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SPATIAL ANALYSIS OF SURFACE PARKING LOTS LOCATION AND CITYSCAPE PRESERVATION IN HISTORIC CENTRAL DISTRICTS: CASE STUDIES IN KYOTO AND PHILADELPHIA

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ABSTRACT

In Japan, surface parking lots for visitors are often located without a careful plan or a particular order. Such random surface parking locations without planning and regulation, combined with eye-soring signs and visually cluttering equipment, negatively affect cityscapes even in historic cities, including Kyoto where a higher attention is paid to historic preservation. In this study, we analyze the spatial distribution and design of surface parking for visitors within historic central districts of two cities—Kyoto, Japan and Philadelphia, U.S.—to examine the discontinuity of cityscape. In addition, we explore how different approaches of historic preservation influence surface parking locations in these two cities.
The preliminary results show that the locational patterns of surface parking differ significantly between the two cities. While many small-size surface parking lots below 500 square meters are distributed throughout the entire city in Kyoto, a relatively smaller number of large-scale surface parking lots are provided with some concentration in the center of historic district in Philadelphia. Moreover, the spatial pattern analysis shows remarkable discontinuity of cityscape especially in Kyoto.

Keywords: surface parking lots location, historical central districts, cityscape preservation, spatial pattern analysis, spatial autocorrelation

1. INTRODUCTION

In Japan, surface parking lots for visitors are often located without a careful plan or a particular order. Such random surface parking locations without planning and regulation, combined with eye-soring signs and visually cluttering equipment, negatively affect cityscapes even in historic cities, including Kyoto where a higher attention is paid to historic preservation. This is because some developers generally plan to possibly hold down development cost to the minimum for the provisional use of land, and develop in little consideration of urban design or aesthetic fit in the neighbourhood (Shoup 2005). Although Japanese planners are increasingly concerned with the negative impacts of the locational disorder and lack of design for surface parking lots on a cityscape in historic preservation districts, there has been little research and practice to systematically examine surface parking lots location as part of cityscape or basic urban infrastructure.

Several previous studies quantitatively examined land area covered by surface parking lots and density of lots in urban areas. For instance, Manville and Shoup (2005) showed surface parking area and density in each city's CBD from transportation data that Kenworthy and Laube (1999) provided for 44 world cities. Although their research grasped the status of surface parking area on the city level from the macroscopic viewpoint, other studies specified each parking lot from the microscopic viewpoint. Davis et al. (2010a) identified surface parking lots in Tippecanoe county of the U.S. based on high resolution aerial photography using GIS, and measured the number and size. Davis et al. (2010b) estimated parking lot footprints across a four state region of the U.S., using the same methodology. In Japan, Chujo and Higuchi (2002) examined types of operation, the number of surface parking lots, the size, and the number of parking spaces collected through a field survey within the central area of Nagaoka City. However, these previous studies did not explicitly analyse the locations, urban design or aesthetic fit in the neighborhood.

There are several studies that have a particular focus on these issues. Crankshaw (2001) identified five spatial models for parking and pedestrian access in historic downtowns of the U.S. from a preservation and design perspective. Then, Mukhija and Shoup (2006) found five different approaches to improve urban design through creative off-street parking requirements: limiting the number of parking spaces, improving the location of parking, and requiring better designs of parking lots, parking structures, and residential garages. And they indicated that planners should pay more attention to not only the quantity but also the quality of parking. Moreover, Ben-Joseph (2012) indicated that it was important to incentivize and promote voluntary initiative to improve a design of surface parking lots, rather than using a command and control strategy. Also in Japan, Oba (2011) pointed out the three problems regarding urban design and cityscape that were caused by an increase of surface parking lots: the eye-soring and visually cluttering parking facility, the discontinuity of cityscape, and the car-oriented cityscape formation. While these previous studies qualitatively discussed the importance of surface parking in cityscape formation and preservation, none of them conducted an empirical data analysis to quantitatively evaluate the impacts of surface parking.

The purpose of this study is to examine surface parking lots for visitors in terms of spatial distribution and facility design and their impacts on continuity and preservation of historic

cityscapes, based on field survey data collected in the historic central districts of two cities—Kyoto, Japan and Philadelphia, U.S.

2. SURVEY AREAS AND DATA COLLECTION

2.1 Target Cities: Kyoto and Philadelphia

Figure 1 shows the locations of two cities in this study. Kyoto is the old capital of Japan known for its substantial historic heritage, such as temples, shrines and gardens, and is located about 460 kilometers west of Tokyo. Philadelphia also has many historic buildings and places for visits as the birthplace of the U.S., and is located in the Mid-Atlantic region of the U.S. The sizes of population in these two cities about the same—1.47 million in Kyoto and 1.50 million in Philadelphia—and share some common features. First, historic central districts of the two cities exhibit a complex pattern of various land uses for business, commerce, and residence. Second, both cities' historic central districts are characterized by a grid street pattern. In addition both cities also have historic preservation policies that have had positive effects on their cityscape as shown Photo 1. In the historic central district of Kyoto, traditional wooden houses called "Machiya" are still found widely, continuously being revitalized and preserved to protect the beautiful cityscape of Kyoto. In the historic central district of Philadelphia, many historic resources are protected from adverse alterations and demolition by listing in the National Register of Historic Places and similar registries.

Figure 1 – Locations of Kyoto and Philadelphia

(Left: Kyoto, Right: Philadelphia)

Photo 1 – Historic cityscape in Kyoto and Philadelphia

2.2 Data Collected Through Field Surveys

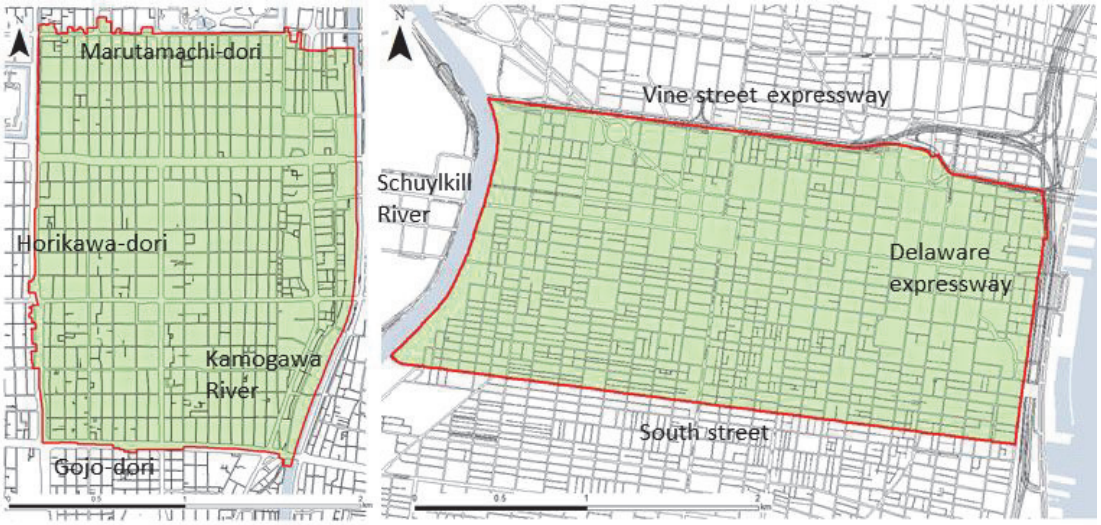
Field surveys were conducted to collect data on conditions of surface parking lots and cityscape preservation in historic central districts (Photo 2). Table 1 shows the overview of the field surveys in the two cities. Furthermore, each survey area is shown in Figure 2.
In this study, field researchers walked through all streets in the surveyed areas and conducted a visual inventory and took photographs of surface parking lots with a focus on the five main categories of information listed in Table 1. Also, this study used GIS to identify locations of surface parking lots, convert the survey data into an electronic form of spatial data, and visualize the spatial distributions of surface parking lots in the historic central districts. It should be noted that the survey data do not include any private and reserved parking lots only for the use of residents, shoppers, or workers.

(Left: Kyoto, Right: Philadelphia)

Photo 2 –Surface parking lots for visitors in Kyoto and Philadelphia

Table 1 – Overview of the field surveys in Kyoto and Philadelphia

City	Kyoto	Philadelphia
Survey Period	July, 2011	August, 2012
Area Size	4.12km^2	5.47km^2
Survey Item	1) Surface parking location 2) Type, size, and design of parking 3) Parking rate 4) Built environment in the surrounding 5) Facility and equipment in use	
Number of Photograph	1,294	1,538



(Left: Kyoto, Right: Philadelphia)

Figure 2 – Survey areas in Kyoto and Philadelphia

3. SPATIAL DISTRIBUTION AND FACILITIES DESIGN OF SURFACE PARKING LOTS

3.1 Spatial Distribution of Surface Parking Lots

This section provides a general picture of the characteristics of surface parking lots and presents the spatial distribution in GIS maps. Table 2 shows the basic statistics of surface parking lots in Kyoto and Philadelphia. Kyoto has 346 surface parking lots with the average size of 195 m^2. The total area of surface parking lots is 67,424m^2, or covering 16.3% of 4.12 km^2 of the surveyed area. In contrast, Philadelphia has surface parking lots at 75 locations with the average size of 2,027m^2. Although the number of surface parking lots is fewer than Kyoto, the total area of surface parking lots in Philadelphia is larger with 152,018m^2, or covering 28.7% of the surveyed area.

Figure 3 and Figure 4 show the spatial distribution of surface parking lots in Kyoto and Philadelphia. As these figures indicate, the spatial patterns are markedly different between the two cities. While a small number of large surface parking lots form clusters in several locations throughout the historic central district of Philadelphia, many small surface parking lots are scattered across space in Kyoto. The main explanation of the size and the special pattern of parking lots in Kyoto is that offices and stores in the kimono industry and private houses in a small size are demolished and converted for the use of parking over years. Thus, the two cities show great differences in the size, number, and spatial distribution of surface parking lots.

Figure 5 shows the number of surface parking lots by size. In Kyoto, the majority of surface parking lots are smaller than 500 m^2, and these small lots account for 95% of all surface parking lots. In Philadelphia, however, a majority of surface parking lots is larger than 1,000m^2, and these large lots are located in 49 locations and account for 65% of all surface parking lots. Having surface parking lots with large spaces covered by asphalt in Philadelphia

is not a human-friendly condition. At the same time, this condition likely has great negative influence on the cityscape.

Table 2 – Statistics of surface parking lots

Item	Kyoto	Philadelphia
Number	346	75
Average Area (m^2)	195	2,027
Maximum Area (m^2)	1,040	14,214
Minimum Area (m^2)	14	292
Total Area (m^2)	67,424	152,018
Parking Coverage (%)	16.3	28.7
Average Hourly Rate*	402JPY (5.02USD)	(915JPY) 11.44USD
Average Daily Rate*	4,486JPY (56.07USD)	(1,610JPY) 20.13USD

* Prices shown in parenthesis are corresponding values under US Dollar - Japanese Yen Exchange Rate: 80 Price of 1 USD in JPY

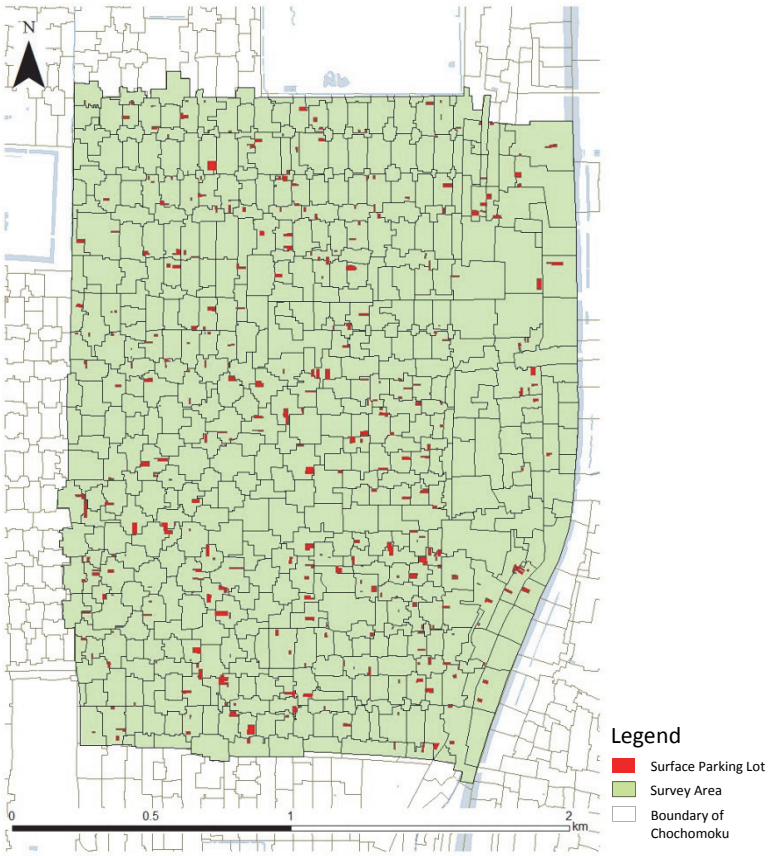


Figure 3 – Surface parking lots map (Kyoto)

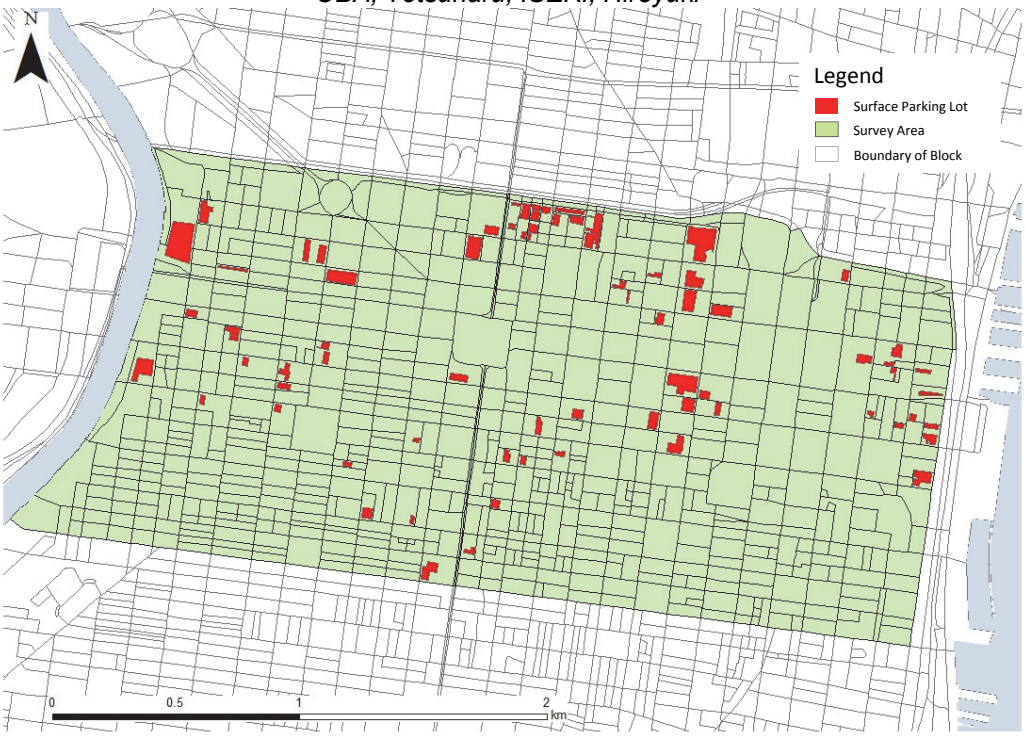


Figure 4 – Surface parking lots map (Philadelphia)

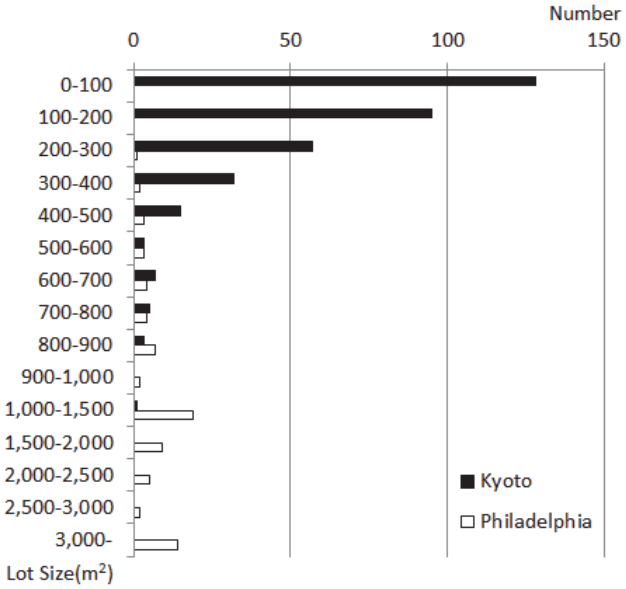


Figure 5 – Number of surface parking by lot size

Photo 3 – Surface parking lots with large spaces covered by asphalt in Philadelphia

3.2 Facilities Design of Surface Parking Lots

This section describes the design conditions of surface parking facility and cityscape using the photographs taken during the visual surveys. This study focuses on the following four components of surface parking lots: 1) the number of streets that a parking lot faces, 2) plants, 3) public art walls, and 4) fences/retaining walls. In particular, plants and public art walls improve the attractiveness of parking lots. The importance of fences/retaining walls that visually block cars parked inside was pointed out by one of the foremost practitioners of New Urbanism, Calthorpe (1995).

Figure 6 shows the percentage of surface parking lots that have these components in Kyoto and Philadelphia. The percentage of surface parking lots facing more than one street is 75% in Philadelphia and 25% in Kyoto. In Kyoto, the remaining 75% are scattered between buildings as shown in Photo 4, creating discontinuity in the cityscape of the historic central district. The percentages of surface parking lots with plants and public art walls are both about 20% in Philadelphia but close to 0% in Kyoto. The percentage of parking lots with fences/retaining walls are 45% in Philadelphia and 5% in Kyoto.

Figure 7 focuses on facility components at surface parking lots, showing the average number of components in nine types that are installed at parking lots. The signage of current occupancy rate (full or not-full), beverage vending machines and flag banners were found in parking lots in Kyoto but were not observed in Philadelphia. In addition, more signboards are installed in surface parking lots in Philadelphia than in Kyoto. This may be resulted from the substantially larger average size of lots in Philadelphia.

The number of facilities installed per 100 m^2 of lot space is shown in Figure 8. The figure clearly indicates that a larger number of facility components is installed in Kyoto than in Philadelphia regardless of types of equipment. While a pay-on-foot type of parking ticket machine is operated at most parking lots in Philadelphia, a flap type, which locks one vehicle axle during the use of parking spot until a payment is done, is popular in Kyoto. As multiple “flaps” are usually installed at a surface parking lot in Kyoto, this increases the number of facility components on the site. While the size of surface parking lots is small in Kyoto, the variety of facility components with eye-soring colors and designs (Photo 5) may degrade the cityscape of the historic central districts.

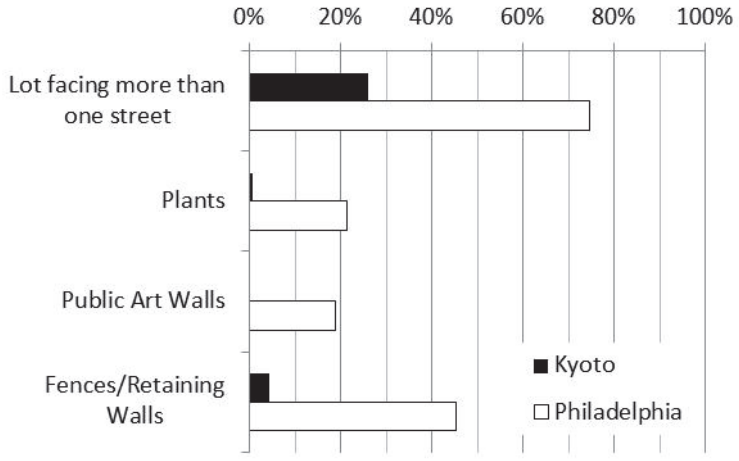


Figure 6 – Percentage of surface parking lots with each component

Photo 4 – Discontinuity in the cityscapes by a surface parking lot in Kyoto

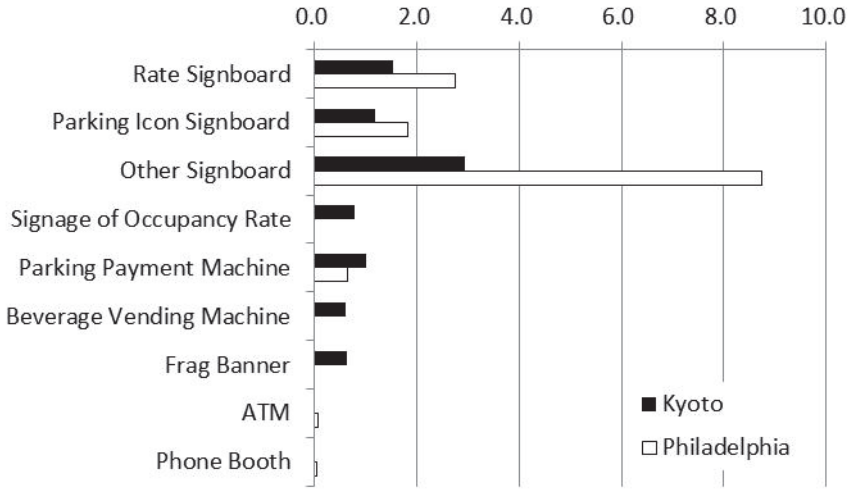


Figure 7 – Number of facilities installed per parking lot

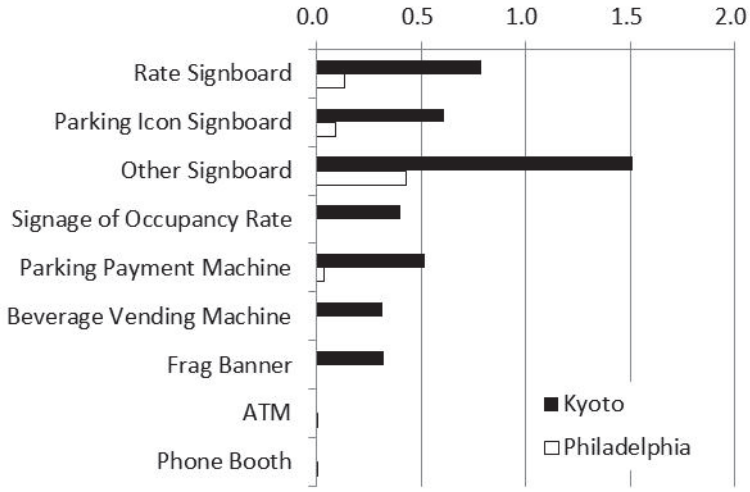


Figure 8 – Number of facilities installed per 100 m^2 of lot space

Photo 5 –Visually cluttering equipment and eye-soring signboard

4. SPATIAL PATTERN ANALYSIS FOR THE DISCONTINUITY OF HISTORIC CITYSCAPE

4.1 Methodology of Spatial Pattern Analysis

This section visualizes the spatial distributions of surface parking lots in the two cities based on spatial data using GIS and explains them by quantitative indices of spatial attributions. It extends an analysis of spatial patterns of the surface parking lots to examine the discontinuity of cityscapes in the historic central districts.

Two methods are used in this study to quantitatively identify spatial patterns. The first method is the average nearest neighbor distance analysis, which allows an identification of geographical distribution of surface parking lots by treating parking lots as discrete point data. This method measures the distance between each parking lot and its nearest neighboring lots, averages all these nearest neighbor distances, and then examines whether the average value of the distance between neighboring points is larger than the expected value of complete special randomness, or smaller (e.g., Mitchell 2009). And the other is the spatial autocorrelation analysis, which can measure and analyze the magnitude of dependency among observed data across space and identify a spatial concentration of surface parking lots, aggregating parking lot data for a unit of polygon. Several statistical measures are available for this method, but this study uses Moran's I and Local Moran's I, both of which are widely used statistics. Moran's I is a measure for identifying the global spatial autocorrelation of a target area (Moran 1948, Cliff and Ord 1981), and Local Moran's I is for identifying the local spatial autocorrelation of a target area (Anselin 1995). Mathematical expressions of these three statistical measures are presented below.

① Average Nearest Neighbor Distance Analysis

The average nearest neighbor ratio r is defined as follows:

$$\mathrm{r} = \frac{\bar{D}_O}{\bar{D}_E} \qquad (1)$$

Where $\bar{D}_O$ is the observed mean distance between each surface parking lot and its nearest neighbors:

$$\overline{D}_O = \frac{\sum_{i=1}^{n} d_i}{n} \tag{2}$$

And $\overline{D}_E$ is the expected mean distance for the surface parking lots given in a hypothetical random pattern of lots across the study area:

$$\overline{D}_E = \frac{0.5}{\sqrt{n/A}} \tag{3}$$

In the above equations, d_i equals the distance between surface parking lot i and its nearest neighboring surface parking lot, n corresponds to the total number of surface parking lots, and A is the area of minimum enclosing rectangle around all surface parking lots.
If the observed mean distance is less than the expected mean distance, r is less than one and the distribution of surface parking lots presents clustered pattern. And if the observed mean distance is more than the expected mean distance, r is more than one and the distribution of surface parking lots presents dispersed pattern.
The average nearest neighbour Z-score for the statistic in order to test statistical significance is calculated as:

$$\mathrm{z} = \frac{\overline{D}_O - \overline{D}_E}{SE} \tag{4}$$

Where:

$$\mathrm{SE} = \frac{0.26136}{\sqrt{n^2/A}} \tag{5}$$

② Moran's I
Moran's I provides a single measurement of spatial autocorrelation for an attribute in a survey area as a whole. Moran's I is defined as:

$$\mathrm{I} = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\,(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{6}$$

Where each of i and j is one of the n areal units in the study area, x_i is the attribute value for each unit i, and w_{ij} is a spatial weight defining the connection between areal unit i and areal unit j. A positive value of I indicates clustering of similar values, while a negative value of I indicates clustering of dissimilar values. And when I is zero, this indicates no spatial autocorrelation.
In a computation of spatial autocorrelation, this study uses a binary queen contiguity weight for the spatial weight w_{ij} defined as:

$$w_{ij} = \begin{cases} 1 & when\ i\ is\ touched\ j \\ 0 & when\ i\ is\ not\ touched\ j \end{cases} \tag{7}$$

③ Local Moran's I

Global spatial autocorrelation, measured by Moran's I, is not suitable for identifying individual local clusters and heterogeneous regional patterns within the survey area. Local Moran's I measures the level of correlation between an attribute value of each unit in the survey area and values in nearby units. This statistics is defined as follows:

$$I_i = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \frac{(x_i - \bar{x})\sum_{j=1}^{n} w_{ij}(x_j - \bar{x})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \quad (8)$$

4.2 Results

Table 3 shows the outcomes of the analyses based on the average nearest neighbor distance method. While the average nearest neighbor distance of surface parking lots is 50 meters in Kyoto, the distance is 336 meters—almost six times longer—in Philadelphia. Also, the obtained values of the average nearest neighbor ratio and the Z-score suggest the trend of cluster distribution in both cities. Relatively lower values indicate that surface parking lots are more clustered in Philadelphia than Kyoto.

Table 4 shows the outcome of Moran's I. In order to calculate Moran's I, the number of surface parking lots, the total lot area, and the proportion of the total area of surface parking lots in the area of geographic unit of analysis were obtained for the geographic unit of analysis, that is, *chochomoku* for Kyoto and block for Philadelphia. When any surface parking lot crosses over boundaries of two or more units, an attribute value is divided by boundaries, allocated to every geographic unit, and summed up to obtain a value for each unit. Moran's I is calculated using OpenGeoDa 1.1.0 which is a free software package for spatial statistical analysis developed by Luc Anselin.

Table 3 – Result of the average nearest neighbor analysis

Item	Kyoto	Philadelphia
Observed Mean Distance (m)	49.893	335.973
Expected Mean Distance (m)	53.700	409.447
Average Nearest Neighbor Ratio	0.929	0.821
Z-score	-2.523	-2.973
P-value	0.012	0.003

Table 4 –Moran's I of three attributes in Kyoto and Philadelphia

Attribute	Kyoto		Philadelphia	
	Moran's I	P-value	Moran's I	P-value
Number of Lots	0.1702	0.0001	0.1279	0.0001
Total Lot Area	0.0456	0.0403	0.0929	0.0005
Area Percentage	0.1041	0.0004	0.1571	0.0001

The values of Moran's I for all three attributes indicate positive spatial autocorrelation. Especially, the number of surface parking lots in Kyoto and the proportion of the total area of surface parking lots to the area of geographic unit in Philadelphia indicate stronger positive spatial autocorrelations than the counterpart.

Figure 9 and Figure 10 show spatial units with significant spatial autocorrelation for each of the three attributes based on the outcomes of Local Moran's I. Local Moran's I is also calculated using OpenGeoDa. Each spatial unit in the figures is labeled by color in five categories: "Not-significant", "High-High", "Low-Low", "Low-High", and "High-Low". The first "High" or "Low" refers to the attribute value of a given unit, and the second "High" or "Low" indicates the spatial lag for the given unit obtained from the attribute values of its surrounding units. Therefore, "High-High" and "Low-Low" mean that the geographic unit in interest has positive spatial autocorrelation. "Low-High" and "High-Low" mean the geographic unit in interest has negative spatial autocorrelation. Comparing the three maps in both Figure 9 and Figure 10, a similar pattern can be observed in the second and third maps, because the area percentage generally tends to be larger when the total lot area becomes larger.

The left map in Figure 9 shows the broader distribution of *chochomoku* categorized as "High-High" throughout the study area in Kyoto in regard to the number of surface parking lots. All maps show a similar pattern of *chochomoku* categorized as "Low-Low" with a large concentration on the right side slightly below the half point. Also, some of the *chochomoku* are located along streets running in the east-west and south-north directions.

In contrast, Figure 10 shows blocks categorized as "High-High" for the area proportion of surface parking lots in the spatial unit form clusters covering entire blocks at several locations in the study area in Philadelphia—particularly in the mid part on the northern end of the study area where many surface parking lots are provided along with warehouses. However, "High-High" are hardly located near the historic sites which are listed in the National Register of Historic Sites (Figure 11). The south western quadrant shows several "High-Low" blocks, which can be explained by isolated surface parking lots located in residential neiborhoods.

5. CONCLUSION

This study examined the conditions and aesthetical impacts of surface parking lots in the historical central districts in Kyoto, Japan and Philadelphia in the U.S. based on the original field survey data. It further conducted a quantitative analysis of the spatial distribution of surface parking lots applying the average nearest neighbor distance and the spatial autocorrelation (Moran's I and Local Moran's I), to examine the relationship between the spatial distribution and cityscape preservation.

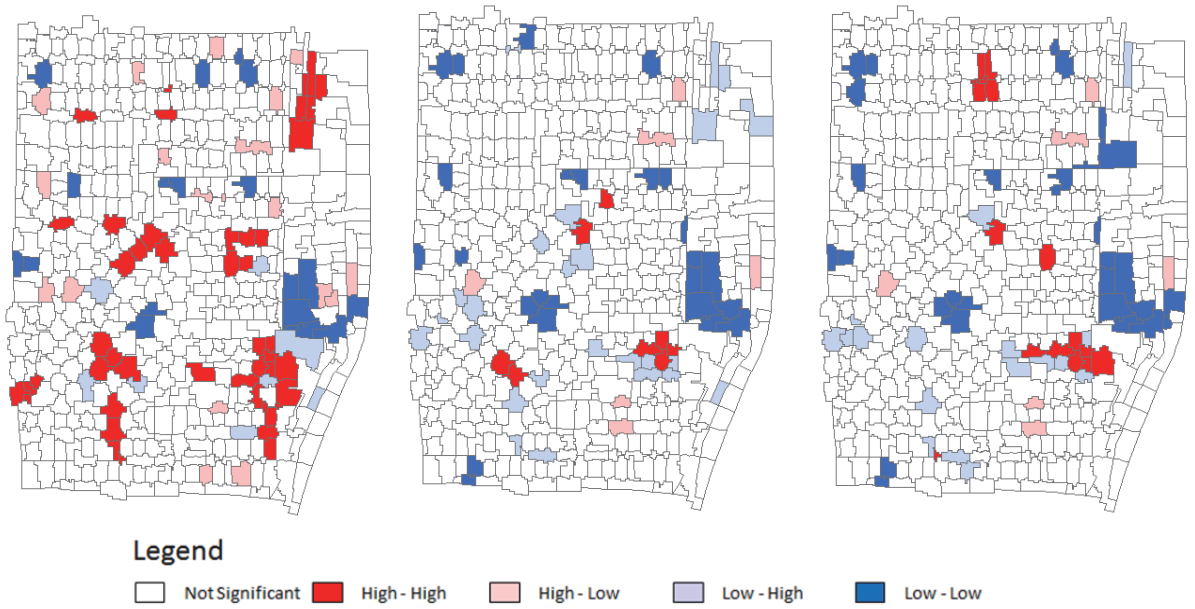
The analysis results showed that many small surface parking lots—smaller than 500 m^2—were distributed throughout the study area in Kyoto, while surface parking lots larger than 1,000 m^2 were sporadically observed in several locations in Philadelphia. These findings indicate the possibility that the large area of surface parking lots covered by asphalt has a great impact on the quality of historic cityscape.

While about 75% of surface parking lots in Philadelphia were located at corners, about 75% of surface parking lots in Kyoto were located in mid-blocks between buildings. The presence

of lots in mid-blocks in Kyoto created discontinuity in the cityscape. In addition, there is a difference in the aesthetic impact derived from attributes of surface parking lots between the two cities. In Philadelphia, surface parking lots had fences/retaining walls that effectively block a sight of vehicles parked inside, and plants and public art walls that added attractiveness to the parking lots. In contrast, these features were rarely seen at surface parking lots in Kyoto, but, the higher per-area-number of parking facility components, some of which are really eye-souring, was installed, compared to Philadelphia.

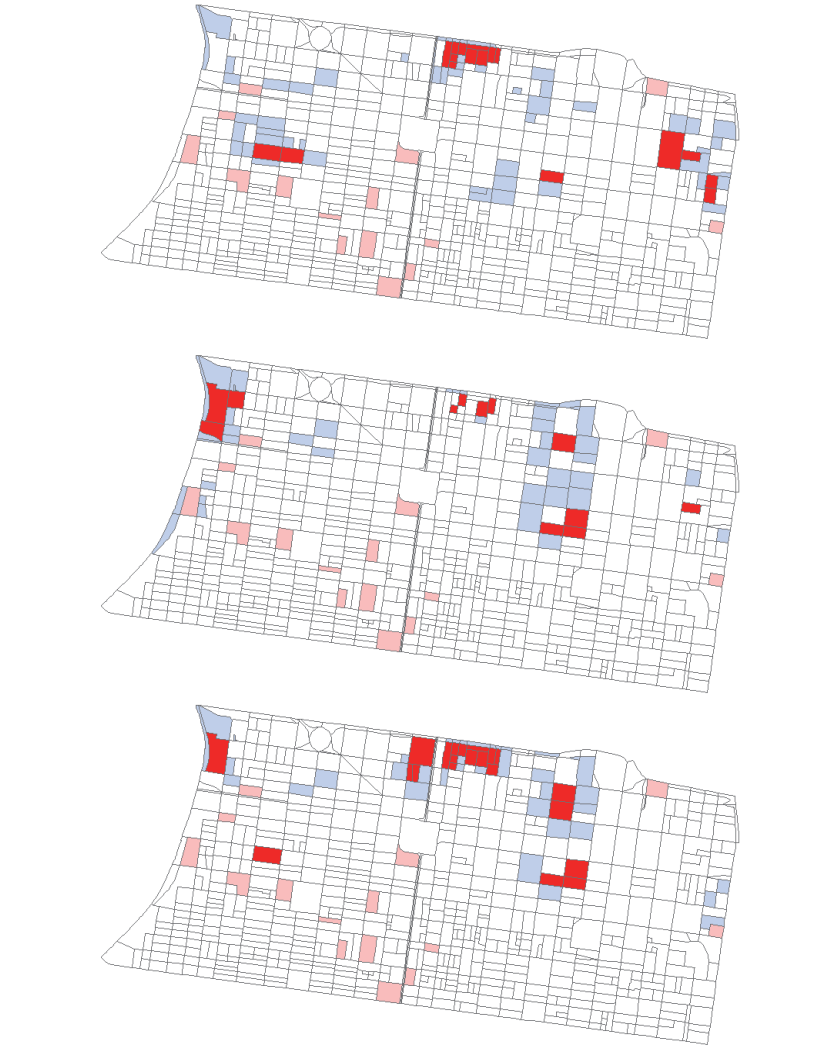
The spatial analysis of the surface parking lots quantitatively revealed the greater distance between nearby surface parking lots in Philadelphia than Kyoto, indicating that surface parking lots were distributed relatively more in several clusters. An examination using a small geographic unit in Kyoto found *chochomoku* with the high autocorrelation of the high number of surface parking lots were distributed throughout the study areas in Kyoto, and were often found in clusters along certain streets. In contrast, blocks showing the high autocorrelation with the high area-proportion of lots were found to form clusters at several locations, but were hardly found near any of the National Register of Historic Sites in Philadelphia.

Overall, both Kyoto and Philadelphia need more judicious planning in regard to the allocation and permission of surface parking lots and are strongly recommended to actively consider urban design or aesthetic fit into the neighbourhood to avoid discontinuation of cityscapes and preserve the quality of historic cityscapes. Such considerations include a promotion of “greening” with trees and plants, restrictions on signs and equipment inconsistent with cityscape, and the use of good designs in surface parking lots.



(Left: Number of Lots, Middle: Total Lot Area, Right: Area Percentage)

Figure 9 – Local Moran's I Cluster Maps in Kyoto



(Top: Number of Lots, Middle: Total Lot Area, Bottom: Area Percentage)

Figure 10 – Local Moran's I Cluster Maps in Philadelphia

Figure 11 – Local Moran's I Cluster Maps of Area Percentage with National Register of Historic Sites in Philadelphia

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