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Urban redevelopment at the block level: Methodology and its application to all Chinese cities

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Abstract
Urban redevelopment is the reconstruction or upgrade of current urban built-up areas; it revitalizes old towns and contributes to sustainable development. This paper proposes a methodological framework that integrates open-source street networks and point-of-interest data and aims to identify and evaluate urban redevelopment at the block level from the perspective of urban form and function. It is found that (1) urban blocks can be categorized into eight groups regarding the spatial form of road junctions that have emerged within them over time, and blocks of each group share common features that can be automatically identified; (2) there are more blocks that have been morphologically redeveloped than functionally redeveloped, and the two types of redevelopments also significantly overlap with one another; and (3) the evaluation of urban redevelopment identification results presents a high accuracy rate that verifies the validity of the proposed framework. Based on the identification results, the impact factors of urban redevelopment are explored on both the inter- and intracity levels. The intercity analysis indicates that Chinese cities with a lower administrative level, lower urbanization rate, and higher density of road junctions tend to be associated with a higher proportion of urban redevelopment.

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Meanwhile, the intracity analysis attempts to determine which kinds of urban blocks are more likely to undergo urban redevelopment, which are found to be the blocks with lower points of interest density, a smaller distance to city centers, higher transit accessibility, a higher land use mixed index, and larger size.

Keywords

Street networks, points of interest, typology, form and function, impact factors

Introduction

Since the mid-20th century, the social-economic environment has been undergoing profound changes in all major industrial countries. After large-scale extension and rapid urbanization since Second World War, the massive expansion in western urban space was nearly paused by the 1980s. Meanwhile, during the transition from industrialization to postindustrialization, fast-growing countries appeared to be suffering from slum or blight due to a declining economy, disordered environment, and rising suburban areas. To solve these problems and revitalize urban centers, large-scale urban redevelopment projects had significantly increased since the 1970s in cities such as Baltimore, Boston, Toronto, and London and set the prototype for a form (Brownill, 2010; Bunting and Rutherford, 2006; Hall, 1991; Harvey, 2001; Thornley, 1991). The cities' intensified land use in urban centers bulldozed plenty of slums and rebuilt new communities. These practices played an active role in improving living conditions and beautifying cities but brought a series of public security and traffic problems. Jacobs (1961) criticized the massive redevelopment and advocated the principle of flexibility and gradualism from the angle of social justice. Mumford (1961) and Schumacher (1973) also advanced that urban planning should pay full attention to the human scale in their works. Under the influence of Humanism, urban redevelopment poses higher requirements not only to improve the city's physical environment but also to adjust and optimize urban patterns on smaller scales. According to international experience, this paper suggests that urban redevelopment will be discussed from two aspects. One aspect that is accompanied with urban form transformation is defined as morphological urban redevelopment, which as the New Urbanism, advocates a return to the layout of streets with dense networks and strong junctions. Another aspect is functional urban redevelopment with a variation in urban function as studied in the case of London's riverside renaissance that transformed abandoned industrial lands into luxury apartments.

This paper proposes a method framework to identify the urban redevelopment that occurred from 2009 to 2014 across China and aims to achieve automatic identification by examining the transformation of the road junction form and points of interest (POIs) at the block level. A significant change in the spatial form and urban function of blocks is the key indicator of morphological and functional urban redevelopment. Due to the limited access to government data in China, the authors innovatively employ the open-source street networks and POI data to derive urban blocks and road junctions and to obtain urban functions. The method is validated with historical satellite imagery over years on Google Earth, whose result presents high accuracy.

Based on the identification results, the big model approach is employed to explain the findings. Concretely, the determinants of urban redevelopment will be explored at both the intercity and intracity levels by running two regression models. Two questions are under discussion: (a) what types of cities present a higher proportion of urban redevelopment; and (b) what types of urban blocks are more likely to be redeveloped? The focus is to eventually determine the impact of spatial form on urban redevelopment and the impact of the economic and social factors that relate to cities and blocks.

Literature review

Theoretical and practical importance

The importance of urban redevelopment in Chinese cities is frequently addressed with the functional and structural adjustment of city centers as the theme for the next decade. Under transition from the large-scale greenfield development to infill development, Chinese cities are faced with multiple urgent tasks to efficiently utilize developable land, to build human scale urban space by restructuring the city with small blocks and denser street networks, and to raise land value by land use conversion (Pan, 2010; Xu and He, 2018; Yang, 2017). The emerging socioeconomic problems, such as unaffordable housing price, traffic congestion, air and water pollution, and insufficient public facilities, also constitute a series of challenges to revitalize old towns, especially in large cities like Shanghai and Beijing. Therefore, the transformation of urban spatial form is supposed to be studied with integration of economic and social factors (Mo, 2017; Yang, 2016). As a production of the massive economic construction and urban expansion during the past decades in China, a number of new towns have been built up to achieve aggregated industrial development, and are now, forced to cope with the task to transform from industrialized zones to urbanized areas. The redevelopment of new towns brings opportunities to merge industry with urban life, to optimize functional zoning and spatial form, and to systematically design redevelopment regimes (Wang, 2017; Yuan et al., 2013). Cities represented by Shanghai propose to build global city by promoting urban redevelopment transition from expansive growth to connotative development whose emphasis is to achieve organic urban renewal by encouraging mixed use of urban land, reconstructing the nonmotorized system, and improving the quality of public space (Zheng, 2017).

In practice, solution to urbanization issues, represented by brownfield renovation and historical site preservation, is derived from proper redevelopment tactics. As many Chinese cities transitioning into the postindustrialization period, utilization of industrial heritage and ecological remediation have become the top priority of urban development. Redevelopment of brownfields not only improves the ecological environment but also raises the efficiency of land utilization and revitalizes the stock land resources (Huang et al., 2018; Wang et al., 2017; Xu et al., 2017). The urgency of brownfield renovation is due to industrial pollution on limited urban land and waste of resources while historical preservation draws attention at the cost of demolishment of quantities of historical buildings, over 30 million square meters in Shanghai for instance (Zheng, 2017). It is crucial to balance renovation with preservation while redeveloping the historical sites, such as Lilong in Shanghai and Hutong in Beijing. Successful redevelopment of historical and cultural areas regenerates the form of community life by renovating urban space and inheriting local culture (Mo and Cen, 2001). Additionally, Zhang et al. (2017) propose that the reconstruction of the built environment imposes direct or indirect impact on the public health by changing the way where people interact with the spatial environment. As a consequence of the urbanization process, the shortage of housing supply, the environment pollution, the food safety, and the transition in daily travelling mode are all possibly influencing urban residents' health. Urban redevelopment plans are supposed to be carefully evaluated from the perspective of land utilization, street and transportation, public and green space design, pedestrian-and-cyclist-friendly design, accessibility of public facilities, and people's exposure to pollutant, to achieve the green development goals.

Previous study methods

Urban redevelopment has become an important component of the urbanization process as one of the prerequisites for urban sustainable development. Studies on urban growth mostly examine urban expansion, brownfield regeneration, and land use conversion, and brownfield regeneration and land use conversion are closely related to urban redevelopment. A majority of these studies employ conventional methods including qualitative policy analysis, case studies on specific projects, or quantitative research based on remote sensing and land use data.

The urban redevelopment process is not only led by city plans as common sense but also subjected to economic factors and timing. Through an experiment regarding a fire disaster in San Francisco, Siodla (2015) proved that urban redevelopment outcomes distinguish more raved land than unburned areas over time. To make both a spatial and temporal comparison, the author digitalized various types of buildings from historical maps and integrated modern land use data from the planning department. Therefore, quantified spatial information is of great importance to support redevelopment policy.

Case studies have been often employed to detect the geospatial and socioeconomic changes and to evaluate the impact of urban redevelopment on a specific site. Zhang and Li (2016) analyzed a specific urban redevelopment case by qualitatively elaborating how a top-down planning system integrated with public participation shapes a successful redevelopment project. It is obvious that the method of case study takes advantage of detailed project information and produces a comprehensive evaluation of redevelopment projects. The case study is, however, hardly applicable to a large-scale analysis, for instance, at the metropolitan level. Extensive research was conducted by Loures (2015) to identify the main barriers and benefits to postindustrial urban redevelopment by collecting and analyzing over 100 recent projects. After elaborating the financial costs and benefits of urban vitality for the experts, as well as the biological impact and benefit of green open space and job opportunities for the public, the conclusion is quite persuasive and inspiring, although the quantitative data collection still relies on questionnaires, and the comprehensive case study requires fairly intensive work.

Land use conversion is an important indicator of urban redevelopment. Existing studies generally employ the official urban land use data acquired from local government, which is perfect for a large-scale urban redevelopment study, and provides accurate land use information over time. By using digital topographic maps and urban land use maps obtained from the planning institute, Zhou et al. (2016) analyzed the spatial pattern of different urban functions during urban redevelopment. With the same type of spatial data collected from the Lands Department, Zheng et al. (2015) simulated land conversion during urban redevelopment and compared it with historical data to calibrate and optimize the model. Given the detailed land use data over years, the results of these studies turn out to be reliable and accurate. Nevertheless, land use data can only be acquired from the government or urban planning department in China, which makes such a study method of urban redevelopment hardly referential to the public.

Because big data and open-source data increasingly impact urban studies, Long et al. (2014) proposed the big model approach, a new paradigm that aims to conduct a large-scale and fine-resolution quantified urban spatial study based on big data and simple modeling. The street networks and POIs over years provide the essential data foundation for such a study. By using street networks extracted from Open Street Map (OSM), Liu and Long (2016) generated blocks and interpreted the features and land use for each block. They also built up the Vector Cellular Automata model to identify urban blocks to conduct a block-level quantified spatial study on 297 cities across China. The big model approach is also the basis for this paper to generate fundamental spatial data.

Spatial quantification, a core component of the big model, relies on the extraction of spatial features from the urban form. Zhou (2015) compared three existing approaches to delineate built-up areas with street network data, including the grid-based approach, kernel density analysis, and the block-based approach. The feasibility of quantitative measurement, visual representation, and time complexity are evaluated for each method. Briefly, the grid-based approach and kernel density analysis detected more built-up areas in a quantitative assessment, while the block-based approach performed better visual representations and took the least amount of time. Therefore, the approach based on blocks is more intuitive and applicable to large-scale urban spatial studies.

As addressed by a series of urban morphology studies, urban blocks and streets are the interacting constituents of urban morphological evolution that cannot be considered in isolation. Street grids tend toward local intensification to produce smaller blocks and a greater density of interface between building fronts and streets (Lim et al., 2015). A systematic classification might be extracted from street and block patterns based on morphology theories. Marshall (2009) proposed three major mechanisms during the formation of street network patterns: building occupied space, parcel division, and road expansion. Road expansion divides a street network into different types based on the number of branches and the spatial relationships among them, which inspires the authors of this paper to group the block by type before identifying urban redevelopment.

Accordingly, existing studies on urban redevelopment are normally limited to the scope of a single city and either adopt official government data for a city-level analysis or conduct a field survey on a specific site. Due to the data acquisition limit, such methods are hardly applicable to a large-scale analysis, and the identification of urban redevelopment is limited to the manual detection of urban land use transformation or information from specific projects. Given the limitations of the conventional approach and the increase of internet big data, this paper aims to propose an innovative method framework by applying open-source street network and POI data over years to the identification and evaluation of urban redevelopment.

Data and framework

Study area

This study is conducted on 659 cities all over China and covers five administrative levels that include the municipality, subprovincial, provincial capital, prefecture, and county levels. The urban areas of all cities are acquired from the open data of Beijing City Lab for all cities to delineate urban blocks as the basic analysis unit of this paper.

Data sources

The street networks of 2009 and 2014 are obtained from OSM to divide urban areas into individual urban blocks and to extract road junctions. The road junctions of 2014 may fall into the urban blocks of 2009 because the density of street networks tends to increase because of urban development, and new road junctions will possibly grow in the original superblocks, which is the logical basis to identify spatial form change as an indication of the occurrence of urban redevelopment. To detect the change in urban functions, the POI data are retrieved from the open-source map platform. Each point could be a residential community, an office building, a commercial store, a public facility, a park, or any other specific location that one can find on open maps such as Google Maps, and each record contains a type of information that records the major function of the corresponding facility. POI type change is examined during 2011 and 2014, which is inconsistent with the time range of street networks because the POIs of 2009 are missing many attributes. As long as change is detected during 2011 and 2014, it also works for the range from 2009 to 2014. Additionally, for the determinant analysis, the demographics of the cities are acquired from open-source websites and government open data, which is used together with the city-level information to explore the impact factors of urban redevelopment.

Framework

This paper focuses on two types of urban redevelopment and has a method framework that proposes to identify morphological urban redevelopment by using the street networks over years and to identify functional redevelopment with POIs. Two types of redevelopment are identified based on the cognition that a significant change in urban form corresponds to morphological redevelopment, which is examined through a typological study, while the variation of predominant urban function indicates functional redevelopment, which is detected with categorized POIs. Both means of identification are conducted at the block level in all Chinese cities. The identification results are presented by type, whose basis is a method that is validated with Google satellite images over years.

Methodology

Urban block generation

The urban blocks of 2009 are delineated by dividing an urban area with street networks. It is processed in ArcMap through the following steps. First, road space is generated as buffers on both sides of the streets of 2009. A varying threshold of buffer that ranges from 3 to 40 meters is adopted for different classes (C1–C5) of roads that correspond to the express way, arterial road, collector road, branch and internal road (C1–40 meters, C2–25 meters, C3–15 meters, C4–10 meters, C5–3 meters). Second, blocks are delineated by erasing road space from the urban areas. Third, superblocks with an area over 1 square kilometer are removed after assuming that they are barely urban blocks. Then, the rest are the urban blocks of 2009.

Morphological redevelopment identification

Siksna (1997) revealed the effects of block size and form on subsequent evolutionary patterns by studying centers of North American and Australian cities and found that the intensification of development tends to occur within large blocks. Additional streets and alleys will grow in the large initial blocks to form small blocks and will produce a better performed circulation network. The number of road junctions is one of the most significant indicators of the level of circulation convenience. Based on these findings, in this paper, morphological redevelopment is identified based on a typological study of road junctions on each urban block. From 2009 to 2014, blocks with a significant change in spatial form are considered to be redeveloped blocks. Two rules are adopted to define “significant change”:

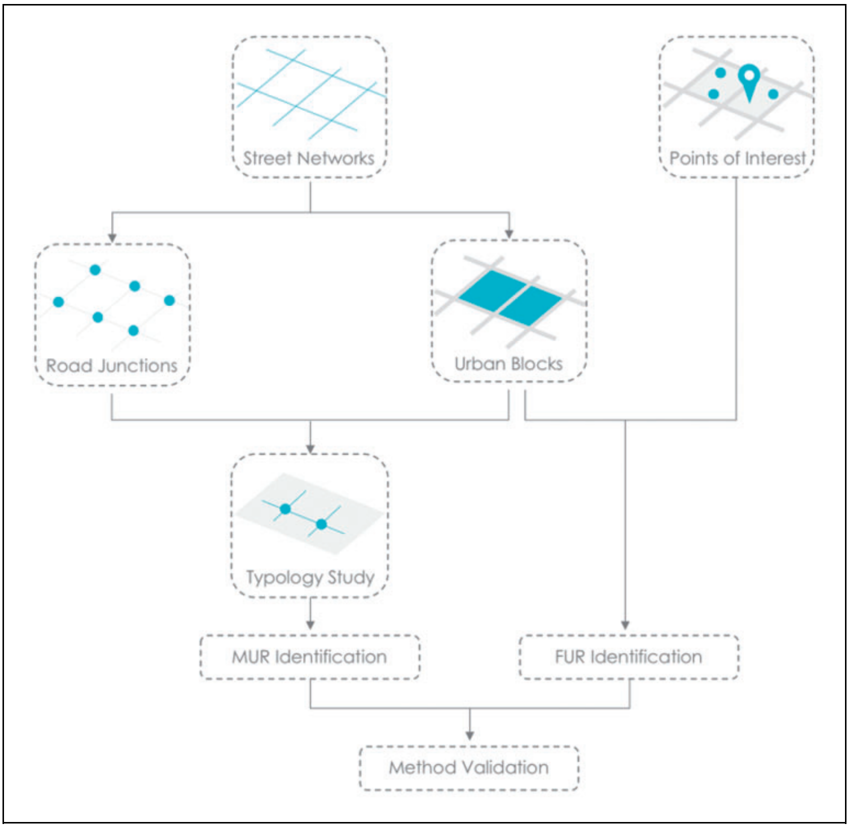

Figure 1. Method framework to identify and evaluate urban redevelopment (created by author). FUR: Functional Urban Redevelopment; MUR: Morphological Urban Redevelopment.

(a) blocks of 2009 with more than three new junctions in 2014; (b) otherwise, the total street length (TSL) is examined by block types, and the TSL is greater than a certain threshold. Blocks with areas that are too large (greater than 1 square kilometers) are excluded since they are barely urban blocks; therefore, only the parameter TSL is adopted, without considering area or density.

Parameters calculation. Given that the study is conducted at the block level, all the following parameters are calculated as attributes of blocks. Two basic parameters are first calculated based on a spatial relationship. One parameter is the number of road junctions in each block, and the other parameter is TSL, which counts the total length of the street segments that are completely within the blocks. Two more parameters are employed to denote the spatial form of road junctions. One parameter is the number of streets that connect two junctions (SCJ), and the other parameter is the number of junctions that intersect with SCJ (JSCJ).

SCJ is one type of street segment, and each goes through exactly two junctions. Figure 2 (left) shows three possible but unique junction forms when there are only two junctions in a block. With each lowercase letter representing one street segment, the count of SCJ is determined by the form of road junctions, whether the two junctions are connected and whether a closed area is formed. Technically in ArcMap, the spatial join tool is applied with

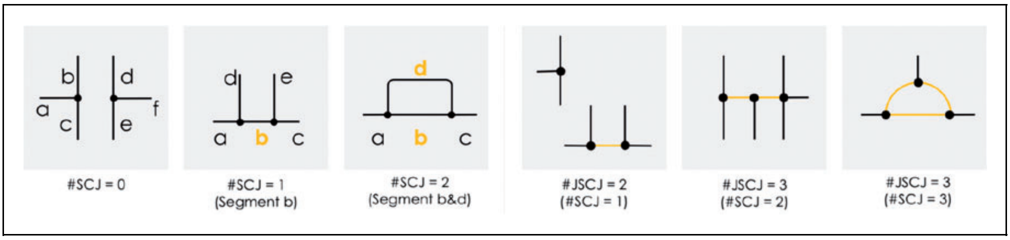

Figure 2. Illustration of the SCJ definition (left) and JSCJ definition (right). JSCJ: number of junctions that intersect with SCJ; SCJ: number of streets that connect two junctions.

street as the target layer to obtain a count of the intersected junctions based on the spatial relationship between streets and junctions. Then, SCJ could be identified by selecting streets with the count of 2. This parameter is very useful to identify whether a closed area is formed by streets in blocks with only two junctions.

In recognizing a special type of street segment, JSCJ is one of the junctions that is connected by SCJ. As is shown in Figure 2 (right), the highlighted street segments are SCJ, and the junctions that intersect with them are JSCJ, which can easily be extracted in ArcMap based on the "INTERSECTS" match option. The count of JSCJ in each block helps identify whether every two junctions are connected in blocks with three junctions. Accordingly, with SCJ labeled on the street layer and JSCJ labeled on the junction layer, these two indicators can be spatially joined to the block layer to obtain a count of both the SCJ and JSCJ within each block.

Typological study. Marshall (2009) proposed that urban streets can be classified by the number of branches that relate to streets and can be even divided into subtypes according to the spatial relationships among them. By referring to this mechanism, the authors categorize urban blocks by the count of road junctions within blocks and further classify blocks with the same number of junctions based on the spatial pattern between streets and junctions that are identified by a typological study conducted on urban blocks with no more than three new junctions. Concretely, the typological study considers the number of road junctions within blocks, the connectivity of all streets within blocks as measured by the number of SCJ, and the existence of a closed area formed by streets as measured by the number of JSCJ. Thus, the quantified classification principles are sufficiently clear to distinguish all possible patterns found within urban blocks, although some blocks in different types might seem similar in spatial form.

As a result, urban blocks are grouped into seven categories based on spatial characteristics, and for each category, the number of blocks, the mean of TSL, and the mean of block areas are calculated. Blocks with only one junction fall into one group, while blocks with 2–3 junctions are divided into three subcategories according to the spatial pattern of the road junctions. As is shown in Figure 3, common features can be extracted from each subcategory. By mentioning trunk ("T") and branch ("B") in the group where blocks have two new junctions, the authors simply mean to elaborate the spatial relationship of the roads within each block rather than discuss the actual road hierarchy.

For urban blocks with 2–3 junctions, Category A shares the common feature that all junctions within the blocks or at least part of them stand alone and are not connected to other junctions. Category B, with all junctions connected by roads, presents the spatial form that the space that is cut by roads is open. For Category C, all junctions are also connected,

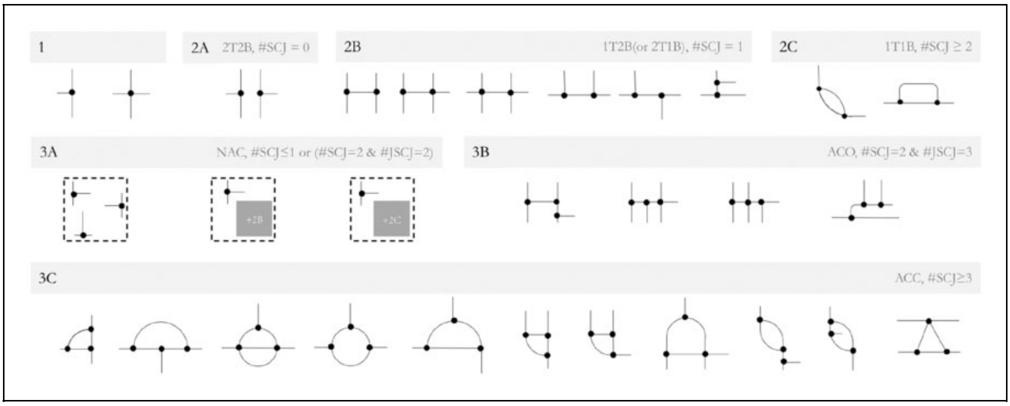

Figure 3. Spatial form of road junctions by category. ACC: all junctions connected and a closed area is formed; ACO: all junctions connected and open; JSCJ: number of junctions that intersect with SCJ; NAC: not all junctions connected; 1T1B: one truck and one branch; SCJ: number of streets that connect two junctions.

but closed areas are formed. Based on these seven types of junction characteristics, the authors can identify different block types by setting parameters that include the number of junctions, SCJ, and JSCJ.

Functional redevelopment identification

During the process of urban redevelopment, urban blocks do not have to be physically reshaped. They are likely to undergo land use conversion, which is the process of functional urban redevelopment. Since the POI data provide detailed information about urban functions, POI types are examined. Urban blocks with a predominant POI type variation detected will be identified as functionally redeveloped blocks.

The POIs are allocated into the seven categories of transportation, commercial, residential, government, office, green land, and education (Long et al., 2016). Every block is likely to be covered by several types of POIs in various amounts. This paper measures the predominant POI type of each block, which is the POI type with the most count. In the case that no POI or less than three POIs are found in a block, the predominant POI type will be labeled as "NA," as it is difficult to scientifically identify the predominant type with too few POIs.

In this paper, the POI type refers to the predominant POI type in each urban block. This paper compares the POI types collected from 2011 and 2014 and detects significant change over the years. There are three standards for "significant change": (a) a block is not considered as long as the POI type of 2014 is "NA," regardless of the type of 2011, because variation cannot be detected given an unknown POI type in 2014; (b) significant change occurs if the type is "NA" in 2011 but a specific type is designated in 2014; and (c) if specific POI types are found in both years, only distinct types indicate significant change.

Determinant analysis

The authors attempt to explore the impact factors of urban redevelopment on both the intercity and intracity levels. The urban form across cities tends toward similar patterns that achieve an optimum performance with the prerequisite of similar urban processes. Block structure evolves when larger blocks are broken down into smaller subblocks or additional streets and alleys grow within initial large blocks (Siksna, 1997). Consequently, urban redevelopment occurs where the performance of urban form has failed to meet the development requirements that are determined by the current urban process. Therefore, the authors propose the first hypothesis that the overall block structure and development level, which correspond to urban form and process, determine the occurrence of urban redevelopment across cities. Average block size and street network density demonstrate the overall block structure of cities, and as a measurement, the density of road junctions is employed to verify the impact of block structure. The urbanization rate and administrative level of cities are collected to measure development levels. Concretely, the hypothesis to be tested is that cities with a low density of road junctions need redevelopment to optimize their structure and that cities at a high development level require more redevelopment to achieve better performance. The intercity analysis will employ a multivariate regression as the hypothesis testing model. The population density in urban areas, local GDP per capita, and city location in the country (in the west or not, in the middle or not) are also included in the model as control variables.

By focusing on individual cities, the authors are inspired by previous studies that the urban functional structure, land value, and efficiency of land utilization determine the redevelopment of urban blocks. The second hypothesis is that urban blocks with a simple use and a greater potential for land appreciation, as well as the urban blocks that are less efficiently utilized, are more likely to be redeveloped. Therefore, whether or not an urban block has been redeveloped, a binary variable is employed as the dependent variable. Currently, a linear regression is no longer applicable as it assumes the errors to be normally distributed, which in this case, are not for the sake that the dependent variable takes only two values. With the aim of predicting the probability of blocks to be redeveloped, a logistic regression is applied to examine the impact of the degree of mixed land use, potential of land appreciation, and land utilization efficiency.

POI density indicates the accessibility to urban facilities in a block, which is the prerequisite of a vibrant urban block, and low density corresponds to low efficiency land utilization. Similarly, the degree of mixed land use indicates the vitality and convenience of urban blocks. Blocks with a simple use or homogeneous function have a greater potential to be redeveloped. The mixed degree of an urban block is calculated based on the seven groups of categorized POIs. Land value can hardly be directly measured due to data limitations; therefore, the distance to the city center and accessibility to public transit are employed to indicate the potential of land appreciation, assuming that blocks close to the center and with easy transit access have greater potential for land value increment. The number of bus service options that are accessible from a block is counted to measure transit accessibility.

Identification results

To obtain a better intuition of how urban redevelopment distributes across the cities, the authors select three typical cities—Hangzhou, Wuhan, and Xi'an—from the eastern, middle, and western parts of China, respectively, to visualize the spatial pattern of redeveloped blocks. Otherwise, the national level distribution pattern is hardly readable since both the indicators and the results are measured in blocks. Generally, 78,527 out of 293,700 urban blocks across 659 Chinese cities have at least one new-growth road junction that emerges inside during the development process from 2009 to 2014. These blocks are categorized into eight groups (Figure 4(a)) based on the typological study to conclude with a universal law of urban redevelopment identification.

Figure 4. Identification results by block type (a) and by redevelopment type (b) in three typical cities. FUR: Functional Urban Redevelopment; MUR: Morphological Urban Redevelopment.

Morphological urban redevelopment

Based on the typological study, urban blocks are grouped into eight categories to extract the common features from blocks with similar patterns in the distribution of road junctions. By analyzing TSL by block type, the findings are listed below as the basis to identify morphological urban redevelopment.

By observing the distribution of TSL, it is found that with the number of junctions increasing, the proportions of blocks with large TSL are growing, which indicates a positive correlation between the TSL and the number of junctions. However, by comparing urban blocks with two or three new junctions to the blocks with a single junction, the authors find little variation in TSL, while the TSL of blocks with four or more junctions is significantly higher. This result verifies the argument that all blocks of Type “4+” are redeveloped blocks.

Concretely, Table 1 shows that the average TSL of “2C” is significantly greater than the average TSL of “2A” and “2B,” while the TSL of “2A” and “2B” is quite close. Similarly, the average TSL of “3C” is greater than the average TSL of “3A” and “3B,” and “3A” and

Table 1. Indicators and parameters by block type.

Type	Common features	#Blocks	TSL (m)	Block area (km^2)
1	#Junction = 1	26,405	132	0.07
2A	(a) 2T2B (b) #SCJ=0	6964	245	0.13
2B	(a) 1T2B (actually equals to 2T1B) (b) #SCJ=1	5582	255	0.08
2C	(a) 1T1B (b) #SCJ$\geq$2	216	410	0.07
3A	(a) Not all three junctions are connected (b) #SCJ$\leq$1, #SCJ=2 & #JSCJ=2	4631	354	0.15
3B	(a) All junctions connected, open (b) #SCJ=2 & #JSCJ=3	2381	342	0.09
3C	(a) All junctions connected, closed area formed (b)#SCJ$\geq$3	1534	384	0.08
4+	#Junction $\geq$ 4	30,813	1195	0.23

JSCJ: number of junctions that intersect with SCJ; 1T1B: one truck and one branch; SCJ: number of streets that connect two junctions.

"3B" also have close TSL values. What "2A" and "3A" have in common is that not all junctions within a block are connected. In contrast, for "2B," "2C," "3B," and "3C," all junctions within a single block are connected to roads. Specially, for "2C" and "3C," closed areas are formed by the roads within blocks.

With the recognition elaborated above, the connection of all junctions within blocks applies a positive impact on TSL, which means that the TSL of blocks with all junctions connected tends to be greater. When closed areas are formed such as in subtype "C," the difference in TSL is even larger. Closed areas and a greater TSL both indicate better connectivity within the blocks. Therefore, the authors employ TSL within urban blocks as the parameter to measure the significance of the change in spatial form. With the threshold set at 300 meters, urban blocks with TSL greater than the threshold are labeled as morphologically redeveloped blocks. Therefore, except for blocks of Type "4+" that are directly labeled to be redeveloped, among the other seven types, "2C," "3A," "3B," and "3C" have undergone morphological urban redevelopment from 2009 to 2014. Corresponding to the analysis above regarding the spatial form of road junctions, the identification of urban redevelopment tends to extract blocks with more junctions and better inner connectivity. In total, there are 39,575 urban blocks across China that are identified as morphologically redeveloped blocks, which include an 8068 square kilometer urban area.

A considerable amount of information can be inferred from the spatial distribution of the morphological urban redevelopment across typical Chinese cities. In the metropolitan area of Shenzhen, for instance, almost half of the redevelopment occurs along the waterfront on the southwest border. Additionally, there is obviously a strong connection from Guangzhou to its west where the city of Foshan is situated. Much urban redevelopment occurs on the band that connects these two cities. Nevertheless, there is much more to explore, which is beyond the focus of this paper.

Functional urban redevelopment

Another type of redevelopment that this paper focuses on is functional urban redevelopment, which is identified by examining the variation of the POI type from 2011 to 2014.

Table 2. POI type change by block type.

Type	#Blocks—total	POI type change	
		#Blocks—significant	Proportion (%)
1	26,405	2336	9
2A	6964	996	14
2B	5582	618	11
2C	216	20	9
3A	4631	850	18
3B	2381	339	14
3C	1534	167	11
Total	47,713	5326	11

POI: points of interest.

Compared to the quantity of POIs in 2014, the quantity of POIs in 2009 is much less, and many type attributes that indicate urban functions are missing, which would produce significant error if applied to the analysis. Therefore, the time range studied in this section is from 2011 to 2014. The focus of this paper is to identify the most likely redeveloped types of urban blocks from the perspective of form and function and to further analyze the common features of redeveloped urban blocks. For conclusion consistency, therefore, the eight block types as the target of morphological redevelopment identification are also adopted as the basis to be inspected regarding POI type variation. The urban blocks in the three selected cities with a significant change in the POI types, which have undergone functional urban redevelopment, are dispersed around the city centers.

The percent of significant blocks is calculated for each block type, and the results are presented in Table 2. Type "4+" is not included in the comparative statistics because the proportion of these blocks with a significant type change is 32%, with 9771 out of 30,813 blocks transformed in urban function, which is far greater than the significant type change of the blocks in the other seven types. Therefore, Type "4+" is labeled as functional redeveloped blocks without further inspection. For the other block types, the proportions of transformed blocks, which vary from 9 to 18%, are quite low, given that no more than one-fifth of the blocks in each type presents significant change. The reason is probably that all cities across China are detected, some of which are not very well developed and have a poor basis to acquire POI data. As a result, a number of blocks remain undetected due to a lack of data rather than undergoing little change. Nevertheless, the variance among different types is notable, especially from Type A to Type C regardless of the junction number. In showing an opposite pattern to the pattern of TSL, the proportion of significance drops as the internal connectivity of blocks rises from A to C while holding the junction number constant. It is reasonable to interpret that there are greater chances to undergo functional redevelopment for the blocks that are spatially less integrated inside.

With the consideration to extract less integrated block types and the threshold set at 11%, which is the average proportion of all target blocks, it is assumed that any type with more than 11% of the blocks showing a significant POI type change has undergone functional urban redevelopment. Therefore, the blocks of Type "2A," "3A," and "3B" together with "4+" are identified as functionally redeveloped blocks. In total, there are 44,789 urban blocks across China identified as functionally redeveloped blocks, which covers an 8821 square kilometer urban area. The authors also investigate the spatial pattern of functional urban redevelopment across typical Chinese cities, which is largely similar to the spatial pattern of morphological urban redevelopment and indicates that there is a certain amount of intersection between these two modes of urban redevelopment. Morphological urban redevelopment generally occurs accompanied with functional variation and vice versa, which could be explored in future studies.

Validation

The authors have conducted experiments to validate the identification methods for various levels of cities and for various size of cities by manually comparing the identification results with the historical satellite imagery on Google Earth. The changes on each identified block over the years (2009, 2011, 2014) are inspected, including the conversion from vacant land into built-up land, green space and parking lots, or the opposite procedure, or from low-rise buildings to high-rise buildings. The identified redevelopment is verified as long as any of these changes are detected. For morphological urban redevelopment, the historical satellite images acquired in 2009 and 2014 are examined, while the acquisition dates are 2011 and 2014 for functional redevelopment.

As a result, the authors gain high accuracy rates from several cities. In Xi'an, a subprovincial city in western China, 174 out of 194 morphologically redeveloped urban blocks and 123 out of 143 functionally redeveloped urban blocks present changes over the years. The precision rate of the morphological urban redevelopment identification is 90%, while the precision rate of functional redevelopment is 86%. A majority of the cities validated, however, present an accuracy rate of identification from 50 to 60%. Some of the misidentified blocks are errors of the identification method since the conclusions are made by block types. Other inaccuracy found through validation is due to poor quality of the satellite images. Some images from early years like 2009 only show the roof top of buildings instead of 3D buildings with façade, and as a result, the building elevation as well as the development intensity of blocks cannot be identified. Besides, some built-up areas are sheltered from the cloud so the transformation cannot be verified. Therefore, the proposed method basically performs well on the identification of urban redevelopment based on road junction form and POI types, while such kind of one-fits-all approach is still to be optimized by integrating the characteristics of different cities where certain block types may behave differently during the redevelopment process.

Determinant analysis of urban redevelopment

The proposed method's framework makes it possible to identify urban redevelopment at the block level across the country. By examining the spatial patterns, the authors wonder what contributes to a larger scale of urban redevelopment in a city and what types of urban blocks are more likely to be redeveloped. Therefore, in this section, the authors attempt to ascertain the determinants of urban redevelopment on both the city and block levels.

Intercity analysis. To test the first hypothesis on city-level redevelopment, namely, that cities with a low density of road junctions and at a high development level tend toward a greater proportion of urban redevelopment occurrence, the multiple regression model is estimated to examine the comprehensive impact of all independent variables including the administrative level, urbanization rate, and average density of road junctions while controlling for the population density, local GDP per capita, and regional location. Due to data

Table 3. Multiple regression results of the intercity analysis.

Variable	Coef.	Std. err.	t-value	p-value
City level	0.005	0.002	2.67	0.008*
Urbanization%	−0.014	0.007	−2.15	0.032*
Junction density	0.008	0.000	30.67	0.000*
Population density	0.005	0.004	1.16	0.247
GDP per capita	−0.001	0.001	−1.22	0.222
West	0.005	0.002	1.91	0.057
Middle	0.004	0.002	1.58	0.116

Obs = 287; Adj. R^2=0.80; Prob>F = 0.00; Alpha = 0.05.
*indicates significance at 5%.

availability, the analysis includes 287 Chinese cities at the prefecture level or above. City levels are labeled from 1 to 4, and a smaller number indicates a higher level.

Generally, the regression results (Table 3) show that the cities with a lower administrative level, lower urbanization rate, and higher density of road junctions tend to present a higher proportion of urban redevelopment, which means that the first hypothesis is unfortunately rejected. On the one hand, it is surprising to discover that the cities with a more urbanized population have a relatively smaller scale of urban redevelopment, which goes against the common recognition that cities with higher urbanization rates are supposed to conduct more infill development rather than extend the urban areas outwards. The cities' administrative level shows the same trend. This result actually reflects the illness of the urbanization mode of most Chinese cities to urbanize the land in the periphery areas rather than the population. By 2014, the growth rate of urban built areas in China was 2.5% higher than the growth rate of the urban population, which leads to an unbalanced spatial structure between the urbanization of land and population (Yuan and Kang, 2016). Quality rather than quantity deserves more attention regarding the urbanization process, and, therefore, urban redevelopment is greatly needed to rebalance people, jobs, and public resources in urban centers. On the other hand, the density of road junctions shows a positive impact on the urban redevelopment scale, which is also an unexpected trend. Using the density of road junctions as a measurement of the overall urban structure of cities could be problematic since the extent of built-up areas may produce a considerable bias on the density calculation. Accordingly, small cities with limited built-up land have the advantage of concentrating resources on infrastructure construction, which contributes to a higher density of road junctions on average. The hypothesis that the urban structure has a significant impact on urban redevelopment will continue to be tested with an intracity analysis, given that urban structure is not directly related to junction density across a city, while it is intuitively associated with block size.

Additionally, regional locations, population density, and local GDP per capita do not show a significant impact on urban redevelopment. The F value indicates that the model is statistically significant and interprets well the urban redevelopment at the city level. The adjusted R-squared is as much as 0.80; therefore, the proportion of urban redevelopment in a city is largely determined by the city's development level and urban form.

Intracity analysis. When focusing on the scope of a single city, the likelihood of a block to be redeveloped varies among different types of blocks; accordingly, the intracity analysis focuses on 252,028 urban blocks in the same 287 cities. It is assumed that the blocks with a simple

Table 4. Logistic regression results of the intracity analysis.

Variable	Odds ratio	Std. err.	z-value	p-value
POI density	0.999	0.000	−9.72	0.000*
Distance to center	0.994	0.001	−9.54	0.000*
Transit accessibility	1.010	0.000	65.53	0.000*
Land use mixed index	7.013	0.160	85.55	0.000*
Block area	56,526	4,374	141.42	0.000*
City level	0.986	0.006	−2.32	0.021
GDP per capita	1.003	0.003	1.08	0.278

POI: points of interest.
Obs = 252,028; Pseudo R^2=0.29; Prob>Chi^2=0.00; Alpha = 0.05.
*indicates significance at 5%.

use, larger size, and greater potential of land appreciation, as well as the blocks that are less efficiently utilized, are more likely to be redeveloped. The second hypothesis is tested with a logistic regression model, and the results (Table 4) are optimistic provided that all independent variables are statistically significant in the model except the two control variables of city level and GDP per capita. The odds ratio indicates a positive impact with a value greater than 1, which means that as the value of a variable increases, the block is more likely to be redeveloped. An odds ratio smaller than 1 corresponds to a negative impact.

POI density measures the efficiency of land utilization. With an odds ratio below 1, blocks with lower POI density are more likely to be redeveloped. Urban facilities attract people, and the vitality of blocks relies on sufficient facilities and mixed use. Additionally, as an intuitive measurement of urban structure, the block area shows a positive impact on block-level redevelopment, which verifies that urban structure tends toward better performance and otherwise, will be optimized. As a superblock contradicts with a city's sustainable development, when the block size is larger, the block is more likely to be redeveloped. Therefore, over the five years studied, Chinese cities are generally revitalizing urban areas by reshaping the city structure to small blocks and dense road networks.

Furthermore, the blocks that are closer to the city center or with better access to transit show a greater potential of land appreciation and are more likely to be redeveloped. Such places are usually core areas of the city. Since urban redevelopment is policy-oriented, city centers, subcenters, and even local centers have priority in rebuilding the environment and reconstructing major destinations. Additionally, blocks near the centers tend to have better access to public transit, which explains the positive impact of transit accessibility on urban redevelopment. Intuitively, however, the blocks with limited access to transit need to be redeveloped. It is not a contradiction to the results because transit accessibility actually indicates the resource allocation of the transportation system in the broader environment rather than the infrastructure supply of the block per se, and the infrastructure supply of the block per se is the measurement in the model.

The second hypothesis is largely accepted except that the trend that is shown by the land use mixed index indicates that the blocks with a highly mixed use are more likely to be redeveloped. The reason is probably that many mixed-use blocks are located in the traditional neighborhood and are very likely to undergo urban renewal due to the public policy over the five years. This type of urban renewal does not necessarily lead to a better urban structure and actually occasionally produces less mixed blocks. Therefore, it is crucial to balance the reinforcement of the built environment and the reshaping of urban functions.

The model is overall statistically significant according to the Chi-squared value, but the pseudo R-squared is only 0.29, which means that the model performs much better in interpretation than in prediction, and there are probably more factors that determine the redevelopment of a block that the authors are reserving for further study.

Conclusion and discussion

In this paper, the authors attempt to identify urban redevelopment across 659 Chinese cities based on the spatial form of road junctions and POI variation. A method framework has been proposed to identify the morphological urban redevelopment with ubiquitous road networks and to identify the functional urban redevelopment by detecting the variation of the predominant function of each block that is extracted from the POI data. To summarize from the perspective of block typology, urban blocks with four or more junctions (Type "4+") are found to have undergone both morphological and functional urban redevelopment. For the blocks with 1–3 junctions, four types of urban blocks ("2C," "3A," "3B," "3C") with more than a 300 meter TSL are identified as morphologically redeveloped blocks. Functional urban redevelopment is identified by the POI type change, with the criterion that the types with more than 11% of the blocks that present significant POI type change are concluded to have been functionally redeveloped, including block types "2A," "3A," and "3B." An intersection is also found in the block types between morphological and functional urban redevelopment, specifically types "3A," "3B," and "4+." Therefore, morphological and functional urban redevelopment rather than performing as an independent redevelopment process occur synchronously at times.

Based on the identification results, the determinant analysis attempts to answer how urban form and economic and social characteristics influence urban redevelopment at the city and block levels. Across the country, cities with a lower administrative level, lower urbanization rate, and higher density of road junctions tend to present a higher proportion of urban redevelopment at the end state. When the authors focus on single cities, it is found that the blocks with a lower POI density, a smaller distance to the city center, better access to transit, a higher land use mixed index, and a larger block size are more likely to be redeveloped. However, the models are hardly applicable to the prediction of urban redevelopment because policy is actually the decisive factor but is not necessarily correlated to the proposed assumptions. The explanatory models could still be continuously improved by integrating more impact factors and by removing highly correlated factors.

The major contribution of this paper is the proposed method's framework that identifies urban redevelopment with high accuracy. Morphological and functional urban redevelopment, two modes that include most redevelopment circumstances, are respectively identified, with morphological urban redevelopment relying on an intuitive typological analysis with road junctions and functional urban redevelopment indicated by POI type change. The road junctions and urban blocks are generated from the street networks, which along with POI, comprise the data basis of the framework and are available from open-source websites.

The entire study is conducted at the block level and automatically identifies urban redevelopment through the automatic classification of road junctions with ArcGIS. Therefore, given the fine accuracy, spatial resolution, and the automatic algorithm, the proposed method's framework is applicable to the large scale of urban systems and the big model study. By taking advantage of the identification results, the authors determine some of the most possible contributors to urban redevelopment and manage to diagnose the urbanization process of Chinese cities in a particular perspective. Nevertheless, an important component of block morphologies, the density of development, is not brought in for block type identification due to the lack of building data. The building-level redevelopment, as a potential bias of this paper, occurs all the time during the development process, especially in the renewal of old towns.

Due to the *experimental nature of the method*, this paper has several limitations. First, the thresholds for typology-based filtering criteria are set manually and intuitively. There is no argument in this paper that supports the measurement of "significant change." As a result, the authors might have excluded some potential redeveloped urban blocks with too rigid criteria or have included blocks with too slight a transformation in spatial form to be counted as redevelopment with inappropriate low criteria. For future study, the criteria should be examined by city and if necessary, customized based on the characteristics of different cities.

Second, blocks with a large number of POIs and the blocks with much fewer POIs are treated equally. In some cities that are not well developed, the coverage of POI data is limited to the center. The interpretation of urban function might be consequently biased for some blocks or even cities, whose validity should be further checked with data from other resources.

Third, this paper is concluded with the most possibly redeveloped urban block types, which is highly summarized and widely applicable. However, the redeveloped blocks in other types are left out while the identified results may also contain errors. Therefore, better ways to present the results should be explored in future study.

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