

Georeferencing Historical Zoning Maps and Their Comparison with Current Zoning: GIS-Based Study of Japanese Regional Cities

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Abstract

Japan's land-use zoning system, established with the 1919 City Building Act, has fundamentally shaped long-term urban spatial structures. This study clarifies the evolution of Japanese zoning by georeferencing historical maps and comparing them with contemporary GIS data for 11 regional cities. We introduced the Historical Zoning Consistency Index (HZCI) to quantify spatial continuity. Integrating HZCI, initial zoning proportions, and area growth rates, we performed principal component and cluster analysis to identify zoning transition patterns. Results reveal that while residential and commercial zones maintained high spatial continuity, industrial zones underwent extensive conversion. We identified three distinct typologies: a "Residential-Specialized and Growth-Restricted" type (stable development), an "Industrial-Maintenance and Expansion" type (robust retention of industrial zones alongside rapid expansion), and an "Industrial-Conversion" type (dynamic transformation of industrial lands). These findings provide empirical evidence for the structural transformation of urban land use, offering insights into the diverse evolutionary trajectories of Japanese cities.

1. Introduction

1.1 Background and Objective

This study examines the historical formation of urban zoning structures in Japan through GIS-based urban planning history analysis. Japan's land use zoning system originated approximately one century ago with the enactment of the City Building Act in 1919. At that time, zoning districts were initially designated in six major cities—Tokyo, Kyoto, Osaka, Yokohama, Kobe, and Nagoya. Subsequently, with the development of the modern planning framework under the City Planning Act, the zoning system was gradually extended to regional cities across Japan.

The spatial patterns established during these early zoning designations are considered to have influenced not only the current zoning system but also the long-term spatial structure of Japanese cities. However, the spatial characteristics of these initial zoning designations and their relationship with present-day zoning patterns have not been sufficiently examined in a quantitative manner.

Therefore, this study aims to digitize historical zoning maps showing the earliest zoning designations by georeferencing them and converting them into GIS datasets. By comparing these historical zoning datasets with current zoning maps, this study quantitatively identifies the spatial characteristics of early zoning designations and their relationship with contemporary zoning structures. The analysis focuses on multiple regional cities, aiming to clarify both city-specific characteristics and general trends in the evolution of zoning systems in Japan.

This study provides insights into urban planning, on long-term control of urban expansion and shrinkage, and contributes to international discussions on zoning-based urban management.

1.2 Research Method

In this study, historical materials are digitized into GIS datasets and compared with current zoning districts within a GIS environment. For this comparison, a new indicator, the Historical Zoning Consistency Index (HZCI), is defined as the proportion of areas where the current zoning designation remains consistent with the original designation within the initially designated boundaries. The HZCI for each zoning category is calculated using Equation (1)

$$HZCI_i = \frac{A_i(t_0 \cap t_1)}{A_i(t_0)} \quad (1)$$

where $A_i(t_0)$ = The total area designated as category i at time t_0
 $A_i(t_0 \cap t_1)$ = The area that remains designated as category i at both t_0 and t_1

Using the HZCI alongside other indicators—such as population and the proportion of area by zoning category—a cluster analysis is conducted to categorize the cities. Through this classification and cross-city comparisons, this study clarifies the specific patterns of zoning modifications, revealing both common trends and city-specific characteristics in the evolution of zoning systems.

1.3 Literature Review

Asano conducted a comparative study of the first zoning plans in 43 small and medium-sized cities in Japan. The results revealed that early zoning designations were not merely a ratification of existing conditions but also included types that were oriented toward future industrial and residential development (Asano, 2012). Sanada showed that while 117 out of 120 cities in Japan before World War II had designated linear commercial districts, these designations were often justified by formulaic explanations (Sanada, 2013). Furthermore, Sugita examined the evolution of

zoning criteria from the 1920s to the 1940s and pointed out that these criteria prioritized the placement of commercial and industrial districts without considering the placement of residential zones themselves (Sugita, 2004).

Research on the long-term transformation of urban structure using GIS-based analysis of historical maps has been conducted by Alvares-Sanches et al. (2020), who examined changes in the city's "center of gravity" over 500 years using georeferenced maps.

While such approaches are effective for analyzing long-term spatial continuity, studies focusing on Japan's zoning system and its relationship with present-day urban structure remain limited. The uniqueness of this study lies in its quantitative analysis of long-term changes in urban structure based on land-use zoning, achieved through the construction of the GIS database and the introduction of the new HZCI.

1.4 Japan's Land Use Zoning System

This section outlines the history of Japan's land use zoning system, which serves as the premise for this study. Japan's land use zoning system was established in 1919 with the enactment of the City Building Act. Initially, the zoning categories consisted of four types: commercial, industrial, residential, and unspecified (unzoned) zones. Following several historical revisions, the system has evolved into the current 13 categories, comprising two commercial, three industrial, and eight residential zone types.

The zoning designation restricts the permissible building uses within a district and dictates the building coverage ratio (BCR) and floor area ratio (FAR). Furthermore, in certain zoning districts, regulations such as building height limits and setback restrictions (slant plane restrictions) to ensure sunlight are enforced. A distinctive feature of the Japanese zoning system is this dual role in regulating both land use and building morphology.

Currently, the revision of zoning designations is managed by local municipalities (cities, towns, and villages) and is implemented through consultation with and the consent of the prefectural government. It should be noted that zoning is not applied to the entire country. Instead, it is designated within specific areas intended for urban land use—excluding forests and agricultural lands—namely, within all Urbanization Promotion Areas and parts of the Non-divided Areas under the broader City Planning Area framework.

In this study, we clarify the long-term changes in land use and urban structure by spatially overlaying and comparing the initial four zoning categories with current designations using GIS. This spatial analysis reveals whether the early zoning designations have been maintained consistently or have been converted to other land uses over time.

2. Data

2.1 Selection of Study Cities

The study cities were selected based on the timing of zoning designation and population size, resulting in a total of 11 cities (Table 1). This study focuses on regional cities, excluding major metropolitan cities that have been frequently examined in previous studies. The population was obtained from *Overview of Urban Planning* published by the Toshikenkyukai in 1932.

City	Population in 1920 (* indicates 1925)		Date of Zoning Approval	Zoning Area (ha)
	City Area	Urban Planning Area		
1 Utsunomiya*	76,138	83,751	May 1934	2,169
2 Shizuoka	74,093	105,054	Apr 1932	3,363
3 Asahikawa*	72,341	83,520	Apr 1935	2,582
4 Hamamatsu	72,258	101,014	May 1931	3,075
5 Toyohashi	65,163	95,918	Apr 1930	3,268
6 Omuta	64,317	121,113	Sep 1928	742
7 Gifu	62,713	96,535	Oct 1927	2,767
8 Takamatsu	62,045	68,788	Sep 1930	1,053
9 Toyama	61,812	76,111	Sep 1931	1,242
10 Kochi	58,109	73,732	Jan 1931	3,063
11 Nagano	57,702	65,019	Jun 1930	1,794

Table 1. Study Cities.

2.2 Historical Zoning Map Data

In this study, historical zoning maps representing the initial zoning designations for each city were collected from the National Archives of Japan, the Municipal Reference Library, and various local public libraries. Many of these maps were originally produced as documents for urban planning councils. The publication years of these maps are summarized in Table 2. They were modified to match the zoning maps from the National Archives of Japan. Although the original projection systems of these historical maps are unknown, they were georeferenced and transformed into modern coordinate systems for analysis.

City	Year of Production (Initial)	Source (Initial)	Year of Production (Current)
1 Utsunomiya	1934	National Archives of Japan	2024
2 Shizuoka	1932	National Archives of Japan	2024
3 Asahikawa	1935	Municipal Reference Library	2024
4 Hamamatsu	1931	National Archives of Japan	2024
5 Toyohashi	1930	National Archives of Japan	2024
6 Omuta	1928	National Archives of Japan	2023
7 Gifu	1927	National Archives of Japan	2023
8 Takamatsu	1931	Municipal Reference Library	2024
9 Toyama	1931	Toyama Prefectural Library	2024
10 Kochi	1931	National Archives of Japan	2024
11 Nagano	1930	Municipal Reference Library	2022

Table 2. Sources and Years of Zoning Data.

For comparison, current zoning data were obtained from the "Land Use and Zoning" dataset (2024) published by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) via the National Land Numerical Information download service. As shown in Table 2, while the data years vary slightly across cities, they represent the most recent available zoning configurations. These datasets are provided in GIS format based on the Japanese Geodetic Datum 2024 (JGD2024); they were subsequently converted into the appropriate local projection systems for each municipality for the purposes of this analysis.

2.3 Georeferencing Method

In this study, GIS datasets for the initial zoning designations were created by georeferencing historical zoning maps. ArcGIS Pro 3.6 was used for both the georeferencing process and subsequent analyses. The same procedures can also be performed using the free and open-source software QGIS.

For georeferencing, multiple control points were established by referencing stable features—such as railway stations, castles, and historic buildings—whose locations have remained unchanged over time. For image transformation, a first-order polynomial (affine) transformation was applied.

3. Characteristics and Comparative Analysis of Zoning

3.1 Characteristics of Initial Zoning

First, the results of the georeferencing process and the comparison with current zoning districts are presented in Figure

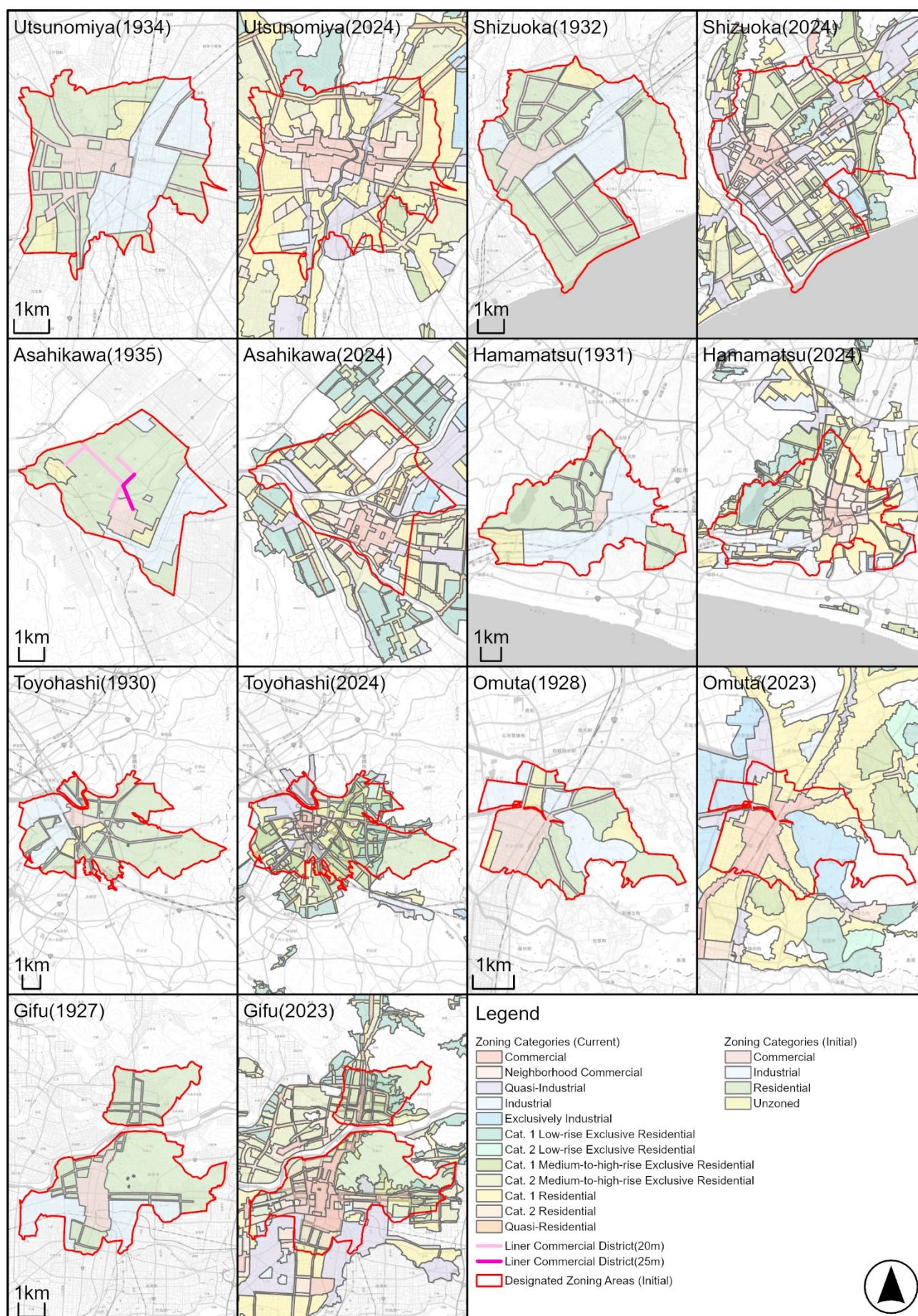


Figure 1. Comparison between Initial and Current Zoning (7 cities).

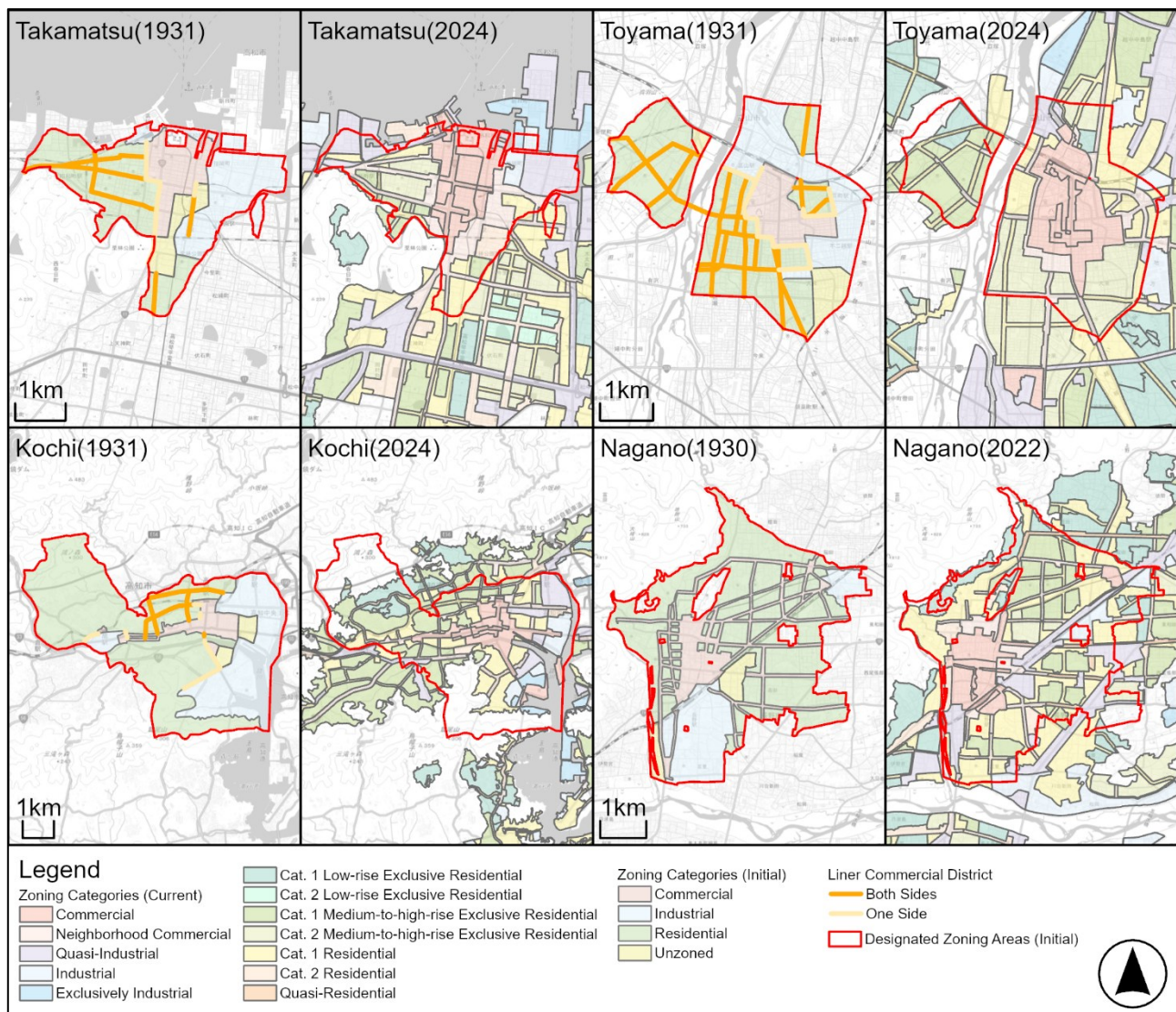


Figure 2. Comparison between Initial and Current Zoning (4 cities).

1 and Figure 2. Additionally, present-day maps are utilized as the basemaps for both. Linear commercial districts, in which commercial zoning was designated along one or both sides of major roads, were identified in all study cities. However, the methods used to designate these districts varied. In some cities, the commercial zone was delineated as a strip on the zoning map, whereas in others it was defined either as the lots directly fronting the designated road or as an area extending to a specified depth from the road. Furthermore, five cities (Utsunomiya, Asahikawa, Toyohashi, Kochi, and Nagano) also designated small, localized commercial districts in suburban areas, separate from the principal commercial district in the city center.

The initial area distribution by zoning category for each city is presented in Figure 3, where the values represent the percentage of the total designated zoning area. Although the absolute areas vary significantly among the cities, the overall average proportions are 14.0% for commercial zones, 25.9% for industrial zones, 54.7% for residential zones, and 5.3% for unspecified zones. This indicates that residential zones occupied the largest share, while unspecified zones remained extremely limited. The spatial characteristics vary substantially across the municipalities; for instance, Omuta exhibited a relatively even distribution among all zoning categories except for the

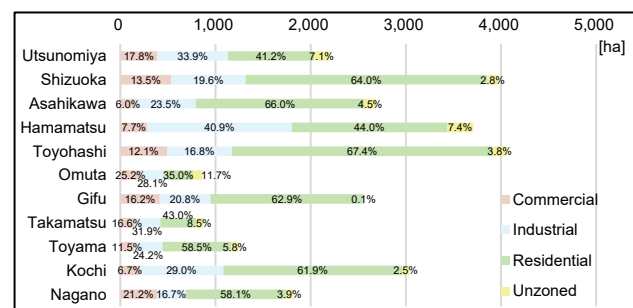


Figure 3. Proportions of Initial Zoning Areas by Category.

unspecified zones, rendering it a highly distinct case compared to the other municipalities.

3.2 Comparison with Current Zoning

Next, a comparison is conducted between the initial and current zoning designations. Although the current zoning system consists of 13 categories, they are aggregated into three primary categories (commercial, industrial, and residential) to capture broad trends and patterns of zoning modifications. Based on this aggregation, the analysis is performed using the changes in area

and the HZCI. The cross-tabulation results of the initial and current zoning designations are presented in Table 3.

Utsunomiya		Current			Subtotal	Out Area	of Total
		Com.	Ind.	Res.			
Initial	Com.	229.9	22.1	133.1	385.0	5.0	390.0
	Ind.	98.0	148.8	483.7	730.5	12.5	743.0
	Res.	93.2	58.6	715.4	867.1	38.1	905.2
	Unz.	13.2	10.3	126.7	150.2	6.2	156.3
Subtotal		434.2	239.8	1,458.9	2,132.8	61.8	2,194.6
Out of Area		43.1	1,599.7	5,544.5	7,187.3	0.0	7,187.3
Total		477.3	1,839.4	7,003.4	9,320.1	61.8	9,381.9
Asahikawa		Current			Subtotal	Out Area	of Total
		Com.	Ind.	Res.			
Initial	Com.	124.6	0.0	28.0	152.6	9.6	162.3
	Ind.	119.2	269.9	206.8	595.9	35.6	631.5
	Res.	86.3	130.6	1,080.5	1,297.4	474.8	1,772.2
	Unz.	48.0	59.5	6.7	114.1	6.1	120.3
Subtotal		378.1	460.0	1,322.0	2,160.1	526.2	2,686.3
Out of Area		107.0	1,303.1	4,399.0	5,809.0	0.0	5,809.0
Total		485.1	1,763.1	5,720.9	7,969.1	526.2	8,495.3
Toyohashi		Current			Subtotal	Out Area	of Total
		Com.	Ind.	Res.			
Initial	Com.	228.6	59.3	172.9	460.9	29.3	490.1
	Ind.	75.8	290.1	219.9	585.8	97.3	683.2
	Res.	83.6	200.7	1,638.8	1,923.1	813.5	2,736.6
	Unz.	77.9	40.8	34.4	153.1	0.0	153.1
Subtotal		465.9	591.0	2,066.0	3,122.9	0.0	4,063.0
Out of Area		34.2	1,648.2	1,363.5	3,045.8	0.0	3,045.8
Total		500.1	2,239.2	3,429.5	6,168.7	0.0	7,108.9
Gifu		Current			Subtotal	Out Area	of Total
		Com.	Ind.	Res.			
Initial	Com.	315.9	3.1	94.7	413.7	1.0	414.7
	Ind.	122.2	158.0	239.6	519.8	13.3	533.1
	Res.	117.6	33.1	802.2	952.9	655.9	1,608.8
	Unz.	0.0	1.2	0.0	1.2	0.4	1.5
Subtotal		555.7	195.3	1,136.5	1,887.5	670.6	2,558.1
Out of Area		377.2	1,131.5	4,780.5	6,289.2	0.0	6,289.2
Total		932.9	1,326.8	5,917.0	8,176.7	670.6	8,847.3
Toyama		Current			Subtotal	Out Area	of Total
		Com.	Ind.	Res.			
Initial	Com.	141.8	0.0	1.3	143.1	0.0	143.1
	Ind.	112.9	41.6	138.1	292.6	6.8	299.4
	Res.	177.3	0.7	499.2	677.1	48.2	725.4
	Unz.	0.6	0.2	70.8	71.6	0.3	71.9
Subtotal		432.6	42.5	709.3	1,184.4	55.3	1,239.7
Out of Area		289.9	2,388.8	4,646.5	7,325.3	0.0	7,325.3
Total		722.5	2,431.4	5,355.8	8,509.7	55.3	8,565.0
Nagano		Current			Subtotal	Out Area	of Total
		Com.	Ind.	Res.			
Initial	Com.	203.9	48.3	126.9	379.0	5.3	384.3
	Ind.	52.2	58.3	191.8	302.4	0.0	302.4
	Res.	85.4	116.5	780.2	982.1	70.5	1,052.6
	Unz.	5.6	38.0	20.5	64.1	7.3	71.4
Subtotal		347.1	261.0	1,119.4	1,727.5	83.1	1,810.7
Out of Area		77.7	923.3	3,428.4	4,429.5	0.0	4,429.5
Total		424.8	1,184.4	4,547.8	6,157.0	83.1	6,240.2
Shizuoka		Current			Subtotal	Out Area	of Total
		Com.	Ind.	Res.			
Initial	Com.	291.8	52.0	186.5	530.2	5.9	536.1
	Ind.	189.6	383.3	201.2	774.1	5.0	779.1
	Res.	124.3	380.4	1,515.9	2,020.6	520.9	2,541.5
	Unz.	0.0	14.2	73.8	88.0	23.3	111.3
Subtotal		605.7	829.9	1,977.3	3,413.0	555.1	3,968.1
Out of Area		348.4	2,249.3	4,444.3	7,042.1	0.0	7,042.1
Total		954.1	3,079.2	6,421.7	10,455.0	555.1	11,010.1
Hamamatsu		Current			Subtotal	Out Area	of Total
		Com.	Ind.	Res.			
Initial	Com.	157.0	2.2	123.2	282.4	2.1	284.5
	Ind.	377.4	185.6	742.4	1,305.4	211.9	1,517.3
	Res.	66.1	24.1	1,441.8	1,532.0	99.0	1,631.0
	Unz.	14.3	69.6	48.4	132.4	142.8	275.2
Subtotal		614.8	281.5	2,355.9	3,252.2	455.8	3,708.0
Out of Area		302.4	1,713.3	4,606.5	6,642.2	0.0	6,642.2
Total		917.2	2,014.8	6,962.4	9,894.3	455.8	10,350.1
Omura		Current			Subtotal	Out Area	of Total
		Com.	Ind.	Res.			
Initial	Com.	142.4	14.9	58.1	215.4	1.9	217.3
	Ind.	19.6	198.3	17.1	235.0	7.3	242.4
	Res.	37.0	17.8	168.4	223.2	79.2	302.3
	Unz.	4.6	18.6	62.1	85.3	16.2	101.4
Subtotal		203.6	249.7	305.7	758.9	104.5	863.5
Out of Area		119.9	962.4	2,052.2	3,134.5	0.0	3,134.5
Total		323.5	1,212.1	2,357.8	3,893.4	104.5	3,998.0
Takamatsu		Current			Subtotal	Out Area	of Total
		Com.	Ind.	Res.			
Initial	Com.	141.4	2.1	0.0	143.6	0.2	143.8
	Ind.	81.3	131.3	64.2	276.8	0.5	277.3
	Res.	109.0	53.5	201.5	364.0	9.2	373.2
	Unz.	65.0	0.0	8.8	73.8	0.0	73.8
Subtotal		396.7	186.9	274.5	858.2	9.9	868.1
Out of Area		301.2	1,351.8	3,967.6	5,620.5	0.0	5,620.5
Total		697.9	1,538.7	4,242.1	6,478.7	9.9	6,488.6
Kochi		Current			Subtotal	Out Area	of Total
		Com.	Ind.	Res.			
Initial	Com.	156.4	3.5	43.2	203.1	1.3	204.5
	Ind.	107.4	325.8	206.6	639.8	239.0	878.9
	Res.	174.5	20.0	893.3	1,087.8	789.7	1,877.5
	Unz.	14.3	13.8	46.6	74.6	0.0	74.6
Subtotal		452.6	363.1	1,189.7	2,005.4	1,030.1	3,035.4
Out of Area		139.2	489.4	2,637.4	3,266.0	0.0	3,266.0
Total		591.8	852.5	3,827.1	5,271.4	1,030.1	6,301.5

Table 3. Cross-tabulation of Initial and Current Zoning Areas (ha).

First, regarding the changes in area, the rate of change (percentage growth from the initial area) is presented in Table 4. With the exception of the industrial zone in Kochi, significant expansion is observed across all zoning categories. However, in terms of average values, the increase rate for industrial zones is particularly substantial at +405.4%, whereas the growth rate for commercial zones remains relatively small. Furthermore, while the total designated zoning area increased by an average of +274.6%, there are considerable variations among the municipalities; for instance, Toyohashi experienced an increase of +51.8%, whereas Takamatsu saw a dramatic expansion of +646.3%.

	Commercial	Industrial	Residential	Total
Utsunomiya	+22.4%	+147.6%	+673.7%	+324.7%
Shizuoka	+78.0%	+295.2%	+152.7%	+163.5%
Asahikawa	+199.0%	+179.2%	+222.8%	+196.7%
Hamamatsu	+222.3%	+32.8%	+326.9%	+166.8%
Toyohashi	+2.0%	+227.8%	+25.3%	+51.8%
Omura	+48.8%	+400.1%	+679.9%	+350.9%
Gifu	+125.0%	+148.9%	+267.8%	+219.6%
Takamatsu	+385.4%	+454.8%	+1036.7%	+646.3%
Toyama	+405.1%	+712.0%	+638.4%	+586.4%
Kochi	+189.4%	-3.0%	+103.8%	+73.7%
Nagano	+10.5%	+291.7%	+332.1%	+240.0%
Average	+153.4%	+262.5%	+405.4%	+274.6%

Table 4. Rate of Change in Area by Zoning Category.

Next, to ascertain the extent to which historical zoning designations have been maintained in the current zoning framework, the HZCI was calculated for each zoning category across all study cities. The calculation method for the HZCI is as described in Section 1.2.

The results are presented in Figure 4. On average, the HZCI values for residential and commercial zones are high, exceeding 60%. This indicates that more than 60% of the areas in these categories have remained unchanged from their initial designations. Conversely, the average HZCI for industrial zones is notably low at 36.0%, revealing that a substantial portion of the initially designated industrial areas has subsequently been converted to residential or commercial uses.

For example, in Hamamatsu, where the industrial HZCI is the lowest at 12.2%, 48.9% (742.4 ha) of the initially designated 1,517.3 ha of industrial land was rezoned to residential categories.

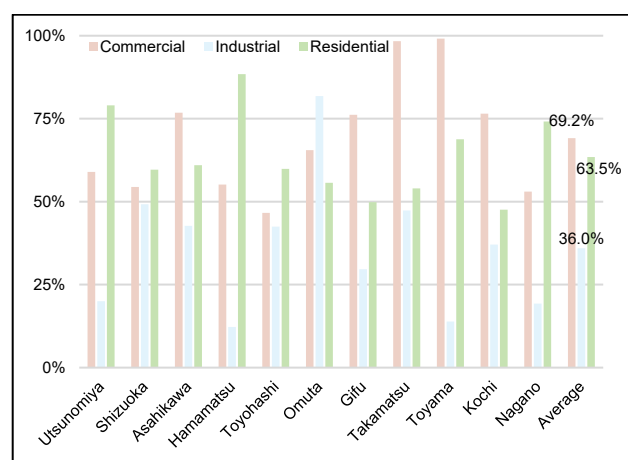


Figure 4. HZCI by Zoning category for Each City.

3.3 Typology via Cluster Analysis

Next, to categorize the zoning transition patterns, a principal component analysis (PCA) and a subsequent cluster analysis were performed. The PCA variables included the initial zoning

category proportions, their respective HZCI values, and the overall zoning area growth rate. The initial PCA results are presented in Table 5.

The first principal component (PC1) represents "Initial Zoning Characteristics." The strong negative loadings for overall area growth rate (-0.512) and initial industrial ratio (-0.455), contrasted with a positive loading for initial residential ratio (0.585), indicate an axis distinguishing cities that were initially industrial-oriented and underwent massive expansion from those that were inherently residential-oriented and matured more stably.

The second principal component (PC2) represents "Land-use Transition." With a strong positive loading for residential HZCI (0.609) and a significant negative loading for industrial HZCI (-0.549), this axis highlights the contrast between cities where original industrial designations have been strongly maintained and cities where significant land-use conversion toward residential use has occurred.

Variables	PC1	PC2
Initial Commercial Ratio	-0.266	-0.314
Initial Industrial Ratio	-0.455	0.318
Initial Residential Ratio	0.585	-0.031
HZCI: Commercial	-0.284	-0.283
HZCI: Industrial	-0.013	-0.549
HZCI: Residential	-0.194	0.609
Overall Area Growth Rate	-0.512	-0.216
Explained Variance Ratio	0.341	0.284
Cumulative Variance Ratio	0.341	0.624

Table 5. Principal Component Loadings and Explained Variance.

Figure 5 presents the results of the hierarchical cluster analysis (Ward's method) using these principal component scores, which classified the 11 study cities into three distinct clusters.

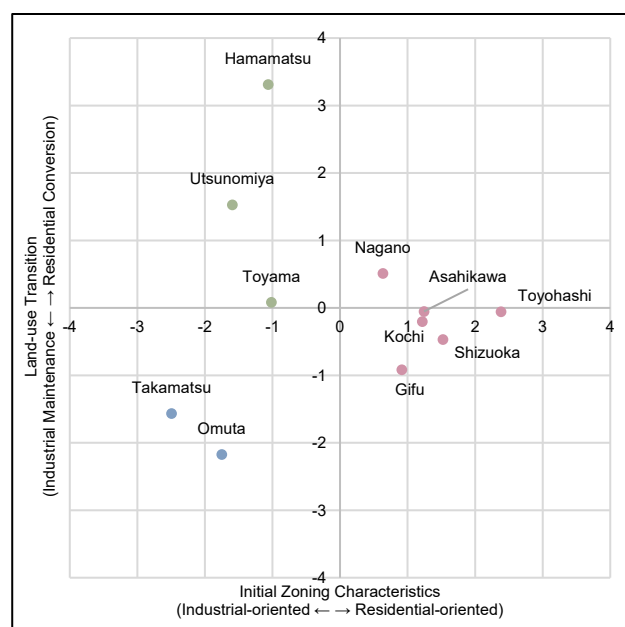


Figure 5. Typology of Zoning Transition Patterns.

The characteristics of each cluster are presented as follows. Table 6 summarizes the mean values for each variable.

	Initial Ratio (%)			HZCI			Rate of change
	Com.	Ind.	Res.	Com.	Ind.	Res.	
CL1	12.6%	21.1%	63.4%	63.9%	36.7%	58.7%	+157.6%
CL2	20.9%	30.0%	39.0%	81.9%	64.6%	54.8%	+498.6%
CL3	12.3%	33.0%	47.9%	71.1%	15.4%	78.7%	+359.3%
Total	14.0%	25.9%	54.7%	69.2%	36.0%	63.5%	+274.6%

Table 6. Mean Values of Variables by Cluster.

Cluster 1 (Shizuoka, Asahikawa, Toyohashi, Gifu, Kochi, Nagano): Residential-Specialized and Growth-Restricted Type.

This cluster exhibits positive values on the "Initial Zoning Characteristics" axis, characterized by an extremely high proportion of initial residential zoning (around 60%). It also shows the lowest mean rate of change, indicating that urban expansion in these cities has been relatively suppressed.

Cluster 2 (Omuta, Takamatsu): Industrial-Maintenance and Expansion Type.

This cluster shows negative values on the "Land-use Transition" axis, characterized by a high HZCI for industrial zones. In particular, Omuta exhibits an industrial HZCI of 81.8%, reflecting the continued maintenance of areas planned for industrial use. On the other hand, this cluster has the highest mean rate of change, indicating that the total designated zoning area itself has expanded significantly.

Cluster 3 (Utsunomiya, Hamamatsu, Toyama): Industrial-Conversion Type.

This group exhibits negative values for "Initial Zoning Characteristics" (high initial industrial ratio) and positive values for "Land-use Transition" (low industrial maintenance rate). As seen in Hamamatsu and Toyama, despite prioritizing industrial use in the initial stages, current industrial HZCI values remain extremely low (e.g., 12.2%–13.9%). This signifies that former industrial areas have undergone large-scale conversion to residential or commercial use in subsequent zoning designations, making this the group that has experienced the most dynamic restructuring of its urban composition compared to others. Conversely, the HZCI for commercial and residential zones is relatively high, indicating that significant land-use changes have occurred specifically within industrial zones.

As demonstrated above, the initial zoning designations and their subsequent transitions were successfully classified into three distinct typologies. Asano (2012) analyzed the initial zoning patterns of 43 Japanese cities and classified them into three types: the Existing Urban Area Type, the Industrial-Oriented Type, and the Residential-Oriented Type. Similarly, in the present study, the first principal component represented the initial zoning characteristics, distinguishing between industrial-oriented and residential-oriented cities, which is consistent with Asano's classification. By extending the analysis to examine the long-term evolution of zoning patterns up to the present, this study further identified a second principal component representing land-use transition. This finding demonstrates that cities with similar initial industrial-oriented zoning did not necessarily follow the same developmental trajectory, but instead evolved into either the Industrial-Maintenance and Expansion Type or the Industrial-Conversion Type.

3.4 Chapter Summary

This chapter quantitatively analyzed the long-term transformation of urban zoning in 11 regional Japanese cities by georeferencing historical maps and comparing them with contemporary data using the Historical Zoning Consistency Index (HZCI). The analysis revealed that while residential and commercial zones have generally maintained high spatial continuity since their initial designation, industrial zones have undergone extensive conversion in many cases. Furthermore, through principal component analysis (PCA) and hierarchical cluster analysis based on initial zoning characteristics, HZCI values, and area growth rates, we identified three distinct evolutionary typologies: "Residential-Specialized and Growth-

Restricted," "Industrial-Maintenance and Expansion," and "Industrial-Conversion" types. These findings quantitatively demonstrate both the city-specific evolutionary trajectories and the broader patterns of land-use transformation in Japanese urban planning.

4. Discussion and Conclusions

4.1 Characteristics of Initial Zoning Designations

Looking back at the origins of these cities, eight of the 11 study cities—Utsunomiya, Shizuoka, Hamamatsu, Toyohashi, Gifu, Takamatsu, Toyama, and Kochi—originated as castle towns. Among them, Gifu Castle was a mountain castle, whereas Takamatsu Castle was a coastal castle. Nagano, meanwhile, developed as a temple town surrounding Zenkoji Temple. In these cities, the areas that had flourished as castle towns or temple towns during the early modern period were generally designated as the main commercial districts.

In contrast, Asahikawa developed as a settlement city during the colonization of Hokkaido in the Meiji era, while Omuta grew as a coal-mining city. Compared with the castle towns and temple town, their urban origins are relatively recent. The official statements explaining the zoning decisions indicate that Asahikawa's commercial zone was designated because the orderly city center contained concentrations of banks and companies, whereas Omuta's commercial zone was designated because it consisted of flat land with thriving commercial activities and well-developed transportation facilities. Thus, in both Asahikawa and Omuta, continuous commercial zones were designated in districts that had already become prosperous.

According to the *Standards for Zoning Decisions* (1927), which established the principles for designating land-use zones, areas that had not yet been urbanized were to be zoned by first establishing commercial zones, then determining the layout of industrial zones, and finally allocating the remaining land to residential zones. Consistent with this policy, linear commercial districts, in which commercial zoning was designated along major roads, were identified in all 11 study cities, whereas localized commercial districts located away from the main commercial district were identified in five cities. Examination of these localized commercial districts revealed that they were situated around a suburban railway station in Utsunomiya; in licensed quarters in Asahikawa and Toyohashi; in an area where a school, a police facility, and a chamber of commerce were concentrated, as well as around a suburban railway station, in Kochi; and around a suburban railway station and at major intersections in Nagano. Although their spatial extent has changed over time, many of these localized commercial districts have remained designated as commercial zones, suggesting that their initial designation has had a lasting influence on subsequent zoning patterns.

Topographical factors also appear to have influenced the initial zoning patterns. In Shizuoka, Omuta, and Takamatsu, the zoned areas faced the sea, while Hamamatsu and Toyohashi were located close to the coast. In Asahikawa, Gifu, Toyama, and Kochi, major rivers divided the urban area, whereas Shizuoka and Nagano were located along major rivers. These geographical features, together with the locations of railway stations, likely influenced the placement of industrial zones. In addition, the surrounding coastline and mountainous terrain may have influenced the direction of urban expansion and the relocation of industrial facilities to suburban areas.

4.2 Patterns of Zoning Transformation

In Chapter 3, the "Patterns of Zoning Transformation" were clarified by conducting a cluster analysis using the HZCI and the area growth rate for each zoning category. Three patterns were identified: the Residential-Specialized and Growth-Restricted Type, the Industrial-Maintenance and Expansion Type, and the Industrial-Conversion Type.

Considering that the early zoning system was introduced primarily to control the location of factories, we first examined the Industrial-Conversion Type. Although this type initially aimed to induce industrial development, it failed to do so, resulting in the conversion of these areas into residential or commercial uses. Specifically, there has been a significant conversion to residential use. For example, in Toyama, 46.1% (138.1 Out of 299.4 ha) of the initially designated industrial zones have now been converted to residential zones. Similarly, this conversion rate is 65.1% (483.7 Out of 743.0 ha) in Utsunomiya, and 48.9% (742.4 Out of 1,517.3 ha) in Hamamatsu.

In Toyama, for instance, actual industrial development occurred in the suburbs along the Fugan Canal to the north, outside the originally designated industrial zones, which likely led to the low retention of the initial industrial areas. It is inferred that this shift was also driven by changes in urban planning policies aimed at separating factories from residential areas in response to heavy industrialization. In Hamamatsu, as well, the southern portion of the initially designated industrial zone on the east side has become residential, while the actual industrial areas have expanded further north and onto reclaimed coastal lands. Utsunomiya exhibits a similar pattern of zoning modification, where industrial zones were relocated to the urban outskirts alongside the development of suburban industrial parks.

On the other hand, both the Residential-Specialized and Growth-Restricted Type and the Industrial-Maintenance and Expansion Type are characterized by a relatively high industrial HZCI. This suggests that in these cities, the location control of factories—the original objective of the urban planning framework—proceeded largely as planned. In particular, in Cluster 2 (Industrial-Maintenance and Expansion Type), industrial areas in Omuta expanded as coastal land reclamation progressed, resulting in a 400.1% increase in industrial zoning area. Similarly, in Takamatsu, coastal land reclamation enabled the addition of new industrial zones, leading to a 454.8% increase in industrial zoning area. These findings suggest that the coastal location of these cities, together with the availability of reclaimed land for industrial development, was a key factor that enabled industrial areas to expand while preserving the continuity of the original industrial zoning pattern.

A different characteristic can be observed in Cluster 1 (Residential-Specialized and Growth-Restricted Type). The average initial zoning area of the six Cluster 1 cities was approximately 3,020.3 ha, compared with 1,774.8 ha for the other five cities. Moreover, the initial zoning plans of the Cluster 1 cities allocated a substantially larger proportion of land to residential use (63.4%) than to commercial (12.6%) or industrial (21.1%) use. Furthermore, the subsequent expansion of the total zoning area was relatively limited (+157.6%) compared with the other clusters. These findings suggest that the initial zoning plans in Cluster 1 may have better anticipated future residential growth, allowing urban development to be guided largely within the original zoning framework. This finding indicates that allocating sufficient land for residential use at the initial planning stage

contributed to accommodating long-term urban growth while maintaining the continuity of the original zoning pattern.

Overall, this study identified common characteristics of the initial zoning patterns and their subsequent transformations, allowing the study cities to be classified into three distinct types. Some cities successfully anticipated future urban development and maintained a high degree of consistency between the initial and current zoning patterns through effective development control. In contrast, other cities exhibited lower HZCI values, either because zoning plans were appropriately revised in response to urban development or because development control was insufficient to maintain the original zoning framework.

By structuring the long-term processes of urban expansion in this way, this study provides useful insights for urban planning in an era of population decline. The findings demonstrate the long-term influence of zoning decisions on urban structure and provide a foundation for considering which land uses should be reduced and which urban centers should be prioritized in future urban shrinkage and compact city planning.

4.3 Significance of GIS in Urban Historical Research

The significance of this study also lies in its methodological approach, which utilizes GIS to conduct quantitative research on urban planning history. In previous studies examining the evolution of zoning, quantitative analysis has often been challenging, with the research scope primarily limited to the visual interpretation of historical maps and the qualitative reading of planning documents. In contrast, by georeferencing historical zoning maps to convert them into GIS datasets and performing spatial overlays, this study enabled the application of analytical methods such as cross-tabulation and cluster analysis. Through these quantitative approaches, it became possible to not only empirically verify phenomena that had previously been discussed only qualitatively, but also to uncover new trends based on numerical evidence.

4.4 Future Research Directions

For future research, we aim to expand the number of case study cities to analyze chronological changes and their underlying trends more comprehensively. Additionally, we plan to conduct comparative analyses with international zoning systems, such as that of St. Louis, which served as a historical reference for the establishment of Japan's zoning framework.

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