Research on the of urban open and green spaces on the light of the Pandemic: The case study of Wuhan, China

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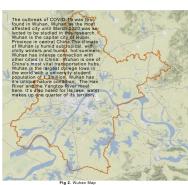*Department of Architecture, Built environment and Construction Engineering, Politecnico di Milano, Italy
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BACKGROUND

The Pandemic

Coronavirus, which has lasted for more than one year, had tremendous influences on social, economic, political aspects [1]. It seriously threatens world public health security [2]. One half of the world's population has been required to stay home as much as possible. The uncertainty of the disease and the social disruptive measures such as lockdowns and quarantines have increased fear and anxiety among people [3], which leading to a series of physical and mental problems such as post-traumatic stress disorder, depression, anxiety, panic disorders, behavioral disorders [4], cardiovascular and cognitive systems dysregulation [5]. Actually, The metropolis already became the incubators of epidemics with the urbanization process [6]. The World Health Organization had proclaimed 6 epidemics to be the public health emergencies of international concern (PHEIC) in this decade [7]. Bill Gates said in a public speech TED: "The greatest threat to humanity in the future is the pandemic."[8]. Therefore, Reasearch about the epidemic is very meaningful for now and future.

Urban Open and Green Space

Urban open and green space (UOGS), which means amenity space with high quality and maintenance, including green space, urban greenery, open space, public garden, parks, etc [9]. It is strongly connected with human health by setting it as an effective tool for planning healthy cities [10]. It can be used to prevent the occurrence and spread of infectious diseases in daily life, slow down the spread of infectious diseases when infectious diseases occur, and restore people's physical and mental health after the epidemic. Specifically, Researchers indicated the presence of green elements could increase the public's attention span, decrease the public's stress level, and have restorative effects on humans [11]. A series of theories such as stress recovery theory [12], biophilia hypothesis [13], and attention restorative theory have been proposed to verify this restorative effect [14]. During the epidemic, green settings facilitated social separation and indirectly mitigated the spread of COVID-19 [15]. UOGS could not only be useful to enhance human health but also provide a safe outdoor space for public social demands during and after the epidemic [16]. On thr other hand, the View of green space is significant to human health, especially mental health [17]. As for the period after the epidemic, the importance of access to green open spaces that are interlaced throughout the built-up grid was highlighted by a rise in pedestrian activity in city parks, peri-urban forest, and protected areas after COVID-19. In Wuhan, after covid, people are more willing to go to green space near communities rather than central green space [18].

Epidemic and Wuhan

Fig 1. Wuhan Location

The outbreak of COVID-19 was first found in Wuhan, Wuhan as the most affected city until March 2020 was selected to be studied in this research. Wuhan is the capital city of Hubei Province in central China. The climate of Wuhan is humid subtropical, with chilly winters and humid, hot summers. Wuhan has intense connection with other cited in China: Wuhan is one of China's most vital transportation hubs. Wuhan is the largest college town in the world with a university student population of 1.3million. Wuhan has it's unique nature condition: The Han River and the Yangtze River meet here. It's also noted for its lake, water makes up one quarter of its territory.

Fig 2. Wuhan Map

One Year After Unblocking

Fig 7. Usage of Urban Open and Green Spaces in Wuhan (May.2021)

METHODOLOGY

Data Collection　1

Table 1. COVID-19 confirmed cases density in Wuhan

Administrative Districts	The Number of Confirmed Cases (Person)	Areas (km²)	COVID-19 Confirmed Cases Density (people/km²)
Caidian District	1416	1093.17	1.295
Dongxihu District	2462	499.71	4.927
Hannan District	1085	287.08	3.779
Hanyang District	4670	111.54	41.868
Hongshan District	4679	213.65	21.900
Huangpi Distric	2114	2261	0.935
Jiang'an District	6549	64.88	100.940
Jianghan District	5183	28.29	183.210
Jiangxia District	848	2009	0.422
Qiaokou District	6834	41.46	164.834
Qingshan District	2782	152.22	18.276
Wuchang District	7458	107.76	69.209
Xinzhou District	1072	1463.43	0.733

Table 2. Variable selection and data sources

Variables	Definitions	Units	Sources
COV (COVID-19 confirmed cases per unit of land area)	The ratio of confirmed cases of COVID-19 to land area	people/km²	Website of Wuhan Municipal Health Commission. The data used for calculation is March 3, 2020
GDPA (GDP per unit of area)	The ratio between Gross Domestic Product and land area	10⁸RMB/km²	Wuhan Statistical Yearbook
BUP (Built up proportion)	The ratio of built-up land area to land area	-	GIS analysis
PAPC (Park area per community)	The ratio between park area to the community number in the district	m²/community	QGIS analysis
OFP (Open Forest area proportion)	The ratio of built-up land area to land area	-	QGIS analysis
WLP (Wetland area proportion)	The ratio of wetland area to land area	-	QGIS analysis
WP (Water area proportion)	The ratio of water area to land area	-	QGIS analysis
GP (Grass area proportion)	The ratio of grass area to land area	-	QGIS analysis
SP (Shrubs area proportion)	The ratio of shrubs area to land area	-	QGIS analysis

During Lockdown

Fig 3. Han Street during the lockdown in Wuhan (retrieved from https://www.zaobao.com.sg/zopinions/views/story20200131-1025120)

Fig 4. Outside of a hospital in Wuhan (retrieved from https://news.youth.cn/sh/202004/t20200408_1227618 8.htm)

Unblocking

Fig 5. Queuing for nucleic acid testing in Wuhan (retrieved from http://m.cnhubei.com/content/2020-05/16/content_13049936.html)

Fig 6. Wuhan University (retrieved from https://china.huanqiu.com/gallery/42l0-joHJ1LL)

Pearson Correlation Analysis　2

The test statistic Pearson's correlation coefficient assesses the statistical link, or association, between two continuous variables. Because it is based on the concept of covariance, it is recognized as the best approach for quantifying the relationship between variables of interest. The Pearson product-moment correlation coefficient (abbreviated as r) is a measure of the strength of a linear relationship between two variables.
p close to 0 : means there is not a significant linear correlation between x and y in the population.
p significantly different from 0 : means there is a significant correlation between x and y in the population.

Moedel Selection　3

The appropriate estimation model was chosen from the least square estimation regression model (OLS) and spatial regression models to avoid estimation divergence caused by spatial dependency. Moran's I and p value could be used to choose between spatial regression model and the least square estimation regression model. Anselin suggest that the least square method should be used to estimate the regression coefficient at first, then the significance of LM-lag, LM-Error, Robust LM-lag, Robust LM-lag could be compared to choose between spatial lag model and spatial error model. [19]. According to this criterion, OLS/SLM/SEM could be selected.

Spatial Regression Analysis　4

The spatial lag model (SLM) and the spatial error model were two classic spatial econometric models (EM). Mathematical expressions are the follows:

$$SLM: y = \rho W y + X\beta + \varepsilon \quad (1)$$

y: dependent variable vector; W: spatial weight matrix; X: independent variable matrix; ρ, β: coefficients; ε: independent and identically distributed residual vector.

$$SEM: y = x\beta + \varepsilon, \quad \varepsilon = \lambda W + \mu \quad (2)$$

y: dependent variable vector; W: spatial weight matrix; X: independent variable matrix; λ, β: coefficients; ε: spatial-dependent residual vector; μ: independent and identically distributed residual vector.

RESULT

Data Collection

Table 3. Descriptive statistics of variables (N=8). COV (COVID-19 cases density, COVID-19 confirmed cases per unit of land area, people/km²), GDPA (GDP per unit of area, 108RMB/km²), BUP (Built up proportion, -), PAPC (Park area per community, m2 /community), OFP (Open Forest area proportion, -), WLP (Wetland area proportion, -), WP (Water area proportion, -), GP (Grass area proportion, -), SP (Shrub area proportion, -).

Variables	Units	Min	Max	Mean	Std.dev.
COV	people/km²	0.422	183.210	47.102	61.695
GDPA	10⁸RMB/km²	0.366	50.495	10.318	13.525
BUP	-	0.089	0.915	0.431	0.310
PAPC	m²/community	10.29	4018.55	1006.26	1240.734
OFP	-	0.007	0.170	0.059	0.046
WLP	-	0.003	0.191	0.078	0.054
WP	-	0.025	0.412	0.114	0.110
GP	-	0.003	0.045	0.021	0.012
SP	-	0.001	0.018	0.007	0.005

The descriptive statistics for the variables are showed in the **Table 3**. Pearson correlation analyses were used for showing the strength of association between each of these contributing factors and the COV (confirmed COIVD-19 instances per unit of area).

Pearson Correlation

Fig 8. Pearson correlation analysis for the influencing factors to the COVID-19 confirmed cases per unit of area. (a) GDPA (GDP per unit of area, 108RMB/km²), (b) BUP (Built up proportion, -), (c) PAPC (Park area per community, m2 /community) .

Spatial Distribution & Model Selection

The spatial distribution of different level of COV (confirmed COVID-19 cases for unit of area) is showed in the **Figure 9**. The Moran's I value of it is 0.252. 999 permutations were used to assess the p value, which is 0.022. It indicated that COV in Wuhan was spatial autocorrelated. Anselin suggest that the least square method should be used to estimate the regression coefficient at first, then the significance of LM-lag, LM-Error, Robust LM-lag, Robust LM-lag could be compared to choose between spatial lag model and spatial error model. (Anselin, 2005). According to this criterion, the SEM (spatial error model) was selected.

Fig 9. Spatial distribution of COV in Wuhan. COV (COVID-19 confirmed cases per unit of area, people/km²). Administrative divisions: 1 (Caidian District), 2 (Dongxihu District), 3 (Hannan District), 4 (Hanyang District), 5 (Hongshan District), 6 (Huangpi District), 7 (Jiang'an District), 8 (Jianghan District), 9 (Jiangxia District), 10 (Qiaokou District), 11 (Qingshan District), 12 (Wuchang District), 13 (Xinzhou District).

OLS | SLM | SEM Results

POSTIVE CONTRIBUTOR:
high level of factor could increase COVID-19 density

GDPA　BUP

OFP　(GP)

NEGATIVE CONTRIBUTOR:
high level of factor could decrease COVID-19 density

PAPC　WLP

WP　(SP)

Fig 10. Negative and Postive Contributors to the COV

Table 4. Regression table of the distribution of COVID-19 confirmed cases in associate with related factors. COV (COVID-19 cases density, COVID-19 confirmed cases per unit of land area, people/km²), GDPA (Gross Domestic Product per unit of area, 108RMB/km²), BUP (Built up proportion, -), PAPC (Park area per community, m2 /community), OFP (Open Forest area proportion, -), WLP (Wetland area proportion, -), WP (Water area proportion, -), GP (Grass area proportion, -), SP (Shrub area proportion, -).

	Dependent Variable: COV		
	OLS	SLM	SEM
CONSTANT	1.975 (0.934)	-1.872 (0.877)	7.470 (0.069)
GDPA	2.421 (0.017) *	2.556 (0) **	2.321 (0) **
BUP	111.388 (0.039) *	100.552 (0) **	107.651 (0) **
PAPC	-0.019 (0.022) *	-0.020 (0) **	-0.020 (0) **
OFP	378.724 (0.107)	355.95 (0.000) **	346.628 (0) **
WLP	-159.016 (0.576)	-69.845 (0.649)	-197.85 (0) **
WP	-157.071 (0.106)	-165.62 ** (0.000)	-166.233 (0) **
GP	-68.585 (0.959)	-570.109 (0.450)	239.235 (0.503)
SP	160.409 (0.951)	811.207 (0.562)	-97.199 (0.891)
p/λ		0.193 (0.192)	-2.430 (0) **
R²	0.976	0.978	1.000
Log likelihood	-47.859	-47.2181	-41.583
Akakie info criterion	113.717	114.436	101.165
Schwarz criterion	118.802	120.086	106.25
Lagrange Multiplier (lag)	0.9562 (0.328)		
Robust LM (lag)	3.3261 (0.068)		
Lagrange Multiplier (error)	3.3426 (0.071) *		
Robust LM (error)	5.7125 (0.036) *		

The relationship between factors of UOGS (urban open and green spaces) to the COV (the number of COVID-19 confirmed cases per unit of area) are showed in the **Table 4**. GDPA, BUP were positive contributors to the COVCC, it indicated that high level of Gross Domestic Product per unit of area and built-up proportion could increase the COVID-19 cases density. Meanwhile, PAPC, WLP, WP have significant negative effect on COVCC, it implied that the increasing the park area per community, wetland proportion and water area proportion could reduce the COVID-19 cases density. Among the factors of UOGS, OFP presents the positive relationship with COV, it suggested that the open forest proportion might increase the COVID-19 cases density. GP and SP also have impact on COV, but it's not significant. This research studied the COVID-19 density in relation to urban open and green space characteristics in Wuhan. Spatial regression analysis was used as the approach. In the end, this research indicated that Urban open and green spaces has effects on COVID-19 density, the COVID-19 distribution in relation to UOGS has been measured in the meantime. These studies may provide useful information for urban development.

Fig 11. The Possible Usage of Urban Open and Green Space in the Future

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