time. As the city expanded, wealthier residents moved to newly developed suburbs, like Jesmond and Gosforth, which became desirable residential districts, characterized by larger homes and greener spaces. In response to the crowded living conditions and health concerns, public parks and open spaces were created. Leazes Park, opened in 1873, provided a recreational area for the city's inhabitants. The 19th century saw growing awareness of public health issues. Poor living conditions and cholera outbreaks prompted the city to improve sanitation, leading to the construction of sewers, better waste management systems, and a clean water supply (Henry Bourne, 1736; Robert John Charleton, 1899; Bill Purdue, 2011).



Fig. 22 Map of Newcastle in 1808

Source: <https://www.mapseekerstore.com/british-town-city-plans/english-welsh-portfolio/old-map-newcastle-tyne-gateshead-1808-cole-roper-20348124.html>



Fig. 23 Map of Newcastle in 1851

Source: <https://www.flickr.com/photos/74726036@N04/7339965022>



Fig. 24 Map of Newcastle in 1917

Source: <https://co-curate.ncl.ac.uk/resources/view/73997/>

(2) Urban transformation in Newcastle

The decline of the traditional industries of Newcastle, such as coal mining, shipbuilding, and manufacturing, in the mid-20th century, led to economic stagnation and urban decay. In response, the 1980s saw the beginnings of urban regeneration initiatives aimed at revitalizing the city's economy and physical landscape. The economy in Newcastle has shifted towards a diverse service-oriented economy, particularly in sectors such as education, healthcare, and digital technology.

The development of the Newcastle Science Central and the expansion of Newcastle

University are key examples of this shift. The Quayside regeneration project is often cited as a successful model of urban redevelopment. This project transformed a formerly derelict industrial area into a vibrant mixed-use development featuring offices, residential units, and cultural amenities. The Ouseburn Valley has undergone a dramatic transformation from post-industrial wasteland to Newcastle's foremost cultural and creative quarter, helped in large part by a raft of investment and community-led regeneration. The Grainger Town Project was a comprehensive program focused on conservation, property development, and enhancement, aiming to restore Grainger Town to its former glory as a high-quality environment befitting a major regional capital. Key initiatives included the extensive restoration of the derelict Union Rooms on Westgate Road and the meticulous repair and cleaning of Grey's Monument. New development projects in this area included The Gate shopping and leisure complex and Barluga. Such strategies have not only revitalized the physical landscape of Newcastle but also attracted investment and tourism, contributing to economic growth (Mike Barke, 2014; Robert J Rogerson & Bob Giddings, 2021).

Environmental sustainability is a critical aspect of Newcastle's urban transformation. The city's commitment to green infrastructure and sustainable urban planning is evident in projects like the Newcastle Great Park, which integrates residential development with extensive green spaces. Efforts to improve public transportation and reduce carbon emissions, such as the implementation of the Metro system, further highlight Newcastle's focus on environmental sustainability (Elizabeth Brooks & Simin Davoudi, 2018; Catherine Heatherington, 2017).

Newcastle's urban transformation is a multifaceted process shaped by historical legacies, economic strategies, social dynamics, and environmental goals. The city's journey from industrial decline to a hub of innovation and sustainability offers valuable insights into the complexities of urban redevelopment.



Fig. 25 River Tyne in Newcastle

Source: <https://www.yopa.co.uk/homeowners-hub/whats-it-like-to-live-in-newcastle-upon-tyne/>

4.4.3 Wolverhampton, UK

(1) Historic Context of Wolverhampton

Wolverhampton is a city and metropolitan borough in the West Midlands, England, located 19 kilometers northwest of Birmingham, with a population of 263,700 in 2021. Wolverhampton has a rich history rooted in the Industrial Revolution. During this period, it became a major center for coal mining, steel production, lock making, and automotive manufacturing. By 1750, the burgeoning iron industry transformed the coal trade, as coal was essential for iron production. Canal networks were developed to transport the coal to the furnaces of the Black Country, and by the end of the nineteenth century, coal production in the area exceeded 8 million tons annually. Wolverhampton experienced rapid growth during this era. The town's population grew from 7,454 in 1750 to 20,710 in 1801, 90,301 in 1851, 94,107 in 1901, and 162,172 by 1951. This industrial boom necessitated the expansion of Wolverhampton's urban area. Infrastructure development became crucial to support industrial activities and the increasing population, leading to the construction of roads, bridges, and railways that connected Wolverhampton to other industrial centers and ports. The rapid urbanization brought challenges, particularly in housing provision and living conditions. Many workers lived in densely packed terraced houses close to the factories, often in poor sanitary conditions. As the population density increased, public health became a significant issue. Poor sanitation and inadequate access to clean water contributed to outbreaks of diseases like cholera and typhoid. These public health challenges eventually prompted improvements in public health infrastructure throughout the century (A. Brew, 2019; Melissa Joyce, 2007; C. Upton, 2007).



Fig. 26 Map of Wolverhampton in 1751

Source:<https://www.vintage-maps.com/en/antique-maps/europe/british-isles/jefferys-british-isles-staffordshire-wolverhampton-1751::946>



Fig. 27 Map of Wolverhampton in 1921

Source: https://commons.wikimedia.org/wiki/File:Wolverhampton_1921.jpg

(2) Urban transformation in Wolverhampton

Many of the traditional industries, such as iron, steel, automobiles, and engineering industries in Wolverhampton, have closed or dramatically downsized especially since the 1970s. The economy of the city is still based on engineering, including a large aerospace industry, as well as the service sector, including business, education, health care, IT, and tourism (Peter J Larkham, 2002; John McCarthy, 2005).

A significant aspect of Wolverhampton's urban transformation is the economic regeneration focus on commercial development. Projects such as the i54 Business Park, have attracted major employers, including Jaguar Land Rover, bringing jobs and investment to the area. The redevelopment of the city center, including the refurbishment of the Mander Centre, which was refurbished in 1987, and the construction of the Westside development, has aimed to boost retail and leisure activities. These initiatives are seen as pivotal in attracting visitors and stimulating the local economy (Steven R Henderson, 2011, 2015).

The improvement of physical urban environment and sustainable practices into urban planning is another component of Wolverhampton's transformation efforts. Projects such as the restoration of West Park and the incorporation of green roofs and energy-efficient buildings in new developments reflect a commitment to environmental sustainability. Balancing development with heritage conservation has been a key consideration, efforts to preserve historic buildings and integrate them into new developments are firmly considered in maintaining Wolverhampton's cultural identity. Improvements in transport infrastructure, including the extension of the Midland Metro

and enhancements to Wolverhampton Railway Station, have aimed to promote sustainable mobility and reduce traffic congestion. These efforts not only improve the aesthetic appeal of the city but also contribute to environmental sustainability by reducing carbon footprints, improving air quality, and providing recreational spaces for the community (D Bridge et al., 1997; Charles Green, 2013; Steven Henderson, 2012).



Fig. 28 i54 Business Park, Wolverhampton

Source: <https://www.rightmove.co.uk/properties>



Fig. 29 Mander Centre, Wolverhampton

Source: <https://www.wolverhampton.gov.uk/news>

Collaborative efforts involving governments, NGOs, private enterprises, and local communities are pivotal in driving urban transformation. In Wolverhampton, these partnerships have been crucial in implementing effective and sustainable urban regeneration strategies. For instance, the Black Country Local Enterprise Partnership (LEP) has played a key role in securing funding and spearheading strategic initiatives

aimed at revitalizing the urban economy, and numerous local projects have been financed by LEP to stimulate economic growth and enhance urban infrastructure (Steven R Henderson, 2015).

The urban transformation of Wolverhampton represents a multifaceted approach to revitalizing a post-industrial city. Through economic regeneration, social inclusion, and environmental sustainability, and proper maintenance of high-end manufacturing, Wolverhampton has made significant progress in overcoming historical challenges and building a resilient future.

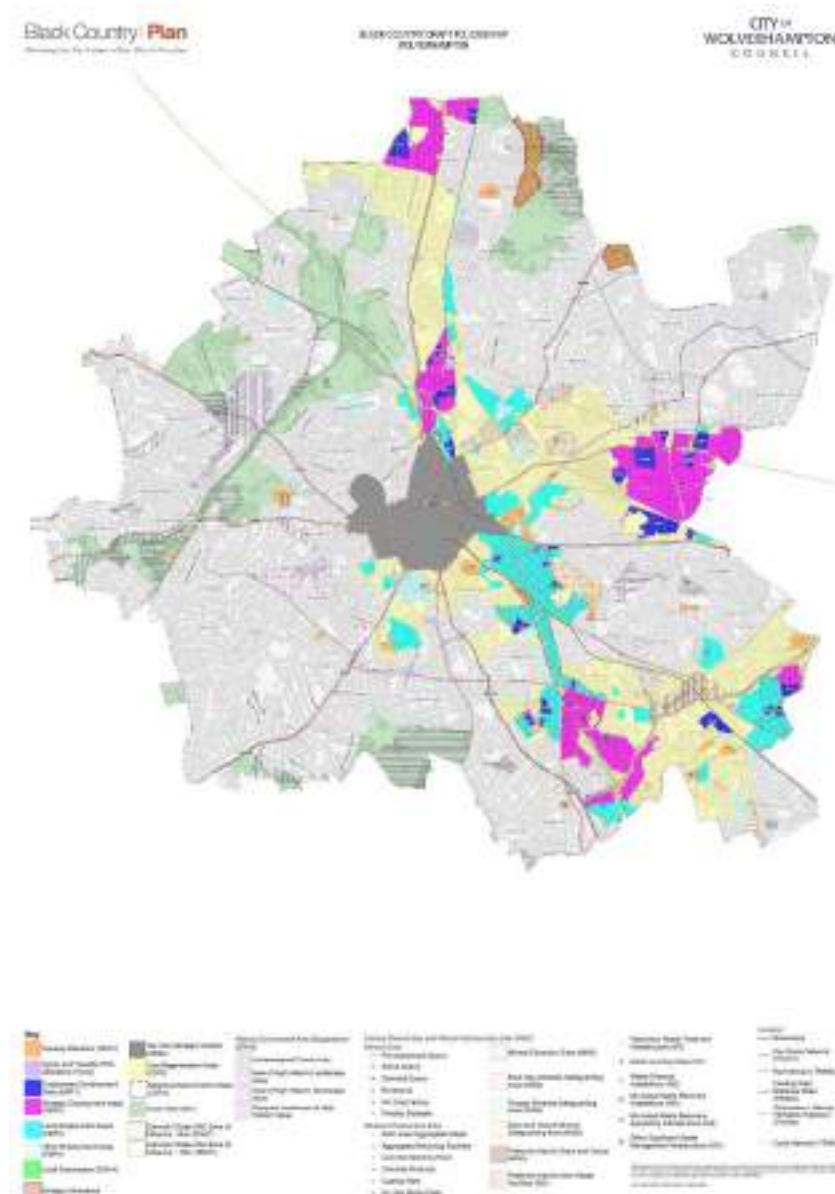


Fig. 30 **Wolverhampton Draft Policies Map**

Source: <https://blackcountryplan.dudley.gov.uk/media/18504/wolverhampton-draft-policies-map-final.pdf>

4.4.4 Kiruna Iron Ore Mine, Sweden

The Kiruna mine, operated by LKAB, is the world's largest and most modern underground iron ore mine. It is located in Kiruna, the northernmost city in Sweden, which had a population of 17,002 in 2016. In 2018, the Kiruna mine produced 26.9 million tonnes of iron ore. The mine's main haulage level is at a depth of 1,365 meters, with on-site ore processing facilities that include concentrators and pellet plants. Utilizing the most advanced mining technology, the mine features extensive automation and remote-controlled systems, such as automated locomotives and electric-powered, remote-controlled drilling and ore-handling equipment (Richard Karlsson, 2018).

Due to the mine's operations undermining the current town center, it was decided in 2004 that the city center would need to be relocated to accommodate mining-related subsidence. The new town center is moved 3 kilometers (1.9 mi) to the east. This relocation began in 2014 and will continue until 2040, and nearly 20,000 people will move into new homes as part of this process (Tom Barratt et al., 2024; Eric Boyd, 2023; Benjamin DiNapoli, 2023; Agatino Rizzo et al., 2024).



Fig. 31 Kiruna town, Sweden

Source: <https://www.bbc.com/news/magazine-26447507>



Fig. 32 Google map of Kiruna Iron Ore Mine in Sweden



Fig. 33 Urban transformation of Kiruna

Source: <https://kirunalapland.se/en/city-transformation/>

4.4.5 Silesian Upland, Poland

The Silesian Upland is among regions in Europe that are richest in energy resources and metal ores, and the Upper-Silesian Industrial Region (also known as the Katowice conurbation or GOP) is one of the largest mining industrial regions in Europe (Krystyna Dwucet et al., 2016).

The economic restructuring of Silesian mining cities has been a critical component of their transformation; efforts have been made to diversify the regional economy by promoting sectors such as services, technology, and manufacturing. The development of special economic zones (SEZs) has played a significant role in attracting new investments and businesses. Katowice has been classified as a centre of commerce,

business, transportation, and culture in southern Poland, with numerous public companies headquartered in the city or its suburbs including energy group Tauron and metal industry corporation, important cultural institutions such as Polish National Radio Symphony Orchestra, award-winning music festivals. The Katowice Special Economic Zone, for instance, has become a hub for automotive and advanced manufacturing industries, providing employment opportunities to former miners and their families.

Environmental rehabilitation is another critical aspect of the transformation process. The extensive mining activities in the Silesian Upland have left a legacy of environmental degradation, including soil contamination, water pollution, and landscape alteration. Yet it is also an area where the nearly 70-year-long efforts aimed at its regeneration have led to significant improvements—multiple locations in the region have been adapted for recreation and tourism purposes (Renata Dulias, 2010; Krystyna Dwucet et al., 2016; Robert Krzysztofik et al., 2019).



Fig. 34 Forest reclamation in Szczakowa Siersza Misiury Sandpit is costly and requires laborious seedlings cultivation (2004)

Sources: From Renata Dulias (Renata Dulias, 2010)



Fig. 35 Pogoria I Reservoir in a sandpit blended in the landscape (2004)

Sources: From Renata Dulias (Renata Dulias, 2010)

**Fig. 36 Sosina Reservoir in the largest sandpit in Poland (Szczakowa) (2004)**

Sources: From Renata Dulias (Renata Dulias, 2010)

4.4.6 Centro Mine Peñarroya, Spain

The Centro Mine Peñarroya (Cordoba) was developing from 1961 to 2010, with 27.3 MM T coal (9.4 MM T underground coal mining and 17.9 tons per mining open pit mine). For almost 50 years, it has been developed in 13 indoor facilities (4 ramps and and 9 wells) and 7 open-pit mining, distributed throughout the municipalities of Fuente Obejuna, Peñarroya -Pueblonuevo, B mez and Espiel.

Before the restoration (2010) the outlook of the mining area was quite bleak: the existence of numerous dumps and adjoining lands that were quite deteriorated. The mine restoration methodology used in the indoor facilities consisted of the removal of materials, the closing of the accesses to the exterior of ramps and shafts, the dismantling or transfer of surface facilities and the recovery of the external waste dumps. Regarding open-pit operations, restoration planning was carried out with the aim of generating stable land surfaces, integrating into the landscape, which could be used for productive use, and trying to restore the function of the pre-existing ecosystem.

This restoration vocation was considered from the stage of development of the exploitation projects, as an integral part of the mining work, so that both the exploitation system and the construction of the exterior and interior dumps should allow and facilitate the agricultural-landscape use of the area once the coal has been benefited. A classic methodology was chosen for the restoration of slag heaps and final exploitation holes consisting of the preparation of the subsoil with shaping work, decompaction of the shaped land to allow water infiltration and the penetration of the roots, previous collection of topsoil and pouring on the new surfaces created with a minimum thickness of 30 cm. The process ended with the conversion of the final holes into mining lakes and the implantation of helophytic vegetation around their perimeter to shelter aquatic birds. (C. J. Pardo Abad, May, 2019)



Fig. 37 Corta Ballesta Este (Espiel), 2010 Fig. 38 Corta Ballesta Este (Espiel), 2013

Fig.37 and 38 Sources: <https://andaluciaecologica.com/endesa-restaura-antiguas-minas-crea-96-hectareas-humedales/>

4.5 Strategies of Mining City Transformation from perspective of healthy city

Strategies of urban transformation emphasize multiple aspects, which should integrate an approach that simultaneously addresses physical, social, economic, and environmental aspects. These strategies should highlight the importance of sustainable development, resource optimization, social inclusion, stakeholder participation, and urban resilience of adaptation to changing circumstances (Peter Roberts & Hugh Sykes, 1999). Healthy cities is a global action strategy proposed in the 1980s, to face the challenges of urbanization to human health (Geoff Barnes, 2008), which is dedicated to improving urban public health and the healthy-wellbeing of residents, (World Health Organization, 1988). Combining the construction concepts and standard requirements of healthy cities, the main strategies of urban transformation from the perspective of a healthy city are as follows (Donald K Carter, 2016):

Green Ecological Protection Priority Strategy: This strategy focuses on prioritizing environmental conservation, pollution control, and sustainable practices to ensure the long-term ecological environment health of mining cities. It emphasizes the restoration of brownfields, disaster risk reduction, and climate change adaptation, aiming to construct a resilient healthy urban ecological environment.

Emerging Diversified Economic Development Strategy: This approach aims to reduce the economic reliance on mining resources by promoting the development of diverse industries. It encourages innovation, entrepreneurship, and investment in emerging sectors such as high-technology, tourism, and renewable energy to create a resilient and healthy local economy.

Urban Construction Renewal and Improvement Strategy: It includes the renovation of old buildings, the redevelopment of public spaces, and the improvement of urban transportation and infrastructure networks, to enhance the quality of urban life. This strategy advocates for the regeneration and improvement of a healthy urban physical environment.

Cultural Heritage Protection and Utilization Strategy: This strategy focuses on preserving and promoting the unique cultural and historical heritage of mining cities. It involves protecting historic sites, celebrating local traditions, and integrating cultural elements into urban development plans to foster a sense of identity and community pride. The aim is to create a healthy urban cultural environment and nurture the development of local cultural and creative industries.

Government and Society Participate Promotion Strategy: This strategy emphasizes the collaboration between government, NGO, communities and private sectors to drive urban transformation. It advocates for participatory governance and co-investment, where community input is valued, and stakeholders work together to implement policies, project investment, and healthy regeneration initiatives effectively.

Education and Scientific Research Encouragement and Support Strategy: This approach promotes investment in education and scientific research to foster innovation and knowledge development. It supports educational institutions, research centers, and vocational training programs to equip residents with the skills and acquire high-tech achievement needed for emerging industries and sustainable healthy practices.

Urban Inclusive and Equitable Development Strategy: This strategy aims to ensure that urban development benefits all residents, promoting inclusivity and equity. It focuses on reducing social disparities, providing equal access to resources and opportunities, and creating a inclusive healthy city that is welcoming and supportive for everyone. (Jürg Utzinger, 2004)

5 Chapter5 Mine Wasteland Restoration and Reuse from the Perspective of Healthy City

According to a research of Tang Liang on the land use of the mining industry around the world, using high-precision satellite image (2018-2020) technology, the total land area occupied by mining waste was about 31396.3 km². The development of mines is likely to cause risk factors such as environmental pollution and geological disasters in the area where it is located, threatening human physical and mental health. For example, in Australia, more than 80,000 idled mines have been recorded, posing a considerable health risk to residents in surrounding areas. (Tang Liang et al., 2021).

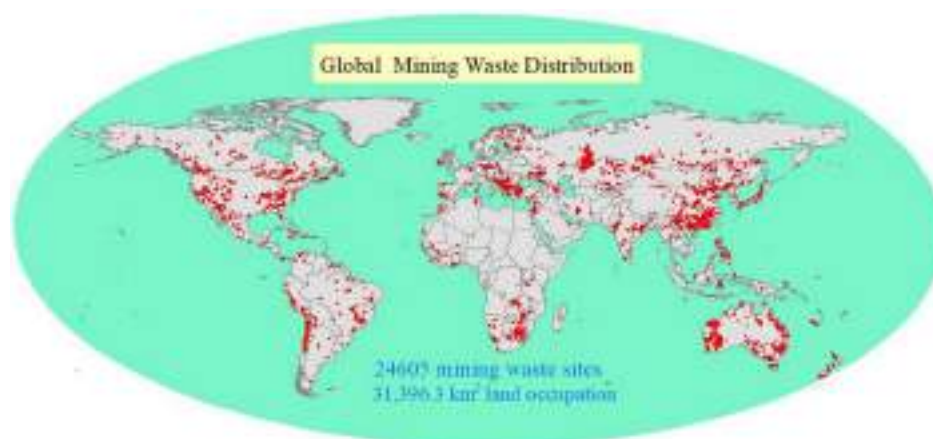


Fig. 39 Global mining waste distribution

Source: From Tang Liang et al. (Tang Liang et al., 2021)

This chapter focuses on summarizing the types, characteristics and health risks of abandoned mines, discussing the basic concepts and models of ecological restoration and reuse of mine wasteland, and analyzing their relationship with human health.

5.1 Conceptual Framework

5.1.1 Mine wasteland, mining brownfield, abandoned Mine lands (AML), mine-scarred lands (MSL)

The concept of mine wasteland is used in some similar words in different context, such as mining brownfield, abandoned mine, mine-scarred lands.

Mine wasteland: Wasteland literally means that land or area of land on which not much can grow or which has been spoiled in some way so as to become unsuitable for cultivation (Manoj Kumar Jhariya et al., 2019). Mine wasteland refers to the land

damaged and occupied by mining activities, which cannot be used without treatment, including the exposed mining rock mouth, waste soil (stone, slag) pile, coal gangue pile, tailings pond, waste plant and other construction land, underground mined out collapse land and the waste land with potential mined out collapse (Xing Fang, Xu quan hui, Hu ying, Cui liang zhong, 2019) . The land is destroyed or polluted during the course of mining, washing and processing, and become to unserviceable land unless being governed (Hu Zhenqi, 2017).

Mining brownfield: brownfield is “a tract of land that has been developed for industrial purposes, polluted, and then abandoned”². United States Environmental Protection Agency (US EPA) define the brownfields as “abandoned, idled, or under used industrial and commercial facilities or sites where expansion or redevelopment is complicated by real or perceived environmental contamination, which can be in urban, suburban, or rural areas” (US EPA, 2005). Mining brownfield is the land that destroyed by mining activities, and which couldn’t be used unless doing some remediation(Hu Zhenqi, 2017).

Abandoned Mine lands (AML): AML refer to the mine operator has ceased operations without reclaiming the site and the owner or operator cannot be located (J. L. Van Genderen, 2012). Abandoned mine lands (AMLs) are those lands, waters and surrounding watersheds where extraction, beneficiation or processing of ores and minerals has occurred (US EPA, 2023). lands adversely affected by past mining and left abandoned or inadequately restored (J. L. Van Genderen, 2012). They generally include a range of mining impacts, or features that may pose a threat to water quality, public safety, or the environment (EP; IO AR, R, 2007).

Mine-scarred lands (MSL): mine-scarred lands are defined as “lands, associated waters, and surrounding. watersheds where extraction, beneficiation, or processing ore and minerals (including coal) has occurred” (US EPA, 2004).

5.1.2 Abandoned mine land ecological restoration and reuse

Abandoned mine lands ecological restoration: AML ecological restoration refer to the practice of renewing and returning a degraded, damaged or destroyed ecosystems to its original (prior to disturbance) condition (Nimisha Tripathi et al., 2016). Mine ecological restoration also means the process during which natural ecosystems and natural ecological functions in the mining areas that have been damaged are rebuilt (Zhenqi Hu, 2014).

There are different terms that have been used for restoration such as reclamation, rehabilitation, revitalization, remediation. Mine reclamation is the process of modifying land that has been mined to ecologically functional or economically usable state (Nimisha Tripathi et al., 2016). Rehabilitation is “the restoration of something damaged or deteriorated to a prior good condition”³. Mine rehabilitation is the restoration of the

² <https://www.merriam-webster.com/dictionary/brownfield>.

³ <https://www.merriam-webster.com/dictionary/rehabilitation>

land on which mining has taken place to the intended post-closure land uses (C Beuermann et al., 2020). Revitalization refer to “to give new life or vigor to”⁴. Remediation is “the act or process of remedying”⁵. And remedy means “something that corrects or counteracts” (Nazan Kuter, 2013).

The ecological restoration of mine wasteland under the concept of healthy city mainly includes the restoration of healthy environmental quality and the restoration of healthy ecosystem. According to the specific problems and characteristics of the site, the ecological management and improvement of the environmental quality elements such as atmosphere, water, soil, noise, solid waste and geological safety in the site are focused on, and the pollutants harmful to human body are cleaned up to meet the requirements and standards of a healthy city. The restoration of healthy ecosystem of mine wasteland is mainly aimed at the ecological factors of natural ecosystem and biodiversity, including the ecological restoration and improvement of the damaged topography, vegetation, water system, animal and plant habitat. Restore the original ecological function of the site, form the green infrastructure of healthy city, and produce the function of health services.

Abandoned mine lands reuse: reuse means “to use again especially in a different way or after reclaiming or reprocessing”. Abandoned mining lands reuse refers to the process of repurposing and redeveloping areas that were previously used for mining activities but have been abandoned (Charles Mborah et al., 2016). Repurposing refers to the beneficial reuse of a closed mining or other industrial operation, whether through value-added changes or reuse of the land (C Beuermann et al., 2020).

5.2 Major Health Hazards of Mine Wastelands

5.2.1 Environmental Pollutions

The exploitation and processing of mining resources can easily lead to the pollution and destruction of the atmosphere, water, soil and other elements of the natural environment in the region where they are located. Due to years of mining activities, mine waste sites are prone to environmental pollution problems such as soil contamination from slag weathering, surface and groundwater contamination from acid mine drainage, air pollution from harmful gas emissions and dust, and accumulation of solid waste such as tailings. Mining areas located in the outskirts of cities are particularly vulnerable to environmental pollution due to their proximity to urban and rural residents' centralized living and construction areas. In the 21st century, with the vigorous development of the global healthy city movement, various health problems brought about by environmental pollution in mining areas have received more and more attention from all walks of life.

The natural ecosystem of a mining area mainly consists of natural elements such as atmosphere, water, soil, rocks, and organisms. The ecological damage caused by the

⁴ <https://www.merriam-webster.com/dictionary/revitalization>

⁵ <https://www.merriam-webster.com/dictionary/remediation>

mining process includes the direct occupation and destruction of the natural elements in the area, as well as the damage to the ecological elements caused by the emission of various harmful pollutants in the mining production waste. As the natural ecosphere of the urban atmosphere, water, soil and other natural ecosystems has strong mobility, pollutants flow through the urban ecosystem cycle, spreading within and between ecosystems, thus polluting and destroying the overall ecological environment of the city, and in particular, causing serious environmental pollution in and around the mining area (M. Sengupta, 2018).

■ Main types of mine wastelands

The main types of mine wasteland include: waste land of waste dump, waste land of Goaf Collapse Area, waste land of gangue hill, waste land of open pit, waste land of industrial buildings and facilities, etc.

Waste land of waste dump: waste land formed by the accumulation of topsoil stripped during the mining process and rocks discharged from the pit.

Gob collapse area wasteland: the mining wasteland formed by the gob and collapse area left after coal mining.

Waste land of Gangue Hill: the remaining coal solid waste after selecting and grading the concentrate is piled up to form a mountain type tailings waste heap.

Open pit wasteland: waste land left over from the mining face.

Waste industrial buildings and facilities: closed mining production and operation facilities, management facilities, auxiliary buildings, road traffic and other waste land (MS Li, 2006; TICE SUS & VELOPMENT PR).

■ Typical hazards of mine wasteland

The impact of mining on the environment can directly or indirectly affect the mining site and surrounding areas, and regional mining activities may even have an impact on the global environment. In the process of mining and smelting, various pollutants are diffused into the adjacent environment, which leads to the pollution of water air, and soil (Xiuwu Zhang et al., 2012). There are a series of environmental and social problems caused in the abandoned mine area, including environmental pollution, ecological function degradation, geological disasters, destruction of surface landscape, occupation of a large number of land, etc.

Physical environmental pollution: refers to the pollution caused by the original natural ecosystem balance damaged by coal mining, mainly including air, soil, surface water and groundwater pollution.

Degradation of ecological function: destroy the vegetation in the coal mining area, or make the land degenerate, which is difficult to support the growth of plants, resulting in the reduction of surface biomass and the weakening or complete loss of ecological service function.

Geological disasters: mining causes surface collapse of the coal mine goaf, and the destruction of the original hydrological and geological conditions of the site, which can

easily lead to geological disasters such as the soil erosion, landslides, collapses, ground fissures, ground subsidence, ground cracks, high-risk slopes, flooding, and mudslides etc. Which affect and destroy the safety of the mining area and surrounding urban and rural construction facilities.

Destroy the surface landscape: make the original surface shape and natural appearance change greatly.

Land occupation: coal mining and primary processing and other production methods, such as open-pit mining waste land, gob collapse area and so on, occupy a lot of land. Many coal industry squares are built on the edge of the city, the outskirts, or within the urban area. Coal mining causes a large number of urban land to be occupied, which aggravates the contradiction of more people and less land.

5.2.2 Major Health Hazards

Suburban large-scale mining areas are prone to environmental pollution problems such as air, water, and soil due to years of mining activities, industrial and agricultural production, and pollution emissions from urban and rural life, leading to serious pollution in and around the mining areas. Atmospheric pollutants include SO_x, NO_x, CO, VOCs, PM_x, NO_x, and dust emission, heavy metal(loid)s, and greenhouse gas emission. Common water pollutants include acidic mine water, heavy metals, and organic pollutants. Soil pollutants include heavy metals, acid salts, and organic pollutants. Atmospheric pollutants can enter the soil and water body through precipitation or drift dust deposition; water pollution can enter the soil through irrigation, runoff carryover, natural infiltration, etc., and part of it volatilizes into the atmosphere; and soil pollution can enter the water body through leaching, and part of it enters into the atmosphere by way of dust lifting. These pollutants can enter the human body through the respiratory system, food chain and skin contact, leading to heavy metal poisoning, respiratory diseases, liver and kidney damage, neurological and brain damage and even cancer and other health hazards (Claudio Bini, 2012). Mining leads to the decline of the groundwater level, which in turn lead to water shortages in the regional areas. And geological disasters caused by mining seriously threaten the personal safety of the urban and rural residents (Carla Candeias et al., 2018; Will H Canu et al., 2017). In addition, the environmental pollution, and destruction of the landscape and ecosystem left behind by mining may also cause psychological problems such as anxiety, depression and other psychological problems in the exposed population (Pietro Marescotti et al., 2018) (Table 13).

5.2.3 Major challenges to green infrastructure (GI)

The challenges of building green infrastructure in mining areas mainly include: Atmospheric pollutants like HF, O₃, SO₂, NO₂ caused by mining and industrial production emissions are harmful to the normal growth of plants. They can induce plant diseases and insect pests, and cause reduction the yield and quality of crops. Mining

leads to the damages on original hydrogeological conditions of the mine site, resulting in frequent droughts or floods in the area, affecting plant growth. Using sewage to irrigate farmland can cause soil contamination. Stripping of the original topsoil and the destruction of the terrain could make the soil barren and surface steep, which is not conducive to plant growth. Heavy metal pollution in the soil, soil salinization and other factors may lead to reduction of crop yields or even no harvest (Table 13).

Table 13 Interactions between environment, health and green infrastructure in mining areas

Environment	Environmental Impact Category	Causes of environmental effects	Environment impacts on public health	Environment impacts on GI
Air	Air quality	Release of heavy metal(loid)s and SO _x , NO _x , CO, VOCs by mining operations or combustion of fuels	Cause respiratory diseases, pulmonary heart disease, brain damage, human poisoning, etc.	HF, O ₃ , SO ₂ , NO ₂ and other pollutants in the atmosphere are harmful to the normal growth and development of plants, induce plant diseases and insect pests, and reduce the yield and quality of crops.
	Atmospheric visibility	PM _x , NO _x , CO, and dust emission due to mining operations or combustion of fuels	Cause respiratory diseases, and produces irritation symptoms and allergic reactions to skin, eyes, nose, throat, traffic accident injuries, etc.	Haze reduces solar radiation, thereby reducing crop yield and quality
	Climate change	Release of GHGS such as methane and carbon dioxide from coal mines	Direct impacts include increased risk of high temperature exposure, extreme weather disaster events, etc.; indirect impacts include increased climate-related communicable and non-communicable diseases, mental health impairment, and more (Pörtner, H. O., et., 2022)	Climate change and extreme weather may induce plant diseases and insect pests and reduce crop yield and quality.
Water	Water quantity	Mining disrupts surface runoff and exacerbates water loss; Mining operations require large amounts of water which is sourced from underground or nearby water bodies; Destruction of underground aquifers and drawdown	Cause shortage of drinking water, Recreational water, industrial and agricultural water in the region; Health risks from geological hazards caused by drawdown	The original hydrogeological conditions of the site have been damaged, resulting in frequent droughts or floods in the area, affecting plant growth.

Water quality	Acid mine drainage (AMD) or acid rock drainage (ARD), processing chemicals discharge, heavy metal pollution and leaching, and erosion and sedimentation (Emmanuel et al. 2018); Discharge of agricultural and domestic sewage in mining areas	Entering the human body through the food chain or skin contact can cause heavy metal poisoning, gastrointestinal diseases, reproductive system diseases, spread of infectious diseases, and even cause cancer	Using sewage to irrigate farmland can pollute the soil and affect crop growth (see Soil quality)
Soil quality	Mining leads to soil erosion and fertility adversely; Contamination of heavy metals, acid salts, organic pollutants, etc. through solid waste accumulation, water infiltration, atmospheric deposition, etc.	Cause decline in the supply of healthy food; Entering the human body through the food chain, breathing or skin contact can cause heavy metal poisoning, gastrointestinal diseases, reproductive system diseases, spread of infectious diseases, and even cause cancer	The soil is thin and the surface is steep, which is not conducive to plant growth. Heavy metal pollution in the soil, soil salinization and other factors may lead to reduced crop yields or even no harvest.

Source: Author's own compilation (ON CLIMATE CHANGE, 2007; Richard Lord et al., 2023; Hans-Otto Pörtner et al., 2022)

5.3 Legislations and Polices of the Ecological Restoration of Mine Wastelands from the Perspective of health city

Legislation is a key factor in ensuring the ecological environment safety and ecological restoration management of mining areas. In the process of mining development, many countries continue to formulate and improve relevant laws and regulations to manage the mining environment and waste lands. Since the 19th century, some early industrial countries in the world, such as the United Kingdom, the United States, and Germany, have successively introduced legislation on mining production and environmental protection. In the 20th century, with the vigorous development of the global mining industry and industry, many countries, regions and international organizations in the world have formulated relevant laws and regulations to regulate and manage mining production and ecological environment protection in mining areas.

5.3.1 International legislations and regulations

The *International Principles and Standards for the Ecological Restoration and Recovery of Mine Sites* (Mine Site Restoration Standards, MSRS), present the first international framework for ecological restoration after mining. There are eight

principles that provide a framework to enable restoration decisions for mining companies, communities, and stakeholders. Those standards are: engage stakeholders throughout the life of mine, draw on many types of knowledge, be informed by appropriate reference ecosystems while considering environmental change, support ecosystem recovery processes, assess against clear goals and objectives using measurable indicators, seek the highest level of recovery attainable, gain cumulative value when applied at large scales, employ a continuum of restorative activities (Renee E. Young et al., 2022). The World Health Organization's environmental health indicators such as atmospheric, water, soil quality and noise are widely used in the environmental impact assessment of abandoned mine sites and their sites after ecological restoration.

5.3.2 Mine reclamation laws and policies at the national level around the world

The legislation of mine reclamation in US including federal and state environmental laws and regulations. In the federal lever, which include The National Environmental Policy Act (NEPA) of 1969, Surface Mining Control & Reclamation Act of 1977 (SMCRA), Comprehensive Env. Response Comp., & Liability Act (CERCLA) and other related laws and regulations.

The National Environmental Policy Act (NEPA) of 1969: It is one of the most important of the many federal laws intended to protect the environment. NEPA's basic policy is to assure that all branches of government give proper consideration to the environment prior to undertaking any major federal action that significantly affects the environment. NEPA's require that all executive Federal agencies prepare environmental assessments (EAs) and environmental impact statements (EISs).

Surface Mining Control & Reclamation Act of 1977 (SMCRA): SMCRA is the primary federal law that regulates the environmental effects of coal mining in the United States. SMCRA created two programs: one for regulating active coal mines and a second for reclaiming abandoned mine lands (AML). It strictly stipulated the reclamation procedures of mining, clarified the ownership of responsibility and the special fund system for the ecological restoration of AML. This law identifies three major systems for ecological compensation: the restoration and management (reclamation) fund system, the mining area reclamation license system, and the restoration and management (reclamation) deposit system. The U.S. SMCRA Act requires responsible entities to take measures to restore land damaged and polluted by mining activities to a reusable state as much as possible. It clearly states that restoration to its original state is the legal minimum ecological restoration standard. On this basis, it also requires that abandoned land be restored to its original state. Land reclamation goals are set out for mining sites and operating mines, with detailed standards and processes in place.

Comprehensive Env. Response Comp., & Liability Act (CERCLA): It has

established a model of comprehensively embodying environmental compensation through environmental management methods. According to the provisions of this law, in terms of the division of responsible entities, for mining areas that have been abandoned before the law is promulgated, and it is difficult for the federal and state governments to find responsible companies through existing conditions, the government shall bear the responsibility for the ecological restoration of the mining area, and the costs will be borne by the government. It is borne by funds established by state appropriations. For mining areas where ecological damage occurs after the promulgation of the law, the mining companies responsible for ecological restoration shall bear the responsibility (EP AR & R IO).

Other Legislation Related to Mine Environment Protection in US (Jerrold J Marcus, 1997)

- Clean Air Act, 1970
- Clean Water Act, 1972
- Clean Air and Water Act Amendments of 1977
- Comprehensive Environmental Response Compensation and Liability Act, 1980
- Deep Seabed Hard Mineral Resources Act of 1980
- Endangered Species Act of 1973
- Federal Land Policy & Management Act of 1976
- Federal Mine Safety and Health Act of 1977
- Federal Water Pollution Control Act of 1972
- Forest Service Organic Act, 1897
- Law of the Sea Treaty
- Mineral Leasing Act for Acquired Lands
- Mining Law of 1872
- National Environmental Policy Act of 1969 (NEPA)
- National Forest Management Act, 1976
- Outer Continental Shelf Lands Act of 1953
- Public Land Laws (2020 Revision)
- Resource Conservation & Recovery Act of 1976(RCRA)
- Submerged Lands Act of 1953
- Superfund Amendments & Reauthorization Act of 1986
- Toxic Substances Control Act of 1976
- Uranium Mill Tailings Radiation Control Act, 1978
- Water Quality Act of 1987

Germany also has a comprehensive legal framework to supervise the implementation of ecological restoration of mines. The Mineral Resources Law stipulates that ecological restoration of mining areas is part of mining activities. It stipulates that land occupied and damaged by mining must be managed in a regular manner, taking into account the public interests, until a good and healthy environment is restored in the mining area. generated, and does not need to be restored to its pre-

mining state. The "Federal Minerals Law" is an important law that stipulates the requirements for land reclamation and ecological reconstruction of mining areas. It requires governments, enterprises, communities, relevant institutions and other parties in the process of resource mining (coal, metal mines, non-metallic mines, etc.) and ecological restoration. Rights and obligations are strictly and clearly defined. The law requires companies that obtain mining licenses to be responsible for the reconstruction of mining areas and prepare detailed plans. The Federal Nature Conservation Act also has clear requirements for environmental reconstruction in mining areas, stipulating that damage to nature and landscape must be compensated in appropriate ways. Balance, such as the ecological restoration of mine wastelands, should consider the protection of natural resources and landscapes and be coordinated with local regional environmental plans. In addition, the planning laws of the federal government and the planning laws of various states have put forward clear development planning requirements for lignite mining areas, including site scope and layout, environmental impact, post-mine land use, etc., stipulating that the planning of lignite mining areas must comply with the requirements of the state where they are located. Spatial development planning and regional planning objectives, companies will not be allowed to mine before lignite planning is approved. Other related indirect laws include: land protection law, water protection law, forest law, air protection law, garbage disposal law, hunting law, etc.(Roderick G Eggert, 2013; John D. Leshy, 2015).

Other industrially developed countries have similar legal frameworks to those of the United States and Germany. They have detailed and clear basic laws and indirect laws to regulate and control mining and ecological restoration activities, and mine reclamation planning and recovery deposit arrangements are included in the approval of mining licenses. in the system. What these legal systems have in common is that they all involve issues such as land protection, environmental impact assessment, licensing systems and land reclamation. 45 Canada's Federal Resources Act, Environmental Protection Act, Environmental Assessment Act, Fisheries Act and other laws all stipulate clear reclamation requirements for abandoned contaminated mines at the national level. At the same time, states also Each has formulated corresponding laws and regulations to ensure the effective reclamation of mining waste lands. Mining activities in Australia are divided between federal and state responsibilities. Each state has the right to formulate mining laws within their respective jurisdictions and supervise their implementation. The federation has the "Mining Environmental Management Code" formulated in 1996, the "Federal Environmental Protection and Biodiversity Conservation Act" promulgated in 1999, and the "Mining Land Reclamation Fund Law" promulgated in 2012. This law requires mining companies to pay reclamation fees. The tax is used for the disposal of abandoned historical mine sites. The legislation of each state, such as Western Australia, enacted the Mining Law, Land Management Law, Agriculture and Related Resources Protection Law, Mining Safety Supervision Law, etc. from the 1970s to the 1990s to manage the mines in the state. Mining and ecological restoration (Susan Baker, 2020; Pãvi Heikkinen et al., 2008) .

The research on the management and reuse of mine wasteland started late in China.

In the early 1980s, Chinese scholars translated foreign works such as "open pit land reclamation" and "mine survey in mining area land reclamation", and introduced international land reclamation and ecological restoration technology to China. In October 1998, the "land management law" was revised, which put forward the requirement of a "balance between occupied farmland and reclaimed farmland", "Land use units and individuals shall be responsible for land reclamation in accordance with the relevant provisions of the state in case of land damage caused by excavation, collapse, occupation, etc.; if there are no conditions for reclamation or the reclamation does not meet the requirements, land reclamation fees shall be paid, which shall be specially used for land reclamation. The reclaimed land shall be given priority to agriculture." In 2015, the Ministry of land and resources issued the "management measures for the pilot reclamation and utilization of industrial and mining wasteland left over from history", which clearly put forward that the special plan for the reclamation and utilization of industrial and mining wasteland should be scientifically and reasonably formulated, marking the further standardization, scientization and legalization of land reclamation in China. The research on ecological restoration and reuse of mine wasteland shows a trend of diversification, integration and interdisciplinary. With the continuous development of ecological restoration technology, many representative cases of ecological restoration and reuse have emerged (Zhenqi Hu, 2014).

5.3.3 Community regulations and rules

The environmental perception of community residents after the ecological restoration of the mine wasteland is of great significance for evaluating the success of the mine restoration (Kamila Svobodova, 2019; Kamila Svobodova et al., 2019), which, combined with responding to the health needs of the community, can provide a healthier and safer environment for the community (Abandoned Mine Lands, 2007). In 1999, the U.S. Environmental Protection Agency proposed the principles of health risk assessment of abandoned mine land based on stakeholder participation, and ecological restoration and reuse to meet community needs (US EPA, 2000; Catherine L Ross et al., 2014; Alyson Warhurst, 1999). In 2019, the International Society for Restoration Ecology (SER) proposed ecological restoration as a means to improve biodiversity and human well-being in the "International Principles and Standards for Ecological Restoration Practices", emphasizing the involvement of stakeholders in the restoration process. This allows communities near degraded systems to gain health and other benefits from restoration (EP AR & R IO; George D Gann et al., 2019).

5.4 Major theories and methods of ecological restoration of mine wastelands on the perspective of health

5.4.1 General theories of ecological restoration of mine wastelands

The practice and research on the ecological restoration of mine wasteland originated from the development of restoration ecology in the early 20th century (Ge Xiaohan Yang Shuyun, Mu Hongna 2023).

Since the 1980s, with the development of healthy city construction practices and research, the health needs of urban and rural residents have been gradually emphasized and applied to the ecological restoration and reuse of mine wasteland. Environmental health impact assessment has received widespread attention, and many case studies around the world have proved that combining environmental health impact assessment with ecological restoration of mine wasteland can more effectively reduce the health risks caused by common environmental pollution problems (Mritunjoy Sengupta, 2021).

Measures to control the air environment mainly include: adjusting the regional industrial layout and industrial structure; improving the energy structure of industrial and agricultural production and urban and rural life in the region, and actively adopting energy-saving measures; vigorously carrying out comprehensive utilization and improving the utilization rate of resources; carrying out green mining and production, optimizing the production process, and reducing and purifying the industrial exhaust; reducing dust in the process of mining, industrial production, and transportation by covering the surfaces and sprinkling water; strengthening the promotion of practical technologies for the prevention and control of air pollution; and improving the environmental supervision and management system. Reduce dust in the process of mining, industrial production and transportation by covering the surface, sprinkling and other measures; strengthen the popularization of practical technologies for air pollution prevention and control; and improve the environmental supervision and management system (Jerrold J Marcus, 1997).

Measures for water environment management mainly include:

Restoration of surface water quantity: mainly including the restoration of the original hydrological environment of the site after mining, and reducing the loss of surface runoff through the restoration of the surface of the mining area, greening and reclamation, strengthening the guidance of surface runoff, rainwater management, increasing water storage facilities and other measures. Reduce water use for regional mining and other industrial and agricultural production.

Surface water quality restoration: mainly including control and elimination of surface runoff sedimentary material pollution; implementation of green mining mining and production, optimization of production processes, the establishment of sewage treatment systems, reduce and purify industrial effluent discharge; effective treatment of polluted open pit water, mine acidic water, and other industrial, agricultural production and domestic sewage from the mining area. Avoid polluting the water bodies

in the mining area due to the massive accumulation of solid wastes such as coal gangue and tailings.

Groundwater quantity restoration: restrict the development and use of groundwater in the area, repair the underground mining area and the geological damage of aquifers, strengthen the water conservation in the area, and increase the recharge of groundwater sources.

Groundwater quality remediation: implement green mining and production, centralize and unify the management of sewage in mines, and effectively deal with industrial production wastewater from mines, polluted underground pit water, acidic mine water, and industrial and agricultural production sewage from mines that seeps into the ground (EP AR & R IO; Jerrold J Marcus, 1997).

Measures for soil environmental management mainly include:

Remediation technology of mine soil environment mainly focuses on four aspects: physical restoration, chemical restoration, biological restoration, and joint restoration.

Physical restoration technology is to control the environmental pollution caused by mining through physical means such as isolation, electrodynamics, soil replacement, and covering. Among them, isolation measures for pollution sources on soil mainly include isolation and closure, construction of isolation walls, and laying of isolation and protection layers.

There are generally two main forms of chemical remediation. Soil drenching remediation methods could leach heavy metals in the soil through water or chemical reagents, promoting the analysis of heavy metals, and making them transfer from solid phase to liquid phase. Soil conditioner methods represent adding curing agents and other chemical methods to inhibit or reduce the water solubility, mobility and bioavailability of pollutants.

Bioremediation technologies mainly include phytoremediation, animal remediation, microbial remediation and other technologies. Which can absorb, degrade and transform pollutants remaining in the soil, thus improving soil quality (EP AR & R IO; V.C. Pandey et al., 2022).

Joint repair refers to the development of a joint repair technology integrated with multiple repair technologies to complement each other's advantages and disadvantages to achieve a better repair effect. In the practice of mine restoration, a single method cannot easily and completely restore the degraded mine ecological environment, and the comprehensive use of multiple restoration technologies may be a future trend.(HU Liang & HE Zhiguo, 2020)

In addition, for different types of mine wastelands, such as waste dumps, wastelands in goaf subsidence areas, wastelands in gangue hills, wastelands in open pits, abandoned industrial buildings and facilities. Because of their different causes and characteristics, different ecological restoration methods should be adopted for different types of abandoned lands (Pävi Heikk inen et al., 2008).

5.4.2 Benefits of green infrastructure on mine ecological restoration

The main ecological and environmental impacts of ecological restoration on mining sites using the green infrastructure model include:

Reducing emissions is always the most effective method of reducing human exposure to pollutants. But GI can alleviate air pollution to a certain extent, plants can generally block suspended matter such as dust and fog droplets in the air and adsorbed pollutants; some plants have a strong ability to absorb and degrade specific atmospheric pollutants; some plants can produce negative oxygen ions and improve the air quality. Planting can change the local distribution of pollution relative to people, such as extending the distance between sources and receptors, enhancing dilution and dispersion, increasing ventilation, reducing urban heat island effect (C. Nick Hewitt et al., 2020), and hence reducing the concentrations of pollutants where most people are most exposed (Helen Pearce et al., 2021).

Green and blue urban surface water drainage infrastructure with low-impact development pattern can help reducing flood, soil erosion and water pollution in a more natural manner. Certain plants have proven effective at absorbing nitrogen, phosphorus, heavy metals, organic pollutants and other pollutants from the water.

Certain plants have proven effective at fixing nitrogen and absorbing heavy metals and other pollutants from the soil. Combined with the construction of green infrastructure, the ecological restoration of soil in mining areas using plant planting methods can help remove soil pollution, increase soil fertility, and improve the overall quality of the soil.

Because the mature green plant community has a strong function of stabilizing the regional ecosystem, it can continuously improve the environmental quality of the regional atmosphere, water, and soil, and has a good promoting effect on the continuous improvement of the regional ecological environment (Table 14).

Table 14 Ecological restoration measures in mining areas

Environment	Environmental Impact Category	Causes of environmental effects	Ecological restoration Measures	Methods and benefits of GI for the ecological environment
Air	Air quality	Release of heavy metal(loid)s and SO _x , NO _x , CO, VOCs by mining operations or combustion of fuels	Adjust regional industrial layout and industrial structure; Improve the regional energy structure and actively adopt energy-saving measures; Vigorously carry out comprehensive utilization and improve resource utilization;	Through GI layout, ventilation corridors are constructed to facilitate the evacuation of pollutants; Plants can generally block suspended matter such as dust and fog droplets in the air and their adsorbed pollutants;
	Atmospheric visibility	PM _x , NO _x , CO, and dust emission due to mining operations or	Implement green and environmentally friendly mining and production, optimize production processes, and reduce and purify industrial waste gas;	Certain plants have a strong ability to absorb and degrade specific

		combustion of fuels	Reduce dust during mining, industrial production, and transportation through covering, watering, and other measures; Carry out greening and reclamation of mining areas; Strengthen the promotion of practical technologies for air pollution prevention and control; Improve the environmental supervision and management system.	atmospheric pollutants; Certain plants can produce negative oxygen ions and improve air quality;
	Climate change	Release of GHGS such as methane and carbon dioxide from coal mines		GI can alleviate the heat island effect; improve the regional microclimate environment; help reduce energy consumption and reduce greenhouse gas emissions;
Water	Water quantity	Mining disrupts surface runoff and exacerbates water loss; Mining operations require large amounts of water which is sourced from underground or nearby water bodies; Destruction of underground aquifers and drawdown	The original hydrological conditions of the site are restored; Strengthen surface runoff guidance and stormwater management; Advocate green production and save water in industrial and agricultural production; Limit the development and use of groundwater; Repair geological damage to underground goafs and aquifers; Increase groundwater supply;	GBI with low-impact development pattern can help regional water conservation and reducing flood, soil erosion
	Water quality	Acid mine drainage (AMD) or acid rock drainage (ARD), processing chemicals discharge, heavy metal pollution and leaching, and erosion and sedimentation (Emmanuel et al. 2018); Discharge of agricultural and domestic sewage in mining areas	Control and eliminate material pollution deposited by surface runoff; Establish a sewage treatment system to effectively collect and treat regional industrial, agricultural and domestic sewage; Optimize production processes and reduce and purify industrial wastewater emissions; Effectively treat mine sewage and acid mine water; Avoid contamination of water bodies due to massive accumulation of solid waste such as coal gangue and tailings;	Certain plants have proven effective at absorbing nitrogen, phosphorus, heavy metals, organic pollutants and other pollutants from the water.

Soil	Soil quality	Mining leads to soil erosion and fertility adversely; Contamination of heavy metals, acid salts, organic pollutants, etc. through solid waste accumulation, water infiltration, atmospheric deposition, etc.	Use engineering measures such as isolation and sealing, building isolation walls, and laying isolation and protective layers to control the spread of pollutants; Physical restoration, including engineering restoration methods (soil removal, soil replacement, topsoil removal, deep plowing, soil plowing, etc.), heat treatment methods, electrolysis methods; chemical restoration, including soil conditioner methods, soil leaching restoration methods, etc.; Bioremediation includes the use of animals, plants, microorganisms, algae, etc. to absorb, degrade and transform pollutants;	Certain plants have proven effective at fixing nitrogen and absorbing heavy metals and other pollutants from the soil, and increasing soil fertility
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Source: Author’s own complication (Camille Parmesan et al., 2022; Helen Pearce et al., 2021)

5.5 General Methods of Reuse of mine wastelands on the perspective of health

The common ecological restoration modes of mine wasteland include single greening mode, agriculture, forestry, fishery and animal husbandry reclamation mode, leisure and tourism utilization mode and comprehensive utilization mode (Wu Qiang et al., 2017). In the early days of healthy city movement, WHO listed a series of basic characteristics of healthy city as a supplement to the concept of healthy city and a guide for healthy city movement. Among them, ten specific standards and contents of healthy cities were published in 1996, such as, providing a clean and safe environment for the public, providing a variety of entertainment and leisure venues to facilitate communication and contact between the public (Europe World Health Organization. Regional Office for, 1996). Combining with the construction concept and mode of healthy city, the restoration and construction can form the available space for urban and rural residents to provide health services, such as fitness exercise, leisure, cultural entertainment, health care and vacation, health food farm, etc. (Danielle Emma Sinnett & Ana Margarida Sardo, 2020). It is a new measure to provide people with mine wasteland governance, which will bring more healthy activity space for people and improve the benefits of mine wasteland with efficiency, promoting the development of urban health and well-being.

5.5.1 Comprehensive reuse methods of mine wastelands

Combined with healthy construction concepts and models, mine waste sites can be rehabilitated and constructed to create usable spaces for urban and rural residents to provide health services such as fitness and exercise, recreation, cultural and recreational activities, health resorts, and healthy food farms (Danielle Emma Sinnett & Ana Margarida Sardo, 2020), and develop a variety of recreational opportunities (US EPA,

2005). The provision of urban and rural leisure tourism facilities and activities is conducive to improving the health and welfare of urban and rural residents (Keri Schwab et al., 2018), enhancing community health equity (Babatunde Abiodun Balogun, 2021), and helping to improve the physical and mental health of the elderly (Manuela Vega-Vázquez et al., 2021). For example, urban recreational parks can increase opportunities for sports and social interaction (Andrew T Kaczynski & Karla A Henderson, 2007) and contribute to the physical and mental well-being of the residents (Edwin Gomez et al., 2015; Paul Heintzman, 2009). Utilizing abandoned mine land to develop low-carbon industries such as new energy and leisure tourism will contribute to the sustainable and healthy socio-economic development of the region (Xin Lyu et al., 2022) (Table 15).

Table 15 List of classification and ecological restoration of mine wasteland

Type	Causes of formation	Characteristics and hazards	Transformation and utilization mode
Waste land of waste dump	The abandoned land is formed by the overburden stripped in the process of coal mining and the accumulation of rocks discharged from the mine pit.	A large amount of land has been destroyed and occupied. Sulfide, nitrogen oxides and suspended particles have seriously polluted the environment, polluted the soil and groundwater, and damaged the ecological environment.	After ecological reclamation and site reconstruction, it will be used as agricultural production land, leisure park, activity distribution site, parking lot, etc.; properly stored stripped topsoil will be used as greening topsoil of the site, and waste soil will be used for terrain shaping.
Abandoned land in mined out subsidence area	Mining wasteland formed by goaf and collapse area left after coal mining.	Without reinforcement and backfilling in the mined out area of coal mine, the ground will subside, form a collapse pit, cause water accumulation, and the farmland vegetation will not grow, and at the same time, it is easy to cause geological disasters such as landslides.	The mined out area can be used as agricultural production land, urban and rural construction land, leisure park, activity distribution site, parking lot, etc.
Waste dump	The residual coal solid waste after the concentrate is selected through screening and grading is piled up to form a mountain type tailings waste heap.	Occupying a large number of land resources, coal dust is large, easy to spontaneous combustion, high content of heavy metals, plants are difficult to grow, seriously affecting the surrounding environment.	Coal gangue bricks and blocks are used as paving materials, directly as subgrade materials; the original coal gangue hills can be used as landscape green land for ecological restoration.
Open pit wasteland	Waste land left over from mining face	Occupying land resources, poor growth of crops and vegetation, and poor ecological environment.	Depending on the geological conditions, the project of ecological reclamation and construction of leisure tourism (such as mine park, hotel, rock climbing, etc.) can be carried out in combination with the

			regional industrial development and leisure tourism demand.
Land for abandoned industrial buildings and facilities	Abandoned land formed by closed mining production and operation facilities, management facilities, auxiliary buildings, road traffic, etc	Generally, the geological conditions are good, and the construction facilities have certain industrial heritage value and landmark, which can be appropriately transformed or retained.	After the ecological restoration and transformation, it can be transformed into industrial heritage tourism (Park), industrial museum, cultural and Creative Industrial Park, comprehensive industrial park, etc.

Source: Author's own complication

5.5.2 Single Reuse Methods of mine wastelands

Green Infrastructure: green Infrastructure can be broadly defined as a strategically planned network of high-quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings (Anastasia Chatzimentor et al., 2020; European Union, 2000). Ecological restoration of abandoned mine land and construction of green infrastructure is a reuse method in line with the development of regional health undertakings.

Agriculture, Husbandry and Fishery: it is a common way to reuse the ecologically restored mine wasteland for agriculture, animal husbandry, fishery and other production. This type of mine is usually located in an area suitable for agricultural development, and is close to rural settlements to facilitate agricultural management. Common potential health threats in this type of ecological restoration include heavy metals or other pollutants in soil, vegetation, and water bodies, which enter the food chain through crops, livestock, and aquatic products growing on the land, causing health risks to exposed people. Its ecological restoration requires strict implementation of relevant health and environmental standards for soil, water, and atmosphere (M. B. Andreucci).

5.6 A summary of relevant representative practice cases in the world

The prominent cases of mine practice projects collected by their ecological restoration models will include as follows. The conclusions will be important difference that is going to be proved by the research.

5.6.1 World heritage

- Wieliczka Salt Mine, Poland (1978)
- Zollverein Coal Mine Industrial Complex in Essen, Germany (2001)
- MiningArea of the Great Copper Mountain in Falun, Sweden (2001)
- Humberstone and Santa Laura Saltpeter Works, Chile (2005)

- Cornwall and West Devon Mining Landscape, Britain (2006)
- Iwami Ginzan Silver Mine and its Cultural Landscape, Japan (2007)
- Erzgebirge/Krušnohoří Mining Region, in south-eastern Germany (Saxony) and north-western Czech (2019)



Fig. 40 Location of mine related world heritage in the world

Source: Author's own work

5.6.2 Greenfield and Park

- Buchard garden, BC, Canada (1904)
- Empire Mine State Historic Park, CA, USA (1975)
- Emscher Park, Germany (1999)
- The garden of Eden, London, UK (2000)
- Akashi Kaikyo National Government Park, Japan (2000)
- Huangshi National Mine Park, Hubei, China (2006)
- Zhonghu mine Wetland Park, Hubei, China (2008)
- Kailuan National Mine Park, Tangshan, Hebei, China (2009)
- Chenshan Botanical Garden, Shanghai, China (2011)
- Tongluoshan, Chongqing, China (2019 ASLA Potomac Professional Award for Analysis and Planning)

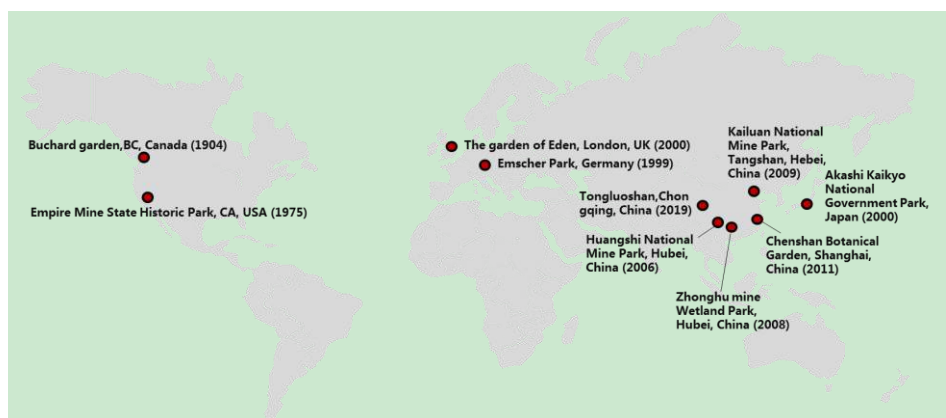


Fig. 41 Location of green field and park of mine restoration in the world

Source: Author's own work

5.6.3 Leisure entertainment and sports field

- Zip world cave, Wales, UK (1960)
- Harbor golf course, Michigan, USA (1990)
- Oak Quarry Golf Club, CA, USA (1990)
- Salina Turda salt mine, Romania (1992)
- Mines and meadows ATV and RV Resort, Pennsylvania, USA (2000)
- Ningbo International circuit, Zhejiang, China (2017)

5.6.4 Land art

- Biennale of earth art, installation art and multimedia art in kotbus, Germany (1991)

5.6.5 Museum

- Big Pit National Coal Museum, Welsh, Britain (1983)
- Fujian Mine Museum, Fujian, China (2019)

5.6.6 Comprehensive utilization area

- Golden City theme park, Johannesburg, South Africa (1980)
- The Cranberry Creek Corridor, Hazleton, Pennsylvania, USA (2005)
- Meizhou Hakka World Resort, Guangdong, China (2006)
- Shupu ancient town film and television base in Haiyan, Zhejiang, China (2013)
- Tianma mountain, Shanghai, China (intercontinental fairyland Hotel, Shanghai) (2015)

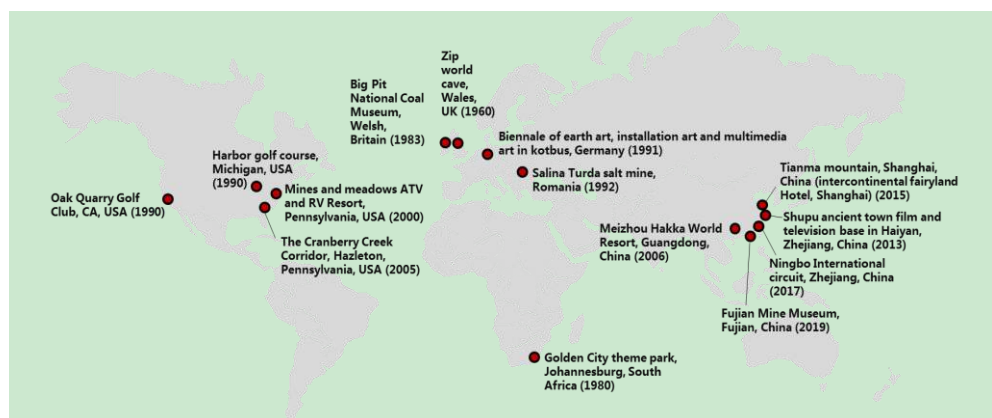


Fig. 42 Location of Leisure entertainment and sports field, land art, museum, comprehensive utilization areas of mine restoration in the world

Source: Author's own work

Part 2 Case study of Urban Transformation of Mining City

6 Chapter6 Case Study of Urban Transformation of Mining City

6.1 Objective and study area

6.1.1 Objective

Based on the perspective of healthy cities, this article quantifies and evaluates the role and health benefits of urban transformation-related policies and strategies on the main aspects of resource-based cities, including urban healthy economic industries, ecological environment, urban construction, and public health services, analyzing and evaluating the development trends of related elements, their causes, and their mutual relationships.

6.1.2 Study area

The study area is located within the municipal jurisdiction of Taiyuan City in central Shanxi Province, China (Fig. 43). Taiyuan City is the capital city of Shanxi Province and one of China's important industrial bases. It has a complete industrial system in metallurgy, coal, machinery, chemicals, electronics and other categories. Due to reasons such as historical evolution and urban development positioning, Taiyuan City has had a high proportion of traditional resource-based industries such as coal and steel for a long time, while the development of new industries has lagged behind. As a representative of China's resource-based cities, Taiyuan City has persisted in promoting and exploring urban transformation and development for decades. In 2006, the Taiyuan Municipal Government put forward the development idea of "innovating development models and promoting green transformation", and since then the city's all-round transformation and development has begun. Taking advantage of Taiyuan City's political, economic, scientific research and education, location and transportation advantages as the provincial capital, it has implemented a number of measures including the transformation and upgrading of traditional industries, the introduction and development of emerging industries, comprehensive management of urban and rural environments, and the improvement and construction of public welfare undertakings. Urban transformation and development have achieved considerable results (Piper Gaubatz & Dean Hanink, 2020; Xi Zhang et al., 2022).



Fig. 43 Taiyuan City Municipal District Map

Source: From Google Map

6.2 Research methods

Based on the perspective of healthy city, this article takes the urban transformation and development of Taiyuan City, Shanxi Province, China as a study case. First of all, this study collected the socio-economic, environmental, and urban construction public data related to healthy city construction of Taiyuan city from 2006 to 2022, as well as relevant public policies and strategies formulated by the Taiyuan Municipal Government (Taiyuan Statistical Yearbook Committee, 2006-2022). And the relevant data of Shanxi Province was also collected as the comparative study background data. Second, this study used qualitative and quantitative approaches to estimate, and analyze the changes, and improvements in the urban economy, environment, and construction in the urban transformation process, and their health benefits were evaluated as well (Fig.44). Third, it summarized the roles, disciplines, development trends, and interrelationships of healthy economic industries, ecological environment, urban construction, and public health services (Min Pang, 2017).

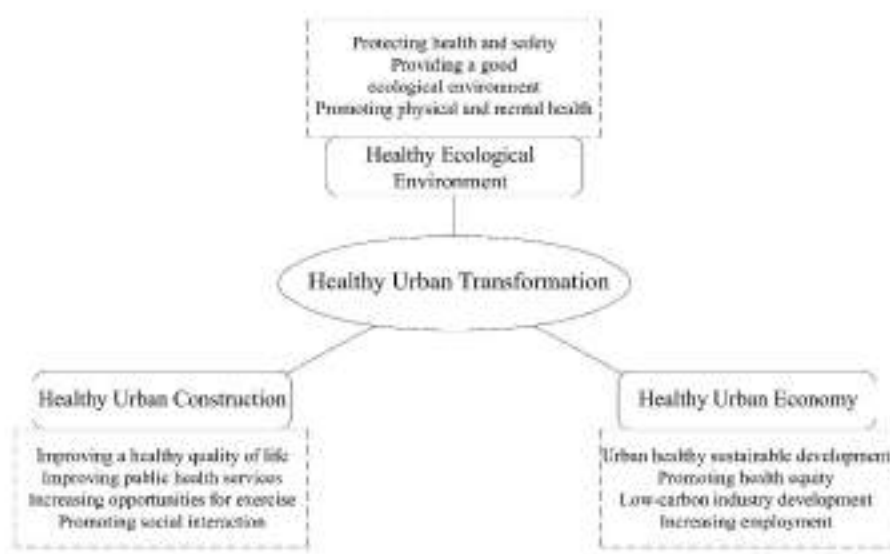


Fig. 44 Diagram of the model for assessing the healthy urban transformation

Source: Author's own work

6.3 Results

In terms of urban urban transformation and development, Taiyuan City actively promotes the optimization and adjustment of urban industrial structures. By implementing strict market access for key industries and strictly controlling project environment access, we will develop and expand emerging industry clusters such as information technology, high-end equipment manufacturing, new materials, and biotechnology, and promote technology, finance, modern logistics, exhibitions, electronics, etc. The development of high-end modern service industries such as business and commerce.

It can be seen from the statistical data of the city's economic industry that Taiyuan City's GDP added value increased from 100.538 billion yuan in 2006 to 557.117 billion yuan in 2022, an increase of 454.14%. The GDP Per capita has increased from 29,263 yuan in 2006 to 102,922 yuan in 2022, with an increasing rate of 251.71% (Fig. 45). The proportion of Taiyuan City's three industries has changed from 1.9: 46.6: 51.5 in 2006 to 0.86: 44.27: 54.87 in 2022. The proportion of the tertiary industry increased by 13.84%, and the proportion of the secondary industry decreased by 11.99%. The overall urban economy and its structure have been significantly improved (Fig. 46). During the same period, in 2006, Taiyuan's top five industries in terms of total industrial output value were the ferrous metal smelting and rolling processing industry, coal mining and washing industry, special equipment manufacturing industry, petroleum coal and other fuel processing industry, chemical raw materials and chemical products Manufacturing industries are almost all traditional energy and heavy chemical industries. By 2020, Taiyuan's top five industries in terms of total industrial output value will become the computer, communications and other electronic equipment manufacturing, ferrous

metal smelting and rolling processing industry, coal mining and washing industry, gas production and supply industry, petroleum and coal industry and other fuel processing industries. Although the energy, heavy and chemical industries still account for a large proportion, the computer, communications and other electronic equipment manufacturing industries have become Taiyuan's leading industries, contributing 26.2% of the city's industrial output value. In 2006, the added value of coal mining and washing accounted for 12.4% of Taiyuan's total industrial output value. By 2020, the proportion dropped significantly to 8.3%. The city's health economic industry has made significant progress and development (Fig. 47).

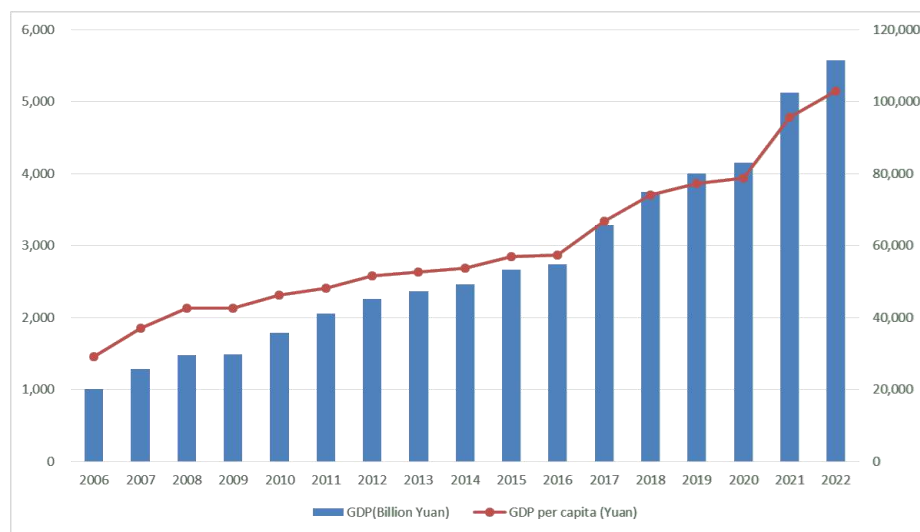


Fig. 45 Changes of the economy growth in Taiyuan City

Source: Author's own work

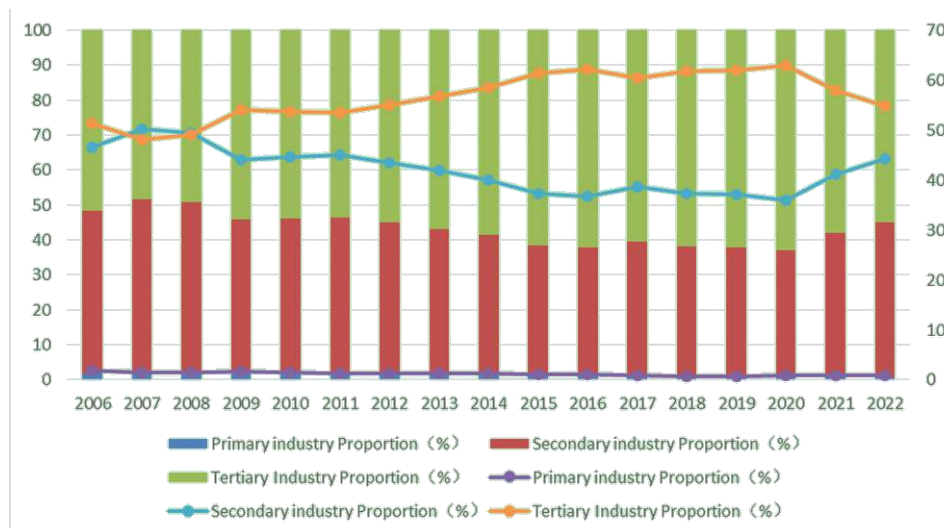


Fig. 46 Changes of the industrial structures in Taiyuan City

Source: Author's own work

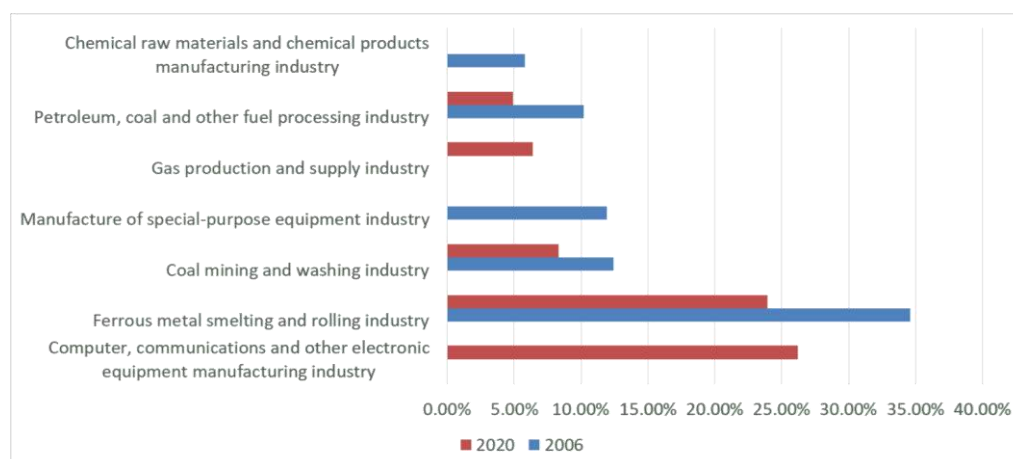


Fig. 47 Top 5 Industries with Total Industrial Output Value Above Scale in Taiyuan City, 2006 and 2020

Source: Author's own work

In terms of urban environmental transformation and construction, Taiyuan City has implemented measures such as shutting down and relocating heavily polluting enterprises, eliminating backward production capacity, and promoting cleaner production. We will further advance the energy revolution and accelerate the development of new energy systems such as wind power, photovoltaics, and hydrogen energy. Vigorously strengthen the comprehensive improvement of urban and rural land and space environment, carry out comprehensive management of urban and rural atmosphere, water, soil, mines, brownfield and other environmental damage and pollution, persist in promoting the integrated protection and restoration of urban and rural mountains, rivers, forests, fields, lakes and grass, expand urban and rural green space, and comprehensively improve Urban and rural ecological environment quality.

It can be seen from the statistical data related to the urban ecological environment that the annual average monitoring value of PM_{10} in Taiyuan City's atmospheric environment was $0.142 \text{ (mg/m}^3\text{)}$ in 2006 and $0.083 \text{ (mg/m}^3\text{)}$ in 2022, with a decrease of 41.55%. The annual average monitoring value of SO_2 in the atmospheric environment of Taiyuan City was $0.08 \text{ (mg/m}^3\text{)}$ in 2006 and $0.012 \text{ (mg/m}^3\text{)}$ in 2022, with a decrease of 85.00%. The annual average monitoring value of Taiyuan City's atmospheric environment Dust Fall was $27.7 \text{ (t/km}^2\text{.month)}$ in 2006 and $6.4 \text{ (t/km}^2\text{.month)}$ in 2022, with a decrease of 76.90% (Fig. 48). Among them, there was a decline in 2013 due to climate change in North China and other reasons, but the urban atmospheric environment generally showed an upward trend. It shows that due to Taiyuan City's industrial structure adjustment, energy conservation and emission reduction and other measures, atmospheric environment indicators such as PM_{10} , SO_2 , Dust Fall, which are closely related to heavy industry pollution emissions, have been significantly improved, and have had a significant effect on improving the urban atmospheric environment (Fig. 49). However, the annual average monitoring value of NO_2 in the urban atmospheric environment increased from $0.025 \text{ (mg/m}^3\text{)}$ in 2006 to $0.04 \text{ (mg/m}^3\text{)}$ in 2022, with an increase of 60.00%. During the same period, the number of cars in

Taiyuan City increased significantly from 299,100 vehicles in 2006 to 2,055,100 vehicles in 2022, with an increase of 587.09%. Due to reasons such as a sharp increase in vehicle exhaust emissions, NO_2 has shown an upward trend. Therefore, the overall atmospheric environment quality of Taiyuan City still faces challenges under the new situation (Fig. 50). The average value of urban noise was 53.1 decibels in 2006 and 50 decibels in 2022. The annual average value of traffic noise was 67.9 decibels in 2006 and 66.1 decibels in 2022. Urban noise shows a downward trend. The overall urban healthy ecological environment has been significantly improved (Fig. 51) (Table 16).

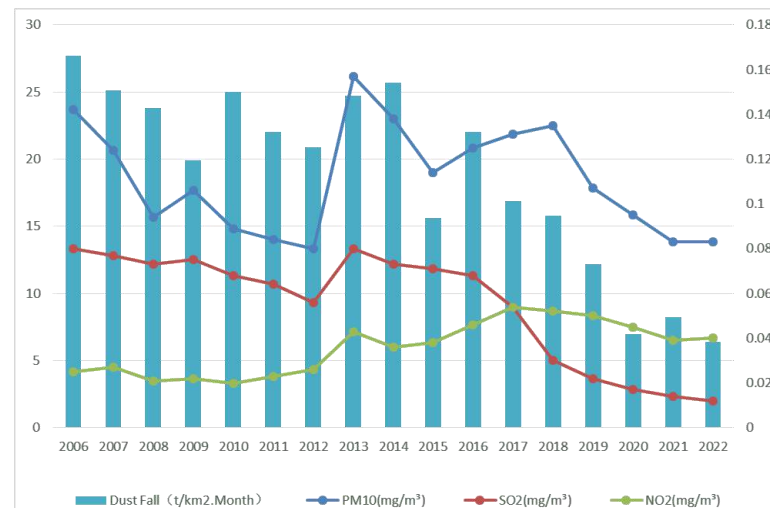


Fig. 48 Changes of urban air environmental quality in Taiyuan City from 2006 to 2022

Source: Author's own work

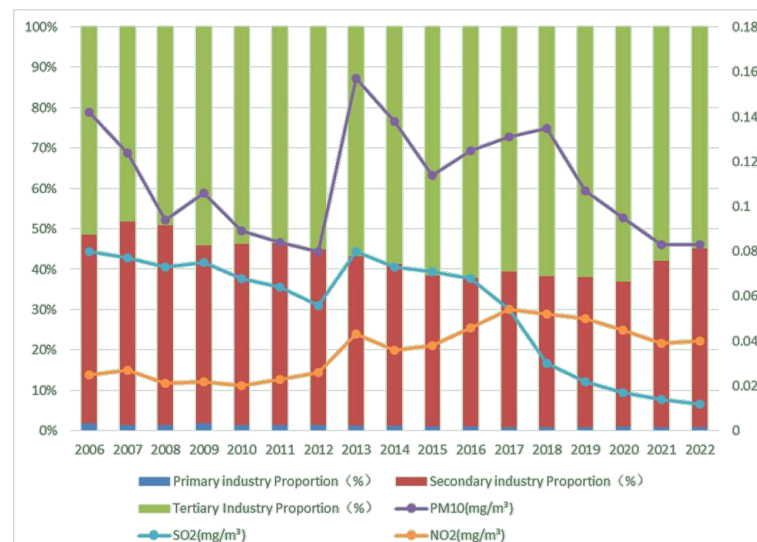


Fig. 49 Changes of air quality & economic structure in Taiyuan City from 2006 to 2022

Source: Author's own work

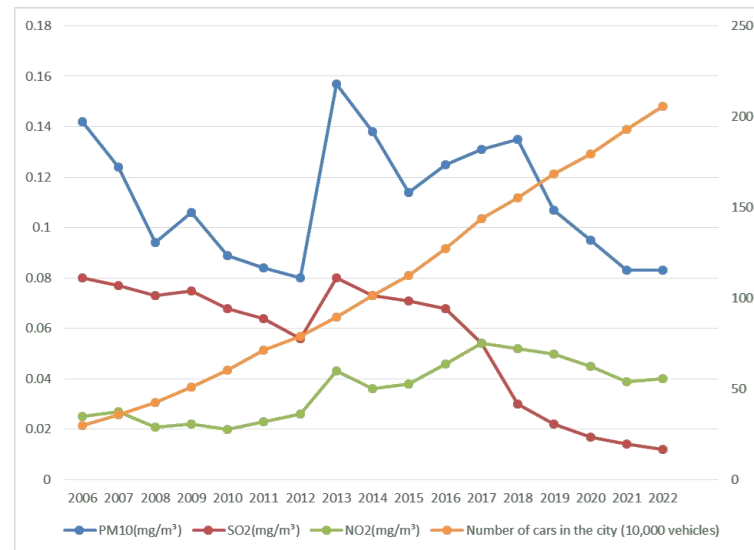


Fig. 50 Changes of urban atmospheric environmental quality and number of cars in Taiyuan City from 2006 to 2022

Source: Author's own work

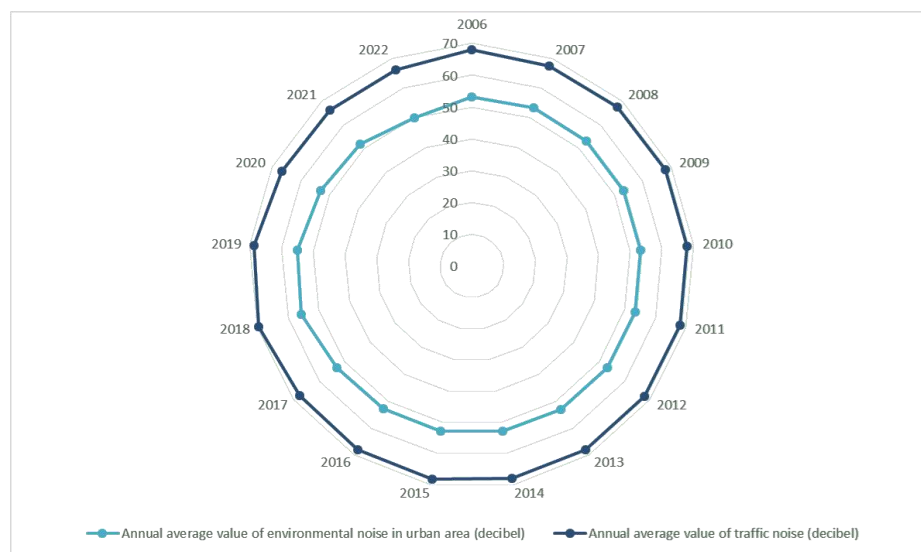


Fig. 51 Changes of urban noise in Taiyuan City from 2006 to 2022

Source: Author's own work

Table 16 Changes of ecological environment in Taiyuan City from 2006 to 2022

Year	PM ₁₀ (mg/m ³)	SO ₂ (mg/m ³)	NO ₂ (mg/m ³)	Dust Fall (t/km ² .month)	Annual average value of environmental noise in urban area (decibel)	Annual average value of traffic noise (decibel)	Number of cars in the city (10,000 vehicles)
2006	0.142	0.08	0.025	27.7	53.1	67.9	29.91
2007	0.124	0.077	0.027	25.1	53.4	67.4	35.65
2008	0.094	0.073	0.021	23.8	53.3	67.8	42.6
2009	0.106	0.075	0.022	19.9	53.1	68	51.08
2010	0.089	0.068	0.02	25	53.1	68	60.53
2011	0.084	0.064	0.023	22	53.2	67.9	71.4
2012	0.08	0.056	0.026	20.9	53.3	67.9	78.84
2013	0.157	0.08	0.043	24.7	53	68	89.5
2014	0.138	0.073	0.036	25.7	52.9	68	101.58
2015	0.114	0.071	0.038	15.6	52.9	68.3	112.29
2016	0.125	0.068	0.046	22	52.9	68.1	127.23
2017	0.131	0.054	0.054	16.9	53.2	67.8	143.63
2018	0.135	0.03	0.052	15.8	55.7	69.7	155.3
2019	0.107	0.022	0.05	12.2	55.1	68.7	168.37
2020	0.095	0.017	0.045	7.000	53	66.8	179.44
2021	0.083	0.014	0.039	8.22	52	66.2	192.92
2022	0.083	0.012	0.04	6.4	50	66.1	205.51

Source: Author's own work

In terms of urban greening construction, Taiyuan City actively carries out greening conservation and construction work in urban parks, street green spaces, country parks, and suburban woodlands. Actively carry out the restoration, management and greening reclamation of abandoned mine lands and industrial brownfields. Combined with urban and rural water supply and drainage municipal infrastructure improvement projects, promote the construction of urban and rural blue-green infrastructure such as "sponge cities" and promote the green transformation and improvement of urban and rural gray infrastructure. After construction from 2006 to 2022, the green coverage area of Taiyuan's urban built-up areas increased from 7,342 hectares in 2006 to 16,228.8 hectares in 2022, an increase of 121.04%. The green coverage rate of built-up areas will increase from 37.3% in 2006 to 45.08% in 2022. The green space rate of built-up areas will increase from 32.2% in 2006 to 39.94% in 2022. The area of garden green space and park green space increased from 6343 hectares and 2270 hectares in 2006 to 14378.4 hectares and 5530.91 hectares in 2022, an increase of 126.68% and 143.65% respectively (Fig. 52) (Table 17).

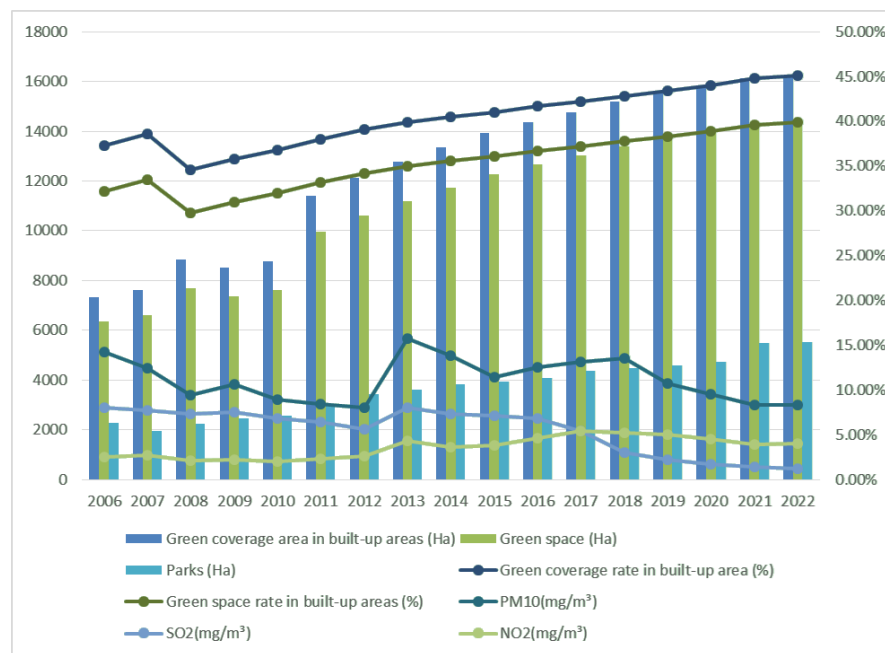


Fig. 52 Urban greening construction in Taiyuan City from 2006 to 2022

Source: Author's own work

Table 17 Changes of urban greening construction in Taiyuan City from 2006 to 2022

Year	Green coverage area in built-up areas (Ha)	Green space (Ha)	Parks (Ha)	Green coverage rate in built-up area (%)	Green space rate in built-up areas (%)
2006	7342	6343	2270	37.30%	32.20%
2007	7615	6610	1961	38.60%	33.50%
2008	8849.75	7704.5	2233.74	34.60%	29.80%
2009	8519	7372	2442	35.80%	31.00%
2010	8759	7611	2576	36.80%	32.00%
2011	11403	9948	3027	38.01%	33.16%
2012	12112	10596	3416	39.07%	34.18%
2013	12762	11190	3617	39.88%	34.97%
2014	13365	11738	3828	40.50%	35.57%
2015	13940	12264	3930	41.00%	36.07%
2016	14369	12655	4099	41.65%	36.68%
2017	14767	13013	4384.8	42.19%	37.18%
2018	15186.9	13397.7	4492.8	42.78%	37.74%
2019	15617	13788	4601	43.38%	38.30%
2020	15840	14004	4716	44.00%	38.90%
2021	16117.2	14270.4	5487.22	44.77%	39.64%
2022	16228.8	14378.4	5530.91	45.08%	39.94%

Source: Author's own work

In terms of urban health development, Taiyuan City has made great efforts to improve the urban and rural medical service system and enhance medical and health service capabilities. Increase and upgrade the construction of general hospitals, primary medical service points, and rural health clinics. Increase the introduction and training of professional doctors, nurses and other health technical personnel. Improve the basic health and welfare system in urban and rural areas. It can be seen from relevant statistics on urban health services that the number of urban health institutions (excluding village clinics) has increased from 3,305 in 2006 to 4,087 in 2022. The number of beds in health institutions will increase from 23,116 beds in 2006 to 46,102 in 2022. The number of health technicians will increase from 32,186 in 2006 to 70,074 in 2022. The city's public health undertakings have made great progress (Fig. 53) (Table 18).

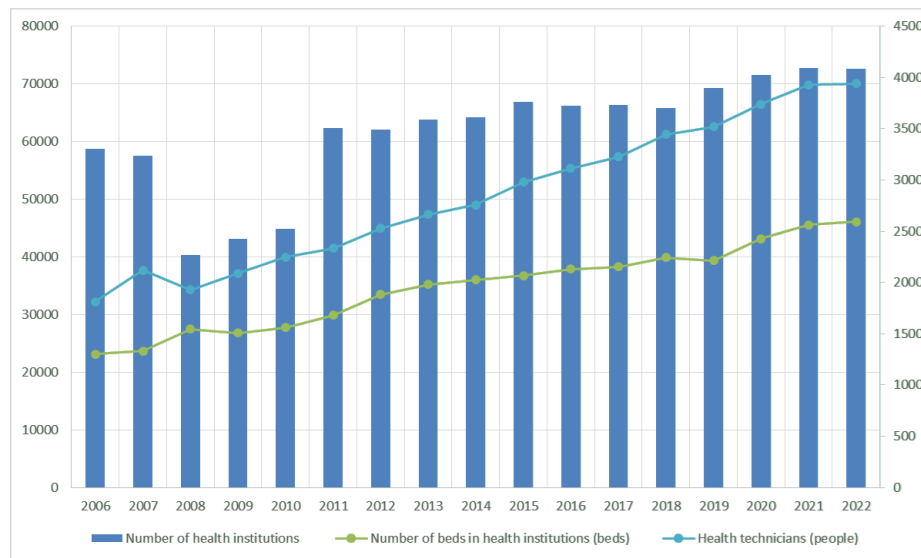


Fig. 53 Changes of urban health services in Taiyuan City from 2006 to 2022

Source: Author's own work

Table 18 Changes of urban health services in Taiyuan City from 2006 to 2022

Year	Number of health institutions	Number of beds in health institutions (beds)	Health technicians (people)
2006	3305	23116	32186
2007	3240	23687	37658
2008	2265	27505	34278
2009	2425	26815	37155
2010	2527	27771	39930
2011	3505	29876	41506
2012	3489	33461	44947
2013	3590	35247	47388
2014	3612	36022	49053
2015	3759	36760	52952
2016	3724	37897	55389
2017	3731	38318	57348
2018	3705	39917	61269
2019	3898	39358	62575
2020	4025	43166	66540
2021	4089	45589	69847
2022	4087	46102	70074

Source: Author's own work

6.4 Discussion

From 2006 to 2022, Taiyuan City has made great progress in the transformation and upgrading of urban industries, improvement of ecological environment, landscaping construction, and improvement of urban and rural health services. Comparing the changes in the four aspects, it can be seen that Taiyuan City's per capita GDP increased by 248.92% in 17 years, and its growth rate was significantly higher than the other three aspects of construction and development. However, the proportion of the tertiary industry in Taiyuan City has experienced an increase first and then a decrease. In 2015, the tertiary industry accounted for 61.5%, but it dropped to 54.87% in 2022. It can be seen that although most of the polluting heavy industries in the city have been transformed by technology. There have been transformations such as upgrading or closure and relocation, but the secondary industry still accounts for a large proportion. During the urban transformation of Taiyuan City, how to increase the proportion of service industries and emerging industries and promote the healthy and sustainable development of urban industries remains a long-term challenge facing the city.

Urban greening construction had rapid growth before 2015, and its growth rate was close to the growth rate of per capita GDP. However, after 2015, the growth rate declined and was significantly lower than the growth rate of urban per capita GDP. This shows that investment in greening construction in Taiyuan City lags behind the regional economic development level after 2015.

The growth rate of urban and rural health services is close to 50% of the growth rate of urban per capita GDP during the same period. This shows that investment in health and sanitation increases simultaneously with urban economic development, but lags behind the level of regional economic development.

Although Taiyuan City's atmospheric environment quality and noise environment quality have fluctuated between 2006 and 2022, they have shown an overall improvement trend, but they are lower than the growth rate of the city's per capita GDP, and lower than the growth rate of urban greening construction and health services. During the same period, the growth rate of Taiyuan City's car ownership (10,000 vehicles) was much higher than the growth rate of per capita GDP and other factors. This shows that the improvement of urban healthy ecological environment still requires increased investment, synchronized with the construction and development of other aspects of the city. Controlling the growth of car use is also an issue that needs to be focused on in building a healthy urban environment in Taiyuan City (Fig. 54) (Table 19).

The construction of a high-quality healthy city, the cultivation of emerging industries and the replacement of old production capacity in regional industrial transformation and upgrading require a long cycle. For further study, Long-term attention to urban transformation, construction, and development is needed.

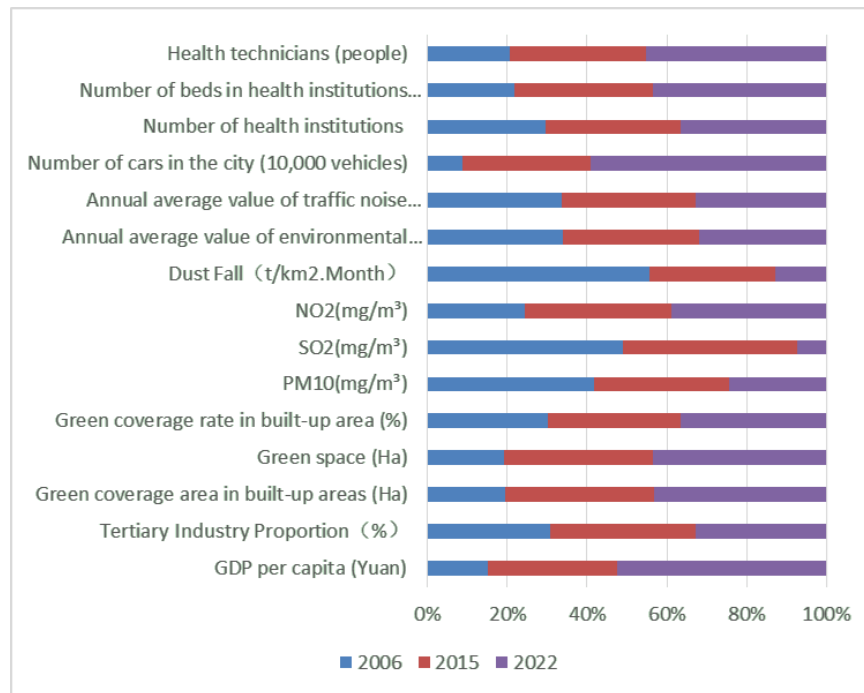


Fig. 54 Changes of main healthy city elements in Taiyuan City from 2006 to 2022

Source: Author's own work

Table 19 Changes of main healthy city elements in Taiyuan City from 2006 to 2022

				Change rate 2006-		Change rate
Year		2006	2015	2015	2022	2006-2022
Health economy	GDP per capita (Yuan)	29497	63483	115.22%	102922	248.92%
	Tertiary Industry Proportion (%)	51.5%	61.5%		54.87%	
				19.42%		6.54%
Greening construction	Green coverage area in built-up areas (Ha)	7342	13940	89.87%	16228.8	121.04%
	Green space (Ha)	6343	12264	93.35%	14378.4	126.68%
	Green coverage rate in built-up area (%)	37.30%	41.00%			
			%	9.92%	45.08%	20.86%
Ecological environment quality	PM ₁₀ (mg/m ³)	0.142	0.114	-19.72%	0.083	-41.55%
	SO ₂ (mg/m ³)	0.08	0.071	-11.25%	0.012	-85.00%
	NO ₂ (mg/m ³)	0.025	0.038	52.00%	0.04	60.00%
	Dust Fall (t/km ² .Month)	27.7	15.6	-43.68%	6.4	-76.90%
	Annual average value of environmental noise in urban area (decibel)	53.1	52.9	-0.38%	50	-5.84%
	Annual average value of traffic noise (decibel)	67.9	68.3	0.59%	66.1	-2.65%
	Number of cars in the city (10,000 vehicles)	29.91	112.2			
			9	275.43%	205.51	587.09%
Health services	Number of health institutions	3305	3759	13.74%	4087	23.66%
	Number of beds in health institutions (beds)	23116	36760	59.02%	46102	99.44%
	Health technicians (people)	32186	52952	64.52%	70074	117.72%

Source: Author's own work

6.5 Conclusions

Research shows that through urban transformation, construction and development, Taiyuan City's healthy social economy, ecological environment and public health have all been comprehensively developed. The main indicators of healthy city construction have been significantly improved. Policies to stimulate the transformation of urban-related industries, environmental protection policies and related construction of healthy

cities have all achieved significant results.

The growth rate of economic development during urban transformation is close to twice the growth rate of urban healthy ecological environment, urban greening construction and health service supply. In the urban economic structure, the proportions of the three industries have fluctuated significantly over the years. It shows that the development of urban healthy economy still needs to further optimize the industrial structure. The urban healthy ecological environment, urban greening construction and health service supply need to be further strengthened to achieve coordinated development with the urban healthy economy.

Healthy urban transformation and development is a long-term and arduous task. It requires the joint support and efforts of the government, enterprises, social institutions, and urban and rural residents. It needs the promotion of the coordinated development of urban public health and industrial transformation through improving the policy system for transformation and development, expanding the content of the health economic industry framework, encouraging the healthy transformation and upgrading of original regional industries, improving the quality of regional health environment, and providing high-quality health benefits and service supply.

Part 3 Case study of Mine Wasteland Regeneration

7 Chapter7 Background of the Mine Wasteland Regeneration Case Study

7.1 Justification of the case study

7.1.1 Selection criteria of the main case study

According to the research object of this thesis, the main research case should be large-scale mine wastelands located in the peri-urban area. The restoration and reused construction of the mine wastelands should have tremendous influence on the urban environment (Table 20).

Table 20 Criteria for case choosing

Serial number	Basic criteria for Case Choosing	Circumstances of Taiyuan Xishan
1	Large-scale mine wasteland	There are about 1,000 abandoned mine pits of various types before treatment
2	A large area of influence	The total area of various mine wastelands and their affected areas is about 483 square kilometers
3	A certain urban and rural population base	The total urban and rural population of Taiyuan is about 5,300,000
4	Located in the peri-urban area of the city	Located in the peri-urban area of Taiyuan city
5	Mine wasteland has been reused for construction	A total of 350.4 hectares of abandoned mine pits were repaired, and 137.51 square kilometers of forest parks were formed through reclamation

Source: Author's own work

7.2 Case study background

7.2.1 General situation of Xishan in Taiyuan City

Taiyuan, located in the middle of Shanxi Province, is the capital city of Shanxi Province, which is a famous cultural city with a history of 2500 years. Xishan area is located in the west of Taiyuan city center, which belongs to the eastern foot of Lvliang mountains, in this area mainly includes Juewei mountain, Mengshan mountain, Taishan

mountain, Longshan mountain, Xuanweng mountain, Tianlong mountain, Miaoqian mountain and other mountains, whose elevations are between 800-1800 meters. And there are many cultural relics and Tourism resources.

The specific research area is located in Jiancaoping District, Wanbolin District, and Jinyuan District of Taiyuan City (total urban and rural population: approximately 5,300,000), Shanxi Province, China, which is the jurisdiction region of the Taiyuan Xishan Ecological and Cultural Tourism Demonstration District (hereafter referred to as Xishan). The specific scope of the base is east to the West Ring Expressway, west to the boundary of Jiancaoping, Wanbailin and Jinyuan District of Taiyuan city, north to the Fen River, and south to the southern boundary of Yaocun Town. Adjacent to the built-up area of Taiyuan city, the total length from north to south is approximately 40 km, the total width from east to west is approximately 19 km, and the total area is approximately 483 km² (Fig. 55).



Fig. 55 Location map of Xishan in Taiyuan city

Source: Author's own work

7.2.2 Overview of Xishan area

Because of its rich natural mineral resources, the region is the main mining area of Shanxi Province from the 1930s. Due to large-scale mining activities in the Xishan area of Taiyuan from 1978 to 2006, problems such as mountain damage, environmental pollution, soil erosion, and geological disasters were caused.

In 2006, the Taiyuan Municipal Government launched a comprehensive ecological environment management project in the Xishan area, and began to gradually shut down small coal mines and polluting enterprises in the area, carried out the ecological restoration of the damaged mountains, and built suburban forest parks. With the transformation of industrial structure in Shanxi Province, the ecological governance and industrial upgrading in Xishan area have been promoted rapidly.

In 2017, the provincial government approved the establishment of Xishan ecological and Cultural Tourism Development Zone with a total area of 483 square kilometers. The scope includes the main resources and ecological restoration area of Xishan in Taiyuan, and which is also the research area of Xishan in this study.

By the end of 2020, there are 350.4 hectares of various mountain damage areas (mine abandoned land) repaired, and 16 suburban forest parks have been built in the Xishan area, covering a total area of 137.51 square kilometers.

In 2021, the mine regeneration case of the Xishan area in Taiyuan City was listed in China's Progress Report on Implementation of the 2030 Agenda for Sustainable Development as part of the Mechanisms to Facilitate the Development of the Innovation Demonstration Zones. (Fig. 56) (Center for International Knowledge on Development, 2021)



Fig. 56 China's Progress Report on Implementation of the 2030 Agenda for Sustainable Development

Source: Center for International Knowledge on Development
(Center for International Knowledge on Development, 2021)

7.2.3 The historical context of mine regeneration in Xishan area

In the Xishan area of Taiyuan City, from 1978 to 2006, mining activities in the past 20 years caused serious damage to the natural ecology of the area, not only brought geological disasters such as land subsidence and cracks, but also caused mountain damage, vegetation degradation, soil pollution, water resources depletion and many other ecological problems. Since 1995, the state has implemented mining

order rectification, and the management order of Xishan mineral resources has been improved in an all-round way. However, at this stage, the ecological restoration work in the Xishan area is progressing slowly, and the ecological loss is still increasing (Fig. 57).

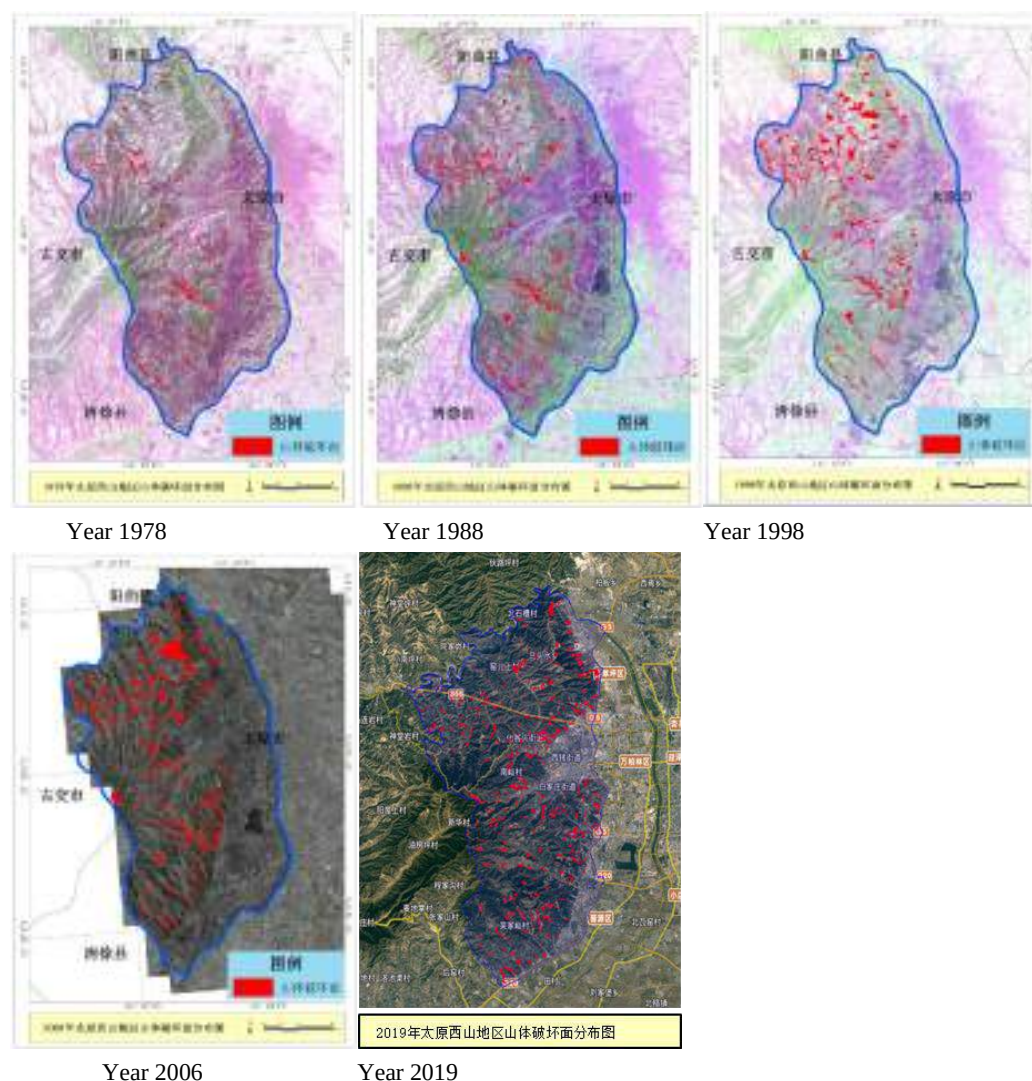


Fig. 57 Evolution of mine wasteland in Xishan area from 1978 to 2019

Source: Author's own work

In 2006, Wanbailin District seized the opportunity of Taiyuan City to build six major forest areas and create a national forest city, and started the construction project of Xishan Wanmu Ecological Park. In 2007, the governments of Shanxi Province and Taiyuan City began to comprehensively control the ecological pollution and environmental damage in the Xishan area. In March 2008, Taiyuan City launched a comprehensive renovation project in the Xishan area. In 2011, the Taiyuan Municipal Government issued the "Implementation Opinions on Accelerating the Construction of Forest Parks in the Suburbs of Xishan City (Trial Implementation)" (Bingzhengbanfa [2011] No. 73), proposing to adopt the "market-oriented operation,

corporate bearing, and park-like construction". mode, encourage the participation of social capital, and promote the ecological restoration and scenic spot construction in the Xishan area. Through government-led, enterprise participation and market-oriented operation, the ecological environment governance in the Xishan area of Taiyuan has been rapidly advanced.

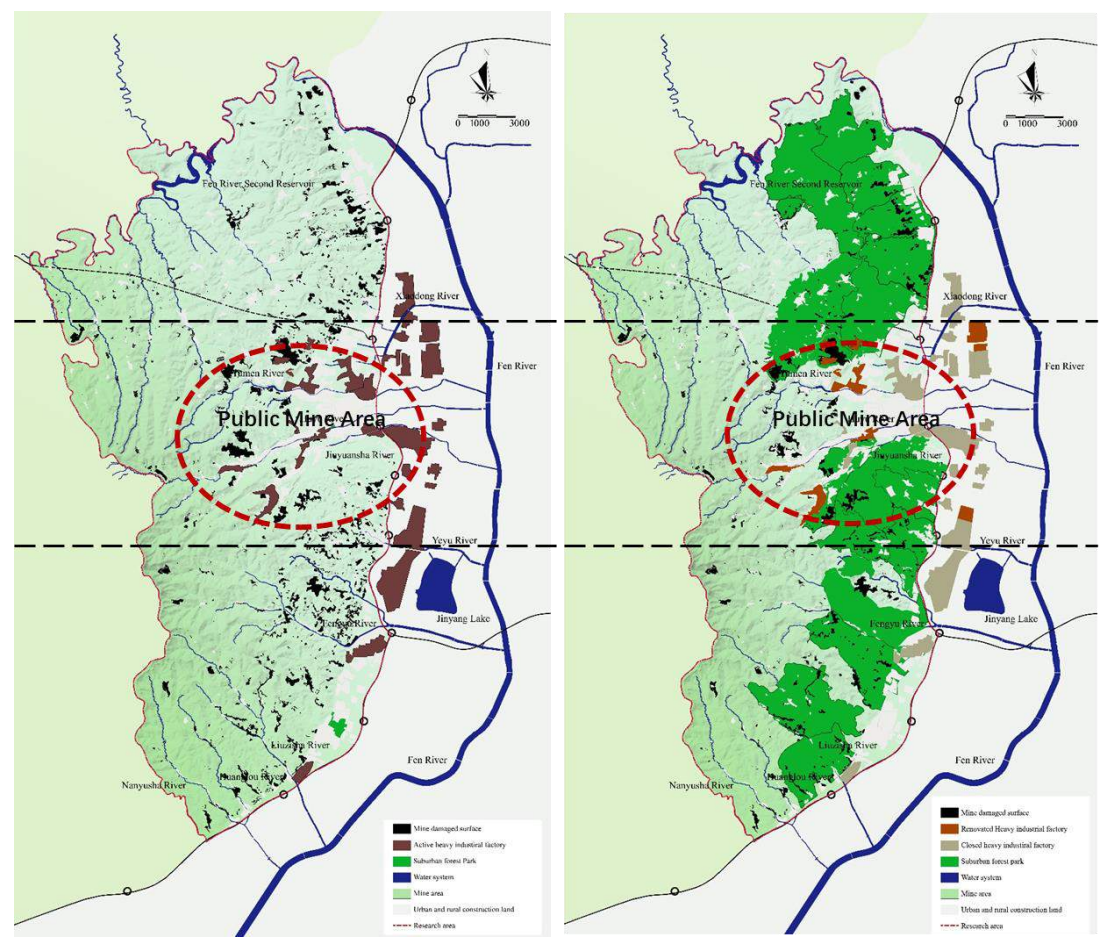
From 2009 to 2016, 8 heavily polluting enterprises were shut down and relocated in Xishan area; 343 polluting enterprises including small chemical industry, small cement, small building materials, and coal gathering yard were closed or eliminated; 76 licensed small coal mines were shut down, block more than 2,000 black holes for private digging and illegal mining; clear and transport more than 3 million tons of garbage and coal gangue, and clean up 350 coal piles, about 7 million tons. As of 2019, about 200,000 mu of green areas have been completed in the Xishan area, and 6.5 million square meters of damaged mountain surfaces have been treated. The overall ecological environment of the region has been greatly improved, and the damaged mountain interface has been initially repaired. Xishan Coal and Electricity Group has integrated and upgraded the original production and mining areas in the region. At present, the integrated production and mining areas in the region include Guandi Mine, Ximing Mine, Duerping Mine, etc., which have all transformed into green mining areas (Fig. 58, Fig. 59) (Table 21).

Table 21 List of existing ecological restoration measures in Xishan Area

Type	Main existing ecological restoration methods	Measures and suggestions
Waste land of waste dump	Clean up the waste, peel off the contaminated waste, and conduct safety protection treatment and isolation. The landscape of the site shall be reshaped and vegetation planting and covering shall be carried out after the terrain is sorted, covered with soil and soil matrix is improved. The leveled land will be used for scenic spot construction.	It is suggested to strengthen the comprehensive topographic arrangement and meet the drainage function and slope stability. Increase the use of ecological organic fertilizer, planting nitrogen fixing plants and other means to enhance land fertility.
Abandoned land in mined out subsidence area	For abandoned underground roadways and mining faces, technical means such as landfill, waste backfill and concrete reinforcement are adopted for reinforcement and backfilling. Increase land reclamation measures, restore and rebuild the original ecological system of the land, strengthen the ecological governance of the goaf, and prevent various possible disasters.	Increase the supervision of the exploration of goaf, carry out environmental impact assessment, and formulate reasonable control measures for goaf with different risk levels. Strengthen the exploration and restoration of water resources in the goaf, especially pay attention to the protection and ecological restoration of groundwater resources.
Waste dump	tidy up the gangue pile. For the gangue pile with steep slope and high mountain, conduct slope cutting and shaping (the slope angle should be fixed at 30 ° and slope protection. Use coal ash or other chemical methods to improve the soil matrix, and carry out green planting. to prevent spontaneous combustion, the main methods are: first, reduce the oxidation reaction of Fe by adding strong alkaline substances; second, directly cover the spontaneous combustion part with soil to prevent it from contacting with combustible gas in the air. A drainage ditch shall be built to discharge the water collected by the gangue hill, so as to avoid washing the soil cover of the slope due to heavy rainfall, exposing the gangue again and causing spontaneous combustion.	It is recommended to adopt ecological planting blanket (made of wheat straw, straw, grass seed and nutrient agent) for slope protection. In combination with biological soil matrix improvement method, use animals and plants to extract, absorb, decompose, transform or fix soil sediment. It is suggested to select more local pioneer trees and fire-resistant trees, and adopt the planting mode of combining trees, shrubs and grass.
Open pit wasteland	Clean up the waste, peel off the contaminated waste, and conduct safety protection treatment and isolation. Land consolidation and green reclamation.	It can be classified and treated according to the geological conditions of the mine pit. If the geological conditions are stable and good, the project construction that adapts to the characteristics of the site can be arranged after the site is leveled; if the geological conditions need to be improved, the greening and project construction can be arranged after the terrain arrangement, covering soil and soil matrix improvement.
Land abandoned for industrial	Clean up the original pollutants in buildings and sites (including soil, water, etc.). Landscape treatment of the site topography.	Strengthen the in-depth study of site pollution, carry out targeted cleaning and ecological restoration, and recommend to select more advanced technologies such as

buildings and facilities	Dismantle dangerous and hazardous buildings, facilities and equipment. Keep useful buildings and facilities. Carry out project construction and landscape greening.	environmental biotechnology to clean up the pollution. The planting selection should be based on the requirements of pollution resistance, pest resistance and barren resistance. Project construction can be carried out in combination with industrial heritage display and tourism development requirements.
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Source: Author's own work



Mine and Industries map, 2006

Mine and Industries map, 2019

Fig.58 Mine and Industries changes between 2006 and 2019

Source: Author's own work



**Fig.59 Comparison of landscape changes of mountains
between 2006 and 2019**

Source: Photos Provided by Xishan Management Committee

In the Taiyuan City Water System "Nine Rivers Governance" project launched in 2017, it was proposed that the rivers including Fengyugou, Yeyugou, Jiuyuan Shahe, Huyuhe, Yumengou, Xiaodongliuhe, etc. The six tributaries of the Fenhe River carry out the management of the shallow mountain section. In the "Black and Smelly Water Treatment Project" in Taiyuan City, which was carried out at the same time, it was proposed to carry out ecological engineering on six sewage canals in the Xishan area, including the North Drainage Ditch, Yumengou, Huyu River, Jiuyuan Shahe, Chemical Flood Drainage Ditch and Qingshui River (Fig. 60).

Combined with the surface ecological restoration project on the damaged surface of the original mining leftover mountain in the Xishan area, as of 2019, tourist attractions such as Jinci, Mengshan Giant Buddha, Tianlong Mountain, Taishan, Juwei Mountain, Wanmu Ecological Garden, and Taiyuan Botanical Garden have been formed. Restoration, greening planting, landscape construction and other measures have been taken, and 16 suburban forest parks have been built successively (the cumulative investment is 11.1 billion yuan, of which the government invested 3.6 billion yuan and the enterprise invested 7.5 billion yuan). And build a number of sports, leisure and entertainment, tourism and vacation and other service facilities.

In terms of infrastructure construction, the Xishan area has successively built a 136-kilometer tourist road connecting the north and south of Xishan, and a 382-kilometer park road. Xishan Tourist Highway is the main road for the "International Road Cycling Race" held in Taiyuan City. A water diversion project was implemented in the region, and a 184-kilometer green water supply pipe network was built. In terms of urban and rural community governance, Xishan area has strengthened rural reconstruction and management, and improved the existing urban living environment and public service facilities. Major achievements have been made in regional ecological governance and urban and rural construction.

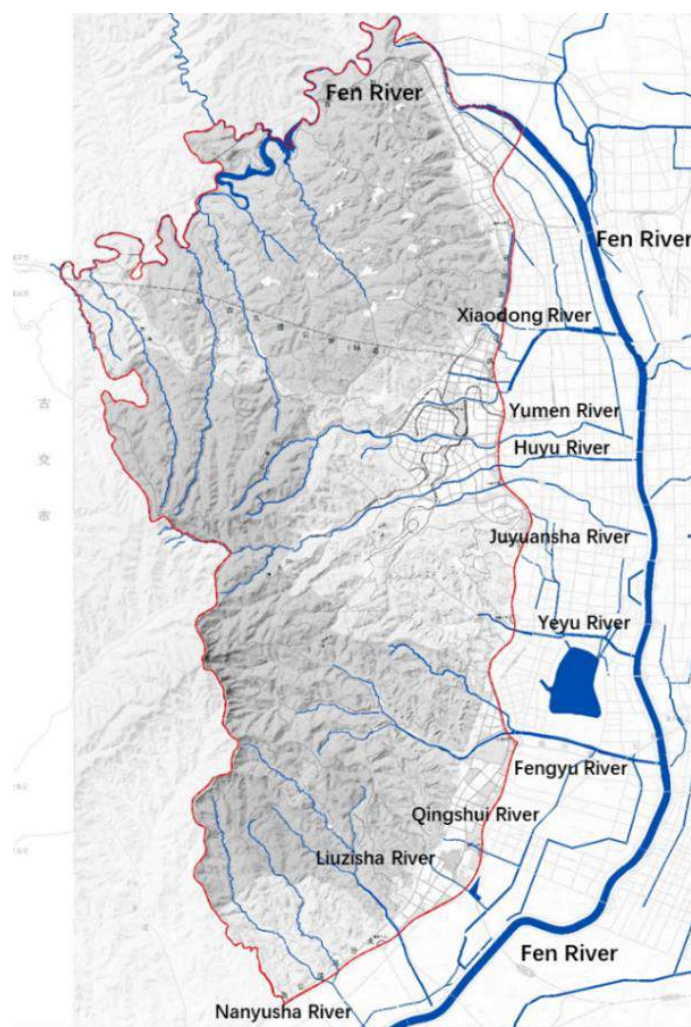


Fig. 60 The map of Water System in Xishan area, Taiyuan

Source: Author's own work

8 Chapter 8 Ecological restoration study of Xishan from the Perspective of Healthy City

8.1 Ecological Restoration Measures and Health Environmental Quality

Assessment Based on the Health Impact Assessment Standard

This article refers to the relevant definitions and requirements of WHO on health assessment, Europe (Health Impact Assessment Toolkit for Cities Document 1.) and the United States (The Health Impact Assessment (HIA) Resource and Tool Compilation, DFH: Design for Health) on health assessment for the relevant standards, relevant evaluation indicators that are closely related to health factors in the Xishan area of Taiyuan were selected. Mainly include health environmental quality indicators: air, water, soil, solid waste etc.

8.1.1 Atmospheric environment

■ Health environmental quality assessment for the atmospheric environment

Refer to the "WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide" published by WHO. →The main elements related to air health exposure risks published in the guidelines are used as the main research objects, combined with other common human exposures Conduct data collection and evaluation research on air pollutant elements of health risks.

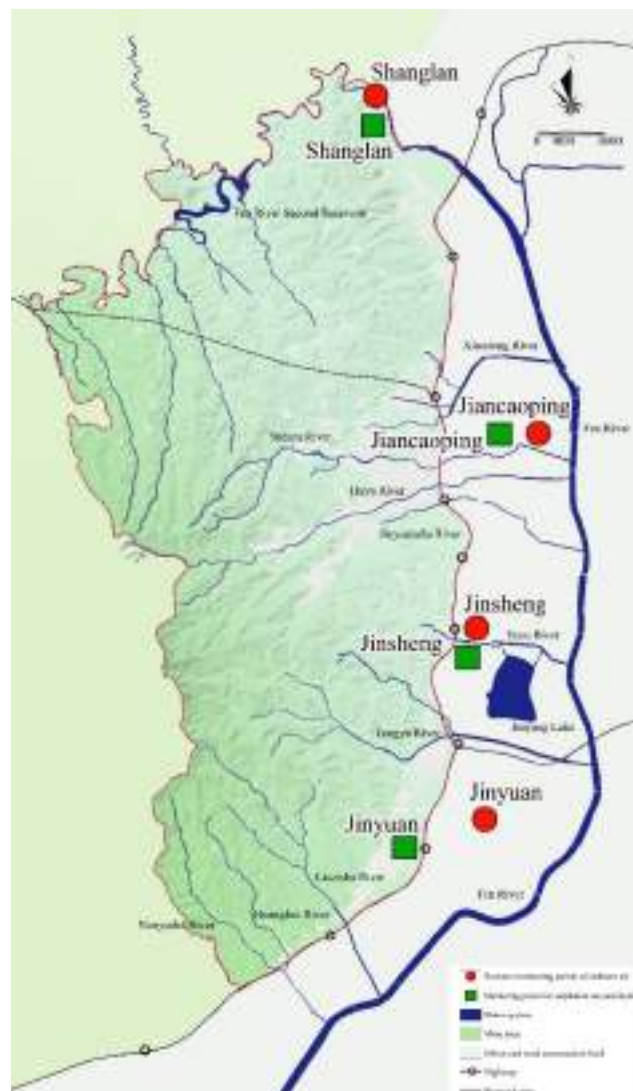
In order to explain the trend of atmospheric environmental quality changes in Xishan area of Taiyuan City, the data of four routine monitoring points set up by Taiyuan ecological environment bureau from 2006 to 2019 (from the beginning to the last environmental statistics year of the comprehensive treatment project of Xishan) were compared and analyzed. The four monitoring points include: Shanglan, Jiancaoping, Jinsheng, Jinyuan, etc. (Taiyuan Environmental Monitoring Center, 2006-2022) (Fig. 61) (Table 22).

Table 22 Atmospheric environment monitoring point setting

Serial number	Name of measuring point	Longitude	Latitude	Control level
1	Shanglan	11226'2.4"	380'38.9"	State and municipal control
2	Jancaoping	11230'50.4"	3753'29.5"	State and municipal control
3	Jinsheng	11228'41.9"	3746'40.1"	State and municipal control
4	Jinyuan	11228'08.4"	3742'44"	State control

Notes: The sampling heights of PM₁₀, PM_{2.5}, SO₂ are 8-11 m, the dust reduction and sulfuric acid salinization rates are 5-14 m, and the precipitation duration is 7-11 m.

Source: Author's compilation (Taiyuan Environmental Monitoring Center, 2006-2022)

**Fig. 61 Atmospheric environment monitoring point setting**

Source: Author's own work

The reference standards for sulfur dioxide, carbon monoxide and particulate matter in the ambient air are the relevant provisions of *The Ambient Air Quality Standard* (GB 3095-2012) and the secondary concentration limit in the modification sheet. The evaluation is conducted according to the technical specification for *Environmental Air Assessment* (HJ 663-2013). The sulphation rate is recommended by the original *National Standard for The Preparation of Environmental Quality Report*. And the dust reduction uses the recommended standards. And refer to the relevant provisions of relevant air pollutant indicators in who air quality standards (Table 23).

Table 23 Ambient Air Pollutant Concentration Limits

Serial number	Name of pollutant	Average time	China National Secondary Standard	WHO (IT-1) standard	WHO AQG standard
1	SO ₂	Annual	60 (μg/m ³)		
2	PM ₁₀	Annual	70 (μg/m ³)	70 (μg/m ³)	15 (μg/m ³)
3	PM _{2.5}	Annual	35 (μg/m ³)	35 (μg/m ³)	5 (μg/m ³)
4	Fallen Dust (Chinese National Recommended Standards)	Annual	9 (t/km ² .month)		
5	Sulfation Rate (Chinese National Recommended Standards)	Annual	0.25 (mg SO ₃ /100 cm ² alkali.day)		

Source: Author's own work

The changes of major air pollutants in Xishan region from 2006 to 2019 are as follows:

PM₁₀: the annual average concentration of inhalable particulate matter in Xishan District of Taiyuan shows an unstable change from 2006 to 2019, including a downward trend from 2006 to 2009 (Fig. 62, Fig. 63).

After 2012, due to winter climate changes and other factors, regional PM₁₀ air pollution broke out in North China, which showed a sudden increase in 2013-2014, and then strengthened atmospheric environmental governance through the region and the Xishan region, and showed a downward trend in 2014-2019.

an upward trend from 2010 to 2013, a downward trend from 2014 to 2015, an upward trend from 2016 to 2018, and a downward trend after 2019. The average concentration of PM₁₀ in Shanglan was 0.072, while that in Jiancaoping, Jinsheng and Jinyuan were 0.119, 0.129 and 0.112, respectively. In 2019, the annual average concentrations of Shanglan, Jiancaoping, Jinsheng and Jinyuan in Xishan of Taiyuan were 0.068, 0.107, 0.11 and 0.109 mg / m³. Compared with the initial stage of ecological management in 2006, it decreased by 0.053, 0.029, 0.026 and 0.002 respectively.

Among them, the annual average concentrations of PM₁₀ in Jiancaoping, Jinsheng and Jinyuan in 2006 were 72.9%, 94.3%, 94.3% and 58.6% higher than those in WHO Interim target-1(IT-1) environmental function zone (0.07). They were 706.7%, 806.7%, 806.7% and 640.0% higher than the WHO standard (0.015).

In 2019, the annual average concentration of Shanglan was lower than that of the WHO Interim target-1(IT-1) environmental function zone (0.07), and the annual average concentrations of Jiancaoping, Jinsheng and Jinyuan were higher than that of the WHO Interim target-1(IT-1) environmental function zone (0.07), which were 52.9%, 57.1% and 55.7% respectively. The annual average concentrations of the monitoring values at Shanglan, Jiancaoping, Jinsheng and Jinyuan were 353.3%, 613.3%, 633.3% and 626.7% higher than the WHO standard (0.015). The PM₁₀ monitoring values of main monitoring points in Xishan area generally show a downward trend (Table 24).

Table 24 PM₁₀ (mg /m³) Annual average in X ishan area from 2006 to 2019

Year	Shanglan	Jiancaoping	Jinsheng	Jinyuan
2006	0.121	0.136	0.136	0.111
2007	0.065	0.13	0.161	0.119
2008	0.049	0.105	0.126	0.082
2009	0.046	0.116	0.141	0.115
2010	0.046	0.09	0.098	0.09
2011	0.054	0.089	0.096	0.08
2012	0.063	0.085	0.09	0.072
2013	0.098	0.158	0.142	0.173
2014	0.088	0.134	0.132	0.124
2015	0.069	0.114	0.127	0.108
2016	0.074	0.126	0.146	0.111
2017	0.079	0.13	0.145	0.133
2018	0.083	0.144	0.15	0.143
2019	0.068	0.107	0.11	0.109

Source: Author's own work

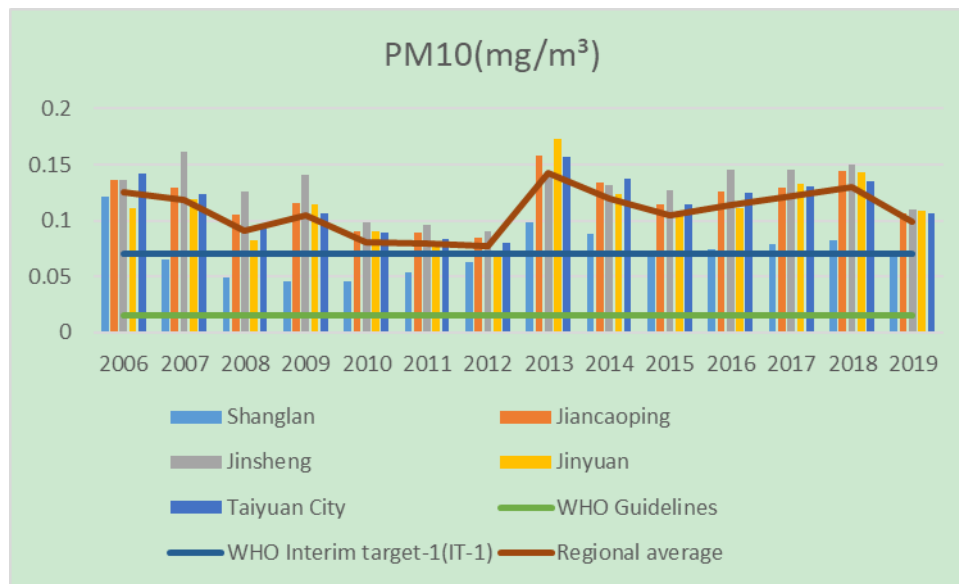


Fig. 62 Histogram of PM₁₀ year mean change in Xishan area of Taiyuan

Source: Author's own work

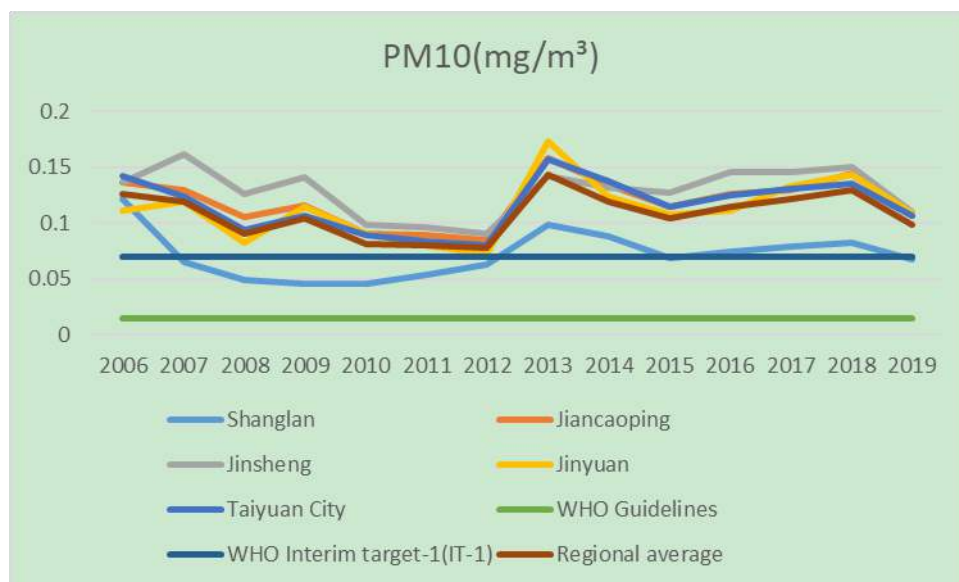


Fig. 63 Annual mean change curve of PM₁₀ in Xishan area

Source: Author's own work

PM_{2.5}: the average annual concentration of PM_{2.5} in Xishan area of Taiyuan from 2013 to 2019 shows a downward trend. Among them, the average values of Shanglan, Jiancaoping, Jinsheng and Jinyuan monitoring points in Xishan of Taiyuan in 2019 are 0.038, 0.051, 0.055 and 0.064 mg / m³ respectively. Compared with 2013, it decreased by 0.018, 0.027, 0.025 and 0.018 respectively (Fig. 64, Fig. 65).

Among them, in 2013, the annual average concentration of Shanglan, Jiancaoping, Jinsheng and Jinyuan was higher than that of PM_{2.5} in WHO Interim target-1(IT-1) environmental functional areas (0.035), which were 60.0%, 122.9%, 128.6% and 134.3% respectively. They were 1020.0%, 1460.0%, 1500.0% and

1540.0% higher than the WHO standard (0.005). In 2019, the annual average concentrations of PM_{2.5} in Shanglan, Jiancaoping, Jinsheng and Jinyuan were higher than those in WHO Interim target-1(IT-1) environmental functional areas (0.035), which were 11.4%, 54.3%, 71.4% and 111.4% respectively. They were 660.0%, 920.0%, 1000.0% and 1180.0% higher than the WHO standard (0.005). The PM_{2.5} monitoring values of main monitoring points in Xishan area generally show a downward trend (Table 25).

Table 25 Annual average of PM_{2.5} (mg/m³) in Xishan area from 2013 to 2019

Year	Shanglan	Jiancaoping	Jinsheng	Jinyuan
2013	0.056	0.078	0.08	0.082
2014	0.047	0.07	0.073	0.075
2015	0.042	0.061	0.069	0.061
2016	0.044	0.066	0.072	0.068
2017	0.043	0.065	0.065	0.072
2018	0.039	0.054	0.06	0.074
2019	0.038	0.051	0.055	0.064

Source: Author's own work

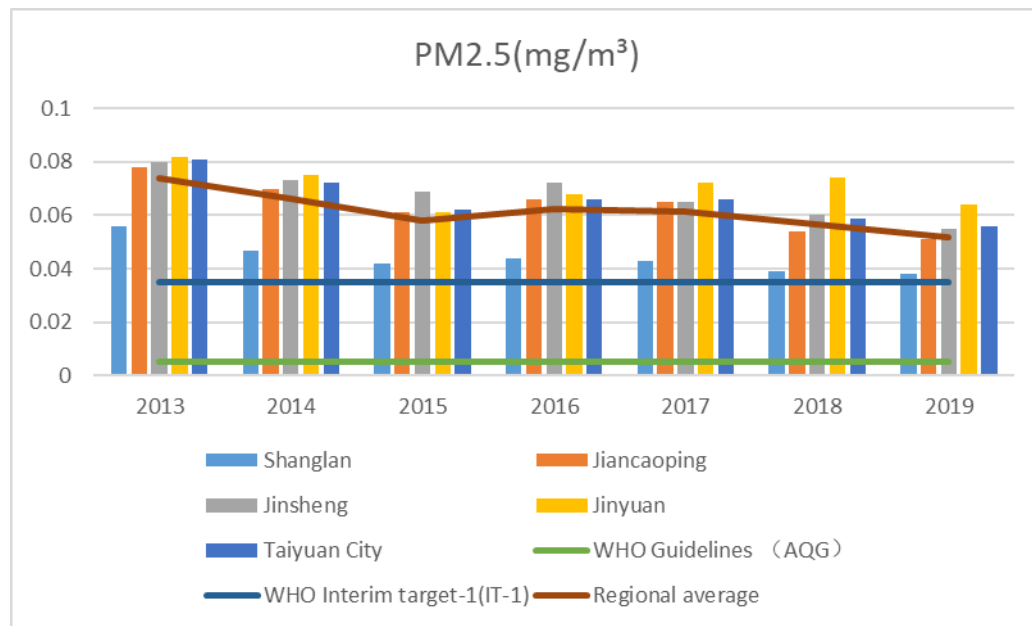


Fig. 64 Histogram of annual mean change of PM_{2.5} in Xishan area

Source: Author's own work

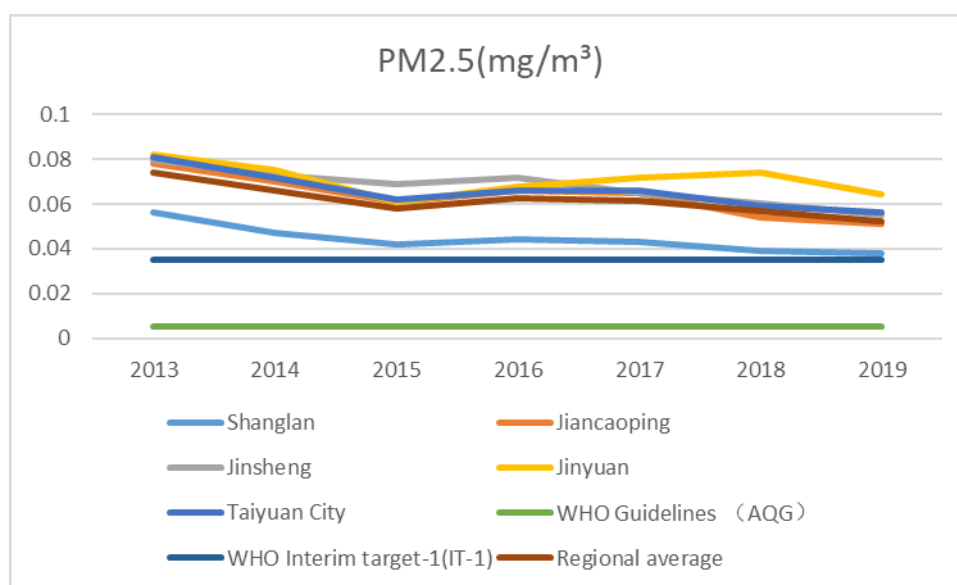


Fig. 65 Annual mean change curve of PM2.5 in Xishan area

Source: Author's own work

SO₂: The annual average concentration of SO₂ in Xishan area of Taiyuan showed a downward trend from 2006 to 2019. The annual average values of Shanglan, Jiancaoping, Jinsheng and Jinyuan monitoring points in Xishan area of Taiyuan in 2006 were 0.058, 0.062, 0.073 and 0.051 mg / m³ respectively; The monitoring annual average values in 2019 are 0.015, 0.02, 0.021 and 0.023 mg / m³ respectively. Compared with 2006, the monitored values in 2019 decreased by 0.043, 0.042, 0.052 and 0.028 mg / m³ respectively (Fig. 66, Fig. 67).

In 2006, the SO₂ concentration monitoring values of Shanglan and Jinyuan were lower than the index requirements of the annual average concentration of SO₂ in the national class II environmental functional area (0.06), and the annual average concentration of SO₂ in Jiancaoping and Jinsheng were higher than the national class II environmental functional area (0.06), which were 3.3% and 21.7% respectively. The monitoring values of Shanglan, Jiancaoping, Jinsheng and Jinyuan were 45%, 55%, 83% and 28% higher than the WHO standard (0.04).

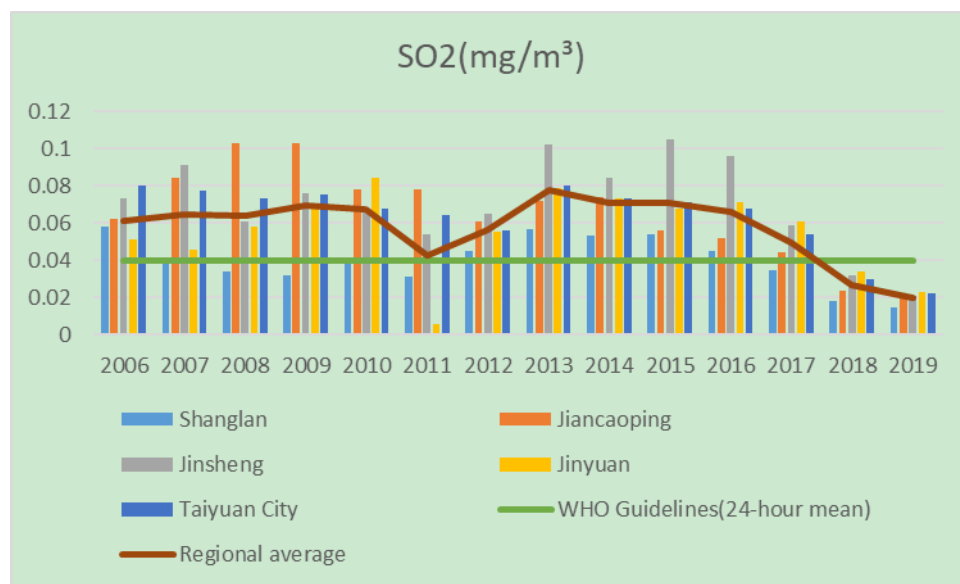
In 2019, the SO₂ concentration monitoring values of Shanglan, Jiancaoping, Jinsheng and Jinyuan are lower than the index requirements of the annual average SO₂ concentration (0.06) in the national class II environmental functional area; Among them, Shanglan and Jianlawn meet the index requirements of annual average SO₂ concentration (0.02) in national class I environmental functional areas. They are reached the index requirements of WHO standard (0.04) in the same year (Table 26).

The SO₂ monitoring values of main monitoring points in Xishan area generally show a downward trend.

Table 26 Annual average of SO₂ (mg/m³) in Xishan area from 2006 to 2019

Year	Shanglan	Jiancaoping	Jinsheng	Jinyuan
2006	0.058	0.062	0.073	0.051
2007	0.038	0.084	0.091	0.046
2008	0.034	0.103	0.061	0.058
2009	0.032	0.103	0.076	0.068
2010	0.04	0.078	0.067	0.084
2011	0.031	0.078	0.054	0.006
2012	0.045	0.061	0.065	0.055
2013	0.057	0.072	0.102	0.079
2014	0.053	0.074	0.084	0.073
2015	0.054	0.056	0.105	0.068
2016	0.045	0.052	0.096	0.071
2017	0.035	0.044	0.059	0.061
2018	0.018	0.024	0.032	0.034
2019	0.015	0.02	0.021	0.023

Source: Author's own work

**Fig. 66 Histogram of annual mean change of SO₂ in Xishan area**

Source: Author's own work

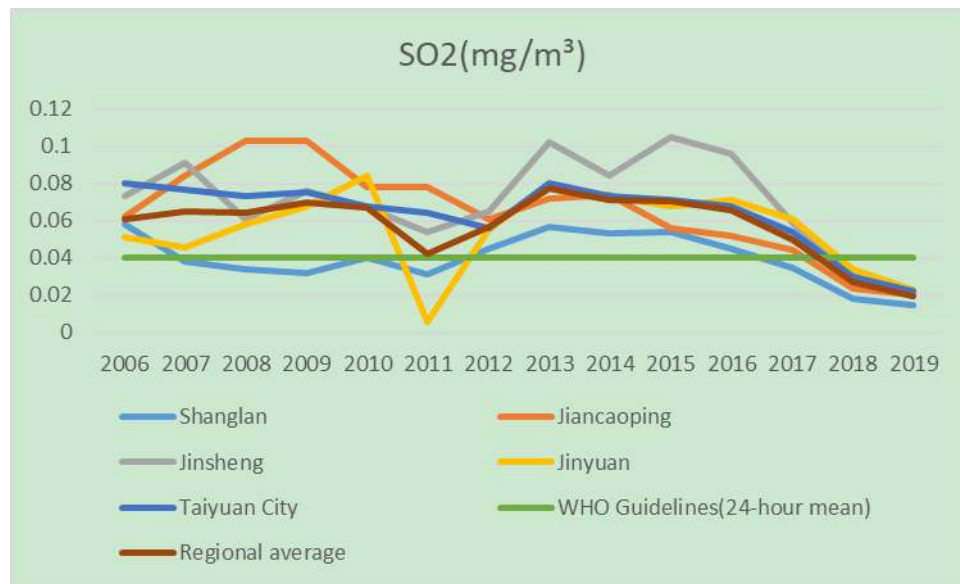


Fig. 67 Annual mean change curve of SO2 in Xishan area

Source: Author's own work

95th percentile value of CO (mg/m³) : The 95% annual average concentration of CO in Xishan area of Taiyuan from 2013 to 2019 shows a downward trend. Among them, the average values of Shanglan, Jiancaoping, Jinsheng and Jinyuan monitoring points in Xishan of Taiyuan in 2019 are 1.3, 1.8, 2 and 2 mg/m³ respectively. Compared with 2013, it decreased by 2.3, 1.5, 1.2 and 2, respectively (Fig. 68, Fig. 69) (Table 27).

Table 27 The annual average of 95th percentile value of CO (mg/m³) in Xishan area from 2013 to 2019

Year	Shanglan	Jiancaoping	Jinsheng	Jinyuan
2013	3.6	3.3	3.2	4
2014	3	3.4	3.2	2.7
2015	2.7	3.7	3.1	3.7
2016	2.1	2.8	3.4	3.5
2017	2	2.4	2.8	3
2018	1.6	1.6	2	2.2
2019	1.3	1.8	2	2

Source: Author's own work

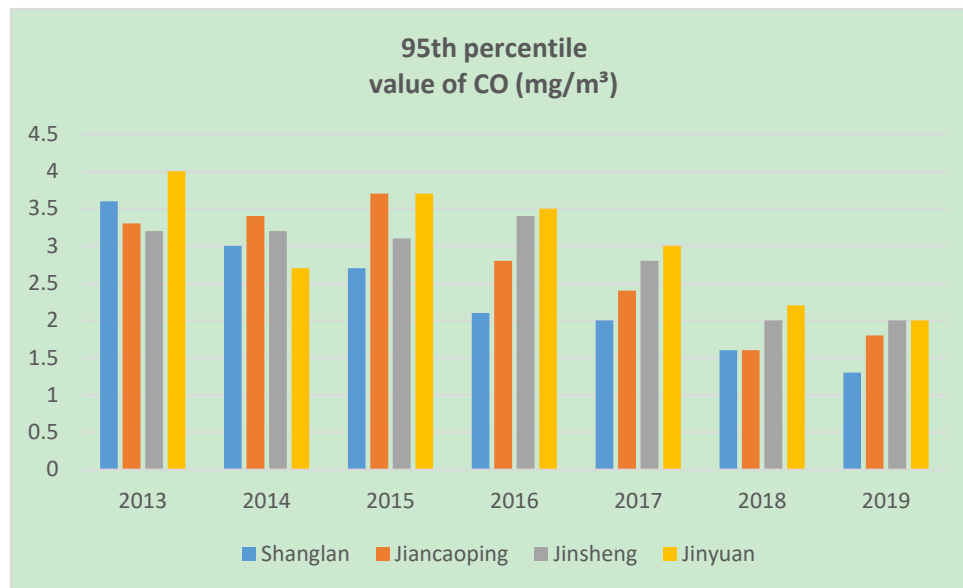


Fig. 68 Histogram of annual mean change of 95th percentile value of CO (mg/m³) in Xishan area

Source: Author's own work

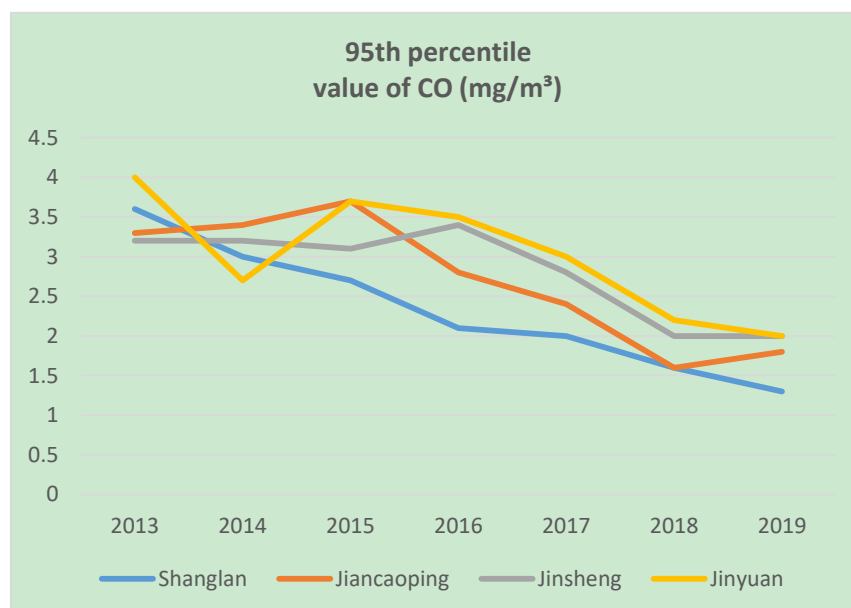


Fig. 69 Curve of annual mean change of 95th percentile value of CO (mg/m³) in Xishan area

Source: Author's own work

Sulphation Rate (mgSO₃/100cm² Alkali.Day): the annual average concentration of sulphation rate in Xishan area of Taiyuan from 2006 to 2019 showed a downward trend. Among them, the annual average values of Shanglan, Jiancaoping, Jinsheng and Jinyuan monitoring points in Xishan of Taiyuan in 2019 were 0.42, 0.53, 0.62 and 0.45 mgSO₃/100cm² Alkali.Day, respectively. Compared with 2006, it

decreased by 0.61, 1.83, 1.29 and 0.77 respectively. The monitoring values of sulphation rate of four monitoring points in 2019 are higher than the national recommended standard value (0.25). Among them, Shanglan, Jiancaoping, Jinsheng and Jinyuan were 68.0%, 112.0%, 148.0% and 80.0% higher than the national recommended values (0.25 mgSO₃/100cm² Alkali.Day) respectively (Fig. 70, Fig. 71) (Table 28).

Table 28 Sulphation Rate (mgSO₃/100cm² Alkali.Day) in Xishan area from 2006 to 2019

Year	Shanglan	Jiancaoping	Jinsheng	Jinyuan
2006	1.03	2.36	1.91	1.22
2007	1.47	2.32	2.54	2.06
2008	1.05	2.6	2.16	1.36
2009	1.04	1.67	1.91	1.35
2010	1.09	1.72	1.83	1.49
2011	1.07	2.06	2.17	1.32
2012	0.83	1.64	1.58	1.1
2013	1	1.58	1.66	1.16
2014	0.99	1.63	1.7	1.17
2015	0.95	1.21	1.57	0.88
2016	0.95	1.46	1.36	1.23
2017	0.47	0.71	0.93	0.55
2018	0.48	0.64	0.53	0.39
2019	0.42	0.53	0.62	0.45

Source: Author's own work

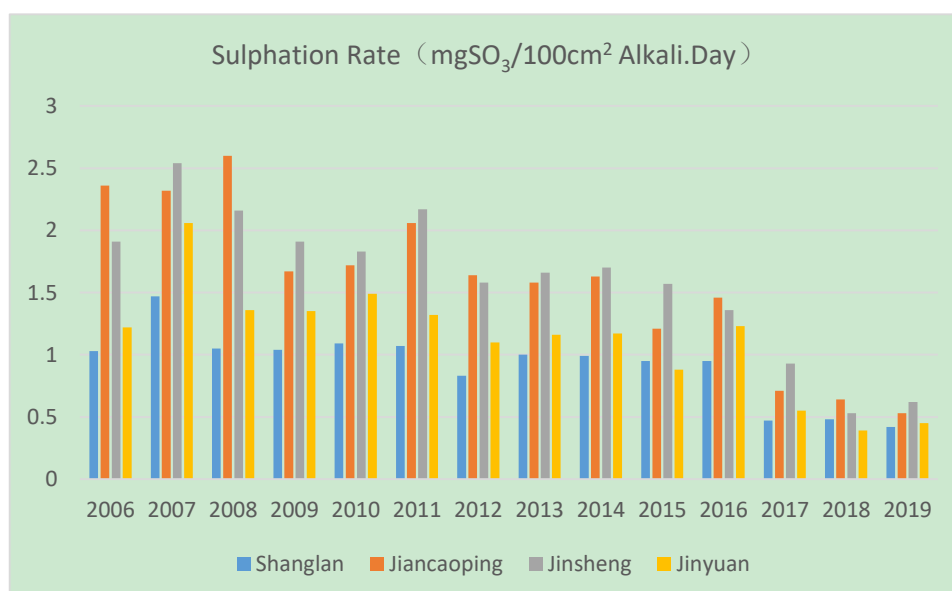


Fig. 70 Histogram of annual mean change of Sulphation Rate (mgSO₃/100cm² Alkali.Day) in Xishan area

Source: Author's own work

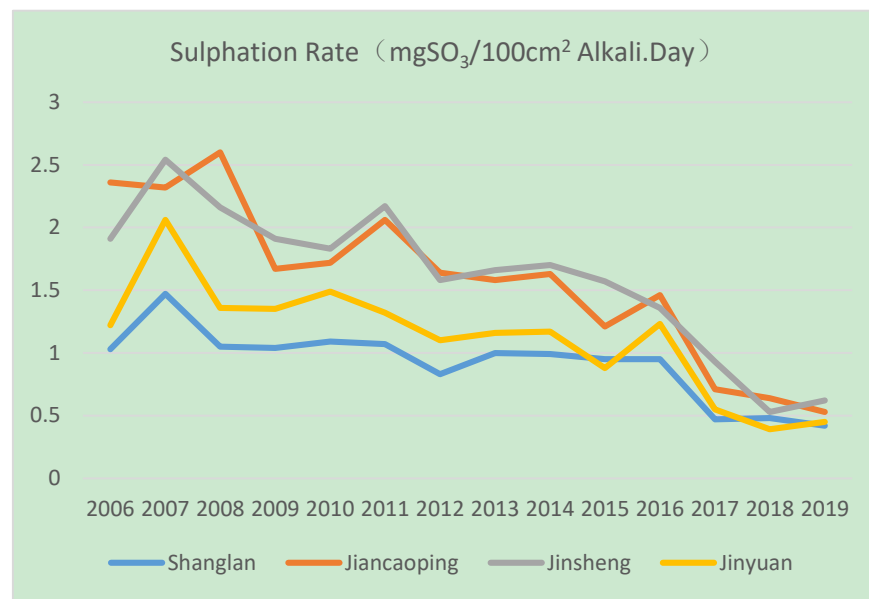


Fig. 71 Curve of annual mean change of Sulphation Rate (mgSO₃/100cm² Alkali.Day) in Xishan area

Source: Author's own work

Dust fall: the average annual dust fall concentration in Xishan area of Taiyuan from 2006 to 2017 showed a downward trend. Among them, the annual average values of Shanglan, Jiancaoping, Jinsheng and Jinyuan monitoring points in Xishan of Taiyuan in 2017 were 9.1, 18.2, 17.4 and 12.3 T / km². Month, respectively. Compared with 2006, it decreased by 4.8, 0.3, 12.8 and 3.2 respectively. The annual average value of dust fall in the four monitoring points is lower than the national recommended standard value (20.3 T / km². Month) (Fig. 72, Fig. 73) (Table 29).

Table 29 Dust fall (t/km².Month) in Xishan area from 2006 to 2017

Year	Shanglan	Jiancaoping	Jinsheng	Jinyuan
2006	13.9	18.5	30.2	15.5
2007	10.5	15.3	27.9	14.2
2008	10	16.5	27.8	12.2
2009	10.7	15.1	20.1	13.3
2010	13.2	20.9	29.8	16.1
2011	12.8	20.3	24.9	13.1
2012	10.2	23.5	21.4	12.2
2013	10.7	22.3	27.2	14.6
2014	9.9	27.2	24.7	12.5
2015	8.7	14.8	16.6	10.4
2016	11	25.1	23.3	13.8
2017	9.1	18.2	17.4	12.3

Source: Author's own work

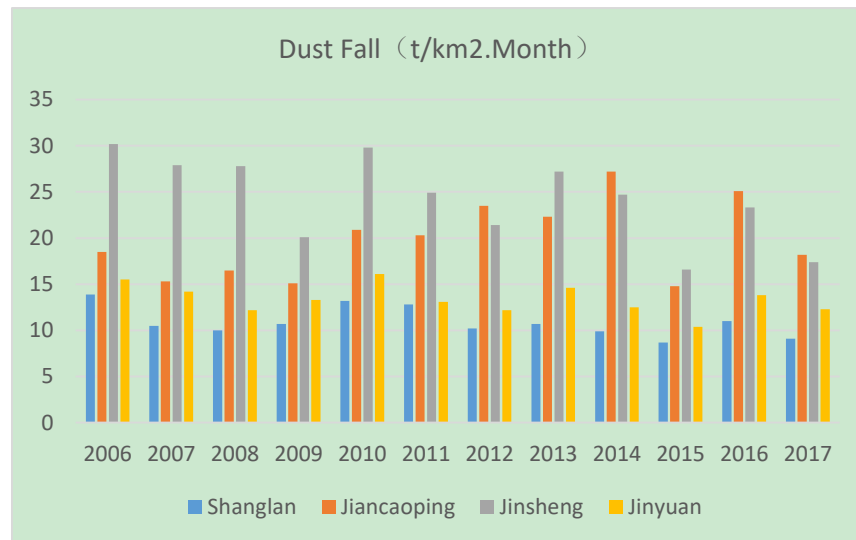


Fig. 72 Histogram of annual mean change of Dust fall (t/km².Month) in Xishan area

Source: Author's own work

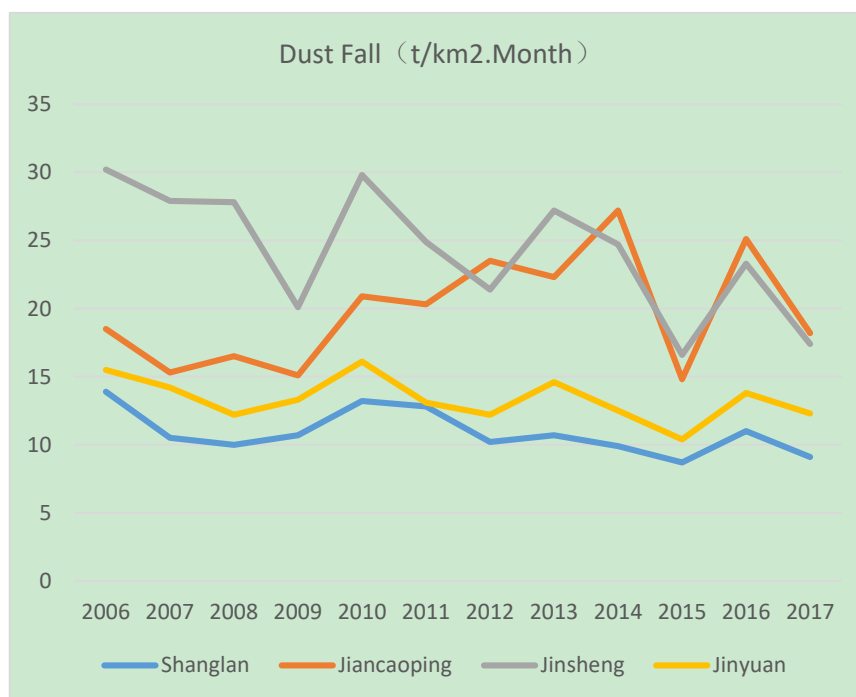


Fig. 73 Curve of annual mean change of Dust fall (t/km².Month) in Xishan area

Source: Author's own work

■ Analysis of regional air pollution change and control effect before and after ecological control

Before ecological management began in 2006, the overall air quality in the Xishan area was poor mainly because many industrial and mining enterprises

produced polluting emissions, centralized heating was not universal in homes, small boilers were common, and coal was commonly burned for heating in winter. In addition, Xishan is the main distribution center for coal and coke products in the neighboring cities and towns of Gujiao, Louxiao and Qingxu counties (cities); most of the coal and coke products are transported by automobiles; thus, dust pollution was very prominent. In 2006, the values of the monitoring data for SO₂, PM₁₀, PM_{2.5}, Dust Fall and Sulphation Rate from the monitoring points of Shanglan, Jianqaoping, Jinsheng, and Jinyuan were far greater than the respective targets of Class II type of environmental functional zone specified by China's indicator requirements. From 2006 to 2019, measures related to the management of the atmospheric environment in Xishan included shutting down and relocating industries, upgrading and transforming polluting industrial and mining enterprises (mostly completed in 2016), comprehensively closing down many types of polluting mining sites, implementing urban and rural clean energy renovation projects, and encouraging the development of new energy industries such as solar energy. Additional measures included repairing and managing the destructive surface of open-pit mining mountains in mining areas, greening and reclaiming land, and constructing suburban forest parks. And the atmospheric pollutants of monitoring sites (Shanglan, Jiancaoping, Jinsheng and Jinyuan) in Xishan area during 2006-2019 decreased as follows (Table 30):

Table 30 2006-2019 Atmospheric Pollutants of Monitoring Sites in Xishan Area

Pollutant	Year	Shang lan	Jiancaop ing	Jin sheng	Jin yuan	Regional average	Taiyuan City
SO₂(mg/m³)	2006	0.058	0.062	0.073	0.051	0.061	0.08
	2019	0.015	0.02	0.021	0.023	0.020	0.022
	Decrease Value	0.043	0.042	0.052	0.028	0.041	0.058
PM₁₀(mg/m³)	2006	0.121	0.136	0.136	0.111	0.126	0.142
	2019	0.068	0.107	0.11	0.109	0.099	0.107
	Decrease Value	0.053	0.029	0.026	0.002	0.028	0.035
PM_{2.5}(mg/m³)	2013	0.056	0.078	0.08	0.082	0.074	0.081
	2019	0.038	0.051	0.055	0.064	0.052	0.056
	Decrease Value	0.018	0.027	0.025	0.018	0.022	0.025
Dust Fall (t/km².month)	2006	13.9	18.5	30.2	15.5	19.525	27.7
	2017	9.1	18.2	17.4	12.3	14.250	16.9
	Decrease Value	4.8	0.3	12.8	3.2	5.275	10.8
Sulphation Rate (mg SO₃/100 cm² alkali.day)	2006	1.03	2.36	1.91	1.22	1.630	1.74
	2019	0.42	0.53	0.62	0.45	0.505	0.52
	Decrease Value	0.61	1.83	1.29	0.77	1.125	1.22

Source: Author's own work

Comparing the atmospheric pollutant data of the monitoring sites (Shanglan, Jiancaoping, Jinsheng and Jinyuan) in Xishan area from 2006 to 2019 reveals that due to the strong mobility of pollutants in the atmosphere, the quality of the regional atmospheric environment is affected by the overall atmospheric environment of Taiyuan city and even North China and by regional climate change. However, in the monitoring data at these four points, the SO₂, PM₁₀, PM_{2.5}, Dust Fall and Sulphation Rate values all show overall decreasing trends. The decreasing trend of the average value of the monitoring data of the four points in Xishan area is close to the decreasing trend of the citywide value of Taiyuan (Table 31).

Table 31 Analysis of the correlation between the atmospheric environment of Xishan area and Taiyuan city (Pearson)

Pollutant	Categories	Shanglan	Jiancaopin g	Jinshen g	Jinyuan	Regional average
SO₂(mg/m³)	Correlation coefficient	0.782**	0.796**	0.835**	0.549*	0.918**
	p	0.001	0.001	0	0.042	0.000
	Sample size	14	14	14	14	14.000
PM₁₀(mg/m³)	Correlation coefficient	0.823**	0.978**	0.773**	0.897**	0.984**
	p	0	0	0.001	0	0.000
	Sample size	14	14	14	14	14.000
PM_{2.5}(mg/m³)	Correlation coefficient	0.986**	0.979**	0.919**	0.771*	0.990**
	p	0	0	0.003	0.042	0.000
	Sample size	7	7	7	7	7.000
Dust Fall (t/km².month)	Correlation coefficient	0.642*	0.34	0.942**	0.736**	0.891**
	p	0.024	0.28	0	0.006	0.000
	Sample size	12	12	12	12	12.000
Sulphation Rate (mg SO₃/100 cm² alkali.day)	Correlation coefficient	0.964**	0.920**	0.971**	0.973**	0.987**
	p	0	0	0	0	0.000
	Sample size	14	14	14	14	14.000

Notes: * p<0.05 ; ** p<0.01

Source: Author's own work

Studies have shown that the ecological restoration and management of the Xishan area have produced obvious effects on the improvement of the regional atmospheric environment and that the atmospheric management of mining areas has been beneficial for enhancing the urban atmospheric environment. However, due to the strong mobility of pollutants in the atmosphere, the atmospheric environment of mining areas is strongly correlated with that of the city in which they are located, so the fundamental improvement in the atmospheric environment in mining areas also relies on the overall enhancement of the urban atmospheric environment. Among the various environmental management measures, controlling and reducing regional air

pollution emissions, which can significantly reduce air pollutants, is the most effective way to manage air pollution in mining areas. The construction of GI, which can reduce surface dust and particulate matter pollution and reduce the regional heat island effect, can alleviate air pollution to a certain extent.

■ Health impact assessment

Before the ecological management, the air quality in Xishan area was poor as a whole, and most of the monitoring values of the main monitoring points greatly exceeded the relevant index requirements of class II environmental function area stipulated by the state. A large number of pollutants in the atmosphere will have many adverse effects on human health. Among them, PM₁₀ can be directly inhaled into the respiratory tract, leading to respiratory diseases; The influence of PM₁₀ on visibility and temperature is very obvious. PM_{2.5} can enter the alveoli through the respiratory tract, which is easy to accumulate toxic metal elements, leading to respiratory diseases and pulmonary heart disease, especially for children and the elderly. Dustfall will cause respiratory diseases, irritative symptoms and allergic reactions to skin, eyes, nose and throat, and affect the normal growth and development of animals and plants. SO₂ is easy to cause respiratory diseases and aggravate the symptoms of patients with respiratory diseases; Industrial smog and acid rain are formed.

After more than ten years of ecological management, the quality of atmospheric environment in Xishan area has been greatly improved. From 2006 to 2019, the concentrations of SO₂, PM₁₀ and PM_{2.5} (2013-2019) in Shanglan, Jiancaoping, Jinsheng and Jinyuan were decreased as follows (Table 32):

Table 32 The decrease of air pollution concentration in Xishan area of Taiyuan

Name of pollutant	Shanglan	Jiancaoping	Jinsheng	Jinyuan
SO ₂ (mg/m ³)	0.043	0.042	0.052	0.028
PM ₁₀ (mg/m ³)	0.053	0.029	0.026	0.002
PM _{2.5} (mg/m ³)	0.018	0.027	0.025	0.018

Source: Author's own work

According to the study on the air pollution to human health in Taiyuan, the results show that the concentration of SO₂, PM₁₀ and PM_{2.5} increases by 10 μ. The non-accident mortality rate increased by 1.00%, 0.64% and 0.66% respectively; The mortality of cardiovascular diseases increased by 1.03%, 0.99% and 0.75% respectively; The mortality rate of respiratory diseases increased by 1.01%, 1.13% and 0.81% respectively.

Ecological management can greatly improve the air environment health level in Xishan area. It has a positive health impact on local residents and people who are active in Xishan. Because Xishan area is still in the middle of ecological governance, there are still many atmospheric indicators that have not met the requirements of the second-class environmental functional zone stipulated by the state. In the follow-up construction of the region, the environmental control and governance should be

further strengthened (Table 33).

Table 33 Air pollutants, sources and health effects in Xishan of Taiyuan

Main air pollutants	Composition of pollution sources in Taiyuan City	Pollution sources in Xishan area	Impact on health	Ecological environment control measures	Effect of ecological management
PM ₁₀	Coal burning (21.95%), automobile exhaust (18.46%), dust (17.4%), construction site dust (10.7%), sulfate (11.2%), nitrate (4.01%), soil dust (15.59%), steel production (6.77%)	Particulate matter emission waste gas emission from industrial zone and thermal power plant; Dust: mining operations (e.g., blasting), transportation (e.g., loading equipment, transport vehicles, conveyor belts),	Can be directly inhaled into the respiratory tract, leading to respiratory diseases, etc.; The influence of PM ₁₀ on visibility and temperature is very obvious.	Serious polluting enterprises have been shut down, relocated and eliminated successively. The coal to gas project has been implemented in winter. The large chemical enterprises of Taihua Group and Taiyuan No.1 power plant around Xishan have been relocated. The private mining small coal kiln has been closed down. The mining mountain damage surface has been controlled, and afforestation has been implemented. Investment and construction of 16 suburban	Levels vary by year, which indicates that we still need to strengthen the utilization and transformation of coal resources.
PM _{2.5}	Coal burning (34.1%), automobile exhaust (28.8%), industrial pollution (21.19%), construction site dust (9%), biomass combustion (6.91%)	Crushing, waste dumping, etc.; Automobile exhaust, etc.	Can enter the alveoli through the respiratory tract, which can easily accumulate toxic metal elements, leading to respiratory diseases, pulmonary heart disease, etc., especially for children and elderly individuals.	plant around Xishan have been relocated. The private mining small coal kiln has been closed down. The mining mountain damage surface has been controlled, and afforestation has been implemented. Investment and construction of 16 suburban	Levels show that the reduction in industrial pollution emissions and coal combustion has a significant impact on the region
Dust Fall	Cement dust, coal powder, lime powder, most metal	Cement dust, pulverized coal, lime powder, fly ash, etc.	It causes respiratory diseases, and produces	implemented. Investment and construction of 16 suburban	Levels vary by year, which indicates that we still need to

	dust and fly ash, etc.		irritation symptoms and allergic reactions to skin, eyes, nose, throat, etc., affecting the normal growth and development of animals and plants.	forest parks has been undertaken.	strengthen the utilization and transformation of coal resources
SO ₂ Sulfation Rate	Coal and oil fired power plants, industrial boilers, domestic heating, diesel engines, metal smelters, etc.	Emissions from coal and oil-fired power plants, industrial boilers, domestic heating, diesel engines, metal smelters and Taiyuan coal preparation plants;	Causes the respiratory system disease, aggravates the respiratory system disease patient's symptom; Causes the formation of industrial smog and acid rain are formed.	Serious polluting enterprises have been shut down, relocated and eliminated successively. Coal to gas project has been implemented in winter.	In recent years, the decreasing trend is significant, which indicates that the reduction in industrial pollution emissions has a significant impact on the region
95th percentile value of CO (mg/m ³)	Motor vehicles, fuel burning, etc.	Motor vehicles, fuel burning, etc.	Vomiting, unconsciousness, brain damage, dyspnea, etc.	Serious polluting enterprises have been shut down, relocated and eliminated. The coal to gas project has been implemented in winter.	In recent years, the decline trend is significant, which shows that the reduction in coal fuel has a significant impact on the region

Source: Author's own work

8.1.2 Hydrological System

(1) Analysis on variation trend of surface water environmental quality

The surface water in the area mainly includes Fenhe River and its tributaries and six sewage channels. In order to explain the change trend of surface water environmental quality in Xishan area of Taiyuan City, the monitoring data of 2010-

2019 from four routine monitoring sections of Taiyuan Ecological Environment Bureau, namely, shuoshiqiao, Shanglan, yingzeqiao and xiaodianqiao, near Xishan in Taiyuan Section of Fenhe River, were compared and analyzed. And check with the water body function of Taiyuan surface water and the water quality requirements of the executive standard (Taiyuan Environmental Monitoring Center, 2006-2022) (Fig. 74) (Table 34).

Table 34 Surface water monitoring point setting

Serial number	Name of water body	Name of measuring point	longitude	latitude	Control level
1	Taiyuan	Shaoshi Bridge	112°15'12"	37°55'40"	City control
2	Section of Fenhe River	Shanglan	112°26'08"	38°00'13"	National and Province control
3		Yingze Bridge	112°31'48"	37°51'26"	City control
4		Xiaodian Bridge	112°32'32"	37°44'08"	Province control

Source: Author’s own work (Taiyuan Environmental Monitoring Center, 2006-2022)



Fig. 74 Surface water monitoring point setting

Source: Author’s own work

According to the division of water body function and relevant provisions of provinces and cities in "environmental function zoning of surface water in Shanxi Province" (db14 / 67-2019), the water body functions and executive standards of surface water in Taiyuan city involved in the planning area are shown as below (Table 35).

Table 35 The function and implementation standard of surface water in Taiyuan

River	Range	Water quality requirements
Taiyuan Section of Fenhe River	Fenhe Reservoir outlet to Fenhe Second Reservoir Dam	III
	Fenhe Second Reservoir Dam to Shanglan	II
	Shanglan to Iron Bridge	III
	Iron Bridge to Xiangyun Bridge	IV
	Xiangyun Bridge to Xiaodian Bridge	V
	Source to Xiaoximing	III
Yumen River	Xiaoximing to Fenhe	IV
	Source to Yayadi village	III
Huyu River	Yayadi village to Fenhe	IV
	Source to Fenhe	IV
Yeyu River	Source to Fenhe	IV
Jiuyansha River	Source to Fenhe	IV
Jinyang Lake	Lake head to Lake tail	IV
Fengyu River	Source to Diantou	III
	Diantou to Fenhe	IV

Source: Author's own work

The water quality monitoring data of the four sections including Saoshi Bridge, Shanglan, Yingze Bridge, and Xiaodian Bridge from 2010 to 2019 are as follows (Fig. 75) (Table 36).

Table 36 List of water quality changes in Xishan area from 2010 to 2019

Year	Shaoshi Bridge	Shanglan	Yingze Bridge	Xiaodian Bridge
2010		III	Inferior V	Inferior V
2011		IV	V	Inferior V
2012		IV	IV	Inferior V
2013		III	IV	Inferior V
2014		III	IV	Inferior V
2015		III	IV	Inferior V
2016	IV	II	IV	Inferior V
2017	IV	II	IV	Inferior V
2018	II	II	III	Inferior V
2019	II	II	III	IV

Source: Author's own work

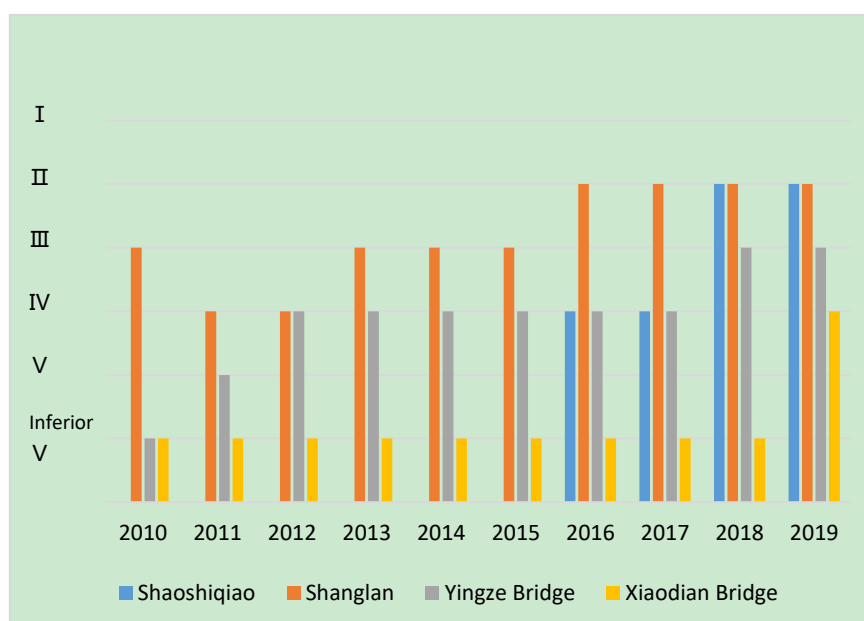


Fig. 75 Histogram of annual mean change of water quality monitoring in Xishan area

Source: Author's own work

In 2019, the water quality of Soshi Bridge and Shanglan were Class II water quality, and the water quality of Yingze Bridge was Class III water quality; Xiaodian Bridge was Class IV water quality, and the water quality was significantly improved. It has been withdrawn from sections with inferior Grade V water quality, and the water quality of each section All meet the functional requirements of the corresponding water environment. The water quality monitoring values of Shanglan Section from 2016 to 2019 all reached the Class II standard of "Surface Water Environmental Quality Standard" (GB3838-2002), and met the corresponding water environment functional requirements. The water quality monitoring values of Yingze Bridge from 2012 to 2017 all stably reached the "Surface Water Environmental Quality Standard" (GB3838-2002) Class IV standard, and in 2018-2019 it reached Class III standard, and met the corresponding water environment functional requirements. The water quality monitoring values of Xiaodian Bridge from 2010 to 2018 are all inferior to Class V. The main excess factors of Xiaodian Bridge section include: COD, BOD₅, ammonia nitrogen, total phosphorus and LAS. The maximum water quality index is 1.74, 3.15, 10.33, 3.45 and 1.81. The analysis is due to the direct discharge of domestic sewage from villages along the river into the Fen River. In 2019, the water quality of Xiaodian Bridge reached Class IV, meeting the corresponding water environment functional requirements.

The six sewage drainage canals in Xishan area (Beijian River, Yumengou, Nansha River, Chengnan Retreat Canal, Yeyugou, Fengyugou) in 2010-2018 are all inferior V, with five-day biochemical oxygen demand and heavy metals The annual average concentration values of lead and arsenic showed fluctuations, and the annual average concentration values of volatile phenol, petroleum, chemical oxygen demand,

permanganate index, cyanide, ammonia nitrogen and mercury, hexavalent chromium, and cadmium decreased respectively. In the year 2018, Taiyuan City carried out the sewage canal treatment project. By the end of 2020, the sewage canal is mainly cleaned and renovated by intercepting sewage pipes, biological treatment, engineering remediation, and reclaimed water supply. The project is being implemented and in progress.

■ **Analysis of surface water quality changes before and after ecological treatment and treatment effect**

Before the ecological treatment in Xishan area, the surface water quality was poor. The main reasons are: some enterprises in the upper reaches of the Fenhe River have relatively fast production and construction speed, but the construction of sewage treatment facilities is relatively lagging, and the waste water is directly discharged into the Fenhe River without treatment, which seriously affects the water quality of the Fenhe River; The sewage treatment of enterprises in Xishan area including metallurgy, coal and coke, electric power, machinery, and chemical industry did not meet the standards, which seriously affected the surface water quality of the area after discharge; urban and rural domestic sewage discharge, domestic garbage dumping, etc. The regional sewage canal is a seasonal flood drainage canal. There is no source of clean water in the upstream, and there is basically no dilution capacity. In addition, industrial wastewater and domestic sewage enter the sewage canal, which increases the pollution load. Therefore, the water pollution of the sewage canal is very serious.

After the ecological treatment of Xishan area, the surface water quality has been significantly improved. Because of the limited water quality data collected in this study, the water quality data of Xishan area in 2010 can be regarded as the water quality data of the rivers entering the Fen River in the initial period of ecological management. The water quality in the area has been significantly improved. Among them, the three monitoring points in the area, Shanglan, Yingze Bridge and Xiaodian Bridge, have been upgraded from Category III, Category V, and Category V in 2010 to Category II and Category III in 2019. The water quality of the four monitoring points meets the indicator requirements of the environmental function zone in the corresponding area. It shows that the closure of small private coal mines in the Xishan area, the relocation and closure of polluting industrial enterprises, and the strengthening of the recovery and recycling of water used in the area for domestic and production have had a significant effect on improving the quality of surface water in the region. However, there are still problems such as disorderly discharge of domestic sewage in villages (some of which are villages in cities) in the Xishan area, which needs to be further improved and improved. The implementation effect of the ongoing flood drainage canal ecological management project has yet to be tested.

(2) Analysis on the Change Trend of Groundwater Environmental Quality

■ **Underground drinking water source**

The main sources of underground drinking water in Xishan area include Lancun, Horticulture, etc. This study collected the results of routine water quality inspections at the two water sources from 2006 to 2019. According to the "Taiyuan City Environmental Quality Report", the evaluation standard of water quality monitoring results implements the Class III standard in the "Groundwater Quality Standard" (GB/T14848-1993) or the "Groundwater Quality Standard" (GB/T14848-2017). From 2006 to 2019, the water quality of the underground drinking water sources (lancun, horst) in Taiyuan City was basically stable, and the testing indicators could reach the national Class III standard.

■ Groundwater environment in Xishan coal mining area

The long-term coal mining and industrial production in Xishan area have major adverse effects on the groundwater environment, including: changing the groundwater flow field, changing the relationship between groundwater and surface water, the impact on shallow and middle pore water, and the impact on deep karst water and large karst springs. Form acid mine water, produce waste polluted groundwater, produce old kiln water, etc.(Li Guomin Qiao Xiaojuan, Zhou Jinlong, Du Jie, Du Chengyuan, sun Zhonghui, Wu runjian, 2010).

● Treatment and utilization of mine water

• Non-acidic mine water

The main pollution of non-acidic mine water in Xishan area of Taiyuan is suspended solids. Mine water containing suspended solids is mostly grayish black. After being discharged into the water body, the appearance of the water body will deteriorate, the turbidity will increase, and the color of the water will be changed. Non-acidic mine water pollutants limit indicators are: pH, suspended solids, CODCr, petroleum (Xi Xiaofang Bi Chongyu, Li Guojun, 2008).

The more mature treatment process includes: coagulation sedimentation, filtration and sterilization, etc. The process flow is mainly to pump the mine water from the underground lifting pump to the pre-sedimentation adjustment tank, so that the mine water can be stored and homogenized. After the water quality and water volume are adjusted, the mine water is added with a coagulant before the pump and a flocculant after the pump. Then enter the hydraulic circulation clarification tank, after mixing, flocculation reaction, and precipitation, the effluent flows into the gravity valveless filter tank by itself, and the filtered effluent is kept below 3 degrees of turbidity (no more than 5 degrees in special circumstances); the effluent enters the clear water The pool is sterilized and then sent to the ground for production water through a water supply pump. The sludge in the mine water pre-sedimentation tank and hydraulic clarification tank is regularly discharged to the slime tank, and after thickening, the slime is pumped to the mineral pressure filter system for treatment. This process can effectively remove suspended solids and colloids in mine water, and can effectively remove oily substances in mine water.

- **Acid mine water**

The iron-containing acid mine water in Xishan area of Taiyuan mainly includes: Duerping Mine (PH 3.9-8.6, SS66.6mg/L, COD 28.9mg/L); Ximing Coal Mine (PH 5.35, SS263.93mg) /L, COD29.28mg/L) and so on.

The formation of acidic mine water is mainly due to the coal seam containing pyrite, which is a relatively stable mineral. Due to coal mining activities, the original reducing environment is turned into an oxidizing environment, and the pyrite associated with coal is oxidized and forms Sulfuric acid, the pH value drops (<6), and the water is acidic. In addition, it is also closely related to the amount of water inflow, airtightness, air circulation, and the type and quantity of microorganisms in the mine. After coal mining, the dissolved oxygen in the water reacts with pyrite to form easily soluble ferrous sulfate. Under reducing conditions, ferrous sulfate can be further oxidized to sulfate ($\text{Fe}_2(\text{SO}_4)_3$), which can only be dissolved in a strong acid solution. Otherwise it will be hydrolyzed to form hydroxide precipitation. If the oxygen content in the coal water is not large, the oxidation will generally not proceed after the formation of FeSO_4 , the free sulfuric acid obtained from the reaction will react with calcium sulfate and magnesium, and finally form SO_4^{2-} , HCO_3^- — Ca^{2+} , Mg^{2+} type water; If the pH value is less than 7, the water contains residual ferrous ions.

For acidic mine water, processes such as alkaline substance neutralization precipitation and coagulation precipitation are mainly used for treatment. The process is divided into two levels of processing. In the primary treatment, the iron-containing acid mine water is transported from the underground sump to the adjustment tank. Before being lifted into the neutralization reaction sedimentation tank, the lime milk is dynamically added through the pH value monitoring and automatic control system, and it is completed in the neutralization reaction sedimentation tank. Neutralization, flocculation, reaction, precipitation and other processes. The effluent after the primary treatment is aerated and oxidized to convert all the remaining ferrous ions into ferric ions. Under alkaline conditions, $\text{Fe}(\text{OH})_3$ can be used as a flocculant, and then an appropriate amount of coagulant and coagulant are added. After mixing, flocculation, and reaction, a large amount of alum is produced, which is discharged after being precipitated in an inclined pipe. Because the process adopts a secondary comprehensive treatment process, and makes full use of the common ion effect, co-precipitation, and flocculation precipitation to effectively remove heavy metal ions and increase the pH value of wastewater, it can achieve up-to-standard discharge and ensure that the effluent does not return to color. The removal rate of COD, Cr, SS and Fe concentration by this process is expected to reach 85%, 87% and 98% or more.

- **Abandoned mine groundwater**

The underground pollution sources of underground water pollution in abandoned mines mainly include: coal, rock, water and rock; man-made excrement and garbage left in abandoned roadways and working faces in underground mines; corrosion of abandoned wood and metal supports, residual oil and its degradation products. In

addition, after the closure of the coal mine, the hydrogeochemical conditions changed, from the original oxidation conditions to the reduction conditions, and the water-rock interaction conditions changed, which resulted in the transformation of mine water pollutants and possible pollution of groundwater (Li Ting, 2014). Water pollution from abandoned mines currently found in Xishan area of Taiyuan mainly includes water pollution from abandoned mines in Niujiakou. After the mine was closed, the original mined-out area was small, and the accumulated water filled the mining space and flowed out of the ground. Sampling and analysis on May 2, 2016, TDS = 4 475 mg / L, HB = 1 885 mg / L, SO₂₋₄ = 3 256 mg / L, pH = 4.522.

The main ecological treatment measures taken in the Xishan area for the pollution of abandoned mines include: strengthening the ecological restoration and treatment of abandoned mines, and according to different mine conditions, adopting methods such as reuse, plugging, and backfilling to carry out ecological restoration and treatment of abandoned mines. . Strengthen the management and supervision of the mining process, and the metal facilities and equipment used in the mining process shall be fully recovered with the mining and shall not be left underground. Increase the survey of the geological conditions of regional mines, prohibit mining in areas where coal mining seriously damages water resources, and prohibit the mining of high-sulfur coal. Increase the supervision of the treatment and utilization of abandoned mine water, strengthen research on groundwater purification technology, increase the treatment rate of available abandoned mine groundwater, and reduce treatment costs (Wang Jinwei Li Zhenshuan, 2019).

(3) Health impact evaluation

A comparison of the surface water monitoring data collected in this study from 2010 to 2019 shows that the surface water quality of the main rivers in the Xishan area significantly improved after ecological management and met the water quality requirements of the corresponding sections of the city. These findings indicate that the health risks caused by direct contact with the surface water environment decreased in the region and that the water resources that can be used for recreation, landscaping, and other healthy uses increased. The water quality of underground drinking water sources in the Xishan area has been stable and up to standard for many years, indicating that the quality of drinking water in the region is better controlled and that the health risks through urban and rural drinking water supplies are lower. After ecological management, the groundwater level in the Xishan area has risen, indicating that the amount of healthy water resources available to the area has increased. However, as ecological management projects in mining areas were not completed as of 2019, potential health risks to the water environment still existed as of then; thus, it is still important to strengthen the monitoring and upgrading of the water environment in the region (Table 37).

Table 37 Water pollutants and their health impacts

Major water pollutants	Main components of water pollution sources	Sources of water pollution in Xishan area	Health effects	Ecological environmental governance measures	Ecological governance achieved results
Inorganic pollutants	Heavy metals (lead, mercury, cadmium, chromium, arsenic, mercury, lead, manganese, etc.), cyanide, nitrate, chloride, etc.	Industrial (mining) wastewater, domestic wastewater, agricultural wastewater, etc.	Heavy metals can enter the human body through drinking water, edible agricultural products, and aquatic products, which can cause acute and chronic poisoning, induce cancer, and even cause malformations in offspring. After nitrite is absorbed, it can cause symptoms such as hypoxia and suffocation. Chemical pollution such as chloride can cause chemical poisoning and carcinogenesis.	Serious polluting enterprises have been shut down, relocated, and eliminated. The control and supervision of sewage discharge from existing industrial enterprises have been strengthened. Six sewage canal treatment projects have been undertaken in the Xishan area. Green mines have been built and mine drainage management and reuse has been strengthened. The treatment of urban and rural sewage discharge has been strengthened. Agricultural nonpoint source pollution has been controlled.	The quality of the main surface water in Xishan area has improved year by year, and in 2019, the water quality of all monitoring points reached the standard.
Organic Pollutants	Benzene, phenol, petroleum and their products, leading to eutrophication of water bodies, etc.	Domestic sewage, agricultural sewage (chemical fertilizers, etc.), garbage, etc.	Human contact with eutrophic water can easily cause eye and skin allergies. Drinking a small amount of water can cause gastroenteritis, and long-term drinking can cause symptoms of liver	Regional municipal infrastructure construction has been improved and regional urban and rural sewage discharge and solid waste recovery and cleaning has been strengthened. Regional agricultural	The quality of the main surface water in Xishan area has improved year by year, and in 2019, the

			cancer and neurotoxicity. Some organic pollutants can cause cancer. They can enter the human body through the food chain, causing poisoning to the human body and even deformity of the offspring.	nonpoint source pollution has been controlled.	water quality of all monitoring points reached the standard.
Biological pollution	Viruses, bacteria, parasites, etc.	Domestic sewage, agricultural sewage (chemical fertilizers, etc.), garbage, etc.	It spreads hepatitis virus, intestinal bacteria (such as coliforms, etc.), pathogenic bacteria (such as salmonella, tuberculosis, etc.), breed intestinal roundworms, whipworms and other parasites.	Regional municipal infrastructure construction has been improved, and regional urban and rural sewage discharge and solid waste recovery and cleaning has been strengthened. Regional agricultural nonpoint source pollution has been controlled.	The quality of the main surface water in Xishan area has improved year by year, and in 2019, the water quality of all monitoring points reached the standard.
Physical pollution	Suspended solids, soil, colored substances, water bodies above normal temperature, etc.	Soil erosion, open-pit mine, industrial cooling water, etc.	Suspended matter can be enriched in heavy metals and other toxic substances. An increase in water temperature will lead to enhanced microbial activity and enhanced toxicity of certain toxic substances.	Private mining small coal kilns have been shut down, damaged surfaces of mining mountains have been treated, and afforestation and greening have been carried out. Investments in the construction of 16 suburban forest parks have been made.	Regional water and soil governance has been continuously strengthened

Source: Author's own work

8.1.3 Soil and solid waste

(1) Health environmental quality assessment for the soil and solid waste environment

The soil pollution caused by production activities in the mining area mainly includes the contaminated soil caused by mining stripping soil, waste pit, tailings, coal gangue and ore washing wastewater sediment, as well as the dry and wet deposition of a large number of industrial and mining enterprises, air pollutants, sewage irrigation areas caused by various sewage discharge, etc. Heavy metal pollution from various pollution sources has a great impact on human body. The soil pollution caused by mining production in Xishan area is also the most prominent harm of heavy metals.

According to the comprehensive renovation plan of Taiyuan Xishan - research topic on ecological environment protection, restoration and renovation (prepared in 2009), the monitoring results of heavy metals in farmland in Xishan area of Taiyuan in 2005 are shown in Table 30.

According to Gao Peng et al., distribution characteristics and ecological risk assessment of heavy metals in soil around Taiyuan City [J], Journal of Agricultural Environmental Sciences, 2015, 34 (5): 866-873. In this document, the agricultural soil around Taiyuan in 2013 was sampled, and a total of 140 samples were collected.

According to Gao Peng, characteristics of soil pollution and health risk assessment in different functional areas of Taiyuan [D], Institute of Loess Plateau, Taiyuan, China, 2016. In the dissertation, 31 soil samples were collected from different functional areas of Taiyuan in 2013, including 8 involving Xishan area, which are areas where mining enterprises are concentrated, "respectively located in farmland and forest grassland around Ximing mine of Taiyuan Xishan Coal Power Co., Ltd. and Duerping mine of Shanxi Coking Coal Xishan Coal Power Group Company". This dissertation evaluates the possible health risks caused by soil pollution.

According to Hua xiaozan, et al., evaluation and spatial distribution characteristics of heavy metal pollution in farmland soil in Taiyuan [J], Journal of irrigation and drainage, 2021, 40 (3): 101-109. In this document, 214 farmland soil samples from July to October 2017 in Taiyuan were collected to determine the amount of Cr, Cd, Pb, Hg and As5 heavy metals in the soil, and the pollution of soil heavy metals was evaluated by single factor index method and Nemero comprehensive index method. The pH value range of farmland soil in Taiyuan is 7.5-8.5.

Refer to the standard values of Cr, Cd, As, Hg and Pb: 120, 0.40, 20, 0.35 and 50 mg / kg in China's environmental quality of green food producing areas (NY / T 391-2013). Refer to the standard values of Cr, Cd, As, Hg and Pb in China's standard for control of soil pollution risk of agricultural land (GB 15618-2018): 250, 0.6, 25, 3.4

and 170 mg / kg. Refer to the standard values of Cd, As, Hg and Pb in China's standard for control of soil pollution risk of construction land (GB 36600-2018): 20, 20, 8 and 400 mg / kg. The maximum values of the monitoring data of five kinds of heavy metals in the soil of Taiyuan and Xishan from 2005 to 2017 collected in this study are less than the soil quality requirements specified in the standard (Table 38).

Table 38 Monitoring data of soil heavy metal content in Xishan area (mg/kg)

Classification	Projects	Elements	Pb	Cd	As	Cr	Hg
Monitoring Data in Xishan area	2008, Soil in Sewage Irrigation Area (Xie Wenyan et al., 2011)	Data range	19.0-40.4	0.11-0.26	5.3-16.3	48.0-93.9	0.03-1.30
	2013, Soil in the mining area (Gao Peng, 2016)	Data range	17.61-120	0.071-0.642	5.81-19.12	49.73-73.22	0.045-0.427
	2017, Farmland soil (Hua xiao zan et al., 2021)	Data range	18.3-33.85	0.075-0.149	2.390-8.064	50.60-74.29	0.020-0.222
	2018, Various soils (Liu Hongbin & Su Shangjun, 2019)	Data range	19.730-30.704	0.193-0.396	9.496-12.099	51.480-105.451	0.143-0.279
Chinese National Standards	Green Food-Environmental quality for production area (NY/T 391-2021)	Indicator value	50	0.40	20	120	0.35
	Soil environmental quality	Indicator value					
	Risk control standard for soil contamination of agricultural land (GB 15618-2018)	Indicator value	170	0.6	25	250	3.4
	Soil environmental quality	Indicator value					
	Risk control standard for soil contamination of development land (GB36600 - 2018)	Indicator value	400	20	20	—	8

Source: Author's own work

(2) Analysis of regional soil pollution change and control effect

before and after ecological treatment

Regional soil and solid waste pollution before ecological restoration and treatment: the collected farmland soil environment data in Xishan region in 2005 meet the relevant index requirements of China on soil pollution risk control of agricultural land, but there is still the risk of accumulation of heavy metal pollution due to

pollution emission from mining production. In addition, due to years of mining and related industrial activities, the region has accumulated a large amount of solid waste. According to Taiyuan Xishan comprehensive renovation plan - research topic on ecological environment protection and Remediation (prepared in 2009), "industrial solid waste in Xishan area is mainly composed of coal gangue (35.9%), tailings (18.7%), smelting waste residue (9.2%), slag (3.8%), fly ash (14.3%), etc., mainly from Xishan Coal Power Group Co., Ltd. and Taiyuan Iron and steel (Group) Ltd., Taiyuan No. 1 thermal power plant, Taiyuan No. 2 thermal power plant, etc. In addition, the occupation of municipal solid waste landfill and the application of chemical fertilizers and pesticides have led to soil and solid waste pollution in Xishan area.

Regional soil pollution after ecological treatment in 2019: in the process of ecological restoration in Xishan area, the treatment measures for soil environment mainly include: shutting down the original gypsum mines, small coal mines and quarries, and ecological restoration of solid waste accumulation sites such as gangue hills, tailings and fly ash by means of cleaning, landfill and remote treatment; Clean up the original urban domestic waste on the site to the urban waste recycling station, and restrict the use of chemical fertilizers and pesticides in rural areas. In the process of harnessing the mountain damage surface in the original Xishan area, 16 suburban forest parks generally covered the treated damage surface with guest soil more than 0.5M, so as to carry out the next step of vegetation greening.

After years of ecological management, the soil environment in Xishan area is generally getting better, and the content of main heavy metals in soil shows an obvious downward trend. The health of soil environment showed an upward trend.

(3) Health impact assessment

The main effects of soil environmental pollution on human body include: some heavy metal pollution in soil can be absorbed by human body through direct contact with human skin or inhalation of volatile gas and flying particles from contaminated soil. Heavy metals in polluted soil will migrate to the surrounding surface water and groundwater. Drinking or skin contact with polluted groundwater, public waters and other water sources is also one of the ways for human body to absorb heavy metals. Planting crops in contaminated soil will cause heavy metal accumulation in agricultural products, and heavy metals can enter the human body through the food chain. The monitoring values of soil heavy metals in Xishan area in 2005 and 2017 did not exceed China's environmental quality of green food producing areas (NY / T 391-2013) and China's standard for soil environmental quality and soil pollution risk control of agricultural land (GB 15618-2018). Therefore, the direct heavy metal pollution risk of soil in this area is small, but there is still a potential risk of soil environment to human health.

After heavy metals enter the human body, they will do serious harm to the human body. For example, lead (Pb) endangers the nervous system and easily leads

to chronic poisoning of human body; Excessive intake of cadmium (CD) endangers human kidney and urinary system, resulting in inability of human body to absorb calcium, osteoporosis, edema and ventilation; Arsenic (as) compounds accumulate in human tissues through blood, resulting in human poisoning; Mercury (Hg) endangers the central nervous system, digestive system and internal organs; Nickel (Ni) is harmful to respiratory system; Excessive intake of chromium (CR) can damage liver tissue and may lead to cancer (Table 39).

Table 39 Soil pollutants and their health impacts

Main soil pollution sources in Xishan area	Source composition of soil pollution in Xishan area	Impact on health	Ecological environment control measures	Ecological governance has achieved results
Solid waste pollution	Pollutants in waste rock (Hill), fly ash, tailings, waste ore and rock stacked on the soil surface flow into the soil with surface runoff	The main harmful substances include heavy metals such as lead, cadmium, chromium, mercury and nickel, which cause	Shut down the original gypsum mines, small coal mines, quarries, etc.; Carry out ecological restoration of solid waste accumulation sites such as waste dump, tailings, fly ash and urban domestic waste by means of cleaning, landfill, soil covering and remote treatment;	The original surface solid waste pollution has been basically restored
air pollution	The polluted mine atmosphere, such as particles and dust in the atmosphere, settles in the soil (farmland, etc.)	poisoning and even cancer through skin contact, inhalation of volatile gases polluting soil, contact with	Combined with atmospheric environment control, shut down, relocate and successively eliminate serious polluting enterprises. Limit the pollution discharge of remaining enterprises. Build green mines.	The average range decreasing trend of pollution particles and dust reduction indices in the regional atmosphere
pollution of waters	The acid wastewater formed in the process of coal mining seeps into the soil, corrodes the ore in the soil, and makes a large number of heavy metals seep into the soil	drinking water and food chain	Combined with water pollution control, strengthen mine drainage treatment and reuse; Strengthen the ecological restoration and treatment of abandoned small coal mines and abandoned mines.	The utilization rate of mine drainage in the region has gradually increased; Abandoned small coal mines (old mine water) have been basically treated

Source: Author's own work

8.2 Conclusion of Ecological Restoration in Xishan

8.2.1 The important steps and measures of the ecological restoration of

Taiyuan Xishan

Based on the theory and case analysis of this paper, in order to provide a healthy physical environment for green infrastructure construction with mine ecological restoration, it is necessary to effectively control the basic physical environment such as atmosphere, surface water and soil in the area where the mine is located. The main paths are:

The first step is to shut down the pollution sources in the area where the mine is located, including closing the mine production areas with serious pollution, enterprises and factories with serious pollution discharge, etc. When it is impossible to shut down all mine production in the region, building green mines, ecological restoration of the mining face of open-pit mines, strengthening the environmental protection management of pollution emission of regional factories and enterprises, and ensuring that factories and enterprises meet the environmental protection standards are considered to be effective ways.

The second step is to clean (or purify) the pollutants left over by the mine site, including polluted water, solid waste, soil, etc. Due to the high correlation of natural elements such as atmosphere, water and soil in the ecosystem of the mine area, the pollution of any element will affect the treatment process of other elements. Therefore, in the ecological restoration of the mine physical environment, we should pay attention to the comprehensive restoration of each element and devote the ecological restoration work to forming an overall healthy ecosystem.

Third, in order to build green infrastructure, the site needs to be further improved, including surface damage surface repair, terrain treatment, slope reinforcement, greening and tree planting, etc. After the surface pollution in the area where the mine is located is basically removed, the site can be greened and reclaimed. Because the mature green plant community has a strong function of stabilizing the regional ecosystem, it can continuously improve the environmental quality of atmosphere, water and soil.

8.2.2 The value and significance of the health impact assessment of the

ecological restoration in Taiyuan Xishan

Because mine pollution itself poses a great threat to the health of surrounding residents. These threats include health threats caused by long-term pollution emissions from mines and related factories and enterprises. Including respiratory

diseases and cor pulmonale caused by air pollution; Chemical poisoning and various water-borne infectious diseases caused by water environmental pollution; Poisoning, infectious diseases, cancer and leukemia caused by soil and solid waste pollution. Comprehensively controlling the pollution emission in the mining area will greatly improve the regional physical environment and ensure the health and safety level of surrounding residents. Comparing the physical environment before and after the ecological restoration of the mine, it can be seen that the governance and improvement of the mine area is of great significance to ensure the healthy life of the surrounding residents.

9 Chapter 9 Healthy Reuse of Xishan Area from the Perspective of Healthy City

9.1 Healthy Reuse Constructions in Xishan

9.1.1 Healthy Economy and Industry

The Xishan area of Taiyuan has transformed and transformed the original high-pollution and high-emission traditional coal mining industry, and gradually formed a collection of new industries including energy, general health, tourism, environmental protection, and agriculture and forestry. The specific composition of its economic industry is as follows:

(1) Energy Industry

The energy industry includes green coal mine production, new energy, etc. Green coal mine production refers to the green transformation and upgrading of the original traditional mining production. The main measures include closing all the small private coal mines in the original Xishan area and carrying out ecological restoration. For the integration and green transformation of the original state-owned mining enterprises, only Liuguandi Mine, Ximing Mine, and Duerping Mine have remained and transformed into green mining areas, according to the national green mine construction standards. Through the upgrading and transformation of the coal mining industry in the Xishan area, scientific and orderly mining was implemented throughout the entire process of mineral resource development. The disturbance to the ecological environment in the mining area and surrounding areas was controlled within a controllable range; the mining method was scientific, the resource utilization was efficient, and the enterprise management was standardized.

The new energy industry mainly uses the barren hills formed after the ecological restoration of the original abandoned mine land to build solar power generation and wind power generation devices and develop new energy enterprises. In 2017, The National Development and Reform Commission and the National Energy Administration approved the microgrid project plan in Xishan New Energy Demonstration Park, which had a total investment of RMB 11.19 billion and was planned to consist of 19 microgrids. The power supply projects included 500MW of photovoltaic power, 60MW of wind power, and 125MW of natural gas cogeneration; the energy storage comprised 400MW of pumped storage, 60MW of battery energy storage, and 126MW of thermal energy storage, and the corresponding load was 470MW. The microgrid system solved most of the problem of electricity consumption for large-scale greening irrigation in the mountainous areas of the Xishan area in

2019.



Fig. 76 Solar and wind energy projects in Xishan area

Source: <http://www.sx.news.cn/20240618/02f599700adc4d5fbc970515917024/c.html>;
<https://news.cctv.com/2024/01/20/ARTIfxb2yXg6HDhErnk8rqK240120.shtml>

(2) Healthcare and Sports Industry

The healthcare and sports industry includes healthcare, sports, pension services, etc. Among them, the healthcare industry uses the large area of forest formed after ecological restoration to develop forest tourism and forest recuperation and provide exemplary healthcare services for urban residents. The sports industry includes the use of the site formed after the ecological restoration of the original mine to develop and construct a football school, horse riding leisure base, bicycle sports base, mountaineering club, rock climbing base, sports fitness park, camping base, and carry out sports events such as cycling and marathon, festivals, etc. The elderly care service industry relies on an excellent ecological environment and urban and rural medical resources in the Xishan area, and the construction of elderly care apartments and rehabilitation centers.

(3) Cultural Tourism Industry

The cultural tourism industry includes cultural exhibitions, cultural education, leisure tourism, and other industries. Relying on the rich historical and cultural resources, good natural environment, and urban service functions of the Xishan area, develop cultural exhibition industries such as conferences, exhibitions, and expositions, and various educational sectors such as children's growth, higher education, vocational and professional skills training, as well as scenic sightseeing, Leisure tourism industry such as cultural leisure experience, tourism, and vacation.

(4) Education and High-tech Industry

The education and high-tech industry relies on the existing urban construction foundation and office and business service functions, combined with the development

needs of Taiyuan's education and information high-tech industry, introducing higher education schools, information, internet and computer science enterprises and other high-tech industry enterprises.

(5) Environmental Protection Industry

The environmental protection industry includes relying on the original mine restoration and environmental protection enterprises and technologies in the Xishan area of Taiyuan, developing an environmental protection industry featuring ecological restoration construction, industrial enterprise circular energy conservation, and green mine construction.

(6) Agriculture and Forestry Industry

Agriculture and forestry include developing ecological agriculture and forestry in combination with the existing rural economy and community revitalization in the Xishan area. Developing organic agriculture, urban farms, and other industrial formats should also be combined with constructing a healthy city in Taiyuan.

9.1.2 Healthy Land Use and Projects

(1) Healthy Land Use

The existing urban construction land in the Xishan area is mainly concentrated in the eastern belt of Xishan, which is flat in front of the mountain and close to the urban center of Taiyuan City. The construction land is mainly distributed in the existing Luocheng Street, Jinyuan Street, and Nanhan Street, Dongshe Street, Shanglan Street, Duerping Street, Jinsheng Town, Jinci Town, and other city streets and townships.

Comprehensive land-use planning takes many factors into account, which include the natural topography and landforms, geological safety and stability, river and lake system distribution, natural vegetation, animal and plant habitat distribution, natural disasters, cultural heritage resource distribution, existing land use conditions, distribution of mining wasteland, internal and external transportation conditions, industry development, and other factors in the Xishan area, to make sure that the selection and layout of the lands are safe, healthy and sustainable for regional construction projects. (Fig. 77)

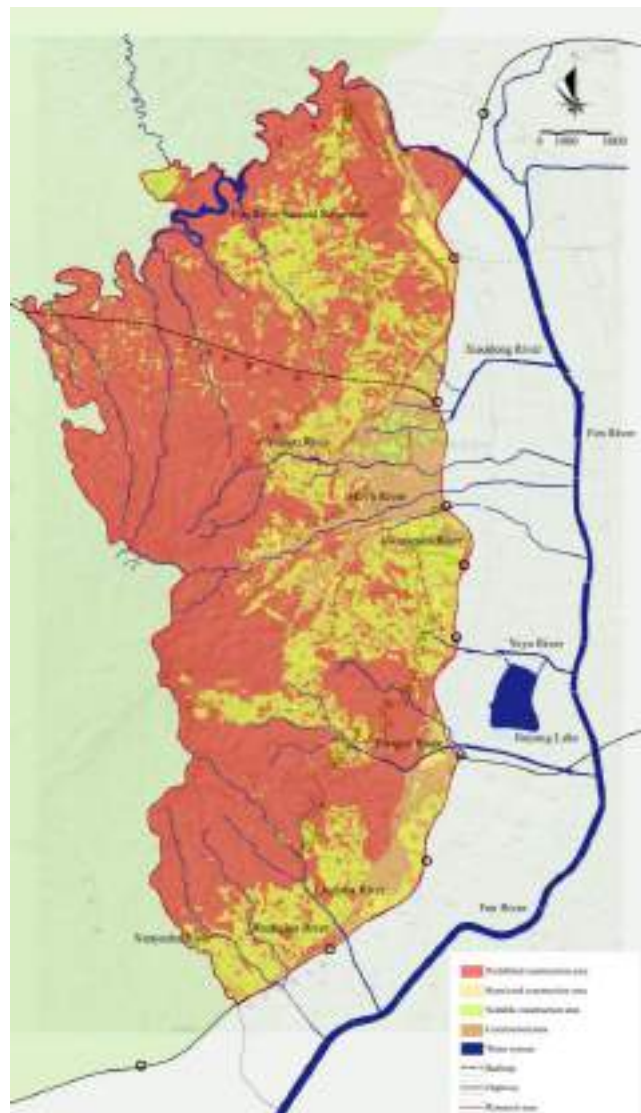


Fig.77 Land construction suitability analysis map

Source: Author's own work

Before ecological restoration, a large amount of construction land in the Xishan area was used for industrial and mining construction of mining and related enterprises. After the ecological restoration, the construction land of the original mining enterprises has been integrated, restricted and contracted. Taiyuan Cement Factory, Taiyuan Lion Head Group, Jinxi Machine Factory and other polluting enterprises were shut down, and the construction land in the area was converted to other functional uses in cities and towns. In the Xishan area, there used to be a large number of abandoned mines of different sizes and scattered everywhere. After ecological restoration and construction, they have been transformed into forest land and green land. In addition, the Xishan area still retains a considerable amount of rural construction land, which has been activated and utilized along with the revitalization and development of the economic industry and rural communities in the Xishan area.

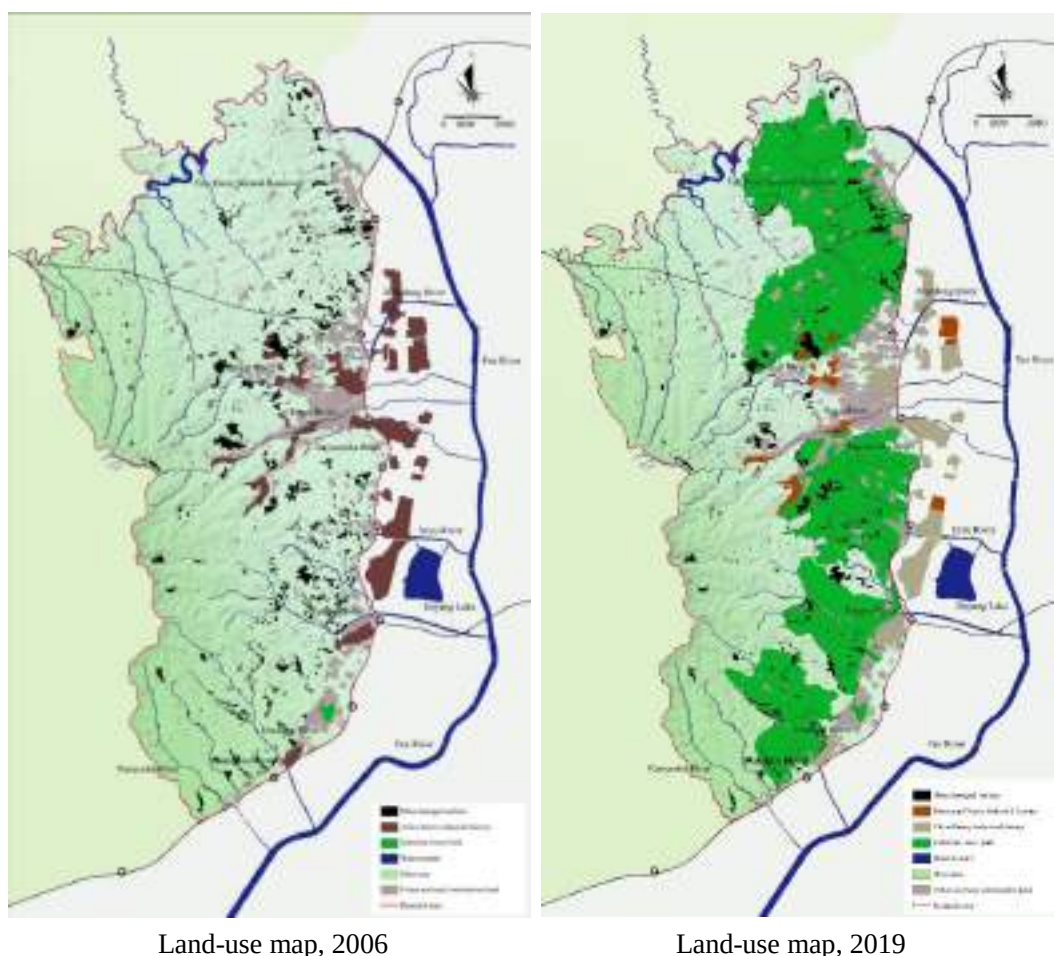


Fig.78 Land-use changes between 2006 and 2019

Source: Author's own work

(2) Healthy Projects

The healthy projects in the unique and diverse Xishan area primarily focus on developing forest parks, sports training schools, industrial heritage parks, leisure and tourism projects, high-technology parks, and residential quarters. Each of these projects is designed to showcase the area's unique features and potential.

Forest Parks mainly include Gangsheng, Yaxin, Yuquan Mountain, Gengyang, Changfeng, Guanshan, Xishan Fengqing, Million Mu Ecological Park, and other parks. It is the primary way of transforming and utilizing the Xishan mining area. Forest ecological tourism, agricultural tourism, outdoor leisure, and other content are developed by restoring mountains and vegetation. For example, in the history of Xishan Ten Thousand Mu ecological park, the ecological environment has been seriously damaged due to the excessive exploitation and accumulation of garbage. Since 2008, ecological restoration and pollution control have been carried out, including mountain greening, river treatment, water storage project, power plant ash pond reconstruction, etc., and leisure tourism projects such as the central sightseeing park, picking Park,

Huangpo site area, clean and honest education base have been successively built. After the ecological restoration and reconstruction of Yuquanshan Park, the forest vegetation coverage has been dramatically improved, and the ecological environment has been greatly enhanced. Since 2014, the annual "Spring Convention" activity with the theme of Cherry Blossom appreciation has been held, and the average number of tourists received during the flower appreciation period is 600000 (Fig. 79) (Table 40).

Sports Training Schools mainly include Xishan Olympic Sports Suburban Forest Park, etc. Based on the original Gangue Hill, through ecological restoration and site arrangement, a project construction area with football, rock climbing, and other sports venues as the central part has been formed. At present, the second youth league and other critical international events have been held (Fig.80).

Industrial Heritage Park mainly includes Xishan National Mine Park, a project that needs to be constructed. The current situation is the leading distribution area of the Xishan coal power plant and the mine entrance. It was built in the period of the Republic of China and is the first state-owned coal mine invested and constructed by Northwest Industrial Company in Shanxi Province in the period of the Republic of China. The project is planned to build a heritage park integrating industrial culture exhibition, leisure, and entertainment, as well as a cultural and creative office of the coal mine through the transformation and utilization of factory buildings.

Leisure and tourism projects mainly include Taiyuan Botanical Garden, Guoxin, Shengke, Haoguang, and other project areas. They are planned to combine the restored forest ecological environment, use the government's land-green policy, select the construction land formed after site consolidation, and develop and construct health and vacation projects. Taiyuan Botanical Garden covers an area of 180 hectares and is divided into five functional areas: entrance management area, plant science classification area, plant science application area, plant evolution display area, and scientific experiment area. The botanical garden has three main venues, namely the exhibition greenhouse, natural science museum and bonsai museum; there are also performance centers, waterfront restaurants, grass music festivals, picking gardens, outdoor sports, camping bases, children's playgrounds and other projects. Taiyuan Botanical Garden was named the best project in the world by ENR 2021(Fig.81, Fig.82).

High Technology Park mainly includes Shengke and other project areas, as well as a modern industrial park focusing on scientific and technological research and development.

Residential quarters are strategically located in the shallow mountain area close to the urban area. In the construction of existing scenic spots, we have used the relevant government land policies to meet the requirements of land space planning and relevant planning laws and regulations. This has allowed us to select a small number of residential quarters with good construction conditions for development, paving the way for the future growth and development of the Xishan area.

Table 40 List of forest park in Xishan, Taiyuan

Serial number	Name of Park	Park size (ha)	Main functions and projects to be transformed and utilized
1	Gangsheng Suburb Forest Park	889.6	Ecological sightseeing and leisure sports
2	Yaxin Suburb Forest Park	670.9	Ecological sightseeing and leisure sports
3	Guoxin Suburban Forest Park	686.1	Tourism industry incubation and recuperation
4	Shengke Suburban Forest Park	1633.9	Religious and cultural exhibition, agricultural sightseeing, health and holiday Resort
5	Suburban Forest Park of traditional Chinese Medicine	113	Traditional Chinese medicine cultural industry and ecological tourism
6	Gengyang Suburb Forest Park	922.2	Religious culture exhibition and natural Eco-tourism
7	Yuquan mountain Suburb Forest Park	1097.5	Leisure sports, health and holiday Resort, science, education and research
8	Changfeng Suburb Forest Park	587.1	Ecological sightseeing, leisure sports, conference and Exhibition
9	Guanshan Suburb Forest Park	461.5	Ecological sightseeing and leisure sports
10	Kangpei Suburb Forest Park	259.7	Painter village, ecological sightseeing
11	Love late Suburb Forest Park	1097.7	Leisure and recreation
12	Huantou Tianli Suburb Forest Park	1284.9	Ecological sightseeing, agricultural tourism and cultural experience
13	Coal gasification Suburban Forest Park	933.2	Cultural experience and leisure Resort
14	Xishan Olympic Sports Suburb Forest Park	591.9	Sports events, leisure sports, health and holiday Resort
15	Xishan National Mining Suburb Forest Park	716.3	Mining cultural tourism, science, education and research
16	Xishan Fengqing Forest Park	1653	Ecological sightseeing
17	Ten thousand mu ecological park	652.2	Ecological sightseeing

Source: Author's own compilation



Fig. 79 On-site comparison photos of Yuquanshan Forest Park before and after renovation

Source: Image provided by Xishan Management Committee



Fig. 80 On-site comparison photos of Olympic Sports Suburb Forest Park before and after renovation

Source: Image provided by Xishan Management Committee



Fig. 81 Taiyuan Botanical Garden

Source: Photographer: CreatAR, 2021 (<https://www.dmaa.at/work/taiyuan-botanical-garden>)



Fig. 82 ENR Global Best Projects Award Winners 2021 of Taiyuan Botanical Garden

Source: <https://www.enr.com/articles/53169-best-project-sports-entertainment-taiyuan-botanical-garden-domes>

9.1.3 Healthy Transportation

(1) Railway

There are currently two railways in the Xishan area, one of which is the Taigulan

Railway, which passes through the Xishan area from the north, with a total length of about 20 kilometers within the Xishan area; the other is the Qianshan Fourth Mine (Baijiazhuang, Guandi, Ximing and Duerping) coal transportation line, with a total length of about 40 kilometers within the Xishan area, is a freight railway, and Yumengou Station is set up. As the Xishan area vacated coal chemical enterprises and built a cultural eco-tourism area, in the urban planning, it was proposed to gradually reduce the impact of the railway on Xishan, and the current Taigulan Railway was planned to be retained; the coal transportation line and Yumengou Station will be retained in the near future, and the long-term reconstruction will be carried out. It is a special line for tourism, combined with the marshalling station facilities of Yumengou Station and the auxiliary industrial storage facilities for comprehensive transformation, to create a cultural and creative park.

(2) Highway

There are currently two expressways in the Xishan area, which are important passages for the external connection of the downtown area of Taiyuan. One is the north-south Xihuan Expressway, which is an elevated line and is located on the east side of Xishan. The other is the East-West Taikoo Expressway, which is a tunnel route. The existing expressway is located on the edge of Xishan Mountain, or is a mountain tunnel road, which has little impact on the overall ecological environment of Xishan Mountain. In urban planning, these two expressways are reserved.

(3) Vehicle Road

The vehicle roads in the Xishan area are of great significance to the development of tourism and agriculture and forestry industries, but the current vehicle road system is not perfect, and some forest parks and tourist attractions do not have convenient vehicle traffic connections. The main driving roads include: external traffic connection roads, one provincial road and three county roads. Among them, Provincial Road 104 connects Xishan Coal and Electricity and Gujiao City; County Road 252 is located in the north of the planning area, connecting Provincial Road 104 to Gujiao County through Wangfeng Township; County Road 226 connects Xishan Coal and Electricity and Gujiao City; County Road 254 Also known as Taikoo Vehicle Road, it connects Jinyang Avenue and Gujiao City. In the urban planning, the existing driving roads in the Xishan area are retained, and suggestions for tourism transformation and upgrading are put forward, such as adding traffic protection green spaces and bicycle lanes along the driving roads. In the Xishan area, there is a special tourist road running through the north and south. The whole process is built according to the landscape road. It used to be a part of the 2019 Ring of Taiyuan International Road Cycling Race, and 6 kilometers of it are paved with colored asphalt. In addition, there are rural roads in the Xishan area that pass through the mountains, forests and farmland, leading to various villages. The traffic volume of the rural roads is small, and the overall environment on both sides of the road is good (Fig. 83, Fig 84).



Fig. 83 Taiyuan Xishan Tourist Road

Source: Image provided by Xishan Management Committee



Fig. 84 2023 3rd Taiyuan Road Cycling Race

Source: http://sports.china.com.cn/zhuanti/shijianzhuanti/detail2_2023_10/14/4180499.html

(4) Bicycle and Trail

All forest parks and scenic spots in the Xishan area have internal roads that have been built or are under construction, including roads for tour cars in the park, fitness trails, bicycle tracks, etc., all of which are health-friendly roads.

The Juwei Mountain Hiking and Fitness Trail is the first national hiking and fitness trail in Taiyuan City. It was completed in October 2014. The trail is 8.3 kilometers long. The hiking trails mainly include sleeper plank roads, wooden plank roads, log plank roads, stone slab roads, gravel roads, sandy roads, and dirt roads, and

has 23 signboards along that indicate how many meters you have walked, the altitude, the positioning code, and the emergency telephone number (Fig. 85).



Fig. 85 Juewei Mountain Hiking and Fitness Trail

Source: https://m.thepaper.cn/newsDetail_forward_11413148;

<https://wapbaike.baidu.com/tashuo/browse/content?id=229718be556daf3eff26ae9f>

Yuquanshan Forest Park has built 15 kilometers of mixed roads for tourist vehicles and bicycles and 20 kilometers of sightseeing trails. Combined with the park's cherry blossom forest and other plant landscapes, a landscape slow-moving system has been formed in the park (Fig. 86).



Fig. 86 Yuquanshan Forest Park Road

Source: Image provided by Xishan Management Committee

9.1.4 Healthy Public Facilities

The existing public service facilities in the Xishan area are mainly concentrated in the town construction area in the middle and south of the mountain. It is mainly based on basic education, medical and health care, sports and elderly care facilities for community services, as well as some vocational training and higher education facilities.

(1) Xishan Coal Power and surrounding areas

Land for education and scientific research: The current supporting primary and secondary schools and kindergartens in this area are four middle schools, thirteen primary schools, and six kindergartens. The land for education and scientific research includes Xishan Safety Training Center, Shanxi Conservatory of Music Xishan Branch, Coking Coal Group Staff University, Xishan Coal and Electricity Group Technical School, Provincial Police Academy, etc.

Land for medical facilities: There are three sites, namely the Municipal Psychiatric Rehabilitation Hospital located in the southwest of Yuanjiazhuang Overpass, the Xishan Coal and Electricity Group Workers Hospital located on the north side of Huyu River, and the Xishan Coal Mine Corporation located on the south side of Huyu River and east of Helao Lane Mine Rescue Brigade.

Land for sports facilities: There is one, which is the Xishan Gymnasium located in the southwest of the intersection of Xikuang Street and Ximing Road.

Other public facilities: There are two, namely the Shanxi Provincial Catholic Church Monastery located on the north side of Yumengou Marshalling Station, and the Municipal Social Welfare Institute located on the south side of Yuanjiazhuang Overpass.

(2) Jinci Town and surrounding areas

Land for education and scientific research: Currently, there are Dongda School, Jinci Middle School, Jinci Central Primary School, Chiqiao Central Primary School, Jinci Town Central Kindergarten, and Tongxing Kindergarten. It also includes Xinhua Microsoft IT School, Shanxi Guangcai Huimin Electromechanical Technical School, Provincial Mobile Training Center and Boqiang Training School.

Medical and health land: mainly includes provincial cadre sanatorium and worker sanatorium.

The distribution of public service facilities in the Xishan area is uneven, public service facilities are missing in some areas, and the land for some facilities is insufficient and the environment is poor. Although Xishan Coal Power and its surrounding areas belong to the main urban area, due to factors such as its geographical location and the self-isolation of industrial and mining enterprises, it has been separated from the main urban area. It has a self-contained system and basically complete types of facilities.

Compared with the per capita public service index of Taiyuan City, the per capita land use of public service facilities is at a low level, and public service facilities such as cultural entertainment, sports, and social welfare are lacking.

9.1.5 Healthy Culture

The Xishan area of Taiyuan has a long history and numerous cultural relics and historic sites. Among them, there are nine national-level key cultural relics protection units (including Jin Temple, Taishan Longquan Temple, Tianlongshan Grottoes, Longshan Grottoes, Doctor Dou Temple, Jingyin Temple, Duofu Temple, Tongzi Temple Site, Mengshan Kaihua Temple Site, etc.), There are 16 municipal-level cultural relics protection units, 35 district-level cultural relics protection units, one national-level historical and cultural village, one provincial-level historical and cultural town, and one Chinese traditional village. The historical and cultural relics in the area are well preserved, and the local traditional rural culture and customs in the villages have regional characteristics and have strong cultural, leisure and health benefits (Fig. 87).



Fig. 87 Historical and Cultural Relics

Source: Image provided by Xishan Management Committee

9.2 Investigation methods

To better understand the public's health perceptions and specific demands for the reuse of the Xishan area, this study used an open-ended internet questionnaire to conduct a random network survey among Taiyuan citizens. Based on the model for assessing the perceived health needs of the population derived from this study (Fig. 88) and with reference to the ten goals of healthy cities announced by the World Health Organization (World Health Organization, 2020b), the international standards for mine ecological restoration and reuse (Renee E. Young et al., 2022), and the guidance of the U.S. Environmental Protection Agency (EPA) on the revitalization and reuse of abandoned mine lands (US EPA, 2023), this study focused on the specific demands of urban and rural residents in Taiyuan with respect to the quality of the natural environment, the construction of facilities and activities, and the development of the local economy and industry. Cross-analysis with the sociodemographic data from the surveys was conducted. The main content of the survey is shown in Table 41.

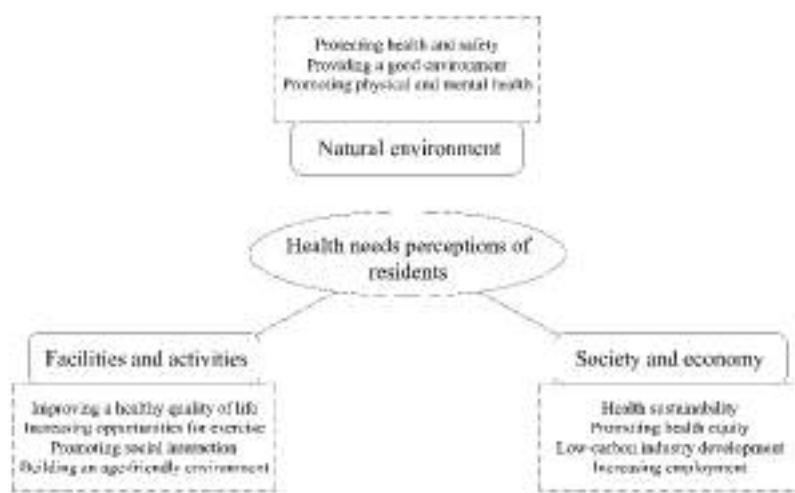


Fig. 88 Diagram of the model for assessing the perceived health needs of residents

Source: Author's own work

The on-line survey mainly includes the following parts:

(1) The basic information of the participants in the survey, includes their age, gender, occupation, education level, length of residence in Taiyuan City, and the distance between their living places and Xishan, etc.

(2) The existing problems in the ecological management of Taiyuan Xishan and the needs for further improvements, include the overall impression of the ecological restoration and treatment of Taiyuan Xishan, the impact on physical and mental health, and the work that needs to be further improved in the ecological management of Xishan.

(3) The existing problems and further needs of Taiyuan Xishan reuse methods, include the construction of regional health project facilities and the development demands of the regional health industry.

9.3 Survey results and analysis

The research questionnaire was published on the Chinese public online survey platform "Questionnaire Star" on 10 November 2021, and a total of 831 random online responses were received from Taiyuan citizens over 39 days until 18 December 2021. Excluding incomplete or random responses (less than 30 seconds), and residents who started living in Taiyuan after 2006, a total of 748 valid questionnaires were collected. Most of the participants were male (60.6%), most lived within 10 km (82.1%) away from Xishan, and most had a high level of education (83.4% with a bachelor's degree or higher) (Table 41).

Combined with site visits and interviews, the results of the questionnaire survey were classified and summarized, and the conclusions of the various demands of the Taiyuan citizens participating in the survey on the mine ecological restoration area were drawn. Statistical analysis of valid responses to questionnaires was carried out by using

SPSS software.

Table 41 Socio-economic and demographic composition of survey participants

Birth of Age	post-50s (1950-1959)	post-60s (1960-1969)	post-70s (1970-1979)	post-80s (1980-1989)	post-90s (1990-1999)	post-00s (2000-2009)	Sum
Proportion (%)	5.2	18.9	26.6	32.1	16.6	0.7	100
Living distance from Xishan	Within Xishan area	Within 1000 meters	1000-5000 meters	5000-10000 meters	Above 10000 meters		
Proportion (%)	49.3	6.7	13.5	12.6	17.9		100
Profession	Employees of enterprises	Student	Civil servant	Farmer	self-employed	Practitioners of environmental engineering, urban planning	Others
Proportion (%)	73.8	1.2	2.3	1.2	2.3	6.6	12.7
Education level	Junior high school and below	High school or technical, vocational school	Undergraduate and junior college	Master's degree or above			
Proportion (%)	4.3	12.3	73.9	9.5			100
Gender	Male	Female					
Proportion (%)	60.6	39.4					100

Source: Author's own work

9.4 Results and Discussion

9.4.1 Basic requirements for site health and environmental quality

In order to comprehensively portray the degree of environmental pollution before the ecological governance in the Xishan area of Taiyuan, this study divides the pollution of the ecological environment into 4 levels and 7 elements of environmental pollution. The four environmental levels include severely polluted environment, moderately polluted environment, lightly polluted environment, and no environmental pollution. Among them, regard the region had 6-7 environmental pollution elements as severely polluted, 4-5 environmental pollution elements as moderately polluted, 1-3

environmental pollution elements as lightly polluted, and 0 environmental pollution elements as no environmental pollution.

According to the feedback from the survey, among them, 42.1% and 37.8% believed that the environment in Xishan was severely polluted and moderately polluted, and the sum of the two was 79.9% (Table 42). As for the overall impression of the ecological management of Taiyuan Xishan, 37.7% were very satisfied, 51.2% were relatively satisfied, and the sum of the two accounted was 88.9%. It can be seen that most of the participants of Taiyuan citizens considered the environmental pollution problems of Xishan before ecological management had been relatively serious (79.9%), while they were generally satisfied (88.9%) with the overall situation after ecological treatment. And 92.9% thought that the site had a greater role in safeguarding their own physical and mental health after ecological treatment. This indicated that the ecological management of the site in Xishan had produced relatively good ecological and social health benefits, and had generally positive effects on the healthy lives of the participants in the survey.

Table 42 List of overall feedback on the site's healthy environmental qualities before and after ecological management

What is your impression of the environmental pollution of Taiyuan Xishan before the ecological restoration in 2006?					
	Severely polluted	Moderately polluted	Lightly polluted	No pollution	Sum
Percentage (%)	42.1	37.8	15.1	4.9	100
Cumulative percentage (%)	42.1	79.9	95.1	100	
Are you satisfied with the environment after the ecological restoration of Taiyuan Xishan in 2019?					
	Very satisfied	Relatively satisfied	Fairly satisfied	Dissatisfied	Sum
Percentage (%)	37.7	51.2	10.3	0.8	100
Cumulative percentage (%)	37.7	88.9	99.2	100	
What do you think of the effects of the ecological restoration of Xishan on your physical and mental health?					
	Positive great effects	Positive moderate effects	No effect	Negative effects	Sum
Percentage (%)	92.9	4.7	2.3	0.1	100
Cumulative percentage (%)	92.9	97.6	99.9	100	

Source: Author's own work

In the investigation of the insufficient ecological environment governance at this

stage, the case percentages of the 7 seven physical environment elements all exceeded or approached 20% (Table 43). Among them, 63.8% of the survey participants hoped for further governance and improvement of the regional water environment, and 52.4% and 49.3% chose the treatment of forest vegetation and mountain damage surface respectively. The results of the questionnaire show that there were varying proportions of participants who had the demands of improvement of the 7 physical environment elements, especially, more than or nearly half of the participants focused on the water, forest vegetation, and mountain damage surface further governance.

Table 43 List of improvement elements of healthy environment governance in Xishan

Questionnaire question	Environmental elements	Response		Percentage of cases
		Cases	Percentage	
In your opinion, which aspects of the ecological restoration of Taiyuan Xishan should be improved? (Multiple choice questions)	Atmosphere	330	14.1%	44.1%
	Water Environment	477	20.4%	63.8%
	Mountain damage surface	369	15.8%	49.3%
	Forest vegetation	392	16.7%	52.4%
	Solid waste	334	14.3%	44.7%
	Farmland soil	145	6.2%	19.4%
	Geologic hazard	249	10.6%	33.3%
	Others	45	1.9%	6.0%
Sum		2341	100.0%	313.0%

Source: Author's own work

9.4.2 Requirements for the construction of regional health projects and facilities

(1) Development demands of regional activity types

The participants in the survey showed diversified development demands for the types of activities in the Xishan area of Taiyuan, including leisure tourism, sports & fitness, park recreation, aged & health care, residential life, work & study, etc. (Table 44). Among them, leisure tourism, sports & fitness, and park recreation accounted for the highest proportions, accounting for 72.1%, 62.4%, and 62.4% respectively. The future construction of the Xishan area can focus on the development of activities such as leisure tourism, sports & fitness, and park recreation. More than 40% of them chose retirement & health care, and residential life, which accounted for 50.7% and 41.7% respectively.

Table 44 List of the development demands of activity types in Xishan

Questionnaire question	Activity project types	Response		Percentage of cases
		Cases	Percentage	
What kind of activities do you want to enjoy in Taiyuan Xishan? (Multiple choice questions)	Park recreation	467	19.6%	62.4%
	Leisure tourism	539	22.6%	72.1%
	Sports & Fitness	467	19.6%	62.4%
	Residential life	312	13.1%	41.7%
	Work & Study	201	8.4%	26.9%
	Aged & Health care	379	15.9%	50.7%
	Others	15	0.6%	2.0%
Sum		2380	100.0%	318.2%

Source: Author's own work

■ Demands of people of different age groups for the types of activities

Different age groups of respondents had different demands for activities in Taiyuan Xishan (Table 45). The degree of dispersion of participants' choices of various activities in the Xishan area was negatively correlated with age. This indicates that the middle-aged and elderly people had a relatively balanced proportion of demand for different types of activities in the Xishan area, while the choices of post-00s were more concentrated in the three activities: park recreation, leisure tourism, and sports & fitness.

The survey found that the case percentages of the demands of aged & health care were positively correlated with the age of the participants, among which, the post-50s (61.5%) and post-60s (64.5%) were the highest chosen proportions. While the demands for park recreation showed a negative correlation with the age of the participants, among them, the highest proportions of choice were the post-00s (80%) and post-90s (66.9%). For leisure tourism (53.8%-79.0%) and sports & fitness (54.8%-66.8%), all the age groups showed a similar demand ratio. For residential life, except for the post-00s, the rest of the age group showed a relatively close willingness ratio (38.8%-46.2%). For work and study, the post-70s (30.7%), post-80s (28.8%), and post-90s (32.3%) age groups showed relatively similar proportions, which was related to the fact that people in these three age groups were in their peak working years.

Table 45 Analysis of the activities that respondents of different age groups hope to engage in Xishan

Age		Park recreation	Leisure tourism	Sports & Fitness	Residential life	Work & Study	Aged & Health care	Other s	Sum	Cases
Post-50s	Cases	19	21	24	18	5	24	0	111	39
	Percentage	17.1%	18.9%	21.6%	16.2%	4.5%	21.6%	0.0%	100.0%	
	Percentage	48.7%	53.8%	61.5%	46.2%	12.8%	61.5%	0.0%	284.6%	
	of cases									
Post-60s	Cases	89	94	91	58	25	91	4	452	141
	Percentage	19.7%	20.8%	20.1%	12.8%	5.5%	20.1%	0.9%	100.0%	
	Percentage	63.1%	66.7%	64.5%	41.1%	17.7%	64.5%	2.8%	320.6%	
	of cases									
Post-70s	Cases	119	146	133	92	61	104	4	659	199
	Percentage	18.1%	22.2%	20.2%	14.0%	9.3%	15.8%	0.6%	100.0%	
	Percentage	59.8%	73.4%	66.8%	46.2%	30.7%	52.3%	2.0%	331.2%	
	of cases									
Post-80s	Cases	153	177	148	93	69	107	4	751	240
	Percentage	20.4%	23.6%	19.7%	12.4%	9.2%	14.2%	0.5%	100.0%	
	Percentage	63.8%	73.8%	61.7%	38.8%	28.8%	44.6%	1.7%	312.9%	
	of cases									
Post-90s	Cases	83	98	68	50	40	53	3	395	124
	Percentage	21.0%	24.8%	17.2%	12.7%	10.1%	13.4%	0.8%	100.0%	
	Percentage	66.9%	79.0%	54.8%	40.3%	32.3%	42.7%	2.4%	318.5%	
	of cases									
Post-00s	Cases	4	3	3	1	1	0	0	12	5
	Percentage	33.3%	25.0%	25.0%	8.3%	8.3%	0.0%	0.0%	100.0%	
	Percentage	80.0%	60.0%	60.0%	20.0%	20.0%	0.0%	0.0%	240.0%	
	of cases									
Sum	Cases	467	539	467	312	201	379	15	2380	748
	Percentage	19.6%	22.6%	19.6%	13.1%	8.4%	15.9%	0.6%	100.0%	
	Percentage	62.4%	72.1%	62.4%	41.7%	26.9%	50.7%	2.0%	318.2%	
	of cases									

Source: Author's own work

■ Demands of people with different living distances for the types of activities

The proportions of participants who chose the three types of activities of residential life, work & study, and aged & health care, showed a negative correlation with the living distances, among those who lived within 10,000 meters distance from

Xishan (Table 46). The participants living in the Xishan area had the highest proportions of choosing these three types of activities among the various living distance groups, which were 55.6%, 33.3%, and 57.5% respectively. It showed that the living and working environment in the Xishan area was well-recognized by people living in close proximity, especially local residents. The proportions of sports & fitness activities among the participants of different living distances are close. It showed that the Xishan area could afford a healthy environment for sports & fitness activities, while those activities have a similar appeal to participants from medium to long distances.

As for leisure tourism options, there was a close to positive correlation with the living distances of participants who lived within 5,000 meters. The proportion of participants within 1000m and 5000m reached 68.0% and 86.1% respectively, while the willingness of people living more than 10,000 meters to visit Xishan for leisure tourism also reached 79.9%, which showed that the attractiveness of the scenic spots built after regional ecological management did not decrease significantly with the increase of the living distance of participants, and still had a strong attraction for residents of medium and long distances.

Table 46 Analysis of the activities that respondents of different distance groups hope to engage in Xishan

Distance		Park recreation	Leisure tourism	Sports & Fitness	Residential life	Work & Study	Aged & Health care	Others	Sum	Cases
Within Xishan area	Cases	239	233	245	205	123	212	9	1266	369
	Percentage	18.9%	18.4%	19.4%	16.2%	9.7%	16.7%	0.7%	100.0%	
	Percentage of cases	64.8%	63.1%	66.4%	55.6%	33.3%	57.5%	2.4%	343.1%	
	Cases	29	34	29	21	13	29	1	156	50
Within 1000m	Percentage	18.6%	21.8%	18.6%	13.5%	8.3%	18.6%	0.6%	100.0%	
	Percentage of cases	58.0%	68.0%	58.0%	42.0%	26.0%	58.0%	2.0%	312.0%	
	Cases	65	87	62	30	23	41	1	309	101
1000m- 5000m	Percentage	21.0%	28.2%	20.1%	9.7%	7.4%	13.3%	0.3%	100.0%	
	Percentage of cases	64.4%	86.1%	61.4%	29.7%	22.8%	40.6%	1.0%	305.9%	
	Cases	57	78	56	19	14	39	1	264	94
5000m- 10000m	Percentage	21.6%	29.5%	21.2%	7.2%	5.3%	14.8%	0.4%	100.0%	
	Percentage of cases	60.6%	83.0%	59.6%	20.2%	14.9%	41.5%	1.1%	280.9%	
	Cases	77	107	75	37	28	58	3	385	134
Above 10000m	Percentage	20.0%	27.8%	19.5%	9.6%	7.3%	15.1%	0.8%	100.0%	
	Percentage of cases	57.5%	79.9%	56.0%	27.6%	20.9%	43.3%	2.2%	287.3%	
	Cases	467	539	467	312	201	379	15	2380	748
Sum	Percentage	19.6%	22.6%	19.6%	13.1%	8.4%	15.9%	0.6%	100.0%	
	Percentage of cases	62.4%	72.1%	62.4%	41.7%	26.9%	50.7%	2.0%	318.2%	
	Cases									

Source: Author's own work

(2) Key requirements for improvement of regional tourist facilities

Regarding the tourist facilities that needed to be improved in the Xishan area, the survey participants showed an overall demand for the comprehensive improvement of various tourist facilities in the area. Among the given 7 specific tourist facility options, the percentage of selected cases exceeded 39% (Table 47). Among them, more than 50% of the people chose the park tour and fitness trail system (68.9%), cultural and leisure tourism facilities (58.7%), children's activity facilities and venues (51.5%), leisure sports facilities and venues (51.3%) and sightseeing and leisure farms (51.2%). Nearly 50% of the staff chose popular science education facilities (46.8%). (Fig. 89, Fig. 90, Fig. 91)

Through cross-analysis with the selection data of respondents of different age groups, different occupations, and different distances, it can be seen that the appeals of different surveyed groups for the improvement of regional tourism facilities were relatively balanced. And it was positively correlated with the overall demands of all participants in the survey. It can be seen that the citizens have a strong overall demand for comprehensively improving the tourist facilities and construction quality in the Xishan area.

Table 47 List of key requirements for regional tourist facilities improvement

Questionnaire question	Tourist Facilities	Response		Percentage of cases
		Cases	Percentage	
In your opinion, which tourist facilities in Xishan need to be improved? (Multiple choice questions)	Park tour and fitness trail system	515	18.6%	68.9%
	Recreational bike path	295	10.6%	39.4%
	Leisure sports facilities and venues	384	13.9%	51.3%
	Children's activity facilities and venues	385	13.9%	51.5%
	Cultural and leisure tourism facilities	439	15.8%	58.7%
	Popular science education facilities	350	12.6%	46.8%
	Sightseeing and leisure farms	383	13.8%	51.2%
	Others	19	0.7%	2.5%
Sum		2770	100.0%	370.3%

Source: Author's own work

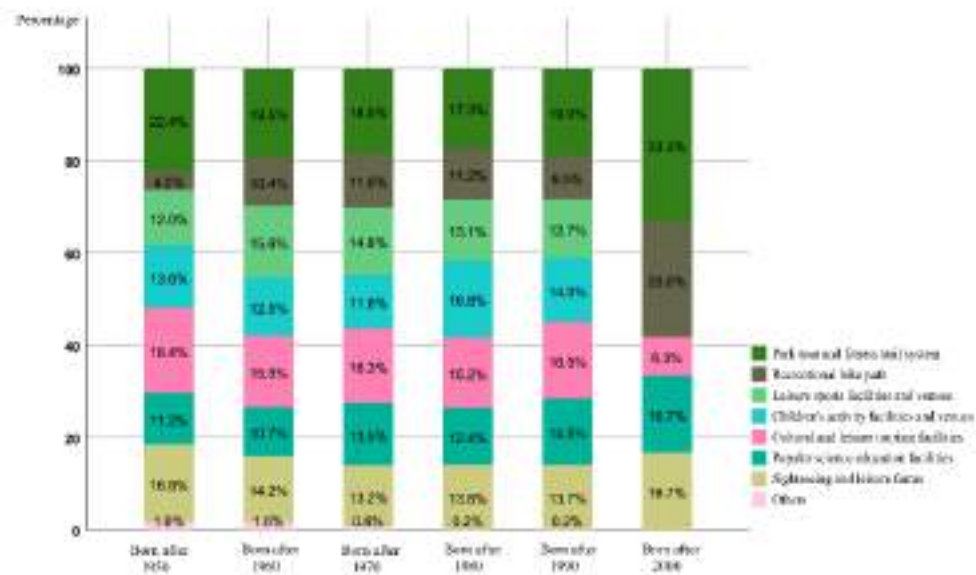


Fig. 89 Demands of different age groups for the improvements of tourist facilities

Source: Author's own work

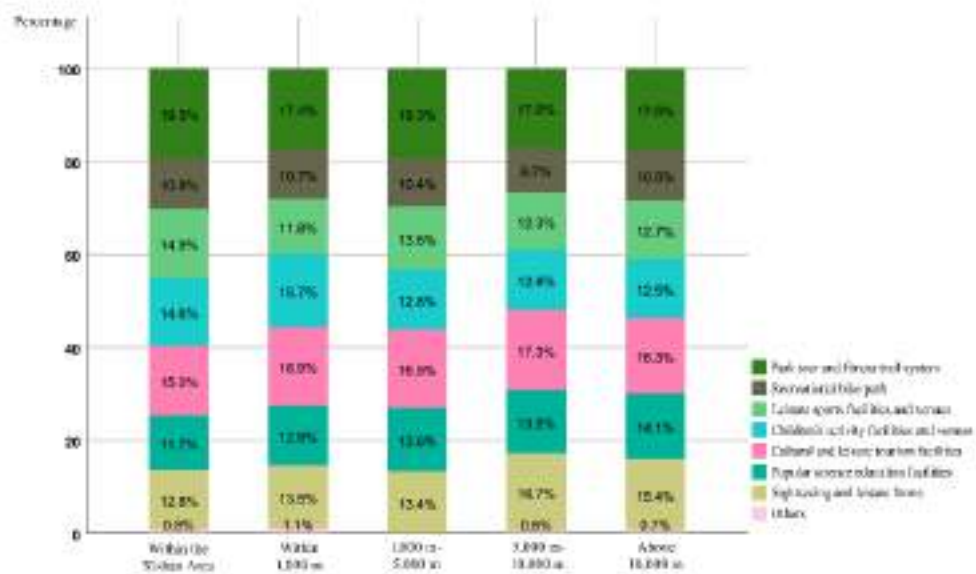


Fig. 90 Demands of different distance groups for the improvements of tourist facilities

Source: Author's own work

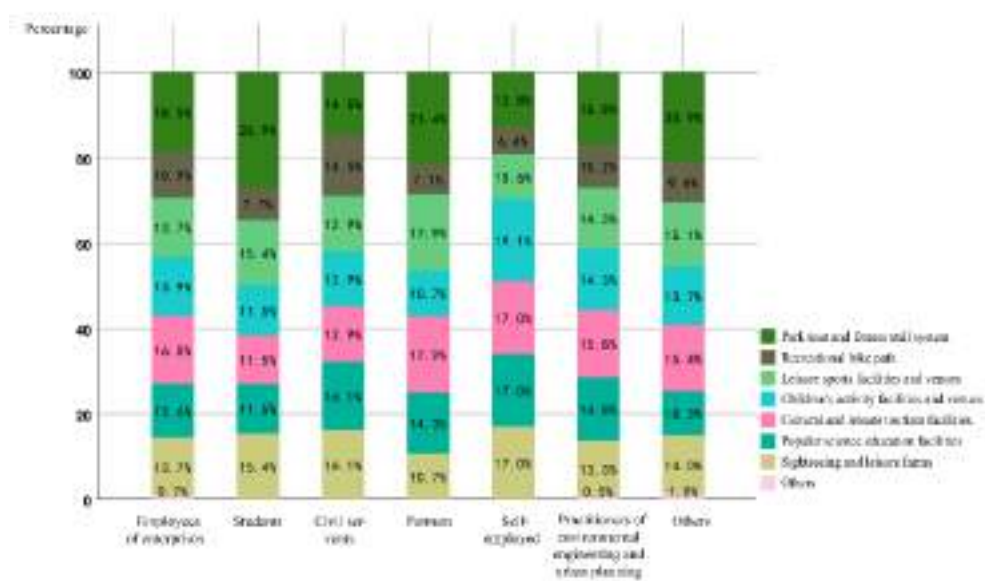


Fig. 91 Demands of different professional groups for the improvements of tourist facilities

Source: Author's own work

(3) Key requirements for improvement of regional public service facilities

As for the public service facilities that needed to be improved in the Xishan area, an overall demand for the comprehensive improvement of all public service facilities was presented by the participants, with more than 30% chosen rate of each public service facility listed in the questionnaire (Table 48). Among them, public transportation was chosen by 64.3%. The main public transportation coverage of Taiyuan City could only reach the foot of Xishan Mountain. There were only 3 public transportation lines including 322, Y1, and 329 that can reach some important sightseeing spots and the existing villages on the mountain. And the overall public transportation coverage in the mountain area was very low, causing lots of inconveniences to citizens of Taiyuan who intended to go up the mountain, which was a prominent and urgent problem to be solved.

Among the public service facilities related to leisure tourism services, the two most chosen options were leisure entertainment and restaurants, accounting for 63.5% and 55.9% respectively. It showed that those two options were the promotional content that everyone paid attention to. Among the options related to public services for the daily life of citizens, 51.7% chose Hospitals & clinics, 40.5% chose schools & training institutions, and 37.8% chose Stores & shopping centers. Among them, the proportions of people who chose these three options were negatively correlated with distance. Since the daily public service facilities were limited by the transportation costs of residents (Zhu et al., 2010), the research showed that the closer the participants lived,

the more they chose the three items above. The improvements of these three facilities needed to pay more attention to the needs of residents in close quarters (Fig. 92).

Table 48 List of key requirements for regional public service facilities Improvement

Questionnaire question	Public service facilities	Response		Percentage of cases
		Cases	Percentage	
In your opinion, which public services in Xishan need to be improved? (Multiple choice questions)	Restaurants	418	16.0%	55.9%
	Hotels	251	9.6%	33.6%
	Leisure Entertainment	475	18.1%	63.5%
	Stores& shopping centers	283	10.8%	37.8%
	Hospitals & clinics	387	14.8%	51.7%
	Schools & training institutions	303	11.6%	40.5%
	Public transportation	481	18.4%	64.3%
	Others	21	0.8%	2.8%
Sum		2619	100.0%	350.1%

Source: Author's own work

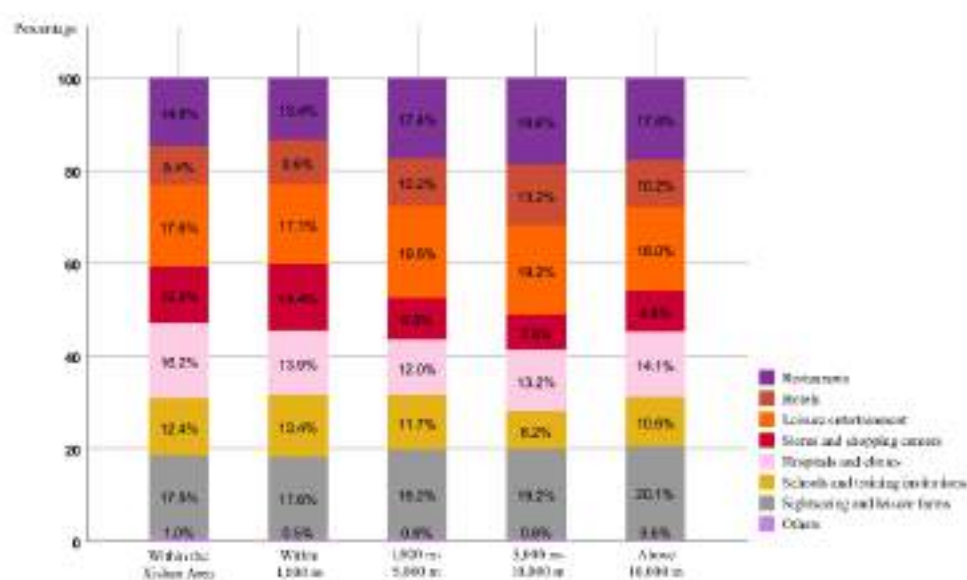


Fig. 92 Demands of different distance groups for the improvements of public service facilities

Source: Author's own work

9.4.3 Requirements for the development of regional health industry

(1) General demands for the development of the health industry

Regarding the land use of mine wastelands utilization after ecological restoration, other than forest & park, the three most popular land use options in the survey included recreational (71.5%), aged & health care (50.4%), educational (32.0%) (Table 41).

Among them, recreational utilization was the highest proportion choice. Moreover, the chosen percentages of residential and commercial land use were 12.8% and 11.9% respectively. Therefore, the development of private industrial projects such as residential real estate and commercial business offices was a type of industrial development that could meet the aspirations of some part of the residents.

It could be seen that the environmental quality of the Xishan area was generally recognized by the public after ecological treatment, and had changed from a mining production area with a poor environment to an area that was generally accepted by residents as an area that could be used for leisure and tourism, work and life, and was conducive to the physical and mental health of the public. Among those who participated in the survey, the proportion of choosing industrial land was the lowest (6%). Therefore, among the reuse methods in the Xishan area, the reduction of traditional industrial projects and the choices of low-carbon industries were the demands of most respondents.

(2) Energy-based industrial development aspirations

Regarding the development of energy industries in the Xishan area, nearly 32.4% of the participants chose traditional energy industries such as coal, indicating that traditional energy industries still had a certain level of public recognition. Among the new energy options, solar energy accounted for the highest proportion (76.5%), followed by wind energy (62.0%). In addition, biomass energy such as biogas accounted for 29.3%. It could be seen that the development of a new energy industry in the Xishan area had been generally recognized by the participants in the survey.

From the perspective of the distance between the living place of participants and Xishan, it was found that the proportion of people who chose traditional energy industries had a negative correlation with their residences. The highest proportion of people who chose the traditional energy industries was the participants within the Xishan area (40.5%). Combined with the on-site interviews, it was clear that there were still three state-owned coal production units in the region (currently under construction as green mining enterprises). And they were one of the main sources of local economy and employment and could not be replaced in the near period of time. It showed that the comprehensive transformation of the traditional energy industries in the region would take time. In addition, the study found a positive correlation between the proportion of participants who chose solar and wind energy and their living distance. Combined with the on-site interviews, it could be known that residents in close proximity had certain concerns about new environmental hazard risks that might be arisen from the development of these two energy sources (such as light pollution from solar photovoltaic equipment, noise pollution from wind energy equipment, etc.).

(3) Rural industrial development aspirations

In response to the demands for the development of local rural industries, nearly 84.0% of the participants chose to develop tertiary industries such as leisure tourism.

Nearly 69.4% chose to develop characteristic agriculture and forestry industries, while only 18.2% chose to develop rural industries. Regarding the relocation of villages, a total of 24.9% chose to relocate all the villages to the foot of the mountain.

Combined with on-site interviews, it could be known that there was a strong overall demand for the development of tertiary industries such as rural leisure tourism in the region, and the development of characteristic agriculture and forestry was also one of the important options. While developing rural industries should be carefully considered (Table 49).

Table 49 List of Regional Health Industry Development Demands

Questionnaire question	Land use forms	Response		Percentage of cases
		Cases	Percentage	
How do you think the mine wastelands in Xishan could be reused after ecological restoration? (Multiple choice questions)	Forest & Park	612	28.8%	81.8%
	Agricultural	113	5.3%	15.1%
	Residential	96	4.5%	12.8%
	Commercial	89	4.2%	11.9%
	Recreational	535	25.2%	71.5%
	Industrial	45	2.1%	6.0%
	Educational	239	11.2%	32.0%
	Aged & Health care	377	17.7%	50.4%
Sum		2125	100.0%	284.1%

Questionnaire question	Energy industries	Response		Percentage of cases
		Cases	Percentage	
What types of energy production do you think could be developed in the future in Xishan? (Multiple choice questions)	Coal and other traditional energy	242	15.7%	32.4%
	Solar energy	572	37.0%	76.5%
	Wind energy	464	30.1%	62.0%
	Biomass energy	219	14.2%	29.3%
	Others	47	3.0%	6.3%
Sum		1544	100.0%	206.4%

Questionnaire question	Energy industries	Response		Percentage of cases
		Cases	Percentage	
How do you think rural development should be guided in Xishan?	Develop characteristic agriculture and forestry	519	34.9%	69.4%
	Develop tertiary industries such as leisure tourism	628	42.2%	84.0%
	Develop rural industries	136	9.1%	18.2%
	Relocated villages to the foot of the mountain	186	12.5%	24.9%
	Others	19	1.3%	2.5%
Sum		1488	100.0%	198.9%

Source: Author's own work

9.4.4 Gender Demands for the Mine Wasteland Regeneration

(1) Health Perception of Ecological Restoration

From the results of the surveyed people's personal perceptions before the Xishan ecological governance in 2006, 42.1% believed that the ecological environment pollution in the Xishan area was very serious, 37.8% believed that the ecological environment pollution was relatively serious, and the total of the two items accounted for 79.9%. It shows that the respondents generally believe that there are serious or relatively serious environmental pollution problems in the Xishan area. Among the men who participated in the survey, 45.7% chose very serious environmental pollution, 37.1% chose relatively serious ecological environment pollution, and the total of these two items accounted for 82.8%. Among the women who participated in the survey, 36.6% chose very serious environmental pollution, 39.0% chose relatively serious ecological environment pollution, and the two items accounted for 75.6% in total. The proportion of male participants in the survey who believed that environmental pollution was very serious or relatively serious before ecological governance was generally higher than that of female groups. Among them, the proportion of men who choose very seriously is 9.1 percentage points higher than that of women. The cumulative proportion of the two items shows that men are 7.2 percentage points higher than women. It shows that men have a higher negative perception of environmental pollution in the Xishan area than women, before the ecological restoration (2006) (Fig. 93) (Table 50).

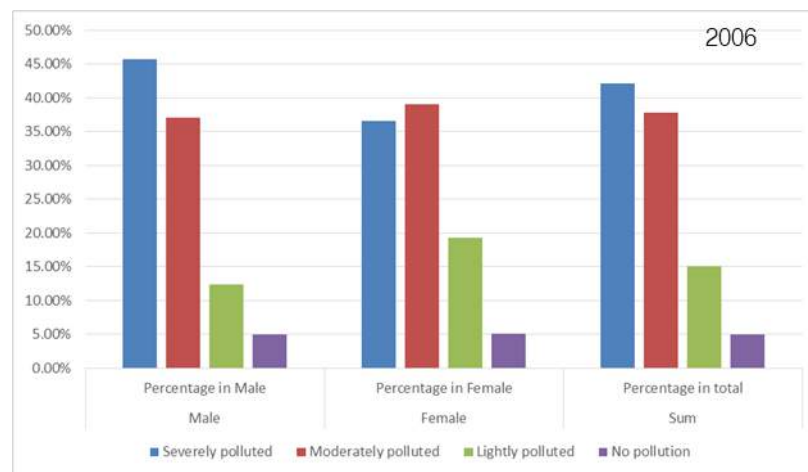


Fig. 93 Personal perception of environmental pollution before the ecological restoration

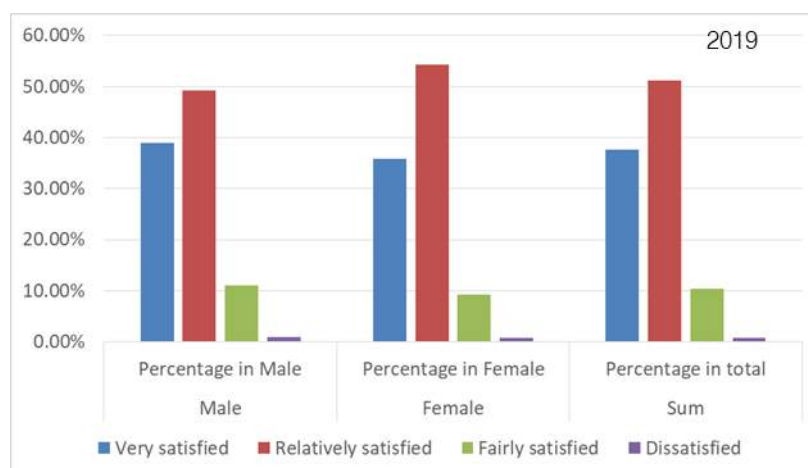
Source: Author's own work

Table 50 Personal Perception of Ecological Environment in Xishan area in 2006

Gender	Response	Severely polluted	Moderately polluted	Lightly polluted	No pollution	Sum
Male	Cases	207	168	56	22	453
	Percentage in Male	45.70%	37.10%	12.40%	4.90%	100.00%
	Percentage in total	27.70%	22.50%	7.50%	2.90%	60.60%
Female	Cases	108	115	57	15	295
	Percentage in Female	36.60%	39.00%	19.30%	5.10%	100.00%
	Percentage in total	14.40%	15.40%	7.60%	2.00%	39.40%
Sum	Cases	315	283	113	37	748
	Percentage in total	42.10%	37.80%	15.10%	4.90%	100.00%

Source: Author's own work

The survey results after the Xishan ecological management in 2019 showed that 37.7% of the people said they were very satisfied with the ecological environment of the Xishan area, 51.2% were relatively satisfied, and the two items accounted for 88.9% in total. Only 0.8% were dissatisfied with their choice. It shows that the respondents are generally satisfied or relatively satisfied with the ecological environment after Xishan's treatment. Among the male group, 38.9% and 49.2% said they were very satisfied and relatively satisfied respectively, with a total of 88.1%. Among the female group, 35.9% and 54.2% said they were very satisfied and relatively satisfied respectively, with a total of 90.1%. The two cumulative results show that the female group is 2 percentage points higher than the male group. It shows that women's overall satisfaction with the ecological environment in the Xishan area after 2019 is slightly higher than that of men (Fig. 94) (Table 51).

**Fig. 94 Personal perception of ecological environment after the ecological restoration**

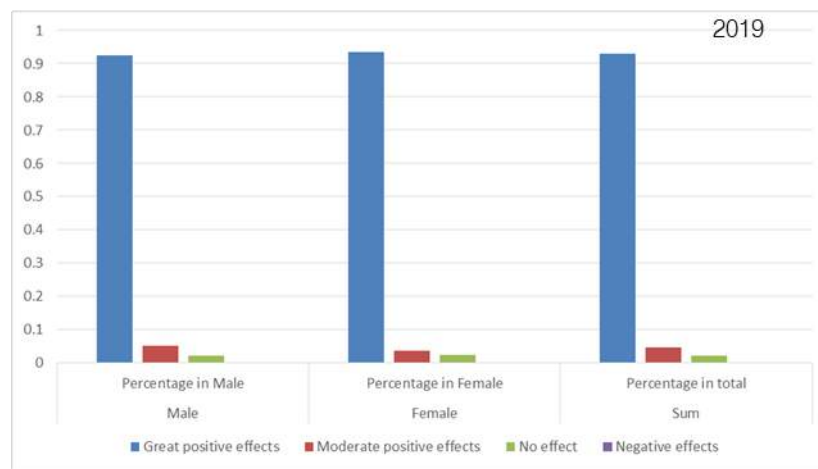
Source: Author's own work

Table 51 Personal Perception of Ecological Environment in Xishan area in 2019

Gender	Response	Relatively		Fairly	Dissatisfied	Sum
		Very satisfied	satisfied	satisfied		
Male	Cases	176	223	50	4	453
	Percentage in Male	38.90%	49.20%	11.00%	0.90%	100.00%
	Percentage in total	23.50%	29.80%	6.70%	0.50%	60.60%
Female	Cases	106	160	27	2	295
	Percentage in Female	35.90%	54.20%	9.20%	0.70%	100.00%
	Percentage in total	14.20%	21.40%	3.60%	0.30%	39.40%
Sum	Cases	282	383	77	6	748
	Percentage in total	37.70%	51.20%	10.30%	0.80%	100.00%

Source: Author's own work

In addition, 92.9% of the participants believed that the ecological environment after ecological governance in the Xishan area has had a very positive impact on their physical and mental health. Among them, 92.5% of men and 93.6% of women chose this option respectively, and the proportions are close. It shows that the vast majority of men and women gave very positive reviews (Fig. 95) (Table 52).

**Fig. 95 Personal perception of health effects after the ecological restoration (2019)**

Source: Author's own work

Table 52 Health effect perception of Xishan after ecological restoration

Gender	Response	Great positive effects	Moderate positive effects	No effect	Negative effects	Sum
Male	Cases	419	24	10	0	453
	Percentage in Male	92.50%	5.30%	2.20%	0.00%	100.00%
	Percentage in total	56.00%	3.20%	1.30%	0.00%	60.60%
Female	Cases	276	11	7	1	295
	Percentage in Female	93.60%	3.70%	2.40%	0.30%	100.00%
	Percentage in total	36.90%	1.50%	0.90%	0.10%	39.40%
Sum	Cases	695	35	17	1	748
	Percentage in total	92.90%	4.70%	2.30%	0.10%	100.00%

Source: Author's own work

According to the survey results on the ecological restoration elements that need to be further strengthened, the total proportion of people who chose Water environment (63.80%), Forest vegetation (52.40%), and Mountain surface damage (49.30%) exceeded or was close to 50%. Choosing Solid waste (44.70%) and Atmosphere (44.10%), Geological hazards (33.30%) exceed 30%. The proportion choosing Farmland soil (19.40%) is close to 20%. Among them, choose Mountain surface damage (male: 51.0%, female: 46.8%), Atmosphere (male: 45.0%, female: 42.7%), Geological hazards (male: 35.5%, female: 29.8%), the proportion of males is slightly larger female. Instead, choose Water environment (male: 60.7%, female: 68.5%), Forest vegetation (male: 49.4%, female: 56.9%), Solid waste (male: 42.6%, female: 47.8%), Farmland soil (male: 19.0 %, female: 20.0%) The proportion of women is slightly larger than that of men. It shows that men are more sensitive to the regional atmospheric environment and geological environment, while women are more sensitive to the water environment, vegetation environment and soil environment (Fig. 96) (Table 53).

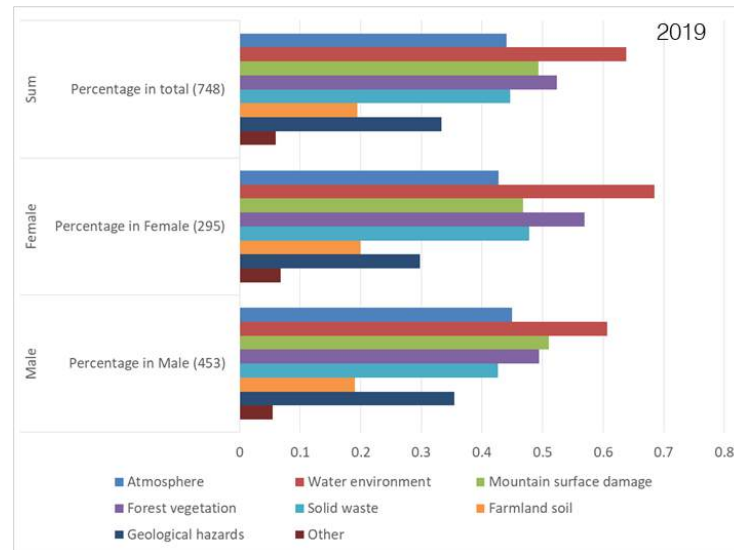


Fig. 96 Personal perception of ecological restoration elements

Source: Author's own work

Table 53 List of environmental governance elements requirements in Xishan

Questionnaire question	Environmental elements	Response				Total Cases (748)	Percentage of total cases (748)
		Male Cases (453)	Percentage in Male (453)	Female Cases (295)	Percentage in Female (295)		
In your opinion, which aspects of the ecological restoration of Taiyuan Xishan should be improved? (multiple-choice questions)	Atmosphere	204	45%	126	42.7%	330	44.1%
	Water environment	275	60.7%	202	68.5%	477	63.8%
	Mountain surface damage	231	51%	138	46.8%	369	49.3%
	Forest vegetation	224	49.4%	168	56.9%	392	52.4%
	Solid waste	193	42.6%	141	47.8%	334	44.7%
	Farmland soil	86	19%	59	20%	145	19.4%
	Geological hazards	161	35.5%	88	29.8%	249	33.3%
	Other	25	5.5%	20	6.8%	45	6%
Sum		1399	308.7%	942	319.3%	2341	313.0%

Source: Author's own work

(2) Health Perception of Activities and Facilities

The survey results of activity settings in Xishan area show that the options most chosen by all surveyed people include Leisure tourism (72.1%), Sports & fitness (62.4%), Park recreation (62.4%), etc. The proportion of people staying in Xishan area for short-term activities, Much higher than the proportion of people who choose long-term stay activities such as Residential life (41.7%), Work & study (26.9%). It can be seen that due to location, transportation, terrain and other reasons, the Xishan area has a high degree of public acceptance as a place for leisure, tourism, sports and other places.

As a place to live, work, study, etc., it can only be accepted by a small number of citizens. In addition, more than half (50.7%) of the people choose Elder care & health care, which shows that the Xishan area has considerable market recognition as a nursing home. Among options with higher activity intensity, such as Leisure tourism (male: 73.3%, female: 70.2%), Sports & fitness (male: 63.4%, female: 61.0%), the proportion of men choosing is slightly higher than that of women. For activities such as Park recreation (male: 60.9%, female: 64.7%), Residential life (male: 41.3%, female: 42.4%), Work & study (male: 26.0%, female: 28.1%), the intensity is lower. Among the options, the proportion chosen by women is slightly higher than that of men. As an elder care & health care place, Xishan area was chosen by nearly half of the men and nearly 60% of the women (male: 46.8%, female: 56.6%). The acceptance rate of the female group is significantly higher than that of the male group (Fig. 97) (Table 54).

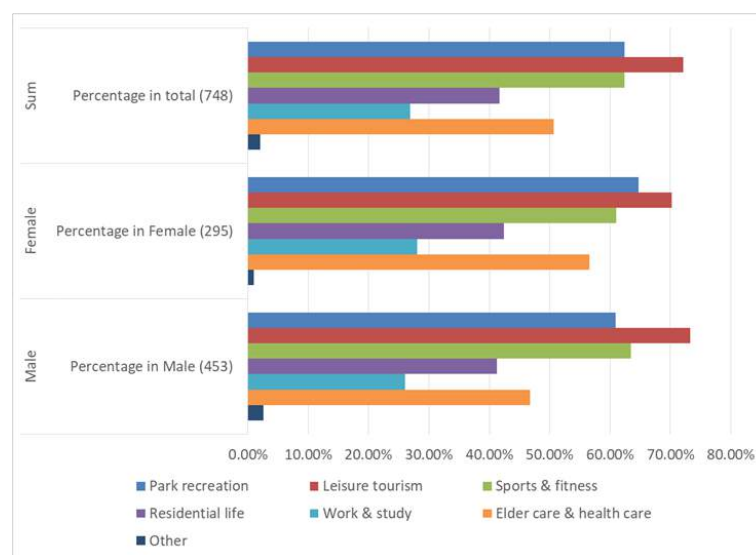


Fig. 97 Personal perception of activity settings in Xishan area

Source: Author's own work

Table 54 List of key requirements for activity types improvement in Xishan

Questionnaire question	Activity project types	Response				Total Cases (748)	Percentage of total cases (748)
		Male Cases (453)	Percentage in Male (453)	Female Cases (295)	Percentage in Female (295)		
What kind of activities do you want to enjoy in Taiyuan Xishan? (multiple-choice questions)	Park recreation	276	60.9%	191	64.7%	467	62.4%
	Leisure tourism	332	73.3%	207	70.2%	539	72.1%
	Sports & fitness	287	63.4%	180	61%	467	62.4%
	Residential life	187	41.3%	125	42.4%	312	41.7%
	Work & study	118	26%	83	28.1%	201	26.9%
	Elder care & health care	212	46.8%	167	56.6%	379	50.7%
	Other	12	2.6%	3	1%	15	2%
Sum		1424	314.3%	956	324.0%	2380	318.2%

Source: Author's own work

When it comes to the choice of leisure facilities in the Xishan area, men and women generally show relatively similar preferences. Among them, the proportion of men who chose Leisure sports facilities and venues (male: 53.4%, female: 48.1%) and Popular science education facilities (male: 47.5%, female: 45.8%) was slightly higher than that of women. And choose Parks and fitness trail system (male:66.2%, female:72.9%), Recreational bike path (male:38.4%, female:41%), Children's activity facilities and venues (male:49.0%, female:55.3%) ,Cultural and leisure tourism facilities (male:57.2%, female:61.0%), Sightseeing and leisure farms (male:50.6%, female:52.2%), the proportion of women is higher than the proportion of men. Combining the results of relevant options in the activity settings, it can be seen that men have greater demand for leisure facilities related to Leisure tourism, Sports & fitness than women. Women's demand for Park recreation-related leisure facilities such as hiking, cycling, and children's activities, as well as cultural and agricultural leisure facilities, is slightly greater than that of men (Fig. 98) (Table 55).

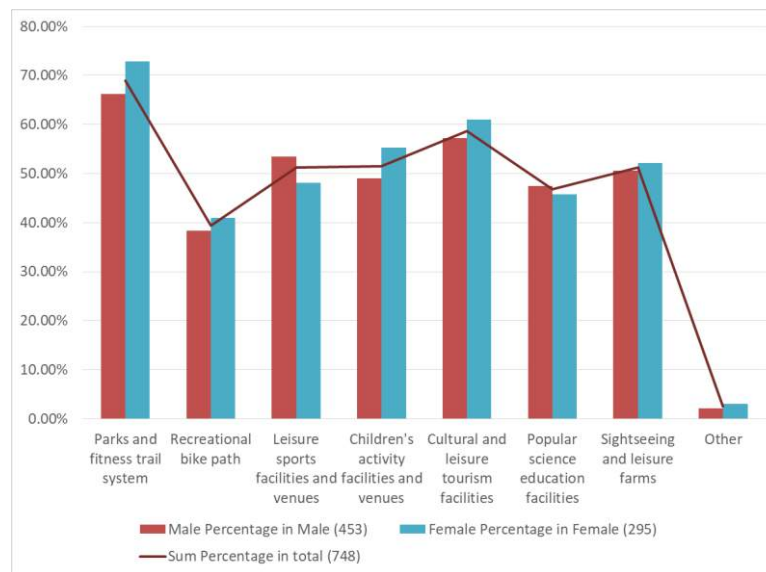


Fig. 98 Personal perception of leisure facilities in Xishan area

Source: Author's own work

Table 55 List of key requirements for regional tourist facility improvement in Xishan

Questionnaire question	Tourist Facilities	Response				Total Cases (748)	Percentage of total cases (748)
		Male Cases (453)	Percentage in Male (453)	Female Cases (295)	Percentage in Female (295)		
In your opinion, which tourist facilities in Xishan need to be improved? (multiple-choice questions)	Park tour and fitness trail system	300	66.2%	215	72.9%	515	68.9%
	Recreational bike path	174	38.4%	121	41%	295	39.4%
	Leisure sports facilities and venues	242	53.4%	142	48.1%	384	51.3%
	Children's activity facilities and venues	222	49%	163	55.3%	385	51.5%
	Cultural and leisure tourism facilities	259	57.2%	180	61%	439	58.7%
	Popular science education facilities	215	47.5%	135	45.8%	350	46.8%
	Sightseeing and leisure farms	229	50.6%	154	52.2%	383	51.2%
	Other	10	2.2%	9	3.1%	19	2.5%
Sum		1651	364.5%	1119	379.4%	2770	370.3%

Source: Author's own work

In the selections of public service facilities in the Xishan area, men and women have different needs. Combined with the results of related options in the activity settings, among options related to Leisure tourism such as Hotels (male: 37.1%, female: 28.1%), Public transportation (male: 66.9%, female: 60.3%), the proportion of men choosing is obvious higher than women. And in Restaurants (male: 54.7%, female: 57.6%), Leisure entertainment (male: 62.5%, female: 65.1%), Stores & shopping centers (male: 34.7%, female: 42.7%) related to Residential life, Among options such as

Hospitals & clinics (male: 49.0%, female: 54.6%), Schools & training institutions (male: 38.9%, female: 43.1%), women are slightly higher than men (Fig. 99) (Table 56).

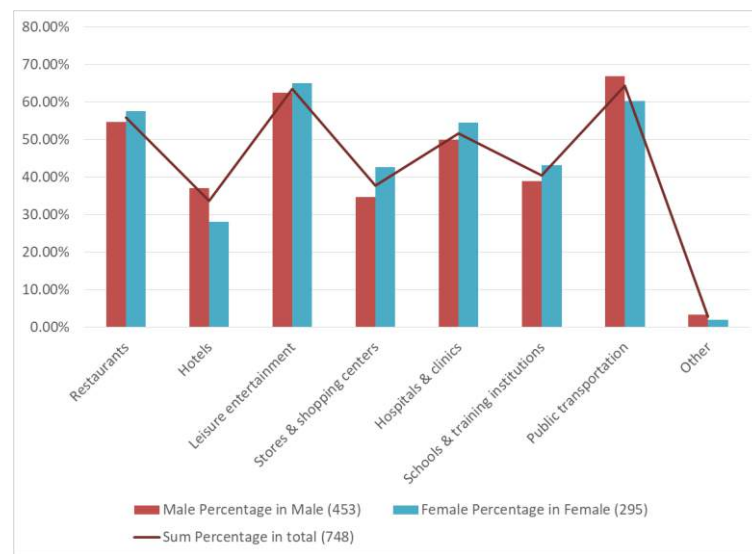


Fig. 99 Personal perception of public service facilities in Xishan area

Source: Author's own work

Table 56 List of key requirements for regional public service facility improvement in Xishan

Question naire question	Public service facilities	Response				Total Cases (748)	Percentage of total cases (748)
		Male Cases (453)	Percentage in Male (453)	Female Cases (295)	Percentage in Female (295)		
In your opinion, which public services in Xishan need to be improved? (multiple- choice questions)	Restaurants	248	54.7%	170	57.6%	418	55.9%
	Hotels	168	37.1%	83	28.1%	251	33.6%
	Leisure entertainment	283	62.5%	192	65.1%	475	63.5%
	Stores & shopping centers	157	34.7%	126	42.7%	283	37.8%
	Hospitals & clinics	226	49.9%	161	54.6%	387	51.7%
	Schools & training institutions	176	38.9%	127	43.1%	303	40.5%
	Public transportation	303	66.9%	178	60.3%	481	64.3%
	Other	15	3.3%	6	2%	21	2.8%
Sum		1576	348.0%	1043	353.5%	2619	350.1%

Source: Author's own work

(3) Health Perception of land-use and Industries

Among the land-use type options in the Xishan area, the highest proportion of all surveyed people selected Forest & park land (81.8%), exceeding 80%, and it was positively correlated with the Park recreation (62.4%) option in the activity setting. Related, it can be seen that most citizens have a positive attitude towards the construction of forest parks in Xishan area. The overall proportion of choosing

Recreational land (71.5%) and Elderly care land (50.4%) exceeds 50%, which is related to the related options in the activity settings (Leisure tourism (72.1%), Sports & fitness (62.4%), Elderly care land (62.4%), care & health care (50.7%).) shows a positive correlation, which shows that these two types of construction land have obvious market demand. Residential land (12.8%) and Commercial land (11.9%) are selected at a lower proportion, and are significantly lower than the proportion of Residential life (41.7%) related to them in the activity setting. The construction demand for this second type of land is far lower than the activity demand. It can be seen that even though many citizens yearn for living in the Xishan area, they still have a negative attitude towards the implementation of residential and commercial land construction. Through interviews, we learned that the improvement of the ecological environment in the Xishan area, the construction of transportation, municipal and other infrastructure, and the possibility of supply of land for this type of construction all affect citizens' choice of demand for land for this type of construction. There is a positive correlation between the selection of Educational land (32.0%) and the proportion of Work & study (26.9%) in the activity setting, indicating that educational land has certain market demand and construction implementation recognition. The proportion of people choosing Industrial land (6.0%) is low, and it is negatively correlated with the proportion of Work & study (26.9%) in the activity setting. This is related to the environmental pollution caused by industrial projects, indicating that most respondents are not willing to invest in Xishan. The region continues to develop industrial-related construction. The proportion of people choosing Agricultural land (15.1%) is low, which is related to the low proportion of existing agricultural land in the Xishan area. This result shows that most respondents have no intention of increasing agricultural land in the Xishan area. Comparing the results of relevant options for men and women, the proportion of men who choose Residential land (male: 14.6%, female: 10.2%) is 4.4 percentage points higher than that of women, and the proportion of men who choose Commercial land (male: 15.5%, female: 6.4%) is higher. The proportion of men who choose Industrial land (male: 6.8%, female: 4.7%) is 2.1 percentage points higher than that of women. These three land uses are negatively correlated with related options in activity settings (Residential life (male: 41.3%, female: 42.4%), Work & study (male: 26.0%, female: 28.1%)). This shows that men are more accepting of construction land development in this area than women. Females are slightly more likely than males to choose Forest & park land (male: 81.5%, female: 82.4%), Agricultural land (male: 13.9%, female: 16.9%), and other non-construction land. The proportion of men and women who chose Recreational land (male: 71.5%, female: 71.5%) was even. In addition, more women than men chose Educational land (male: 31.1%, female: 33.2%), Elderly care land (male: 47.9%, female: 54.2%). This result is consistent with the related options in the activity settings (Work & study, There is a positive correlation between the male and female ratios in Elder care & health care (Fig. 100) (Table 57).

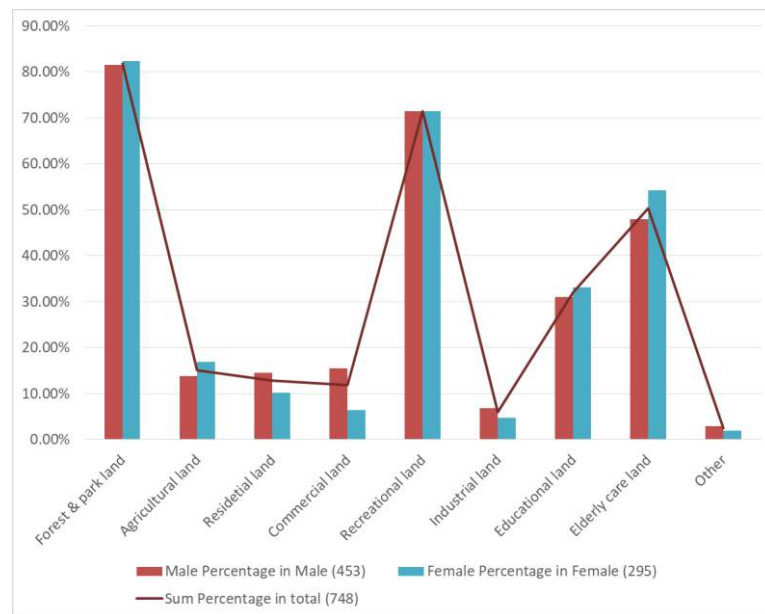


Fig. 100 Personal perception of land-use categories in Xishan area

Source: Author's own work

Table 57 List of land-use form demands in Xishan

Question naire question	Land-use forms	Response				Total Cases (748)	Percentage of total cases (748)
		Male Cases (453)	Percentage in Male (453)	Female Cases (295)	Percentage in Female (295)		
How do you think the mine wastelands in Xishan could be reused after ecological restoration? (multiple- choice questions)	Forest & park	369	81.5%	243	82.4%	612	81.8%
	Agricultural	63	13.9%	50	16.9%	113	15.1%
	Residential	66	14.6%	30	10.2%	96	12.8%
	Commercial	70	15.5%	19	6.4%	89	11.9%
	Recreational	324	71.5%	211	71.5%	535	71.5%
	Industrial	31	6.8%	14	4.7%	45	6.0%
	Educational	141	31.1%	98	33.2%	239	32.0%
	Elder care & health care	217	47.9%	160	54.2%	377	50.4%
	Other	13	2.9%	6	2%	19	2.5%
Sum		1294	285.70%	831	281.50%	2125	284.00%

Source: Author's own work

Among the options for rural development in the Xishan area, most respondents chose Develop tertiary industries (such as leisure tourism) (84.0%), which is positively correlated with the proportion of leisure tourism (72.1%) selected in the activity setting. It can be seen that the development of the tertiary industry in Xishan rural areas is recognized by most of the respondents. Develop characteristic agriculture and forestry (69.4%) occupies a larger proportion, and is positively correlated with the proportion of Forest & park land (81.8%) among the land types in the Xishan area, indicating that the development of agriculture and forestry is in line with the respondents' expectations for ecological development in rural Xishan areas. industries, as well as the demand for ecological land after ecological restoration. The proportion of Develop rural industries

(18.2%) is relatively low, indicating that most respondents are unwilling to continue to develop industrial-related construction in Xishan rural areas and oppose rural industrial pollution. Relocate villages to the foot of the mountain (24.9%), indicating that most respondents support the construction and development of local communities and have a negative attitude towards the overall relocation of existing villages. Among them, the proportion of men to Develop rural industries (male: 18.8%, female: 17.3%) and Relocate villages to the foot of the mountain (male: 32.0%, female: 13.9%) is higher than that of women, indicating that men are more important to the development of rural areas. Attitudes to both industrial and village relocation were relatively tolerant. However, women's support rate for Develop characteristic agriculture and forestry (male:68.9%, female:70.2%) and Develop tertiary industries such as leisure tourism (male:81.7%, female:87.5%) is higher than that of men, indicating that women have a strong support for rural areas. The support rate for regional development of ecological industries is higher than that of men (Fig. 101) (Table 58).

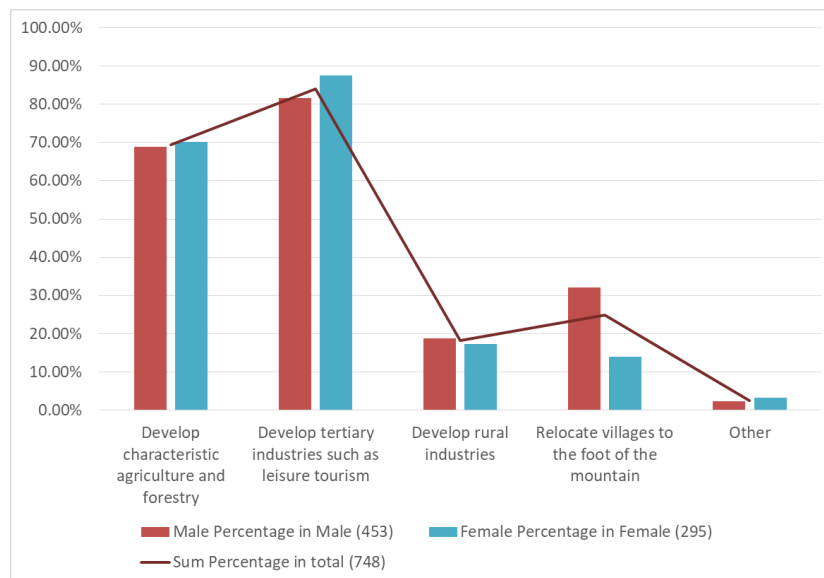


Fig. 101 Personal perception of rural development in Xishan area

Source: Author's own work

Table 58 List of rural development demands in Xishan

Question naire question	Rural development	Response				Total Cases (748)	Percentage of total cases (748)
		Male Cases (453)	Percentage in Male (453)	Female Cases (295)	Percentage in Female (295)		
	Develop characteristic agriculture and forestry	312	68.9%	207	70.2%	519	69.4%
How do you think rural developme nt should be guided in Xishan?	Develop tertiary industries such as leisure tourism	370	81.7%	258	87.5%	628	84%
	Develop rural industries	85	18.8%	51	17.3%	136	18.2%
	Relocate villages to the foot of the mountain	145	32%	41	13.9%	186	24.9%
	Other	10	2.2%	9	3.1%	19	2.5%
	Sum	922	203.60%	566	192.00%	1488	199.0%

Source: Author's own work

Among the options for developing the energy industry in Xishan area, the proportion of those who choose traditional coal and other traditional energy (32.4%) is low. It can be seen that due to pollution emissions and resource depletion, the respondents are willing to continue to develop the traditional energy industry in Xishan area. lower. The proportion of developing Solar energy (76.5%) and Wind energy (62.0%) both exceeded 60%, indicating that the respondents have a high willingness to develop new energy industries. The proportion of people who choose Biomass energy (29.3%) is relatively low. The main reason is that the source of raw materials for producing Biomass energy and its usage are subject to certain restrictions in the Xishan area, so it is not generally recognized by the respondents. The proportions of men and women choosing various energy industries are relatively similar. Among them, the proportion of men and women who choose to develop Coal and other traditional energy (male: 32.0%, female: 32.9%) is almost the same, indicating that both male and female respondents are less willing to develop traditional energy industries in the Xishan area. Choosing to develop Solar energy (male:77.3%, female:75.3%), the proportion of males is slightly higher than that of females. The proportion of women who choose to develop Wind energy (male: 60.9%, female: 63.7%) and Biomass energy (male: 26.3%, female: 33.9%) is slightly higher than that of men. This shows that men and women have strong consistency in their recognition of various energy industries (Fig. 102) (Table 59).

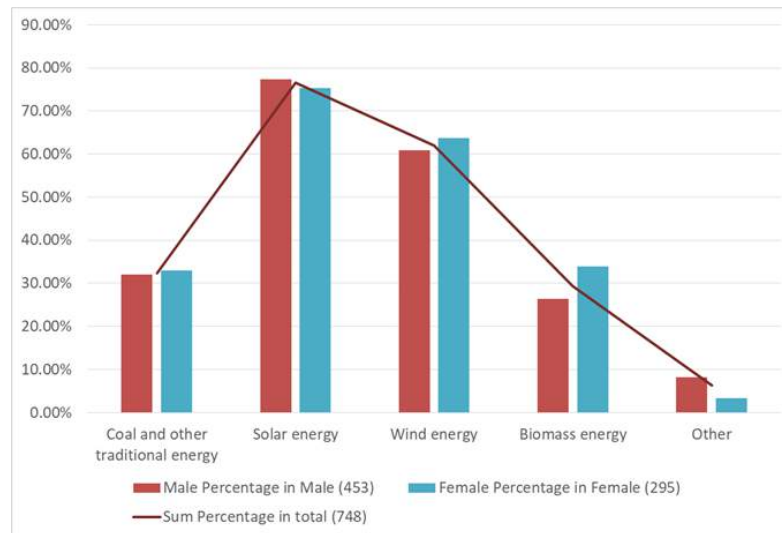


Fig. 102 Personal perception of energy industry development in Xishan area

Source: Author's own work

Table 59 List of energy industry development demands in Xishan

Questionnaire question	Energy industries	Response				Total Cases (748)	Percentage of total cases (748)
		Male Cases (453)	Percentage in Male (453)	Female Cases (295)	Percentage in Female (295)		
What types of energy production do you think could be developed in the future in Xishan? (multiple-choice questions)	Coal and other traditional energy	145	32%	97	32.9%	242	32.4%
	Solar energy	350	77.3%	222	75.3%	572	76.5%
	Wind energy	276	60.9%	188	63.7%	464	62%
	Biomass energy	119	26.3%	100	33.9%	219	29.3%
	Other	37	8.2%	10	3.4%	47	6.3%
	Sum	927	204.70%	617	209.20%	1544	206.50%

Source: Author's own work

(4) Health Perception of suburban forest parks

Among the options of 16 suburban forest parks in the Xishan area, the parks that were selected by more than 30% of the total were Yuquanshan Suburban Forest Park (72.8%), Xishan National Mine Suburban Forest Park (37.3%), Xishan Maple Forest Park (36.3%), Changfeng Suburban Forest Park (32.1%). Suburban Forest Park (37.3%), Xishan Maple Forest Park (36.3%), Changfeng Suburban Forest Park (32.1%). Among them, the selection of Yuquanshan Suburban Forest Park is significantly higher than the others, which is related to its higher level of construction and better facilities. The parks with an total selection rate of less than 5% were Shengke Suburban Forest Park (4.6%), Yaxin Suburban Forest Park (4.4%), Traditional Chinese Medicine Suburban Forest Park (4.3%).). The parks with the lower percentage of selections were all parks with lower levels of construction and simpler facilities. The total percentage

of selection was positively correlated with the overall construction level of the parks.

However, among the options of 16 suburban forest parks in the Xishan area, men and women showed different tastes. In 12 parks, the proportion of men's choices was higher than women's. In 4 parks, the proportion of women's choices was higher than that of men's choices. There are three parks where the gap between the proportions chosen by men and women is less than 1%, including Shengke Suburban Forest Park (men: 4.9%; women: 4.1%), Guanshan Suburban Forest Park (men: 19%; women: 18.6%) and Gasification Suburban Forest Park (men: 6.2%; women: 6.4%). In another 13 parks, the gap between the proportion of male and female choices was greater than 1%. Among them, those with a gap of more than 5% include Changfeng Suburban Forest Park (men: 37.4%; women: 24.1%), Yuquanshan Suburban Forest Park (men: 69%; women: 78.6%) and Xishan Maple Forest Park (men: 33.6%; women: 40.3%). The result shows that men and women have certain differences in their preferences for parks. The main reasons include that Changfeng Suburban Forest Park is mainly a high-end business and sports park, and the proportion of men using it is significantly higher than that of women, and the gender choice gap reaches 13.3%. Yuquanshan Suburban Forest Park and Xishan Maple Forest Park are both comprehensive country parks with a relatively high level of construction. The gap between the proportions of men and women choosing them is 9.6% and 6.7% respectively, indicating that women prefer these types of parks (Fig. 103) (Table 60).

Table 60 List of personal preferences of 16 suburban forest parks in Xishan

Suburban forest parks	Response				Total Cases (748)	Percentage of total cases (748)
	Male Cases (453)	Percentage in Male (453)	Female Cases (295)	Percentage in Female (295)		
Gangsheng Suburban Forest Park	45	10%	18	6.1%	63	8.4%
Yaxin Suburban Forest Park	26	5.8%	7	2.4%	33	4.4%
Guoxin Suburban Forest Park	49	10.8%	27	9.2%	76	10.2%
Shengke Suburban Forest Park	22	4.9%	12	4.1%	34	4.6%
Traditional Chinese Medicine Suburban Forest Park	24	5.3%	8	2.7%	32	4.3%
Gengyang Suburban Forest Park	28	6.2%	11	3.7%	39	5.2%
Yuquanshan Suburban Forest Park	312	69%	232	78.6%	544	72.8%
Changfeng Suburban Forest Park	169	37.4%	71	24.1%	240	32.1%
Guanshan Suburban Forest Park	86	19%	55	18.6%	141	18.9%
Kangpei Suburban Forest Park	52	11.5%	22	7.5%	74	9.9%
Aiwan Suburban Forest Park	44	9.7%	24	8.1%	68	9.1%
Huantou Tianli Suburban Forest Park	22	4.9%	10	3.4%	32	4.3%
Gasification Suburban Forest Park	28	6.20%	19	6.4%	47	6.3%
Xishan Olympic Sports Suburban Forest Park	87	19.2%	61	20.7%	148	19.8%
Xishan National Mine Suburban Forest Park	175	38.7%	104	35.3%	279	37.3%
Xishan Maple Forest Park	152	33.6%	119	40.3%	271	36.3%
Sum	1321	292.2%	800	271.20%	2121	283.90%

Source: Author's own work

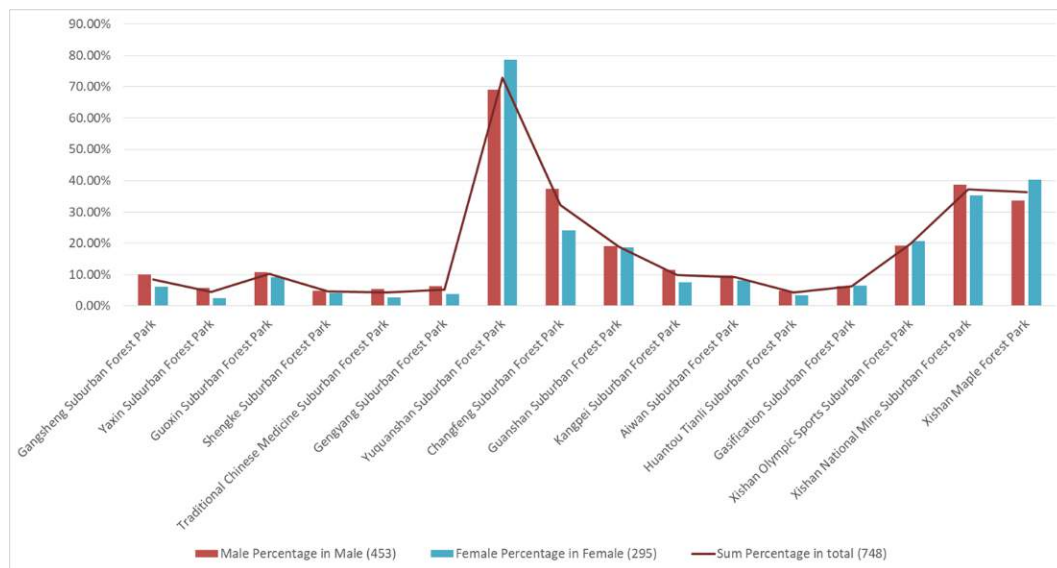


Fig. 103 Personal perception of 16 suburban forest parks in Xishan area

Source: Author's own work

9.5 Conclusion of healthy reuse study of Xishan

Based on the perspective of urban and rural residents' perception of health needs, this study re-examined the reuse methods of the Xishan mine wasteland and investigated urban and rural residents' perceptions of the Xishan governance project and their demands for further construction and development. The results showed that the health and safety of the environmental quality after the ecological restoration in the Xishan area had been recognized by Taiyuan citizens, especially those in close proximity to the area. And the majority of those who participated in the survey believe that the environmental improvements in the Xishan area had contributed to their physical and mental health. Those participants had high expectations for the quality of the healthy environment in the Xishan area, especially for environmental quality such as water, mountain surface restoration, and air. There was still widespread public demand for continuous promotion and improvement of regional ecological governance.

The demands of participants for public projects such as green space and leisure tourism in the Xishan area are significantly higher than those for private projects such as residences and commerce. And the equity of the social service scope of regional construction projects needed to be reflected in a greater way. The results of the study also showed that the participants of Taiyuan citizens had diversified appeals for the types of land use and activities that could be provided in the Xishan area, and a single reuse model was difficult to meet the development needs of citizens in the new era, for different participating groups had different activity preferences. Therefore, the next step of governance and construction in the Xishan area should comprehensively consider the specific needs of various groups of people. This study also confirmed that the development of leisure tourism was one of the most important reuse methods in the

Xishan area, and it was also one of the most practical and effective ways to promote the feasible and healthy development of the area where the ecological restoration of mine wasteland was located. In addition, the low-carbon development of the regional industrial economy in the Xishan area had become the consensus of most participants.

In addition, different gender group citizens have different demand for the programs and services provided by the mine regeneration. In the process of ecological restoration of mining areas, construction of related projects, and setting up activities, the different perception characteristics of men and women should be taken into account in order to satisfy the public's satisfaction with regional restoration construction and achieve a more equitable construction. In order to promote the gender equity of mine reuse construction, it is necessary to promote the development and improvement of gender equity of mine regeneration construction from the aspects of improving the management measures, encouraging the public to participate in the planning and construction, promoting the integration of the regional health economy and industry, expanding the content of health services, and strengthening the creation of a healthy environment for both genders.

In summary, in order to adapt to the urban and rural construction and the health needs of Taiyuan citizens, the mine wasteland reuse construction in the Xishan area should be paid more attention to the development demands of health safety, health equity, health service quality, and low-carbon industry options.

Due to time and financial constraints, this study was only a free questionnaire survey using a public web platform for the study case of Xishan, and there was a certain deviation between the structure of the participants and the demographic structure of the citizens of Taiyuan, concentrating more on those who are close stakeholders at this stage, such as urban residents, people with higher education, middle-aged and elderly people, and urban and rural residents who live within 10 kilometers from Xishan. More research is needed to derive the perceived overall health needs of Taiyuan citizens in the Xishan area, with additional studies in different urban and rural areas, different educational backgrounds, different age groups of people, etc.

In addition, the restoration and construction of the Xishan area in Taiyuan is a work that is constantly advancing and developing dynamically. The success of its final construction requires continuous attention to the health needs of residents and their potential changes. The research on residents' perception of health needs for mine wasteland reuse construction is still in the early stage. Based on the case study of Xishan, this research proposes to relevant government management, planning and design, and construction implementation staff that considering the health needs of stakeholders is an important factor in ensuring the success of the reuse of abandoned mine land and promoting the sustainable development of regional health undertakings.

Part 4 Conclusions and Discussion

10 Chapter 10 Conclusion and Discussion

10.1 Conclusion

This thesis studies the ecological restoration benefits and the ecological services of the restored mine wasteland under the concept of healthy city, the feasibility and paths of ecological restoration of mine wasteland and transformation into a healthier place. It reveals the healthier benefits of reusing the restored mine wasteland to its inhabitants. Through public environmental data collection and analysis, on-site interviews, and public surveys, it presents the key points and strategies for reusing after the ecological restoration of mine wasteland.

Conclusion 1: Based on the theory and case analysis of this thesis, the main steps and measures for the restoration and management of the atmosphere, water, soil and other ecological environments in mining areas guided by the healthy ecological models include:

The first is to close and control sources of environmental pollution in the areas where mines are located, including closing mine production and mining areas with serious pollution, enterprises and factories that discharge serious pollutants, etc. Promote the transformation and upgrading of production technology in existing industrial and mining enterprises, improve existing production processes, promote recycling production, clean production, and build green mines. Strengthen environmental supervision and management of pollution emissions from regional factories and enterprises to ensure that factories and enterprises meet environmental protection standards. The second step is to clean up (or purify) the pollutants left behind by the mine, including sewage, solid waste, contaminated soil, etc. Due to the strong correlation between the atmosphere, water, soil and other natural elements in the mining area ecosystem, pollution of one element will affect the ecological security of other elements. Therefore, mining areas should carry out coordinated management of various elements and strive to comprehensively restore the ecosystem. Achieve relevant ecological and environmental indicators to meet the standards of a healthy city. The third is the need to repair green infrastructure construction sites. Including engineering treatment and repair of surface damage caused by mining, natural terrain restoration, surface covering, geological disaster prevention, etc. The restored site will meet the standards for green infrastructure plant planting and related project construction. The fourth is to carry out green planting on the site. Combined with the construction requirements of green infrastructure projects and the specific problems and conditions of site contamination, the short-term and long-term ecological restoration effects of

different vegetation, as well as the beneficial effects on human health, are fully considered for vegetation selection and planting restoration. The fifth is to carry out green infrastructure and healthy project construction in combination with the relevant goals and requirements of ecological environment management and healthy cities. Full consideration should be given to the greening of the original gray infrastructure in the mining area, and technical means such as low-impact development should be adopted to restore the original hydrological environment of the site. Encourage and promote the development of regional green transportation, green energy, etc. Encourage the construction of regional health service projects, and promote healthy urban construction environment and services to fully meet standards.

Conclusion 2: The atmosphere, water, and soil environment in the mining area are organic components of the urban ecosystem, affecting each other and having different degrees of correlation. Among them, the atmospheric environment in mining areas has the strongest correlation with the urban atmospheric environment, followed by the water environment, and the external influence of the soil environment is weak. Among the main ecological management measures, controlling and reducing related pollution emissions to the atmosphere, water and soil at the site is the most effective way to improve regional environmental health. The construction of green infrastructure plays a supporting role in improving the environmental quality of the site, but due to its ecological characteristics, it can reduce secondary pollution that may be caused by the use of other ecological management methods. Achieving healthy environmental quality standards for the atmosphere, water, and soil in mining areas through ecological management is the most effective way to reduce exposure to regional environmental pollution and protect population health. Green infrastructure (GI) plays a certain supporting role in reducing exposure to environmental pollution. Since GI can provide healthy activity venues and services, the ecological management of mining areas combined with GI construction can further improve the health benefits of regional ecological management.

Research shows that the ecological environment of the mining area after comprehensive restoration and treatment has good internal and external ecological environmental benefits, and can significantly improve the ecological environment quality of the mining area and surrounding urban areas. Ecological governance in mining areas is conducive to promoting the health of the ecological environment in the city to meet standards. Using the renovated mining sites for green infrastructure construction can create a green, ecological, healthy and high-quality regional environment, provide urban and rural residents with good healthy activity venues and services, and help improve the health and well-being of urban and rural residents, attract social investment, and promote The overall improvement and standard of healthy city construction in the city where it is located. It is an effective means to transform traditional mining cities into healthy and sustainable cities.

Conclusion 3: The research indicates that compared with a single green reclamation model, the comprehensive development model of composite functions can better meet the demands of urban and rural residents for high-quality healthy environment and

services related to the reuse construction of large-scale abandoned mine lands in peri-urban areas. The research results also indicate that full attention should be paid to the development demands of the region in areas such as health safety, health equity, health facility and service quality, and healthy low-carbon industry options. This includes the sustainable restoration and improvement of the natural ecological environment of all factors to ensure regional ecological health and safety; improving the types and levels of regional facilities and activities; promoting the health equity and fairness of local communities; and promoting the low-carbon development of regional economic industries. In addition, the preferences and biases of people of different age groups, with different professions, and from different living distances should be fully considered. Considering the health needs of stakeholders can ensure that the reuse of mine wastelands is in line with the public interest, increase the public's satisfaction with the implementation of construction, attract market demand, facilitate input–output balance for construction, and promote the creation of a high quality, healthy and sustainable urban environment.

10.2 Research innovation

The ecological restoration and reuse construction of mining areas are hot research issues in the field of urban planning, and are also practical issues that need to be solved urgently in the process of transformation and sustainable development of global resource-based cities. From the perspective of a healthy city, this article takes the abandoned land in large-scale mining areas in the suburbs as the research object, and takes the comprehensive management and construction project of the ecological and cultural tourism demonstration zone in Xishan Mining Area, Taiyuan City, Shanxi Province, China as a case study to explore the ecological restoration and restoration of mining areas in conjunction with healthy city construction. Reuse construction measures, steps, strategies and their impact on urban sustainable development. It is forward-looking in topic selection, and the innovation points in three levels of cognition, method and practical application are as follows.

Innovation point 1: At the cognitive level, the concept, connotation, key elements, and scope of application of “urban health” and “mine areas” are put forward, and made development on relative conceptual contributions. It provides an understanding of the relationship between ecological restoration and reuse construction in mining areas, urban and rural public health promotion and healthy city construction. The study defines and evaluates the site and environment formed after the ecological restoration and reuse construction of the mining area based on the target concept and decisive factors of a healthy city. The key elements and required characteristics of ecological restoration and reuse construction in healthy mining areas are summarized, with collections of the set of presentative global practice cases.

Innovation point 2: At the method level, a theoretical framework for healthy ecological restoration and reuse models and methods in mining areas is proposed. Through research and summary of relevant theories such as environmental governance

in mining areas, healthy cities and ecological cities, smart Growth, green infrastructure, sustainable development, etc., a theoretical framework for the construction model of healthy mining areas is established. The study also re-examined the relationship between mining areas and urban space from the perspective of public health, summarized their mutual influence and correlation, and proposed concepts, models and methods for mutual promotion of development.

Innovation point 3: At the practical application level, measures, steps, and strategies for ecological restoration and reuse of healthy mining areas are proposed. Through an in-depth study of the Taiyuan Xishan case, we summarized the construction conditions needed to build a healthy mining area, as well as the key technical measures and development steps for ecological restoration and reuse construction. Comprehensive analysis of the development strategies and implementation effects of healthy mining areas from the aspects of policies and regulations, economic society, land use, public service facilities, etc.

10.3 Limitation and further discussion

Research on healthy ecological restoration and reuse methods for large-scale mine wastelands in suburban areas is still in its infancy. The ecological restoration and reuse construction of large-scale mining areas is a long-term and dynamic development task. Future research on its health effects will also need to continue to pay attention to possible changes in the regional ecological environment and urban and rural construction environments, as well as potential changes in the health needs of residents and different types of people in different regions and categories.

Overall, this study focuses on the healthy ecological restoration and reuse of large suburban mining areas. There are still many valuable research questions to be further explored. On the basis of this study, the following research can be carried out in the future:

(1) Further explore policies and strategies for laws and regulations, government management and supervision, financing support guarantees, promotion of regional industrial transformation and upgrading, technological innovation, public participation, etc. for the restoration and reuse of healthy ecosystems in mining areas.

(2) Based on the static spatial pattern analysis, further explore the possible changes and interrelationships in the time dimension between mining area governance and construction, urban health promotion and healthy space, and conduct a multi-scenario simulation analysis of possible future spatial patterns. Propose coping strategies in the professional field of urban and rural planning.

(3) From the perspective of healthy management and construction of other types of mining areas and brownfields, further expand this research direction. Urban and rural brownfields destroy the ecological environment and intensify the tension between urban and rural populations, land, resources, and environment. The healthy transformation and development of urban and rural brownfields can improve the urban and rural ecological environment, expand urban and rural development space, improve

urban quality, and then solve more problems. Problems faced in the field of urban and rural planning and construction.

Based on the basic theories of urban and rural planning and public health, environmental studies and other related interdisciplinary theories, combined with cases related to mining area governance and construction and healthy cities, this paper explores the research framework and methods for ecological restoration and reuse construction of healthy mining areas. The research results can provide valuable references for government management, related research, planning and design, development and construction implementation and other related work.

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Appendices

Appendix 1

Questionnaire for health needs perceptions of Taiyuan Xishan

Dear citizens of Taiyuan, the healthy environment and services of Xishan are very important for our daily lives. This is a questionnaire for your health needs perceptions of the reuse construction of Xishan. The specific scope of Taiyuan Xishan is referred to as the Taiyuan Xishan Ecological and Cultural Tourism Demonstration Zone. The base is located in the Jiancaoping District, Wanbailin District, and Jinyuan District of Taiyuan City, which is east to the West Ring Expressway, west to the boundary of Jiancaoping, Wanbailin, and Jinyuan District of Taiyuan city, north to the Fen River, and south to the southern boundary of Yaocun Town. and please take your precious time to complete the following questionnaire survey. Thank you!

1. What is your impression of the environmental pollution of Taiyuan Xishan before the ecological restoration in 2006? (single-choice question)
 - Environmental pollution is severely polluted
 - Environmental pollution is moderately polluted
 - Environmental pollution is lightly polluted
 - The environment is not polluted
2. Are you satisfied with the environment after the ecological restoration of Taiyuan Xishan in 2019? (single-choice question)
 - Very satisfied
 - Relatively satisfied
 - Fairly satisfied
 - Dissatisfied
3. What do you think of the effects of the ecological restoration of Xishan on your physical and mental health? (single-choice question)
 - Great positive effects
 - Moderate positive effects
 - No effect
 - Negative effects

4. In your opinion, which aspects of the ecological restoration of Taiyuan Xishan should be improved? (multiple-choice question)
- Atmosphere
 - Water environment
 - Mountain surface damage
 - Forest vegetation
 - Solid waste
 - Farmland soil
 - Geologic hazards
 - Other
5. What kind of activities do you want to enjoy in Taiyuan Xishan? (multiple-choice questions)
- Park recreation
 - Leisure tourism
 - Sports and Fitness
 - Residential life
 - Work and study
 - Elder care and healthcare
 - Other
6. How do you think the mine wastelands in Xishan could be reused after ecological restoration? (multiple-choice question)
- Forest and park
 - Agricultural
 - Residential
 - Commercial
 - Recreational
 - Industrial
 - Educational
 - Elder care and healthcare
 - Other
7. In your opinion, which public services in Xishan need to be improved? (multiple-choice question)
- Restaurants
 - Hotels
 - Leisure entertainment

- Stores and shopping centers
 - Hospitals and clinics
 - Schools and training institutions
 - Public transportation
 - Other
8. In your opinion, which tourist facilities in Taiyuan Xishan need to be improved?
(multiple-choice question)
- Park tour and fitness trail system
 - Recreational bike path
 - Leisure sports facilities and venues
 - Children's activity facilities and venues
 - Cultural and leisure and tourism facilities
 - Popular science education facilities
 - Sightseeing and leisure farms
 - Other
9. What types of energy production do you think could be developed in the future in Xishan? (multiple-choice questions)
- Coal and other traditional energy
 - Solar energy
 - Wind energy
 - Biomass energy
 - Other
10. How do you think rural development should be guided in Xishan?
- Develop characteristic agriculture and forestry
 - Develop tertiary industries such as leisure tourism
 - Develop rural industries
 - Relocate villages to the foot of the mountain
 - Other
11. What is your gender?
- Male
 - Female
12. When were you born?
- Born after 1950 (1950-1959)
 - Born after 1960 (1960-1969)
 - Born after 1970 (1970-1979)
 - Born after 1980 (1980-1989)
 - Born after 1990 (1990-1999)

- Born after 2000 (2000-2009)
13. What is your profession?
- Employees of enterprises
 - Students
 - Civil servants
 - Farmers
 - Self-employed
 - Practitioners of environmental engineering and urban planning
 - Other
14. What is your educational background?
- Junior high school or below
 - High school or technical, vocational school
 - Undergraduate and junior college
 - Master's degree or above
15. What is the distance between your residential area and Taiyuan Xishan?
- Within the Xishan area
 - Within 1,000 meters
 - 1,000-5,000 meters
 - 5,000-10,000 meters
 - More than 10,000 meters