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Measuring the Urban Forms of Shanghai's City Center and Its New Districts: A Neighborhood-Level Comparative Analysis

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Abstract: Rapid urban expansion has radically transformed the city centers and the new districts of Chinese cities. Both areas have undergone unique redevelopment and development over the past decades, generating unique urban forms worthy of study. To date, few studies have investigated development patterns and land use intensities at the neighborhood level. The present study aims to fill the gap and compare the densities of different types of developments and the spatial compositions of different commercial uses at the neighborhood level. We captured the attributes of their built environment that support instrumental activities of daily living of 710 neighborhoods centered on the public elementary schools of the entire Shanghai municipality using application programming interfaces provided in Baidu Map services. The 200 m neighborhood provided the best fit to capture the variations of the built environment. Overall, city center neighborhoods had significantly higher residential densities and housed more daily routine destinations than their counterparts in the new districts. Unexpectedly, however, the total length of streets was considerably smaller in city-center neighborhoods, likely reflecting the prominence of the wide multilane vehicular roads surrounding large center city redevelopment projects. The findings point to convergence between the city center's urban forms and that of the new districts.

Keywords: built environment; planning; neighborhood; urban form; Chinese cities; Shanghai

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1. Introduction

Pre-1979 Chinese cities were compact [1]. Since the 1980s, the rapid expansion of built-up areas has transformed Chinese urban landscapes [1]. As the gateway to China's modernity [2] and the financial center for socialist China [3], Shanghai exemplifies these transformations.

In the early 20th century, Shanghai was composed of compact, crowded, and multifunctional neighborhoods where people conducted most of their daily activities near their homes, and where almost all daily needs could be met within walking distance [4]. Between the 1950s and 1970s, new workers' villages or integral residential communities with schools, retail, and other public service facilities were built at the fringes of the existing city [5,6]. The planning and design of workers' new villages generally followed principles similar to those of Perry's neighborhood unit [5,7,8]. These urban forms continue to affect travel behavior today; walking and biking account for more than half of travel mode share for subsistence and maintenance trips in Shanghai's city center [9].

The economic reform starting in 1978 brought significant urban and economic development in Chinese cities [10,11]. In already developed urban areas, redevelopment took place following the ten years of stagnation experienced during the Cultural Revolution (1966 to 1976) [12]. Like other Chinese cities, Shanghai city center went through staggering transformations [13,14] as old buildings were demolished and replaced with commercial blocks and multistory dwellings [15].

There was also massive urban development beyond existing cities. In Shanghai, the urban area grew from 832.46 km^2 in 1990 to 2968.01 km^2 in 2009, an astonishing 257% increase [16]. Much of the urban expansion took place on converted arable land [17,18]. New districts in Shanghai, such as Minhang, Pudong, Baoshan, Jiading, Qingpu, Songjiang, and Jinshan, were created in counties that were rural in the 1990s. Development was done on a project by project basis, using relatively low-density schemes that leapfrogged each other within the large zones that had been slated for the new development [11,19]. In these new urban forms, walking and biking trips only now account for 10% of travel mode share for subsistence and maintenance trips [20]. The city center and the new urban districts of Shanghai have experienced different development patterns and intensity of land uses.

The neighborhood has been a basic spatial unit to examine the physical form of cities and towns [7]. The neighborhood is a self-contained spatial unit, and its center has been defined around schools, community centers, parks, or retail services [8,21,22]. Schools are essential neighborhood elements because they exert essential influence on residential location decisions and area-specific housing demand [23,24]. As such, they are one of the most ubiquitous institutions shaping the city and regional ecology, policy, and everyday experience [25]. In China particularly, education has always been a vital means of personal advancement and Chinese parents place a strong emphasis on the role of schools and teachers in the education of their children [26]. The importance of school is coincident with Perry's (1929) position that the elementary school is the central institution to which families with young children were related, and neighborhoods should, accordingly, be built around elementary schools [27]. Hence, elementary schools are an especially relevant factor determining Chinese households' residential location choice. The enrollment of school-age children to public elementary schools in Chinese cities is proximity-based [28]. Housing values in Shanghai and other Chinese cities are in great part based on access to schools [29,30]. As for children, schools and the environment around schools have been found to impact on how children commute to school [31], their food choices [32], and physical activity [33]. It follows that considering a school, and in particular, a public elementary school, as the center of a neighborhood makes sense since it will capture an area that will be the center of a household's everyday life.

Most previous studies that investigated physical changes of Chinese cities since the economic reform of 1978 were conducted either at the macro level, from the perspective of regional expansion [34–39], or at the micro level, focusing on buildings as agents of urban form transformation [19,40–45]. However, less is known on the magnitude of and differences in development patterns and land use intensities at the neighborhood level. Access to public data has been a significant challenge for Chinese scholars, especially for those specialized in the humanities and social sciences [46]. Meanwhile, web mapping services such as Baidu Maps, a Chinese version of Google Maps, have rapidly developed and are widely used. Land use information can be obtained as online points of interest (POI) data using application programming interfaces (APIs) provided by Baidu online mapping services [47]. Baidu Maps APIs now yield such current land use data as detailed commercial activity at the building level and land-use intensity at the neighborhood level of Chinese cities. Online mapping with APIs thus offers an alternative approach to acquire built environment data on Chinese cities.

In recent years, urban open data such as OpenStreetMap data and online POIs data start to be used in studies on urban form and functions in Chinese cities [48–52]. Liu and colleagues summarized urban open data available in China and introduced studies using OpenStreetMap and online POI data at the 1 km by 1 km grid and subdistrict level to investigate Chinese urbanization [48]. Long and colleagues used urban open data to identify natural cities in China [49]. A recent study applied POIs data to identify live-work-play centers in 285 Chinese cities [50]. Other studies examined the density, diversity, and accessibility of road networks in Chinese cities [51,52].

The present study aims to fill the gap and to investigate neighborhood-level densities of different types of development and the spatial compositions of different commercial land uses, which past research has shown to be related to residents' daily life [40]. Specifically, the objective of the study is to probe into differences in the built environment of the city center, which has been redeveloped, and of the newly developed areas to understand the known differences in the travel behaviors of the two areas.

The novelty of the study lies in taking advantage of the recent availability of online mapping services and advanced GIS techniques in China, which make it possible to conduct systematic investigations of urban form and the built environment at the neighborhood level. The present novel approach can be generalized and applied to objectively measuring the built environment of other Chinese cities.

2. Materials and Methods

2.1. Study Area

Located in the Yangtze river delta with a population of 24 million and a total land area of 6,340.5 square kilometers [53], Shanghai is the most developed city in China in terms of gross domestic product (GDP). There are 15 districts and one rural county in Shanghai (Figure 1). Among those 15 districts, seven (Yangpu, Hongkou, Putuo, Changning, Xuhui, Jing'an, and Huangpu) comprise the Puxi area, or the city center located west of the Huangpu river (dark color in Figure 1). The remaining districts are the new districts, which were developed after the 1980s.

2.2. Data

A total of 715 public elementary school addresses were obtained from the Shanghai Municipal Education Commission in 2014. Of those, 710 (99%) were geocoded using Baidu Maps, the desktop and mobile web mapping service application provided by Baidu (a Chinese web services company). In 2014, Shanghai street network data of 2010 (the latest data available at that time) were purchased from AutoNavi Software Co., Ltd., a corporation of web mapping content and navigation, and location-based solutions in China. Figure 1 displays the spatial distribution of public elementary schools in Shanghai.

2.3. Built Environment Attributes

The built environment attributes of school-centered neighborhoods were captured using application programming interfaces (APIs) provided by Baidu Maps. There seems to be no consensus on what constitutes an appropriate size of an urban neighborhood. Perry's neighborhood unit was contained within the area defined roughly by a 400 m radius [54]. Similarly, a conventional transit-oriented development (TOD) district was defined as a circle centered at the transit station within a 400–500 m radius [55]. Meanwhile, walkability studies have suggested that a half-mile (about 800 m) or a 10-min walk is appropriate in today's mobility standards, and used 800 m to define walkable neighborhoods [56,57].

Subsequently, several buffer sizes were used to define the school-centered neighborhoods to include the 100 m and 200 m radii used to test variations of physical characteristics; the 400 m buffer radius originally used in Perry's neighborhood unit, and the 800 m buffer defining the neighborhood area that can be accessed in a 10-minute walk to and from school. Table 1 lists attributes of the built environment measures, which were captured in 2015 and selected based on locations and facilities that support instrumental activities of daily living (IADL) used in public health profession and defined as those activities that allow a senior to live independently in a community [58–61]. IADL include activities such as shopping, cooking, use of transportation, managing money, managing medication, etc. [59]. Specifically, land uses such as retail stores, supermarkets, and farmer's markets could support for daily shopping, regular restaurants and fast-food restaurants could be substituted for cooking, transportation facilities such as bus stops, subway stations, gas stations, train stations, parking lots, and street intersections are for use of transportation, banks for managing money, and drug stores and hospitals for managing medication. Measuring residential and office buildings was to acquire information such as density and the predominant land use type in the neighborhood. Parks, green open space, are important for resident's physical activity and mental wellbeing [62,63]. Education uses are to acquire information on additional educational uses such as kindergarden, middle school, and high school. Euclidean distance was calculated from each elementary school to People's Square, Shanghai's current political and economic center and the location of Shanghai municipal government headquarters, which replaced the 1862 horse racing track in 1949 [64], as a measure of the regional location to capture distance to the city's primary center. Total street network length was summed up for all four buffers as well, excluding streets and roads that only allow automobile access such as highways and therefore do not contribute to everyday life within the neighborhood. The rest of the built environment attributes were also tallied individually for all four buffers. Of note, information on building size, height, or total floor area was not available in Baidu Maps.

Table 1. Built environment measurements captured in 2015.

Categories	Items	Measures
Distance (Euclidian)	Distance to the city center	Distance to People's Square
Buildings	Residential buildings Office buildings	Counts in a 100 m buffer, 200 m buffer, 400 m buffer, and 800 m buffer
Transportation facility	Street network length	The total length of streets in a 100 m buffer, 200 m buffer, 400 m buffer, and 800 m buffer
	Street intersection Bus stop Subway station Gas station Train station Parking lot	Counts in a 100 m buffer, 200 m buffer, 400 m buffer, and 800 m buffer
Land use	Regular restaurant Fast food restaurant Hotel Retail store Supermarket Farmer's market Bank Hospital Drug store Educational use Park	Counts in a 100 m buffer, 200 m buffer, 400 m buffer, and 800 m buffer

2.4. Regression Model Development

To identify built environment attributes that are associated with whether a school is located in the city center or the new districts of Shanghai, four sets of binary logistic regression models were developed for built environment attributes measured in the four buffers, respectively. Built environment measures that were significantly correlated with each other, and specifically those correlated with residential building counts, were excluded from the regression models to avoid multicollinearity. Residential density (measured in this study as residential building counts in the different buffers) being a distinct dimension of urban form [65–69], was retained in all regression models for its theoretical significance. To address spatial autocorrelation, the Euclidean distance from a school to the city center was included as the autocovariate [70], which is an indicator of an endogenous process where distance is reversely associated with being located in the city center. As the built environment attributes were measured in four buffers, four regression models were developed accordingly, with built environment attributes from the same buffer in the same model.

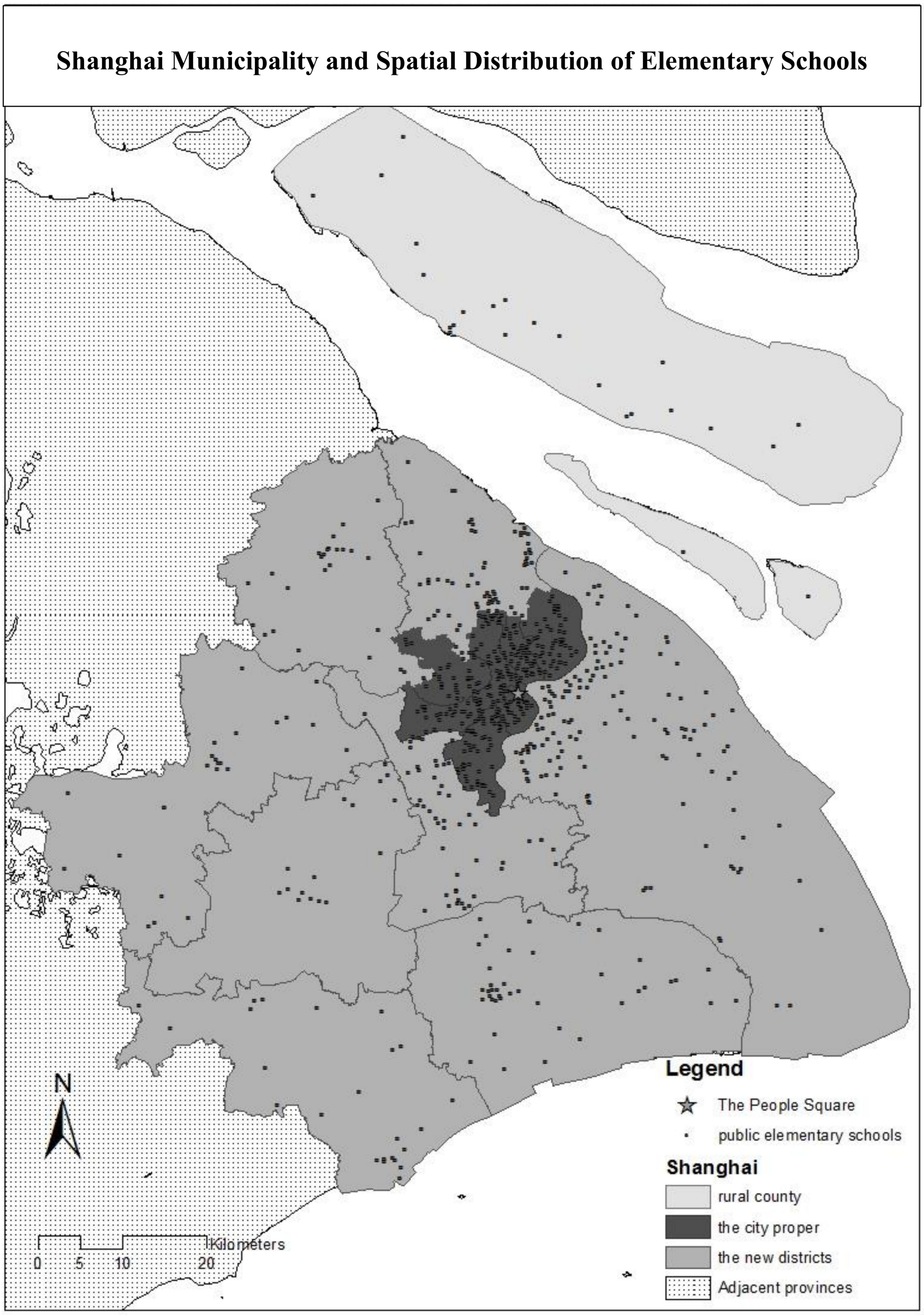

Figure 1. Shanghai municipality and spatial distribution of elementary schools in Shanghai.

2.5. Models Selection

Models were selected using the goodness of fit. The goodness of fit of different models was assessed using two penalized model selection criteria: the Bayesian information criterion (BIC) and the Akaike information criterion (AIC) [71]. Preferred models would have lower values of BIC and AIC:

$$\text{BIC} = -2 \log \text{likelihood} + \ln (n)^{*}p \quad (1)$$

$$\text{AIC} = -2 \log \text{likelihood} + 2p \quad (2)$$

where p denotes the number of parameters used in models; and n denotes the number of observations.

3. Results

3.1. Descriptive and Bivariate Statistics

Of the 710 elementary schools that could be geocoded, 289 (40.7%) were located in the city center and 421 (59.3%) were in the new districts. Table 2 summarizes descriptive statistics of residential and office buildings and transportation facilities and Table 3 presents the descriptive summaries of different land use in the four neighborhood buffers by the city center and new districts. P-values of bivariate analyses between each built environment attribute and whether a school was located in the city center or new districts were included in the tables as well. Most of the built environment attributes showed a significant difference between the city center and new districts, except for six transportation facility attributes (counts of bus stops in the 100 m buffer, counts of metro stations in the 200 m buffer, counts of gas stations in the 100 and 200 m buffers, street network length in the 100 m buffer, and counts of street intersections in the 200 m buffer), and seven land use attributes (counts of hotels in the 200 m buffer, counts of supermarkets in the 100 and 200 m buffers, counts of farmer's markets in the 100 and 200 m buffers, counts of drug stores in the 200 m buffer, and counts of parks in the 200 m buffer). Counts of residential buildings, office buildings, and parking lots in all four buffers are significantly different between the city center and new districts. As for land use attributes, counts of regular restaurants, fast-food restaurants, retail stores, banks, hospitals, and education use in all four buffers also exhibited significant differences between the city center and new districts.

Shanghai has many regular restaurants and fast-food restaurants. Specifically, 44% of schools (312) had at least one regular restaurant and 39% (278 schools) had at least one fast-food restaurant within 100 m, and 33% (234 schools) had more than 100 regular restaurants and 22% had more than 100 fast-food restaurants within 800 m.

Residential buildings measured in the 100 m, 200 m, 400 m, and 800 m buffers were significantly correlated with office buildings, parking lots, regular restaurants, fast-food restaurants, hotels, supermarkets, farmer's markets, banks, hospitals, and drug stores that were measured within the same buffers (results are shown in the Supplementary Table S1). Except for counts of farmer's markets and hospitals in the 200 m buffer, and banks and hospitals in the 100 m buffer, the tallies of regular restaurants, fast-food restaurants, hotels, retail stores, supermarket, farmer's markets, banks, hospitals, and drug stores within the four buffers were correlated with each other. As expected, total street network length measured in the four buffers was significantly and positively associated with counts of street intersections in the corresponding buffers. Except for a few variables, however, most of the built environment attributes were not associated with street network length or street intersections.

3.2. Binary Logistic Regression Results

Distance to the city center was included in all models as were residential building counts. Built environment variables that were correlated with residential building counts were excluded. If a built environment variable was not correlated with residential building counts but correlated with other independent variables included in the models, the variable was excluded as well. For the model using the 100 m buffer measures, the two attributes chosen were bus stop and total street network length. The 200 m model included street network length and educational use. The 400 m model included bus stop and street network length, and the 800 m model included street network length.

Table 4 shows the results of binary logistic regression models for all four buffers estimating the likelihood of a school to be located in the city center or a new district. As expected, the distance to the city center was consistently significantly negatively associated with a school being located in the city center. In the 100 m model, residential buildings counts exhibited a strong and significant positive association with a neighborhood being located in the city center, but total street network length and counts of bus stops were not significant (Table 4).

Table 2. Descriptive statistics of the built environment attribute by the city center and new districts—buildings and transportation facility.

			City Center	New Districts	Total	*p*-Value
Distance to People's Square		Distance in meters	6217.11 ± 3211.97	26,658.49 ± 24,933.77	710	**0.000**
		Distance natural log transformed	8.57 ± 0.64	9.95 ± 0.67	710	**0.000**
Residential building	100 m buffer	0 residential building	15.5%	84.5%	310	**0.000**
		1 to 10 residential buildings	54.3%	45.7%	291	
		11 and more residential buildings	76.1%	23.9%	109	
	200 m buffer	0 residential building	2.3%	97.7%	173	**0.000**
		1 to 10 residential buildings	28.0%	72.0%	175	
		11 to 40 residential buildings	57.7%	42.3%	182	
		41 and more residential buildings	72.8%	27.2%	180	
	400 m buffer	0 residential building	15.7%	84.3%	102	**0.000**
		1 to 10 residential buildings	3.7%	96.3%	164	
		11 to 99 residential buildings	51.8%	48.2%	168	
		100 and more residential buildings	65.2%	34.8%	276	
	800 m buffer	1 to 10 residential buildings	8.3%	91.7%	169	**0.000**
		11 to 99 residential buildings	16.4%	83.6%	128	
		100 and more residential buildings	61.5%	38.5%	413	
Office building	100 m buffer	0 office building	37.5%	62.5%	666	**0.000**
		1 and more office buildings	88.6%	11.4%	44	
	200 m buffer	0 office building	34.2%	65.8%	600	**0.000**
		1 and more office buildings	76.4%	23.6%	110	
	400 m buffer	0 office building	21.5%	78.5%	423	**0.000**
		1 and more office buildings	69.0%	31.0%	287	
	800 m buffer	0 office building	11.2%	88.8%	241	**0.000**
		1 to 10 office buildings	36.0%	64.0%	297	
		11 and more office buildings	90.1%	9.9%	172	
Bus stop	100 m buffer	0 bus stop	40.9%	59.1%	609	0.808
		1 to 3 bus stops	39.6%	60.4%	101	
	200 m buffer	0 bus stop	44.1%	55.9%	426	**0.023**
		1 to 5 bus stops	35.6%	64.4%	284	
	400 m buffer		2.41 ± 1.58	2.09 ± 1.65	710	**0.010**
	800 m buffer		9.56 ± 4.36	7.61 ± 4.77	710	**0.000**

Table 2. *Cont.*

			City Center	New Districts	Total	*p*-Value
Subway station	100 m buffer	0 subway station	40.7%	59.3%	710	
	200 m buffer	0 subway station	40.7%	59.3%	703	0.907
		1 subway station	42.9%	57.1%	7	
	400 m buffer	0 subway station	38.7%	61.3%	664	**0.000**
		1 and more subway stations	69.6%	30.4%	46	
	800 m buffer	0 subway station	28.4%	71.6%	510	**0.000**
		1 and more gas stations	72.0%	28.0%	200	
Gas station	100 m buffer	0 gas station	40.5%	59.5%	708	0.087
		1 gas station	100.0%	0.0%	2	
	200 m buffer	0 gas station	40.4%	59.6%	698	0.210
		1 and more gas stations	58.3%	41.7%	12	
	400 m buffer	0 gas station	38.5%	61.5%	650	**0.000**
		1 and more gas stations	65.0%	35.0%	60	
	800 m buffer	0 gas station	32.4%	67.6%	479	**0.000**
		1 and more gas stations	58.0%	42.0%	231	
Parking lot	100 m buffer	0 parking lot	38.8%	61.2%	649	**0.001**
		1 and more parking lots	60.7%	39.3%	61	
	200 m buffer	0 parking lot	37.2%	62.8%	570	**0.000**
		1 and more parking lots	55.0%	45.0%	140	
	400 m buffer	0 parking lot	23.5%	76.5%	327	**0.000**
		1 and more parking lots	55.4%	44.6%	383	
	800 m buffer		13.92 ± 10.57	3.86 ± 4.96	710	**0.000**
Street network length	100 m buffer	0 m	52.9%	47.1%	102	0.075
		1 to 200 m	42.5%	57.5%	134	
		200.01 to 400 m	34.8%	65.2%	201	
		400.01 to 600 m	40.1%	59.9%	142	
		600.01 to 800 m	41.3%	58.7%	75	
		800.01 and more	35.7%	64.3%	56	
	200 m buffer	Measured in km	1.39 ± 0.79	1.52 ± 0.82	710	**0.034**
	400 m buffer	Measured in km	5.07 ± 2.57	6.08 ± 2.52	710	**0.000**
	800 m buffer	Measured in km	19.78 ± 8.94	24.15 ± 8.44	710	**0.000**
Street intersection	100 m buffer	0 intersections	47.5%	52.5%	240	**0.026**
		1 to 2 intersections	35.9%	64.1%	237	
		3 and more intersections	38.6%	61.4%	233	
	200 m buffer		8.92 ± 7.49	9.75 ± 7.94	710	0.185
	400 m buffer		31.31 ± 22.85	38.29 ± 24.73	710	**0.000**
	800 m buffer		118.75 ± 78.21	150.36 ± 76.99	710	**0.000**

Note: *p*-value less than 0.05 is bolded.

Table 3. Descriptive statistics of the built environment attribute by the city center and new districts—land use.

			City Center	New Districts	Total	p-Value
Regular restaurant	100 m buffer	0 restaurant	30.7%	69.3%	398	**0.000**
		1 and more than 1 restaurant	53.5%	46.5%	312	
	200 m buffer	0 restaurant	39.4%	60.6%	241	**0.000**
		1 to 5 restaurants	29.7%	70.3%	246	
		6 and more restaurants	54.3%	45.7%	223	
	400 m buffer	fewer than 10 restaurants	17.6%	82.4%	239	**0.000**
		10 to 19 restaurants	33.8%	66.2%	148	
		20 to 29 restaurants	48.4%	51.6%	124	
		30 to 39 restaurants	51.4%	48.6%	70	
		40 to 49 restaurants	70.0%	30.0%	40	
		50 and more restaurants	82.0%	18.0%	89	
	800 m buffer	Fewer than 35 restaurants	12.4%	87.6%	233	**0.000**
		36 to 99 restaurants	36.2%	63.8%	243	
		100 and more restaurants	73.5%	26.5%	234	
Fast food restaurant	100 m buffer	0 fast-food restaurant	28.7%	71.3%	432	**0.000**
		1 and more fast food restaurant	59.4%	40.6%	278	
	200 m buffer	0 fast-food restaurant	35.1%	64.9%	291	**0.000**
		1 to 5 fast-food restaurants	30.2%	69.8%	242	
		6 and more fast-food restaurants	64.4%	35.6%	177	
	400 m buffer	0 fast-food restaurant	13.3%	86.7%	90	**0.000**
		1 to 5 fast-food restaurants	15.0%	85.0%	140	
		6 to 10 fast-food restaurants	30.9%	69.1%	110	
		11 to 15 fast-food restaurants	46.2%	53.8%	78	
		16 to 20 fast-food restaurants	45.3%	54.7%	64	
		21 to 25 fast-food restaurants	58.5%	41.5%	53	
		26 to 30 fast-food restaurants	52.5%	47.5%	40	
		31 to 45 fast-food restaurants	71.8%	28.2%	71	
		46 and more fast-food restaurants	84.4%	15.6%	64	
	800 m buffer	few than 10 fast-food restaurants	9.7%	90.3%	144	**0.000**
		11 to 30 fast-food restaurants	14.8%	85.2%	122	
		31 to 60 fast-food restaurants	33.5%	66.5%	167	
		61 to 99 fast-food restaurants	57.0%	43.0%	121	
		100 and more fast-food restaurants	84.6%	15.4%	156	

Table 3. *Cont.*

			City Center	New Districts	Total	*p*-Value
Hotel	100 m buffer	0 hotel	36.6%	63.4%	593	**0.000**
		1 and more hotels	61.5%	38.5%	117	
	200 m buffer	0 hotel	38.4%	61.6%	451	0.093
		1 and more hotels	44.8%	55.2%	259	
	400 m buffer	0 hotel	23.5%	76.5%	170	**0.000**
		1 to 2 hotels	31.8%	68.2%	214	
		3 to 5 hotels	47.6%	52.4%	170	
		6 and more hotels	64.1%	35.9%	156	
	800 m buffer		19.96 ± 15.47	8.78 ± 8.01	710	**0.000**
Retail store	100 m buffer	0 retail store	40.3%	59.7%	699	**0.119**
		1 and more retail stores	63.6%	36.4%	11	
	200 m buffer	0 retail store	40.5%	59.5%	677	**0.569**
		1 and more retail stores	45.5%	54.5%	33	
	400 m buffer	0 retail store	38.1%	61.9%	561	**0.007**
		1 and more retail stores	50.3%	49.7%	149	
	800 m buffer	0 retail store	30.2%	69.8%	311	**0.000**
		1 and more retail stores	48.9%	51.1%	399	
Supermarket	100 m buffer	0 supermarket	39.8%	60.2%	600	0.270
		1 and more supermarkets	45.5%	54.5%	110	
	200 m buffer	0 supermarket	42.4%	57.6%	425	0.275
		1 and more supermarkets	38.2%	61.8%	285	
	400 m buffer		3.26 ± 2.33	2.47 ± 2.16	710	**0.000**
	800 m buffer		11.79 ± 5.03	7.89 ± 4.63	710	**0.000**
Farmer's market	100 m buffer	0 farmer's market	40.3%	59.7%	648	0.455
		1 and more farmer's market	45.2%	54.8%	62	
	200 m buffer	0 farmer's market	39.4%	60.6%	530	0.237
		1 and more farmer's market	44.4%	55.6%	180	
	400 m buffer	0 farmer's market	27.3%	72.7%	227	**0.000**
		1 to 2 farmer's markets	40.8%	59.2%	294	
		3 and more farmer's markets	56.6%	43.4%	189	
	800 m buffer		8.07 ± 5.44	4.24 ± 3.45	710	**0.000**
Bank	100 m buffer	0 bank	38.1%	61.9%	625	**0.000**
		1 and more banks	60.0%	40.0%	85	
	200 m buffer	0 bank	38.0%	62.0%	527	**0.011**
		1 and more banks	48.6%	51.4%	183	
	400 m buffer	0 bank	24.0%	76.0%	233	**0.000**
		1 to 4 banks	38.5%	61.5%	247	
		5 and more banks	60.0%	40.0%	230	
	800 m buffer		23.97 ± 17.97	9.14 ± 8.87	710	**0.000**

Table 3. *Cont.*

			City Center	New Districts	Total	*p*-Value
Hospital	100 m buffer	0 hospital	39.5%	60.5%	686	**0.001**
		1 and more hospitals	75.0%	25.0%	24	
	200 m buffer	0 hospital	38.0%	62.0%	634	**0.000**
		1 and more hospitals	63.2%	36.8%	76	
	400 m buffer	0 hospital	27.7%	72.3%	458	**0.000**
		1 and more hospitals	64.3%	35.7%	252	
	800 m buffer	0 hospital	12.1%	87.9%	207	**0.000**
		1 to 3 hospitals	29.4%	70.6%	255	
		4 and more hospitals	76.2%	23.8%	248	
Drug store	100 m buffer	0 drug store	39.5%	60.5%	648	**0.036**
		1 and more drug stores	53.2%	46.8%	62	
	200 m buffer	0 drug store	38.8%	61.2%	505	0.107
		1 and more drug stores	45.4%	54.6%	205	
	400 m buffer	0 drug store	28.4%	71.6%	190	**0.000**
		1 drug store	39.9%	60.1%	223	
		2 and more drug stores	49.2%	50.8%	297	
	800 m buffer		6.84 ± 3.25	4.09 ± 3.02	710	**0.000**
Educational use	100 m buffer	0 school	27.8%	72.2%	198	**0.000**
		1 school	47.0%	53.0%	328	
		2 and more schools	43.5%	56.5%	184	
	200 m buffer	0 school	52.3%	47.7%	149	**0.000**
		1 school	28.4%	71.6%	264	
		2 schools	37.6%	62.4%	178	
		3 and more schools	58.0%	42.0%	119	
	400 m buffer		5.57 ± 3.92	2.82 ± 2.93	710	**0.000**
	800 m buffer		18.64 ± 12.81	6.75 ± 6.84	710	**0.000**
Park	100 m buffer	0 park	40.4%	59.6%	705	**0.073**
		1 and more parks	80.0%	20.0%	5	
	200 m buffer	0 park	40.5%	59.5%	696	0.475
		1 and more parks	50.0%	50.0%	14	
	400 m buffer	0 park	38.5%	61.5%	633	**0.001**
		1 and more parks	58.4%	41.6%	77	
	800 m buffer	0 park	30.7%	69.3%	453	**0.000**
		1 and more parks	58.4%	41.6%	257	

Note: *p*-value less than 0.05 is bolded.

Table 4. Binary logistic regression models.

	Model—100 m			Model—200 m			Model—400 m			Model—800 m		
	Measures	ß	Sig.	Measures	ß	Sig.	Measures	ß	Sig.	Measures	ß	Sig.
Constant		33.793	**0.000**		32.997	**0.000**		35.054	**0.000**		36.449	**0.000**
Distance to the city center	Distance to the city center (natural log transformed)	−3.686	**0.000**	Distance to the city center (natural log transformed)	-3.599	**0.000**	Distance to the city center (natural log transformed)	−3.710	**0.000**	Distance to the city center (natural log transformed)	−3.888	**0.000**
Residential buildings	0 residential buildings #	0.000		0 residential buildings #	0.000		0 residential buildings #	0.000		1 to 10 residential buildings #	0.000	
	1 to 10 residential buildings	0.565	**0.063**	1 to 10 residential buildings	0.926	0.154	1 to 10 residential buildings	−1.228	**0.069**	11 to 99 residential buildings	0.435	0.470
	11 and more residential buildings	1.49	**0.000**	11 and 40 residential buildings	1.519	**0.014**	11 and 99 residential buildings	−0.243	0.663	100 and more residential buildings	1.260	**0.008**
				41 and more residential buildings	1.893	**0.002**	100 and more residential buildings	0.375	0.466			
Street network length	0 m #	0.000		Street network length (continuous variable, measured in km)	−0.349	**0.033**	Street network length (continuous variable, measured in km)	−0.206	**0.000**	Street network length (continuous variable, measured in km)	−0.086	**0.000**
	1 to 200 m	−0.712	0.105									
	200.01 to 400 m	−0.933	**0.020**									
	400.01 to 600 m	−0.885	**0.035**									
	600.01 to 800 m	−0.434	0.394									
	greater than 800 m	−0.926	**0.076**									
Bus stop	0 bus stop #	0.000					Bus stop (continuous variable)	−0.002	0.981			
	1 to 3 bus stops	−0.112	0.754									
Educational use				0 school #	0.000							
				1 school	−1.706	**0.000**						
				2 schools	−1.159	**0.004**						
				3 and more schools	−0.813	0.069						
Total of observations		710			710			710			710	
−2 log likelihood		404.617			364.402			387.914			375.674	

Reference category. *p*-value less than 0.05 is bolded.

Similarly, in the 200 m model, residential buildings significantly positively associated with a school located in the city center. Meanwhile, total street network length and counts of education land use were significantly but negatively associated with a school located in the city center (Table 4).

In the 400 m model, a school was more likely to be located in Shanghai's new districts if, controlling for other variables, it had one to ten residential buildings within the buffer. In the same model, the total street network length consistently showed a significant negative association with a school located in the city center. The count of bus stops was not significant (Table 4).

In the 800 m model, a school was more likely to be located in the city center if, controlling for other variables, it had more than 100 residential buildings within the buffer. Similar to the results of the 200 m and 400 m models, the total street network length showed a significant negative association with a school being located in the city center (Table 4).

BIC and AIC indicators were calculated to compare goodness of fit of different regression models (Table 5). The 200 m model, which included four independent variables, distance to the city center, counts of the residential building, total street network length, and counts of educational uses had the lowest BIC and AIC values.

Table 5. BIC and AIC tests of the models.

	−2 log Likelihood	# Parameters	# of Observations	BIC	AIC
model—100 m	404.617	4	710	430.878	412.617
model—200 m	**364.402**	**4**	**710**	**390.663**	**372.402**
model—400 m	387.914	4	710	414.175	395.914
model—800 m	375.674	3	710	395.370	381.674

Note: the row of model—200 m is bolded.

4. Discussion

Chinese cities have experienced rapid urban expansion, suburbanization, and urban sprawl since the 1980s [72–75]. Our findings showed that school-centered neighborhoods in Shanghai's new urban districts had a lower intensity of residential and commercial development than their city center counterparts. Few land uses that are known to be associated with neighborhood-level activities were eventually included in the models because of their strong correlation with counts of residential buildings. Only in the 200 m model did tallies of educational uses display a significant negative association with a neighborhood being located in the city center, indicating that educational facilities (including, but not limited to elementary schools) tended to cluster more in Shanghai's new districts. However, correlations between residential building counts and daily routine destinations showed that the latter tended to cluster spatially near higher-density residential areas. City-center neighborhoods not only had higher residential density but were also equipped with more daily routine destinations than their counterparts in the new districts. These findings are consistent with previous studies of the compactness of the pre-1979 areas of Chinese cities [1,4,19]. Figure 2 illustrates a neighborhood near Haining Road and Henan N Road in the city center of Shanghai, located about 2 km northeast of People's Square.

A surprising result was the consistently negative association found between street network length and neighborhoods being located in the city center. Urban built environment studies of cities in China and other countries have shown that downtown and city center neighborhoods have denser street networks, because they were originally designed for slow travel, than newer district neighborhoods, where streets were designed for faster vehicular travel [76–79]. This counterintuitive result likely reflects the particularities of post-1980 inner-city redevelopment in China [14,19,80,81]. Since that time, in Shanghai, as in other Chinese cities, many inner city neighborhoods have been demolished, and their residents relocated to new districts, to make room for more profitable new residential and commercial uses [15]. Redeveloped city center neighborhoods typically comprise very large blocks of high rise buildings [10,81]. Many of their erstwhile narrow streets and dense street networks have been replaced with monumental multilane vehicular boulevards [82], effectively reducing street network length (see Figure 2). Figure 3 is an aerial view of a subdistrict near in Songjiang district, one of the new districts of Shanghai, about 20 km southwest of People's Square. Interestingly, this aspect of inner city redevelopment in China suggests that urban form attributes in the city center are converging with those in newly developed districts (see Figure 3).

Figure 2. A neighborhood near Haining Road and Henan N Road in the city center of Shanghai, about 2 km northeast of People's Square (Photo by the leading author when taking urban rail line 10).

Figure 3. A sub-district in Songjiang district, one of the new districts of Shanghai, about 20 km southwest of People's Square (photo by the leading author when taking a flight arriving Shanghai).

Having the lowest BIC and AIC values, the 200 m model indicated that the four independent variables, distance to the city center, counts of residential buildings, total street network length, and counts of educational best captured differences in built environment variations of the city center and new district neighborhoods. This might imply that a school-centered neighborhood in Shanghai could be delineated within a 200 m radius of an elementary school. This neighborhood size is small, compared to Perry's 400 m neighborhood unit [8,54], the 500 m transit-oriented development (TOD) catchment area in China [55,83], and the 800 m walkable neighborhood in the US [56,57]. Future studies should further test the size or sizes of neighborhoods in Chinese cities. Collecting observations of resident's daily spatial behaviors will shed light on what might be an appropriate neighborhood size for future planning purposes.

Descriptive statistics also showed that elementary schools had a large number of restaurants, especially fast-food restaurants nearby. Specifically, 44% of schools (312 schools) had a restaurant within 100 m, of which 89% (278 schools) have a fast food restaurant within 100 m. When the search extended to 200 m, more than half of the elementary schools (59%, or 419 schools) had at least one fast-food restaurant, and almost one quarter (24.9%, or 177 schools) had six or more fast-food restaurants. In comparison, a Chicago study found that 78% of the schools had at least one fast-food restaurant within 800 m [84]. Given past evidence gathered on the negative effects of school proximity to fast-food restaurants and, more generally, of exposure to poor-quality food environments on adolescent eating patterns and overweight status [85,86], future studies are needed to understand potential associations on children's eating patterns in Shanghai. Technological advances and the now available online mapping services in China enabled us to carry out a regional study in a small spatial unit of analysis. Our approach, which captured detailed objective neighborhood-level built environment attributes using Baidu Map and its APIs, could be readily applied to studies on urban design and planning, public health and built environment, and urban morphology in other Chinese cities.

The study has limitations. We centered our definition of neighborhoods on elementary schools. As for defining appropriate neighborhood size, collecting data on resident's daily activities and perception of their neighborhood will help verify whether and how much neighborhoods centered on a school overlap spatially with neighborhoods centered on commercial, institutional or recreational land uses. The count data of residential and office buildings and different commercial land uses and transportation facilities also have limitations. Additional information on building size, heights, total floor area, population density, and socioeconomic levels would provide further insights on urban form variations in Shanghai. Finally, we only had built environment data at one time point. Clearly, having longitudinal data on detailed land uses and destinations at the fine spatial scale would offer objective evidence on the physical changes detected in a region's urban form over time.

5. Conclusions

Shanghai's physical transformations, which are documented in this study, exemplify China's rapid urbanization and expansion since the economic reform in 1978. Specifically, the study provides information on changes in the urban form of Chinese cities over the last four decades.

This study quantitatively compared the urban form of the city center and the new districts of Shanghai. Our findings support a more nuanced understanding of urban form of Chinese cities. On one hand, we found that divergence between the city center and the new districts seemed to persist. Neighborhoods in the city center had higher residential density and were equipped with more daily routine destinations than their counterparts in the new districts in Shanghai. On the other hand, there was a convergence between Shanghai's city center and the new districts as the street network length was longer in the new district neighborhoods than in the city center. Second, a 200 m radius of a neighborhood centered on an elementary school seemed to best catch the built environment variation the most. Future studies should verify that this neighborhood size does correspond to the resident's daily activities and their perception of the neighborhood. Finally, employing Baidu online mapping services and their APIs appeared to be an effective way to secure detailed objective data on the urban physical features of Chinese cities. The approach promises to support future studies in the areas of urban design and planning, public health and built environment, and urban morphology.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su13158481/s1, Table S1: Bivariate analysis results.

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