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ISSN (Print: 2357-0849, online: 2357-0857)

Environmental Science and Sustainable Development

Research Paper
Received: 23 July 2023, Accepted: 16 August 2023, Published online: 30 September 2023
DOI: 10.21625/essd.v8i4.976

Using Resilience to Analyze Changes in an Industrial Community in China

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Abstract

Besides its systematic identification with disasters and hazards, resilience could be a powerful tool for understanding changes in the built environment. This study analyses the development of the workers' residential area in an industrial community (IC) in China after its economic transformation. How can a resilience approach help analyze the impact of economic changes on the built environment?

ICs were self-contained and multifunctional compounds that first emerged in socialist China in the 1950s and were used to organize social production (factory) and collective life (workers' residential areas). Although existing research has explored the possible changes in the built environment of ICs before and after economic transformation, these changes that have either taken place or are still happening have never been quantified. Additionally, the impact of changes in the level of enclosure of workers' residential areas after the factory bankruptcy, a distinctive aspect of the built environment, has seldom been explored. Thus, this study uses a resilience approach to analyze the impact of changes in the level of enclosure on the built environment of the workers' residential area after the factory bankruptcy by taking the case of Shanxi Knitting Factory (SKF) in Taiyuan, China.

This study seeks to use resilience to understand changes in ICs under the background of China's economic transformation. The finding shows that the factory bankruptcy significantly impacts the changes in the built environment of its workers' residential area, as well as affecting the level of enclosure in the built environment. With the disappearance of enclosures after the factory bankruptcy, the workers' residential area of the SKF is gradually shifting from an enclosed, isolated, and self-contained industrial auxiliary facility to an open, diversified, and heterogeneous space. It is gradually integrating into the surrounding urban neighborhoods.

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Keywords

Resilience; Built environment; Industrial communities; Factory bankruptcy; Workers' residential area;

1. Introduction

After the founding of the People's Republic in 1949, most factories were structured into a state production unit administrative system known as industrial communities (ICs) (Lü & Perry, 2015). From then until the 1980s, ICs served not only as workplaces but also as the principal social institutions around which the lives of most urban

residents were organized (Schurmann, 1966). A typical IC primarily consisted of three elements located in close geographical proximity: production, housing, and social facilities (Whyte & Parish, 1985). These components were further integrated into two main sections of an IC: the factory used for production and the workers' residential area, which contained most social facilities. The factory comprised a series of workshops, warehouses, and equipment rooms. In contrast, the workers' residential area provided housing and other essential social facilities, such as health care, recreation, and education (Bonino & De Pieri, 2015).

ICs played a pivotal role in Chinese society, combining political, economic, and social functions (Dittmer & Xiaobo, 1996). To demonstrate and highlight the advantages of the socialist system, ICs provided their members with a comprehensive welfare arrangement known as taking care of people "from the cradle to the grave" (Walder, 1986). For instance, IC members could secure lifelong jobs with a stable income in these factories, a social assurance termed the "iron rice bowl" (Ding et al., 2020). In return, members and their families could access various social facilities in workers' residential areas, catering to their daily needs.

A primary feature of ICs was their strategic space allocation and functional division, both of which were essential for efficient production and the promotion of collective living. Walls, in this context, played a significant role. As Bray (2005) observed, walls not only established the boundaries of ICs but also separated them into distinct working and living areas. This perspective is further supported by Lü & Perry (2015), who pointed out that walls when combined with gates, set ICs apart from the wider cityscape. Additionally, within the workers' residential areas, walls further divided space into smaller living units and public spaces, thereby enhancing the privacy of their residents (Gaubatz, 1998).

However, during China's economic transformation in the 1980s, the public perception of ICs began to shift. They were increasingly regarded as relics — both institutionally and physically — that hindered urban development (Zhang et al., 2021). The following decade witnessed numerous factories, compromised by poor management, that finally succumbed to bankruptcy. Due to the strains of enterprise reform and escalating market competition, a significant number of ICs were repurposed for commercial endeavors. As a result, the identity that once characterized ICs diminished, with their sense of collectivism being eroded in the face of economic change. This transformation inevitably influenced the built environment, reshaping social dynamics and lifestyles of residents within workers' residential areas, and potentially introducing new societal spaces and tensions (Ye et al., 2021). Nevertheless, few studies have focused on the relationship between changes in the built environment of the workers' residential areas within ICs, as industrial auxiliary facilities, and the operating status of the factory.

In recent years, the concept of resilience has emerged in urban studies as a valuable tool for explaining changes in the built environment, particularly for alleviating the effects of political, economic, or natural crises on urban landscapes (Garcia, 2013). Given the rapid renewal of the urban landscape following China's economic transformation, to what extent can resilience theory describe changes happening in ICs? How can resilience be applied to assess changes in the built environment of workers' residential areas before and after the factory bankruptcy? Additionally, in what ways can resilience be used to evaluate the impact of changes in the level of enclosure on the built environment of the workers' residential area after the factory bankruptcy? This study focuses on the Shanxi Knitting Factory (SKF), situated in the industrial city of Taiyuan, China, as a representative example of an IC. It study stands as the first to apply resilience theory in exploring the impacts of China's economic transformation on the built environment of workers' residential areas of ICs. By analyzing urban landscape changes based on resilience theory, this study aims to provide valuable insights to city managers, architects, and designers. It highlights the value of resilience theory in understanding the challenges China faced during its rapid urban renewal within the context of economic transformation.

The subsequent section offers a literature review on the built environment and the concept of resilience in urban studies. Section 3 details the data and methodology used in this study. The concluding section addresses the research question and discusses whether the once enclosed, isolated, and self-contained workers' residential areas of ICs are evolving into open, diversified, heterogeneous, and mixed-use urban neighborhoods.

2. Literature review

2.1 The built environment

The concept of the built environment was first introduced by social scientists (Rapoport, 1976). Broadly speaking, it includes man-made buildings and infrastructure that constitute the physical, natural, economic, social, and cultural capital (Hassler & Kohler, 2014). The built environment forms the foundation of the urban texture, a complex socio-technical system comprising interrelated elements. These elements include building footprints, plots, blocks, streets, and building fabric, representing the dynamic three-dimensional form of the urban landscape (Conzen, 1960). Additionally, the built environment refers to specific elements related to buildings, such as doors and walls, or the spatial subdivisions of buildings involving their functions and arrangements (Lawrence & Low, 1990).

In the context of cities, buildings are the fundamental units that sit on plots of land. These plots, often with street access, play a vital role in shaping the urban texture (Garcia, 2013). The surrounding land formed by multiple plots constitutes blocks, and the size of these blocks is determined by the width of the streets and the distance between them. Several blocks can be combined into larger units, like communities. Each community exhibits its own unique history, distinct street patterns, and functional characteristics, and a city contains a series of communities (Garcia & Vale, 2017).

In-depth analysis of changes in the built environment is crucial for urban planning and design because it helps us understand changes that have already happened or are currently taking place in cities, thereby providing valuable insights for decision-makers and urban planners. Hence, in the context of rapid urban transformation, there is a need to explore methods and strategies that can guide cities towards more sustainable development.

2.2 Resilience in the built environment of cities

The concept of resilience has its roots in engineering and is described as the ability of systems to absorb changes and persist (Walker & Holling, 2004). It has been developed since the 1970s in various fields, such as psychology and ecology. Three features related to resilience explain the functioning and development of systems. Firstly, changes are cyclical because the system is always in the process of exploitation, conservation, release, and reorganization (Holling & Gunderson, 2002). The adaptive cycle can be used to describe these cyclical changes. Secondly, such cyclical changes usually occur simultaneously on different scales and speeds (Garcia, 2020). Thus, a nested set of adaptive cycles forms a Panarchy, describing the dynamic hierarchy that involves adaptation across multiple scales (Garcia, 2013). Thirdly, changes across multiple scales result in a landscape that is both discontinuous and heterogeneous. They are critical to understanding the complexity and resilience of systems as heterogeneity and discontinuity contribute to the diversity of the system (Holling & Gunderson, 2002).

At the start of the 21st century, ecological resilience received attention in the field of urban studies because the city itself was in the process of constant change, and the built environment can be regarded as a record of long-term adaptation and overcoming the catastrophes of history (Garcia & Vale, 2017). Therefore, resilience theory can be used to explain the cyclical changes, renewal, restructuring, and development of cities. For example, the cyclical change in the urban landscape is called the burgage cycle, as it experiences phases of continuous production, growth, waste, and shrinkage (Feliciotti et al., 2018). Panarchy can also explain changes in elements of the built environment, such as streets, as these elements undergo discrete changes at different speeds and quantities (Garcia & Vale, 2017).

Scholars, like Garcia (2013), find that creating timelines and identifying key variables at different temporal and spatial scales is a reasonable way to assess the complexity of urban systems. This is because timelines provide important insights into the events and essential breakpoints that have shocked the system and the possible causes that triggered the changes. This process enables a deeper understanding of the heterogeneity and diversity of the built environment and the dynamics of change that occur at different scales (Dhar & Khirfan, 2017). Most existing research linked resilience in the built environment to alleviating shocks caused by earthquakes, floods, and tsunamis. However, few studies focus on analyzing and developing methods to improve the resilience of the built environment to the problems that arise due to its complexity. This study uses resilience theory to describe the changes in the built environments of

the workers' residential area of ICs. Because resilience helps to understand the history and development of ICs, revealing the complexity, organization, and relationships of the built environment.

3. Data & methodology

3.1 Case study

This study uses the Shanxi Knitting Factory (SKF) as a representative example of an IC. Founded in 1950 and situated in the south of Taiyuan, the SKF covers approximately 2.3 km^2 and is home to about 6,800 residents. Currently, the factory of the SKF is gradually being replaced by new high-rise commercial complexes after its bankruptcy in 2007. Nevertheless, the workers' residential area remains the home of the former factory employees and their families. (Fig. 1)

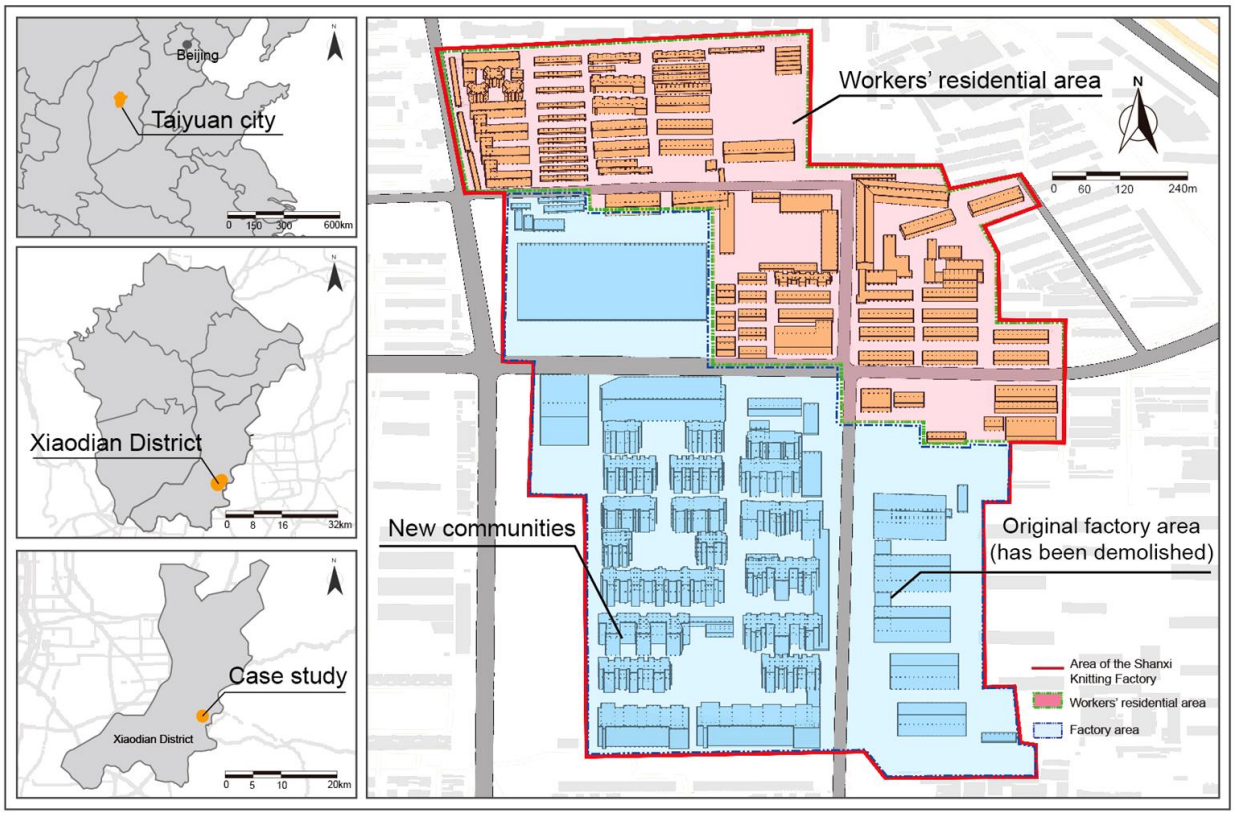


Fig. 1 Current location and layout of the SKF

As characterized by Bonino & De Pieri (2015), such ICs operated much like encompassing “all the functions of a city”. In the case of SKF, both its factory and the workers’ residential area were constructed on the same site. This design facilitated easy and efficient commuting for workers and contributed to the compact landscape within the SKF. In the factory, giant office buildings and squares typically occupied central positions, symbolizing the supreme power of the Communist Party in socialist China. Workshops, warehouses, and equipment rooms surrounded these central structures, demonstrating that all production activities should support industrial solidarity and serve the supreme power. In the workers’ residential areas, a variety of facilities, including cafeterias, grocery stores, and schools, were available to enhance the living conditions and welfare of the residents and their families. (Fig. 2)

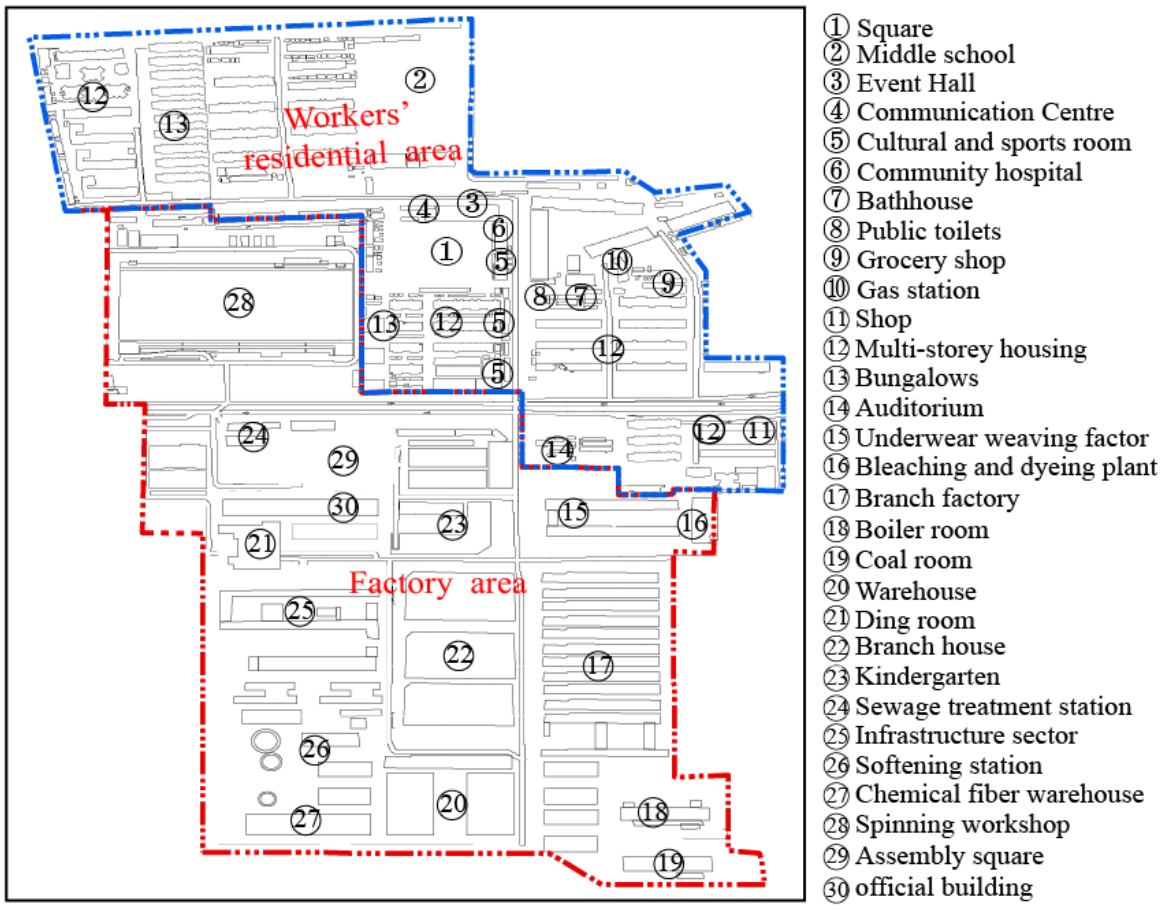


Fig. 2 The layout of the SKF before the factory bankruptcy

Scholars such as Bjorklund (1986) and Bray (2005) have observed that enclosed spaces, often surrounded by walls, were prevalent in traditional China because they efficiently organized various social activities. This insight sheds light on the fact that the construction of walls was usually the first step in establishing ICs. Beyond the conventional walls, building facades also served as boundary walls. In the case of the SKF, some of these buildings, positioned alongside city streets or internal roads, were specifically designed to integrate their facades with conventional walls. This design highlighted the most prominent feature of the enclosure for the SKF as an IC.

Gates, apart from walls, were another element contributing to the enclosure of the SKF. While walls symbolized strong state control and spatial division, gates managed the interactions between the enclosed SKF and the external city. Specifically, they reinforced the isolation of the SKF yet provided controlled access points, enabling necessary communication with the surrounding urban landscape. Thus, gates functioned as both barriers ensuring isolation and connectors facilitating interaction within the SKF. (Fig. 3) Moreover, the road network not only shaped the spatial organization of the SKF but also played a pivotal role in shaping, defining, and segregating various spatial functionalities. It contributed to the SKF as a multi-functional compound, including diverse land use for production, office, residential, and social activities (Zhang & Chai, 2014).

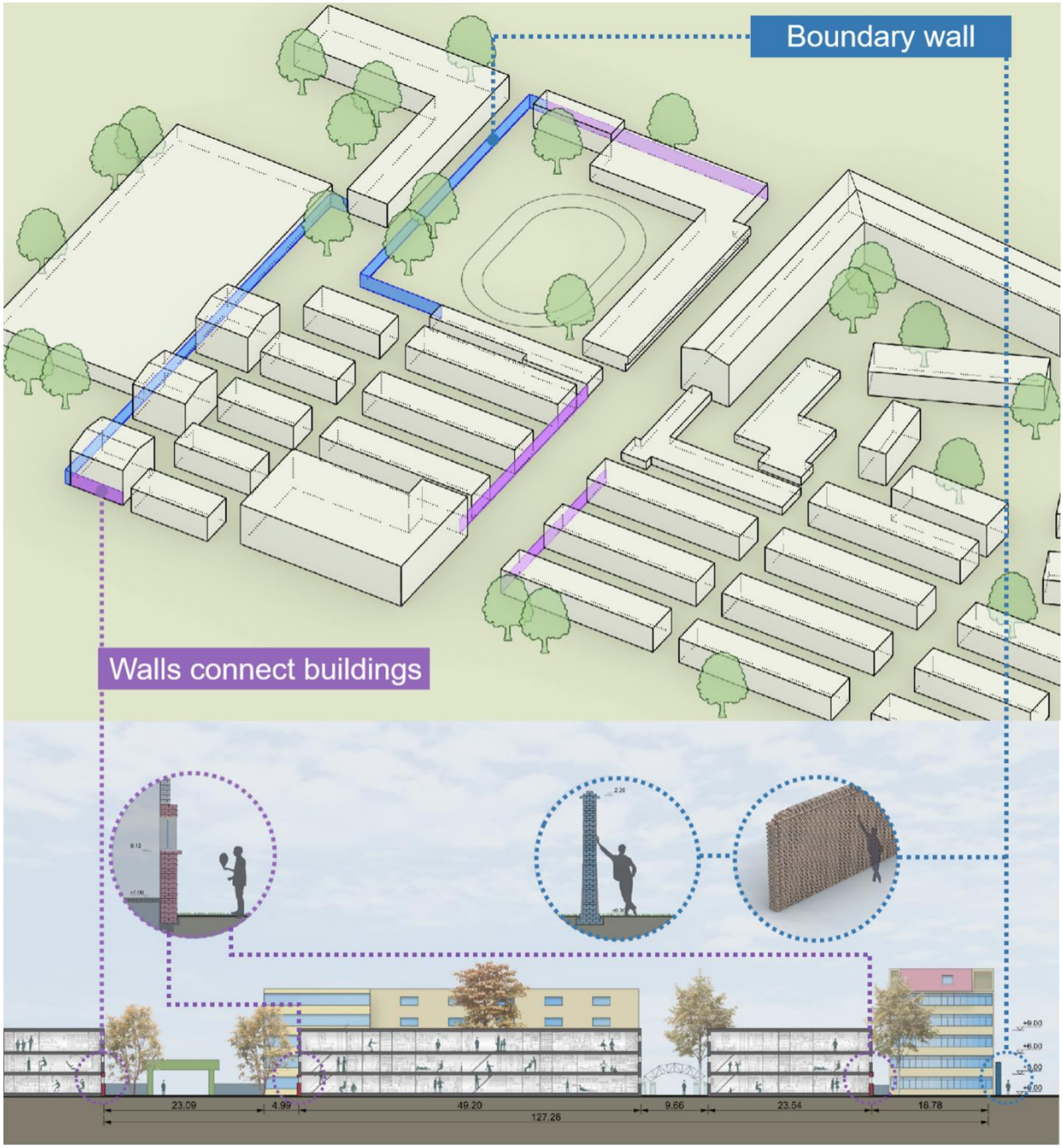


Fig. 3 Gates and walls inside and as boundaries of the workers' residential area

Since the economic transformation in the 1980s, the development of the SKF has been significantly influenced by the implementation of a series of reform policies related to enterprise restructuring, housing, and land. However, after the enterprise restructuring, the SKF factory faced challenges in adapting to the new economic environment, resulting in decreased production efficiency and massive worker layoffs, particularly after the 1990s. These difficulties eventually led to the factory's bankruptcy in 2007. Subsequently, the local government sold the brownfield to property developers to create new communities. Despite the demolition of the factory, the remaining workers' residential area persisted, continuing to accommodate former employees and their families.

In recent years, many buildings located close to main roads within the residential area and adjacent to the city streets have been demolished as part of efforts to reorganize the workers' residential area and widen the external city roads. Additionally, there has been a noticeable reduction of enclosure in the workers' residential areas, with increased gates and decreased walls, especially in response to the social appeal to "open up the enclosed community" after 2000. From this perspective, the decreased enclosure may allow the city to be more accessible to the workers' residential area of the SKF, allowing its boundaries to support a wider variety of functions and activities. It might also increase

the complexity of the road network, given the rise in connections between various functional land uses and service facilities within the area.

The SKF was chosen as the case study because its factory underwent rapid development, followed by a decline and eventual bankruptcy. Considering its role as an industrial auxiliary facility, the workers' residential area likely experienced significant changes. Using resilience theory, this study analyses the changes in the built environment of the SKF workers' residential area impacted by the factory bankruptcy. The aim is to grasp the adaptive capacities of the workers' residential area when facing disturbances. This, in turn, provides insights into the complexities and sustainability challenges cities face during China's economic transformation.

3.2 Data collection

This study focuses on the following research questions: (1) to what extent can resilience theory describe changes happening in the SKF? (2) How can resilience theory be applied to assess changes in the built environment of workers' residential areas of the SKF before and after the factory bankruptcy? (3) In what ways can resilience theory be used to evaluate the influence of changes in the level of enclosure on the built environment of the workers' residential area after the factory bankruptcy?

For the purpose of drawing comparisons across a time domain, this study started by creating a timeline based on key events associated with the development of the SKF. The bankruptcy of the SKF factory stands out as the most significant breakpoint, thus positioning 2007 as the midpoint of the timeline. Given these events, this study designates 1978 and 2022 as the starting and ending breakpoints of the timeline, respectively. The rationale for selecting 1978 as the starting breakpoint stems from the shift of the SKF factory from state financial support to independent operation after the economic transformation. This meant that the economic efficiency of the factory could directly influence the development pace of its surrounding residential area. Consequently, the timeline was divided into two phases: "before factory bankruptcy" and "after factory bankruptcy." Further essential breakpoints were incorporated into the timeline, including 1978, 2000, 2003, and 2007 (before the factory bankruptcy), as well as 2014, 2016, 2018, and 2022 (after the factory bankruptcy).

To address the research question, a quantitative study on the resilience of the built environment in the workers' residential area of the SKF was conducted. Raw data were gathered using various methods, including library resources, land use maps, the Open Street Map API, and field research. Microsoft Office software was employed for statistical analysis. Further, the analysis of changes in the built environment was carried out by using ArcGIS and Adobe Illustrator software. Different data collection methods were applied for different development periods of the SKF. (Tab. 1) Specifically, data before the factory bankruptcy were obtained from library resources and land use maps. On the other hand, data after the factory bankruptcy were obtained from library resources, land use maps, the Open Street Map API, and field research.

Table. 1 Method of data collection

Period	Methods of data collection
Before the factory went bankrupt (1978-2007)	Library resources; Land use maps
After the factory went bankrupt (2007-2022)	Library resources; Land use maps; Open Street Map API; Field research

This study analyses ten elements of the built environment in the workers' residential area of the SKF. Elements related to enclosure include GATE, boundary walls (BW), and buildings as boundary walls (BBW). Other elements influenced by enclosure comprise the total road length (TRL), building density (BD), green space (GS), commercial land (CL), residential land (RL), public service facility land (PSFL), and mixed-use land (ML). (Tab. 2)

Tab. 2 Elements in the built environment of the workers' residential area of SKF

Content		Elements
Built environment	Enclosure	GATE
		Boundary walls (m) (BW)
		Buildings as boundary walls (m) (BBW)
	Other built environment elements	Total road length (m) (TRL)
		Building density (%) (BD)
		Greenfield space (%) (GS)
		Commercial land (%) (CL)
		Residential land (%) (RL)
		Public service facility land (%) (PSFL)
		Mixed-use land (%) (ML)

3.3 Research method & hypotheses

To answer the first proposed research question, firstly, we aim to demonstrate that changes in the built environment are cyclical. To this end, we assess the land changes for residential purposes within the workers' residential area of the SKF to determine if these changes can be associated with phases of the adaptive cycle in resilience. Secondly, it is essential to create a diagram for the quantitative observation of relationships among elements of the built environment in the workers' residential area. If these elements reflect the independence of their respective development, it suggests a hierarchy in the built environment that can be compared to Panarchy in resilience. Thirdly, in Panarchy, small-scale changes occur more frequently than large-scale changes. Consequently, we need to track the quantity and frequency of change in these built environment elements of different scales to determine if these changes can be linked to resilience. Finally, if evidence from the three steps supports the idea that resilience theory can be applied to analyze changes in the built environment of the workers' residential area of the SKF, it would answer the first research question.

The differential analysis will be employed to address the second research question of this study. Specifically, this method facilitates a comparison of the built environment changes in the workers' residential area of the SKF before and after the factory bankruptcy. Our null hypothesis (H0) posits that there is no association between the factory bankruptcy and changes in the built environment of the workers' residential area. In contrast, the alternative hypothesis (H1) suggests that significant differences exist between the two periods. If the result shows that differences are significant, we would then accept the alternative hypothesis and reject the null hypothesis.

To address the third research question, we turn to multiple linear regression analysis. Here, the null hypothesis (H0) is that changes in the level of enclosure have no impact on the built environment of the workers' residential area after the factory bankruptcy. The alternative hypothesis (H1), on the other hand, contends that changes in the level of enclosure indeed affect the built environment of the workers' residential area after the factory bankruptcy. If subsequent findings demonstrate that the level of enclosure influences other built environment elements and significant correlations exist among them, it would validate the alternative hypothesis (H1) and reject the null hypothesis (H0).

A combination of quantitative and visual data software was used to map changes in the built environment of the workers' residential area of the SKF. If a diverse trend of functional land use is observed as the enclosure declines, the association between heterogeneity and resilience can help explain the ongoing changes in the built environment. Finally, this study concludes by discussing whether the workers' residential area of the SKF is gradually integrating into the surrounding urban neighborhoods.

3.4 Data analysis

(1) Analysing changes in the built environment of ICs

Fig.4 depicts the land changes for residential purposes in the workers' residential area of the SKF from 1978 to 2022. In 1978, the percentage stood at 33.14%. After that, it gradually increased to 46.74% in 2007 when the factory went bankrupt. Since then, the land allocated for residential purposes sharply declined to 34.65% in 2016, before rebounding to 38.63% in 2022. These fluctuations suggest a cyclical change comprising four phases: exploitation and conservation from 1978 to 2007, followed by release and reorganization from 2007 to 2022.

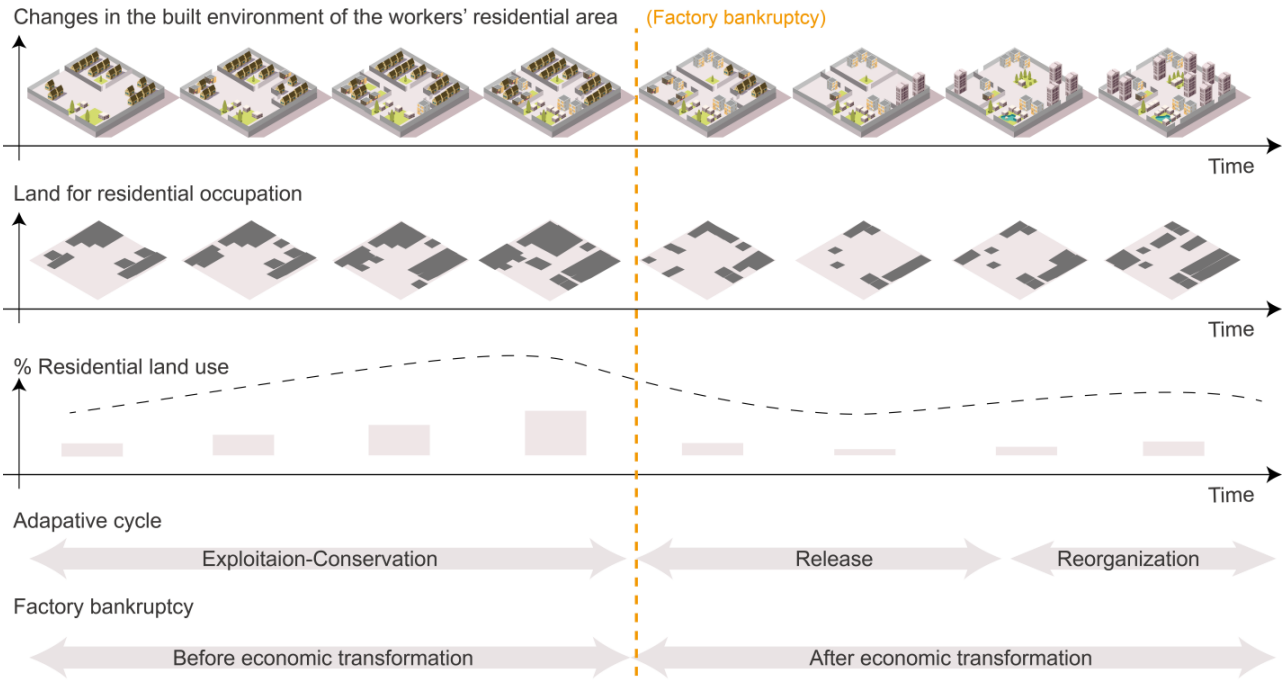
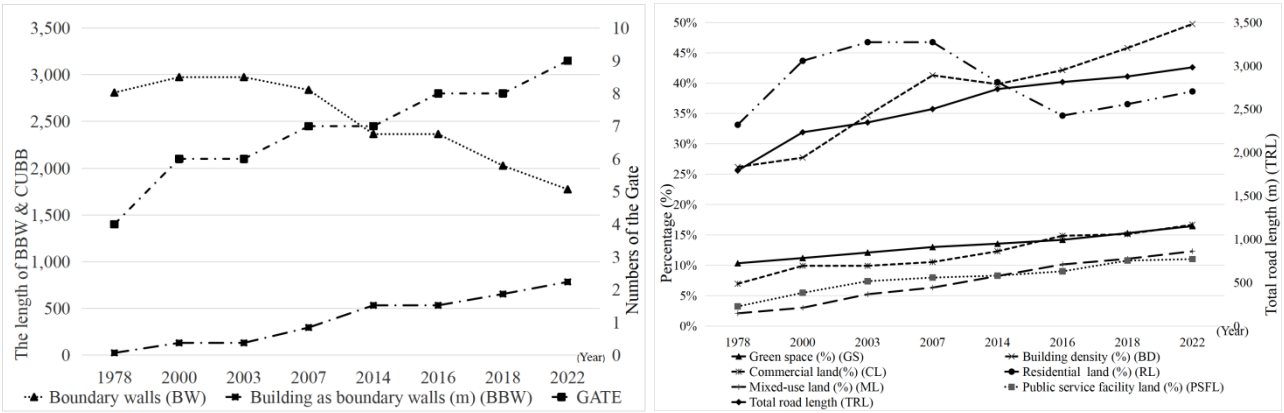


Fig. 4 Burgage cycle in the workers' residential area of the SKF

The changes in the built environment of the workers' residential area of the SKF are depicted in Fig. 5, with each line representing a built environment element from 1978 to 2022. Despite belonging to the same landscape, these elements are independent and do not intersect. The observed changes offer evidence of the complexity of the built environment, which can be associated with the Panarchy theory.



(a) Changes of elements related to the enclosure (b) Changes in the other built environment elements

Fig. 5 Different built environment elements in the workers' residential area of the SKF (1978-2022)

Tab. 3 presents the percentage of changes in the built environment elements of the workers' residential area. It is observed that TRL (33.49%) and BW (-36.86%) act as slow variables, contributing to landscape stability, while GATE (125%), BBW (679.37%), and various functional lands such as ML (308.97%), PSFL (101.65%), CL (68.24%), and GS (47%) are fast variables. Additionally, RL (-16.65%) demonstrates a decreasing trend due to the local government's planning after 2007, which aligns with the concept of Panarchy. Overall, the three steps confirm

that resilience can be employed to analyze changes in the built environment of the workers' residential area of the SKF, thus supporting the first hypothesis.

Tab. 3 Percentage of changes in the built environment

Element	1978	2022	Percentage of change
GATE	4	9	125%
BW	2809.21	1773.76	-36.86%
BBW	89.21	783	679.37%
TRL	1791.95	2982	33.49%
GS	26.20%	49.73%	89.8%
BD	10.34%	16.46%	46.96%
CL	6.96%	16.69%	68.24%
RL	33.14%	38.63%	-16.65%
PSFL	3.23%	11.03%	101.65%
ML	2.1%	12.31%	308.97%

(2) Measuring the impact of the factory bankruptcy on the built environment

Tab. 4 provides a differential analysis comparing data from two distinct periods: before and after the factory bankruptcy. The results highlight a variation in the mean value (M) between these two periods. After the factory's bankruptcy, all elements increased, except for the decrease of BW and RL. Among all variables, BW and BBW showed the most pronounced changes ($t > \pm 5$). Moreover, the P-values for all variables are consistently <0.05, suggesting a significant association between factory bankruptcy and changes in the built environment. Consequently, we accept the alternative hypothesis (H1) and reject the null hypothesis (H0). The results of the differential analysis indicate that changes in the operating status of the factory, specifically the factory bankruptcy, have a significant impact on the changes in the built environment of the workers' residential area of the SKF.

Tab. 4 The result of the difference analysis

Elements	Year	N	M	SD	t	p
GATE	1988-2007	4	5.75	1.26	-3	0.015*
	2007-2021	4	8.00	0.82		
BW	1988-2007	4	2898.99	87.82	5.1	0.003**
	2007-2021	4	2132.75	287.48		
CUBB	1988-2007	4	149.59	127.47	-5.43	0.001**
	2007-2021	4	625.18	119.69		
TRL	1988-2007	4	2218.42	304.71	-3.92	0.009**
	2007-2021	4	2850.64	105.76		
GS	1988-2007	4	11.66	1.15	-4.92	0.003**
	2007-2021	4	14.88	1.28		
BD	1988-2007	4	32.48	6.94	-2.9	0.017*
	2007-2021	4	44.37	4.34		
CL	1988-2007	4	9.34	1.61	-4.47	0.002**
	2007-2021	4	14.75	1.81		
RL	1988-2007	4	44.32	3.14	3.45	0.007**
	2007-2021	4	37.50	2.41		
PSFL	1988-2007	4	6.02	2.15	-2.98	0.015*
	2007-2021	4	9.78	1.33		
ML	1988-2007	4	3.65	2.80	-4.15	0.004**
	2007-2021	4	10.44	1.71		
* $p<0.05$ ** $p<0.01$						

(3) Assessing the impact of changes in the level of enclosure on the built environment

The multiple linear regression analysis reveals the relationship between the level of enclosure and the elements of the built environment in the workers' residential area (Tab. 5). Initially, we focused on the influence of GATE (independent variable) on the other built environment elements (dependent variables). Except for RL (Beta=-0.52, p=0.183), all elements showed a positive association with GATE (Beta>0, p<0.05 or p<0.01). For example, 95% of the changes in mixed-use land (ML) (R^2=0.95) can be attributed to GATE. As for BW, while RL displayed a significant positive relationship (Beta=0.90, p=0.002), most other built environment elements showed notable correlations with BW (Beta<0, p<0.05 or p<0.01). Regarding BBW, it consistently impacted all elements of the built environment. An exception to this trend was found in RL, which had a minor negative correlation (Beta<0, p=0.032). On the other hand, all other elements had significant positive correlations with BBW, indicating its consistent positive influence (Beta>0, p<0.05 or p<0.01). Therefore, based on the results from the multiple linear regression analysis, we accept the alternative hypothesis (H1) and reject the null hypothesis (H0).

Tab. 5 The result of multiple linear regression analysis

IV		DV	Non-SC		SC	t	p	R^2	F
			B	SE	Beta				
Enclosure	ENTRANCE	TRL	0.004	0.00	0.98	11.22	0.000**	0.95	125.8
		GLU	80.03	10.10	0.96	7.92	0.000**	0.90	62.74
		BD	17.54	2.64	0.94	6.65	0.001**	0.88	44.22
		CLU	51.70	7.56	0.94	6.84	0.000**	0.89	46.83
		RLU	-18.15	12.07	-0.52	-1.50	0.183	0.27	2.26
		PFLU	57.29	6.73	0.96	8.51	0.000**	0.92	72.47
		MLU	35.80	3.46	0.97	10.35	0.000**	0.95	107.0
	BW	TRL	-0.92	0.275	-0.81	-3.35	0.015*	0.65	11.24
		GLU	-21746.91	4619.65	-0.89	-4.71	0.003**	0.79	22.16
		BD	-4555.81	1234.32	-0.83	-3.69	0.010*	0.70	13.62
		CLU	-15093.71	2253.85	-0.93	-6.70	0.001**	0.89	44.85
		RLU	9148.35	1796.93	0.90	5.09	0.002**	0.81	25.92
		PFLU	-27037.47	4339.94	-0.86	-6.23	0.000**	0.73	38.81
		MLU	-9222.08	2268.77	-0.86	-4.06	0.007**	0.73	16.52
	SBW	TRL	0.62	0.091	0.95	7.27	0.000**	0.90	52.78
		GLU	14569.34	1484.45	0.97	9.82	0.000**	0.93	96.33
		BD	3114.42	502.94	0.93	6.19	0.001**	0.87	38.35
		CLU	9727.30	618.36	0.98	15.73	0.000**	0.98	247.4
		RLU	-4667.05	1677.76	-0.75	-2.78	0.032*	0.57	7.74
		PFLU	19749.49	5073.08	0.72	3.89	0.002**	0.52	15.16
		MLU	6342.63	738.06	0.97	8.60	0.000**	0.93	73.85

* p<0.05 ** p<0.01

3.5 Result

(1) The decreased enclosure in the workers' residential area

The traditional ICs in socialist urban China are often depicted as enclosed compounds consolidating the proletarian regime (Zhang & Chai, 2014). However, this situation has totally changed with the widespread bankruptcy of factories after the economic transformation. In the case of the SKF, we found that the number of walls in the workers' residential area significantly reduced after its factory went bankrupt, while the number of gates increased. (Fig. 6)

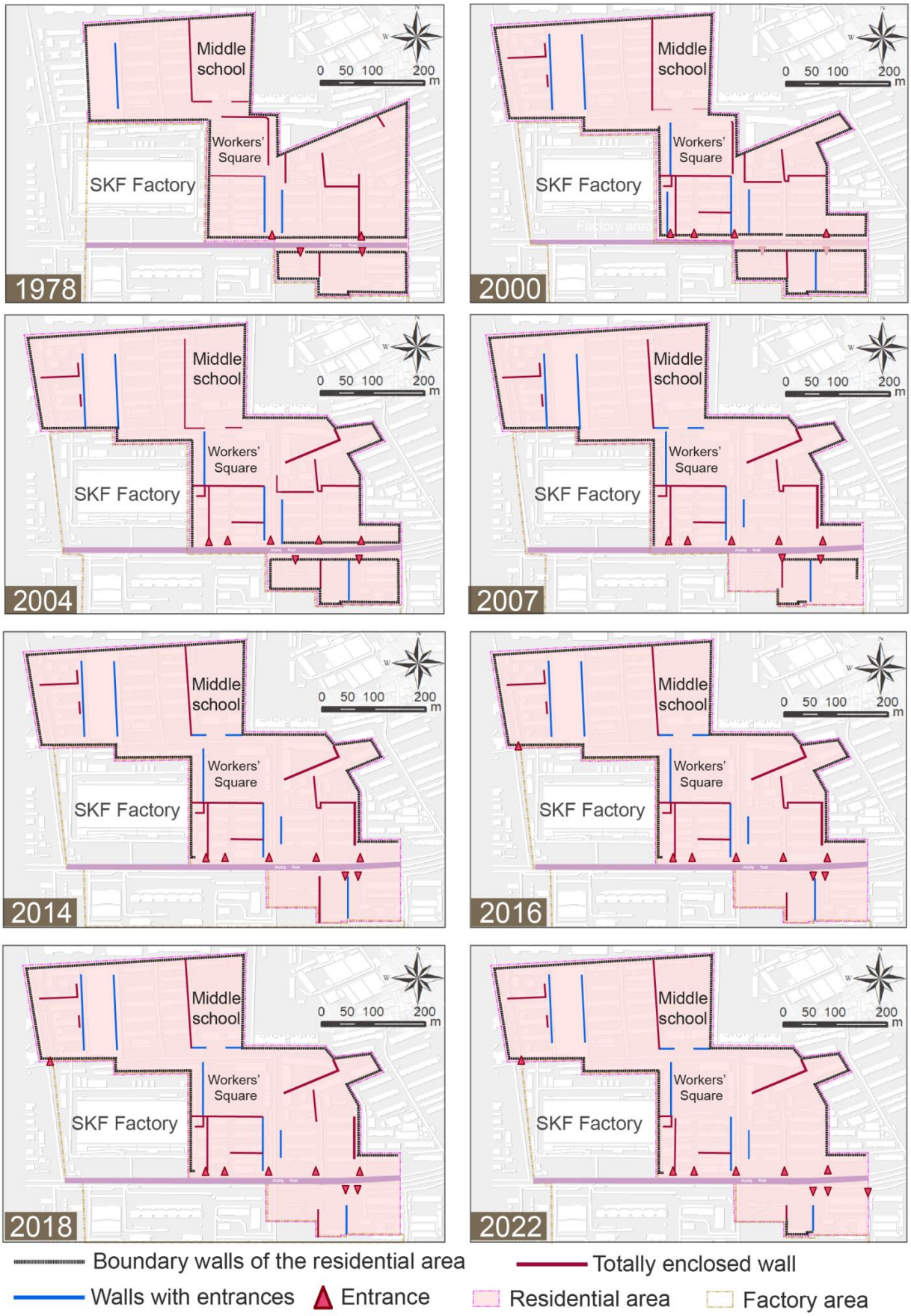


Fig. 6 The trend of decreasing walls and increasing gates

Specifically, in 1978, there were only 4 gates between the SKF workers' residential area and the city, but this number rose to 9 by 2022. This change is attributed to the construction of new public facilities and efforts to better meet the residents' needs. Moreover, the reduction of walls in the residential area is often associated with the demolition of old houses due to urban development plans and real estate projects. Beyond removing some boundary walls close to the city streets, the internal walls within the residential area have also been gradually demolished to give space for new facilities and land uses. As a result, the SKF workers' residential area is transitioning into an open and less clearly defined boundary space.

(2) Increased diversification of the land use in the workers' residential area

In the case of the SKF, we observe that its workers' residential area has undergone an increasing diversification of land use. For instance, from 1978 to 2022, the land dedicated to PSFL (+11.03%), ML (+12.31%), CL (+9.73%), and GS (+6.12%) all experienced growth. Particularly, after the factory bankruptcy in 2007, PSFL, ML, and CL in the workers' residential area of the SKF have shown rapid expansion due to the decrease of enclosure and the increase in the mobile population. Residents have also started selling inexpensive goods and services within the workers' residential area of the SKF to alleviate the economic pressures caused by unemployment and fulfill their needs. For example, the ground floors of residential buildings have been converted into informal shops, contributing to the increase of mixed land use in the workers' residential area.

The government and property management companies have also created land for GS by integrating and filling empty spaces in the workers' residential areas of the SKF. Conversely, RL decreased from 40.14% in 1978 to 34.65% in 2022 due to municipal planning, which provides more space for future development. In summary, alongside the functional change of SKF, the land use in the workers' residential area has become more diversified and mixed-use. (Fig. 7)

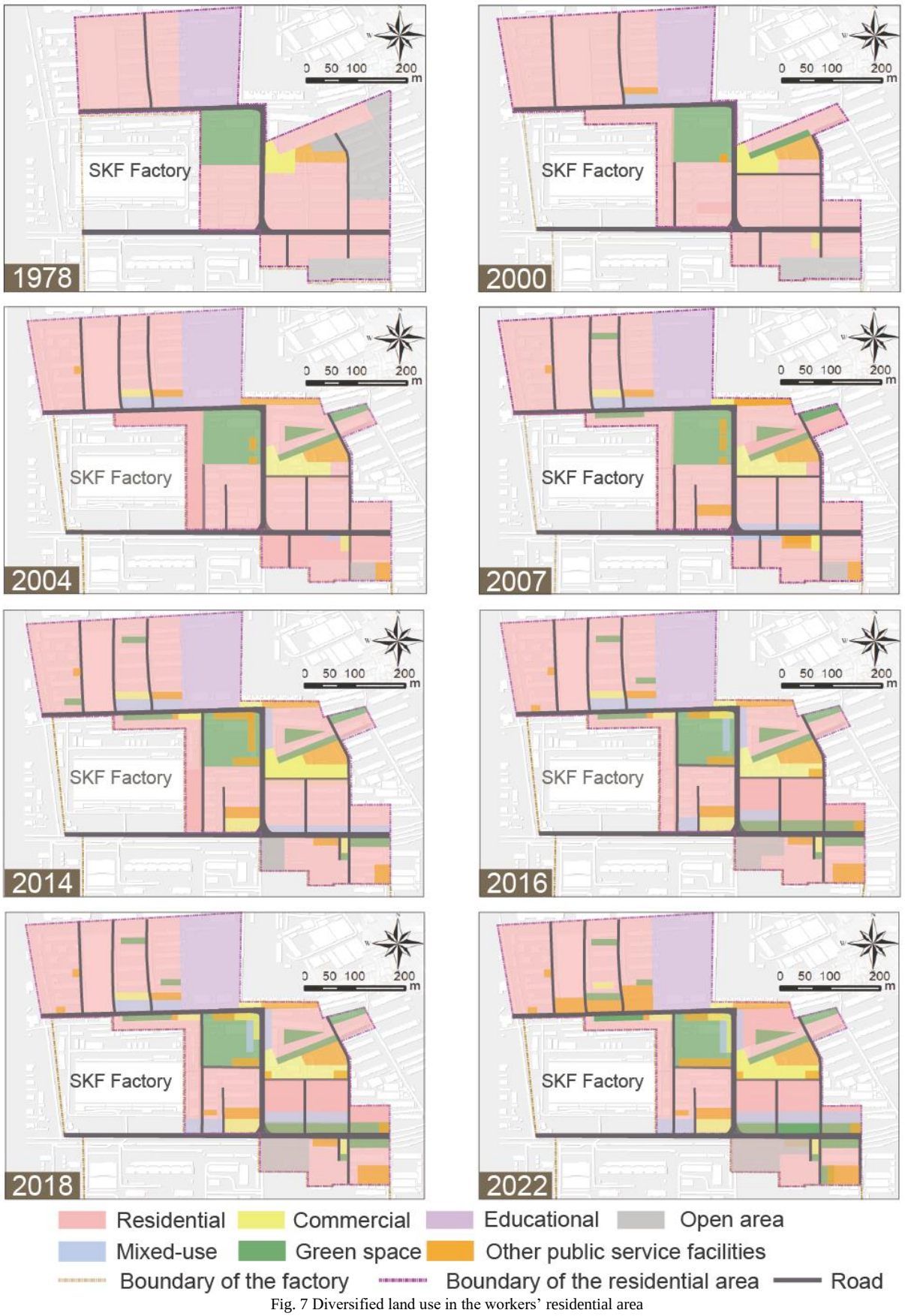


Fig. 7 Diversified land use in the workers' residential area

(3) Increased public facilities and commercialization of land functions

In the early days of socialist China, ICs were designed with a variety of public facilities that functioned as “social condensers” to strengthen the collective spirit of their members in workers’ residential areas (Peiling, 2014). These facilities encompassed comprehensive social services to residents. Even though these public facilities were set for its members, residents could access services from other ICs. However, since every IC was self-sufficient, residents had little reason to seek facilities outside their community. In the case of the SKF, most of the land for public facilities was initially concentrated in the central area of the workers’ residential area in 1978. However, driven by market interests and commercial needs, these lands gradually clustered near the community boundaries and main roads within the workers’ residential area to attract more clients. (Fig. 7) This shift indicates that the workers’ residential area of the SKF is undergoing a process of decentralization and commercialization after the factory's bankruptcy.

4. Discussion & conclusion

Industrial communities, as the most significant social products of China's industrial development in the 1950s, still preserve the spatial imprint, routine lifestyle, and collective memory of that period (Zhang & Chai, 2014). However, after the economic transformation in the 1980s, a large number of bankrupt factories led to a new round of development in the ICs, stimulated by the market economy. As industrial auxiliaries, the built environment of ICs is undergoing rapid changes. Therefore, this study seeks to use resilience to describe changes in the built environment of workers’ residential areas of ICs. Because resilience helps to understand the history and development of ICs, revealing the complexity, organization, and relationships of the built environment.

The findings demonstrate that resilience can indeed interpret the ongoing cyclical changes in the built environment, involving exploration, conservation, release, and reorganization. For instance, the workers’ residential area of the SKF was originally established in the 1950s and flourished until the factory went bankrupt in 2007. It underwent a release phase, characterized by reducing walls and demolishing old housing, leading to its reorganization and integration into the surrounding neighborhoods. These cyclical changes in the built environment occur at various temporal and spatial scales, maintaining independence without intersection and highlighting the complexity of the workers’ residential area. Additionally, the study adopts the concept of Panarchy to analyze the dynamic changes in the built environment, considering the size and speed of changes. For instance, streets within the residential area of the SKF exhibit minor variations, contributing to the overall landscape stability. In contrast, functional land use undergoes rapid changes, directly reflecting the development direction of the workers’ residential area after the factory bankruptcy.

Despite the significant impact of the factory bankruptcy on the workers’ residential areas of ICs, they demonstrate a quick response and adaptability to changes. The evidence could be found in reduced walls, increased gates, and developed multi-functional land. This indicates that despite the disturbance caused by the factory's bankruptcy, the remaining workers’ residential areas still maintain their development through the adaptability of their built environment. The decrease in the enclosure of the workers’ residential area after the factory bankruptcy can be attributed to both the persistence of certain elements and changes in resilience. It aligns with the idea that the identity of a complex system constantly adapts, releasing certain elements to maintain persistence. In the case of SKF, we delve into understanding how these changes affect its identity, linking resilience with its historical and cultural heritage. After the bankruptcy, the workers’ residential areas transitioned from factory-dependent, isolated industrial auxiliaries to more open, diversified, mixed-use, and heterogeneous areas. They are gradually integrating into the surrounding neighborhoods of cities.

It is important to acknowledge the limitations of this study. Firstly, this research primarily focuses on analyzing the changes in the built environment of workers’ residential areas in ICs. Although the study highlights the impact of factory bankruptcy on the workers’ residential area, there is no holistic integration of both the factory and the workers’ residential area to analyze changes in the built environment at the IC scale. Secondly, this study mainly focuses on quantitative methods, but future research might benefit from qualitative research. By conducting interviews with former residents (who were previously employed by the factory), new immigrants, community committees, property managers, and former factory managers, we could gain valuable insights into their perceptions of the recent changes

in ICs. Attending public forums that foster dialogue between communities and planning offices could further illuminate an understanding of the realities and challenges facing ICs. Lastly, comparing multiple case studies across different regions of China would be beneficial. Because these comparisons highlight the regional differences or similarities, offering a deeper understanding of the resilience of ICs once they lose their industrial identity.

Acknowledgments

The abstract of this paper was presented in Resilient and Responsible Architecture and Urbanism (RRAU) – 5th Edition which was held on the 20th of April 2023.

Funding declaration:

This research did not receive any specific grants from funding agencies in the public, commercial, or not-for-profit sectors/individuals.

Ethics approval:

Not applicable.

Conflict of interest:

The authors declare that there is no competing interest.

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