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RESEARCH ARTICLE

# Characteristics of road network forms in historic districts of Japan



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## KEYWORDS

Road network forms;  
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Graph theory;  
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## Abstract

This study focused on the structure and the platform of the road space of historic districts. We analyzed the road networks of 16 historic districts in Japan from the perspectives of circularity, accessibility and indirection based on graph theory. By calculating and comparing the indexes of each road network (NW1 and NW2) forms, we quantitatively describe the effects of the main prefectural roads (more than 4 m in width) and narrow streets (less than 4 m in width) on the spatial characteristics. And it turned out that we could divided the 16 objective historic districts into 4 types. Moreover, we qualitatively studied the characteristics of each type of historic districts based on their development background and the structure of road network.

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## 1. Introduction

Many cities and villages in Japan have a long history. The spatial form of these historic districts has changed with the progression of urbanization, but many such districts and villages still apply old road networks as spatial frameworks. These frameworks contain not only old streets that serve as the main prefectural roads but also winding narrow alleys that are less than 4 m wide. Although traffic capacities vary, these streets complement one another and jointly constitute the road network form that fits the local lifestyle while maintaining the uniqueness of the area. People wandering in these historic districts are often fascinated by the sequence landscape along the road and the

rich variations in the road itself. Thus, these historic streets must be preserved in merging modern urban design with the characteristics of the local area.

Since Japan established the Important Preservation Districts for Groups of Traditional Buildings in 1975, an active movement has been initiated to protect and re-develop historic districts throughout the country. Given the sub-optimal awareness regarding the spatial structure of historic districts in preparing local development plans, many old streets were modified after being regarded as unfavorable factors that impede traffic. As a result, the road network in some originally unique historic districts changed and a few historical surroundings were demolished. Apart from recognizing the importance of historic streets from the perspectives of landscape and culture, the features of spatial structures must be interpreted objectively to avoid conflicts between the re-development of historic districts and the preservation of the historic environment.

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On the basis of the afore mentioned viewpoints, 16 historic districts of various formation backgrounds in Japan were taken as examples in this study to analyze the circularity, accessibility, and indirection of the road network individually. This procedure can help quantitatively clarify the features of the road network form in these districts and explore the relationship between road formation and spatial characteristics further.

## 2. Previous studies

To date, researchers in many disciplines have studied the spatial features of historic roads in Japan. In geographic research, for example, historic streets in Japan were classified according to natural and artificial road formation conditions, and the relationship between the characteristics of road sections and the use of land along the road was identified (Rin et al., 1995; Kamae et al., 1995). In landscape-related studies, the roles of the historic roads in the area within the sequence landscape were explored by analyzing the shapes and angles of the roads and of the surrounding physical environment (Iwakuma, 1997; Miyawaki, 2012; Kawakami et al., 2012). In papers discussing local communities, the influence of road spatial features in various scales on the communication behavior within the neighborhood inside blocks was determined through field investigations into the environment of historic roads in Kyoto and the functions of the buildings along the roads (Okada and Miyazaki, 2012).

The results from the afore mentioned studies indicate that historic road space plays an important role in the formation of local communities and in the continued implementation of urban characteristics in Japan. However, most previous works described the physical characteristics of road spaces from their respective viewpoints. Moreover, research on the overall composition and potential non-visual characteristics of historic road networks in Japan remains scarce.

In studies that examine the re-development of historic regions, many historic districts may emphasize accessibility and circularity; researchers argue that some old streets are highly circuitous and thus contribute little to traffic (Kozuka

et al., 2005; Shimizu and Ono, 2006; Aoki et al., 2010). Hence, proposals to demolish and change original road network structures have been presented. However, problems regarding the exact situation of the original road network and the extent to which certain roads affect the overall characteristics of the area are rarely addressed objectively (Tanaka and Akasaki, 2000; Nishiguchi, 2004).

In the current study, we focus on the structure and the platform of the road space. Furthermore, we analyze the spatial characteristics of the road networks in historic districts with different formation backgrounds in terms of three aspects that have attracted much attention in regional development, namely, circularity, accessibility, and indirection (Punnoi et al., 2010; Miyashita et al., 2013). This analysis can help quantitatively illustrate the spatial characteristics and the status quo of the historic roads. This study also presents methods and basic data to effectively recognize road space for coordinating future development plans related to historic regions (Fig. 1).

## 3. Research method

### 3.1. Indicators

In this study, the circularity, accessibility, and indirection of road networks are defined based on graph theory (Watanabe et al., 1983). The selected indicators that can be used to quantitatively describe the geometric features of these aspects are listed in Table 1.

First, the circularity of the road network refers to the extent of repetition by people wandering around the road network purposelessly (Takagi et al., 1991). From a geometrical point of view, this metric depends on the number of circular roads in the network and the number of nodes and links that constitute the circular road (Beineke and Wilson, 1978; Ando et al., 2001). Therefore, circularity can be evaluated through three indicators  $\alpha$ ,  $\beta$ , and  $\gamma$  (Sakai and Naya, 1992; Saito, 2002, 2011). If any given link in a network is removed, thereby preventing the formation of a complete graph, then the graph is considered a “tree-type” graph. If every node in the graph can be connected directly, then the graph is regarded as a “complete link

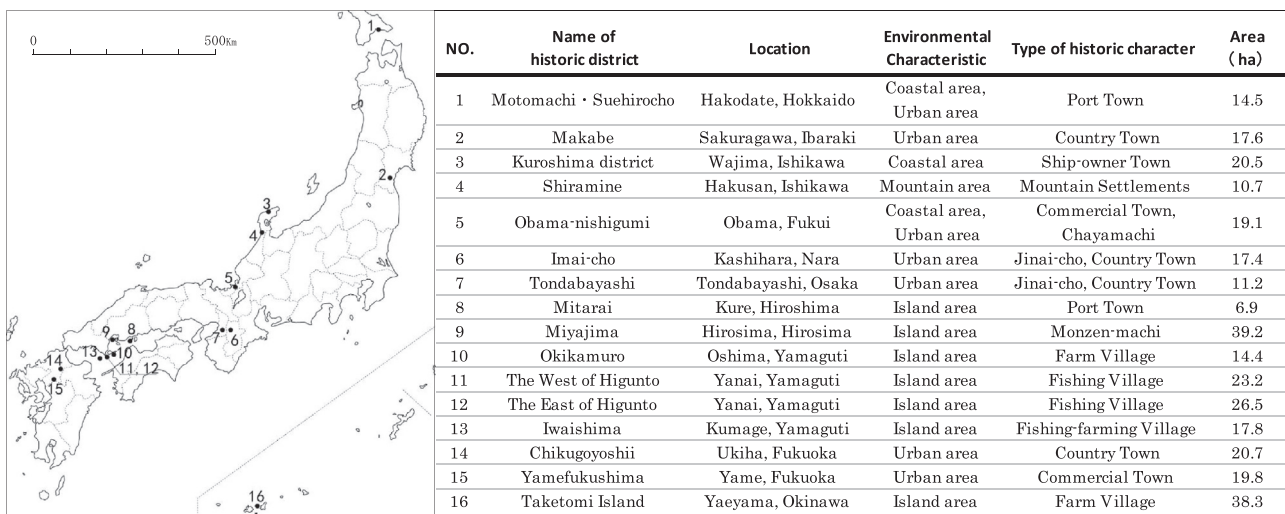


Fig. 1 The basic information of the research areas.

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