

Facing global epidemic disease from **spatial planning perspectives**: a lesson from COVID-19 in Taichung City

Chun-Lin Lee^{1,2}, Yen-Jong Chen^{1,2}, Tsu-An Shen¹, and Fang-Pang Lin³

Email: chunlin_lee@gs.ncku.edu.tw

¹ Department of Urban Planning, National Chung-Kung University

² Taiwan Institute of Urban Planning (TIUP)

³ National Center for High-Performance Computing

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Speech Outline

- **Introduction**
 - COVID-19 in the world and Taiwan
 - Global research focuses about COVID-19
 - Influence factors of COVID-19 from spatial perspectives
- **Background**
 - COVID-19 in Taichung City
 - Urban planning and development in Taichung
 - Prevention policy of COVID-19 in Taiwan
- **Research design**
- **Results (temporary)**
 - Footprint numbers of confirmed COVID-19 cases
 - Variables from Land-use approach
 - Variables from transportation approach
 - Correlation and Regression analyses
- **Discussion with COVID-19**
 - Land-use diversity and mixed land-use policy
 - Development density and TOD policy
 - Public transportation with different influence
 - Open spaces in urban area
- **Conclusion remarks**

Introduction

- COVID-19 in the world and Taiwan
- Global research focuses about COVID-19
- Influence factors of COVID-19 from spatial perspectives

Introduction

• COVID-19 in the world and Taiwan

Global—

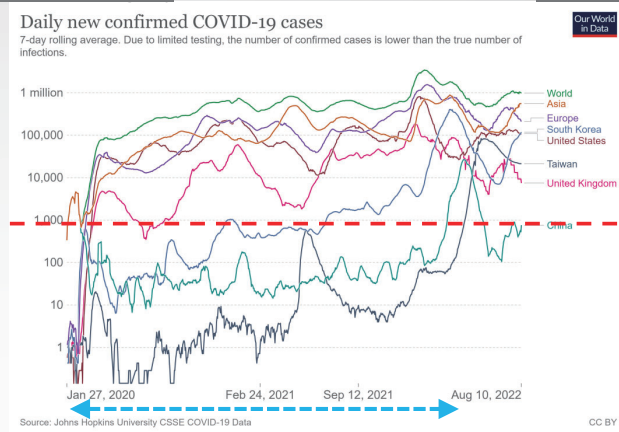
- From 2020 to 2022, the most significant number of cases has confirmed in China, the United States, the United Kingdom, Germany and South Korea
- **Most of countries' daily new confirmed COVID-19 cases are over 1,000 and gave up detailed investigation of footprints for every COVID-19 case.**

Taiwan—

- In the early stage of the outbreak, the number of confirmed cases was lower than most of the country
- **From May 2020 to Jun 2022, there are adequate footprints data for every COVID-19 case in Taiwan.**

• Global research focuses of COVID-19

- Most of analyses are from the perspectives of medicine, psychology, epidemiology, economics.
- **Lack of the research on spatial planning and analysis**



Daily new confirmed COVID-19 cases in most country



Global research on COVID-19

Introduction

Table. Global research on COVID-19 in urban planning

Research	Author · Year	Research Outline	Covid Metrics (Y)	Urban Factors(X)		Variable factors calculation	Methods
Associating COVID-19 Severity with Urban Factors: A Case Study of Wuhan	(Xin Li, et al. 2020)	Based on the help data from Weibo, infer the spatial distribution pattern and impact of the epidemic.	Dwelling address of the confirmed cases	Sociodemographic	Aging rate	Kernel Density Estimate	GWR model
				Urban sprawl	Volume rate		
				Urban facilities	Hospital density Subway station density Commercial facility density Road density Shannon		
				Land use			
交通暴露與土地利用模式對社區covid-19傳播風險的影響	(Li, et al. 2020)	Based on modeling, inferred the key spatial parameters effecting community level covid-19 risk are the two aspects from traffic exposure and land use.	Dwelling address of the confirmed cases	Traffic exposure	Proximity of transportation facilities to important locations	Kernel Density Estimate	GLM model
				Land use	Mixed use		
Spatio-temporal analysis of COVID-19 incidence rate using GIS: a case study—Tehran metropolitan, Iran	(Nasiri, et al. 2021)	Build the spatial models of COVID-19 incidence, mortality, and mobility patterns, and encountered the relationship between COVID-19 and comorbidities, population density, and land use.	Incidence, mortality rate, Dwelling address of the confirmed cases	Sociodemographic	Population density	Hotspots Analysis	Inverse Distance Weighted GWR model

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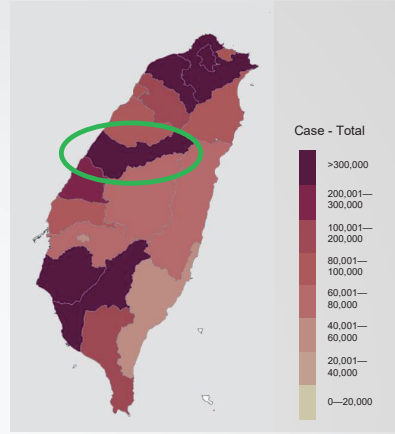
Background

- COVID-19 in Taichung City
- Features of Urban Planning in Taichung
- Prevention policy of COVID-19 in Taiwan

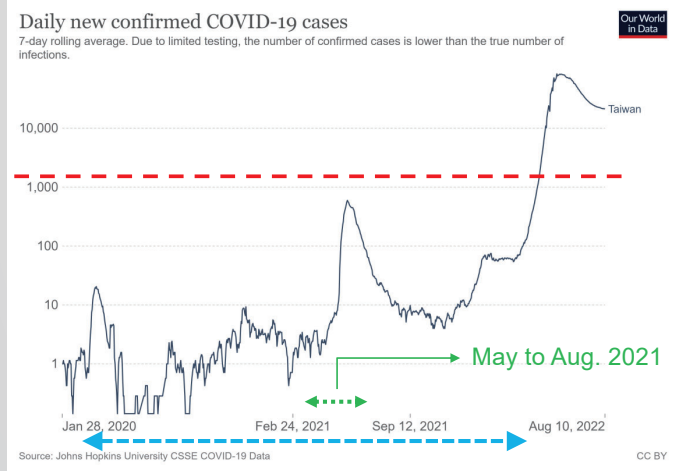
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Background

- COVID-19 development in Taiwan and Taichung
 - The COVID-19 spread from the capital (Taipei city) to the central and southern districts (like Taichung, Tainan, Kaohsiung and so on.)
 - Footprint data from May to August 2021 in Taichung are the only data that central and local government are willingness to release.

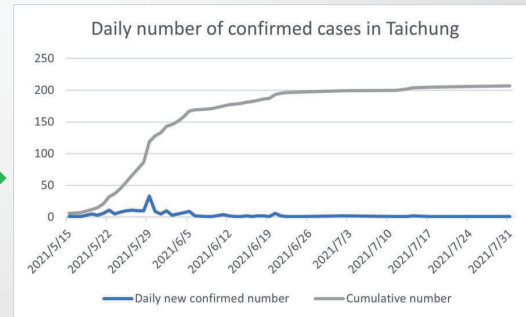


Taiwan confirmed cases of COVID-19 (NCHC) / Retrieve date : 2022/08/08



Daily new confirmed COVID-19 cases in Taiwan

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Daily number of confirmed cases in Taichung

Background

- The second round of attack from COVID-19 was in May 2021 to August 2021.
- The only open data from the government are the confirmed cases footprint in Taichung from May 2021 to August 2021.

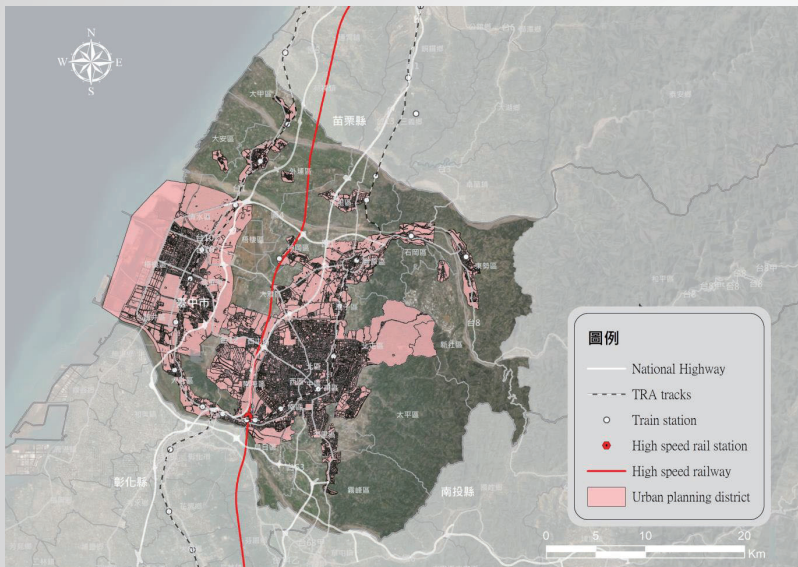


Fig.5 Urban planning district in Taichung

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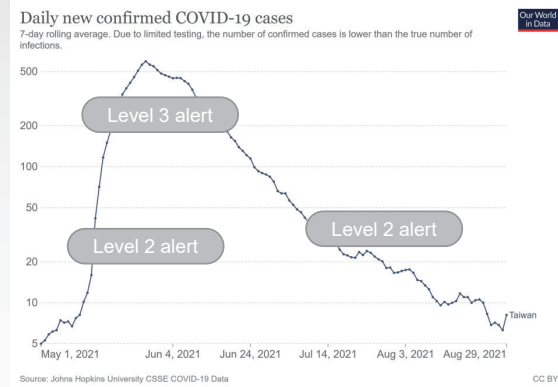


Fig.6 Daily new confirmed COVID-19 cases in Taiwan

- Taichung City: Population:2,800,000
Area: 2,215 km²
- Urban area: 538.7 km²
- MRT (one line) was established in 2021.
- Most of people rely on private vehicles, bus and train system in Taichung.
- **Urban plans and zoning control from American urban planning system but allow mixed land-use.**

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Background

Daily new confirmed COVID-19 cases

7-day rolling average. Due to limited testing, the number of confirmed cases is lower than the true number of

Our World in Data



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Background

Level 2 alert

Ensure social distancing and mask-wearing.

Cancel outdoor activities of more than 500 people and indoor activities of more than 100 people.

Arrange designated seats for participants and spare a seat from the next participant and prohibit consumption of food and beverages.

Consumption of food and beverages is prohibited on transportations and no standing ticket shall be sold.

Level 3 alert

More than 5 people indoors and 10 people outdoors are forbidden.

Leisure and entertainment venues are ordered to suspend operations.

Enhanced foot traffic controls at large scale retailers, supermarkets, businesses and government offices.

FROM MAY 11 TO JUNE 8
Raises epidemic warning to Level 2

PERSONAL AND OUTGOING CONTROL
Members of the public should avoid crowded venues and to wear a mask all the time at places with high risks of infection and transmissions. Those who do not wear face masks may be fined a penalty of more than NT\$3000 but less than NT\$15,000.

EVENT CONTROL
Organizers should cancel outdoor activities of more than 500 people and indoor activities of more than 100 people. However, if organizers of such gatherings and activities can arrange designated seats for participants and spare a seat from the next participant, keep a record of participant contact information, ensure participants wear masks all the time, and prohibit consumption of food and beverages, organizers may hold such events after submitting disease prevention plans to the local regulatory authority and obtaining permission.

EXTENSIVE BUSINESS RESTRICTIONS
1. Business owners and public venue management units should take measures that ensure social distancing and mask-wearing, use partitions, keep a record of customer contact information, take temperatures, sanitize environments, and institute crowd flow control, capacity limits and queue arrangements. Those failing to take these measures should suspend their business. When necessary, entertainment and leisure businesses and public areas will be closed.
2. Food service: Food and beverage service owners should keep a record of customers' contact information, sanitize/desinfect environments regularly, ensure staff members wear masks, maintain hand hygiene, take customers' temperatures, sanitize customers' hands, provide serving utensils, and provide assistance in other personal protective measures for customers, and install partitions between customers. Members of the public are advised to choose takeout at food and beverage service venues willing to adopt these measures.
3. Transportation: Consumption of food and beverages is prohibited on Taiwan High Speed Rail (THSR) trains, Taiwan Railways Administration (TRA) trains, and intercity buses. Starting May 15, no standing ticket shall be sold on THSR intercity trains and TRA intercity buses.

Extended Level 3 alert and relaxed regulations

Level 3 alert extension

- Masks must be worn outdoors at all times
- Family or social gatherings of more than 5 people indoors and 10 people outdoors are forbidden (not including those who live together)
- Social inspections will be conducted at leisure and entertainment venues ordered to suspend operations
- Current rules governing the operation of schools, kindergartens, after-school child care services and cram schools will remain in place
- Enhanced foot traffic controls will continue at large scale retailers and supermarkets.
- Holding business and public event services are forbidden
- Suspension of religious gatherings (including pilgrimages, processions, ghost festival events)
- Suspension of trade fairs, conferences and group dinners
- Businesses and government offices must implement foot traffic controls, with all visitors required to wear masks and social distance
- Workplaces and work locations must follow the provisions contained in the Guidelines for Enterprise Planning of Business Community
- Enhanced pandemic prevention management and emergency response measures will be implemented in markets and businesses

Relaxed regulations

- Conditional relaxed regulations (to be adjusted by local governments in accordance with pandemic prevention needs)
 - Outdoors: National parks, national scenic areas, amusement parks, sightseeing farms, forest recreation areas, botanical gardens, cultural parks, school playgrounds, driving classes
 - Indoors: Art museums, museums, cinemas, performance venues (with no audience), social education halls, science museums, cultural centers
 - Sports venues (not including swimming pools, gym, professional sports)
 - Food and beverage establishments (restaurants, night markets, food streets/food courts) that meet Central Epidemic Command Center guidelines can serve sit-down customers
 - Small local tour groups (note people maximum), filming
 - TV shows/movies
- The above relaxed regulations must adhere to the principle of standardization and guidance provided by the competent authority
 - Real-name registration, access controls, foot traffic controls to reduce number of visitors
 - Social distance and always wear a mask other than when eating and drinking
 - Employee health management and measures for dealing with staff who test positive for COVID-19

The COVID-19 level 2 and 3 alert (WDA)



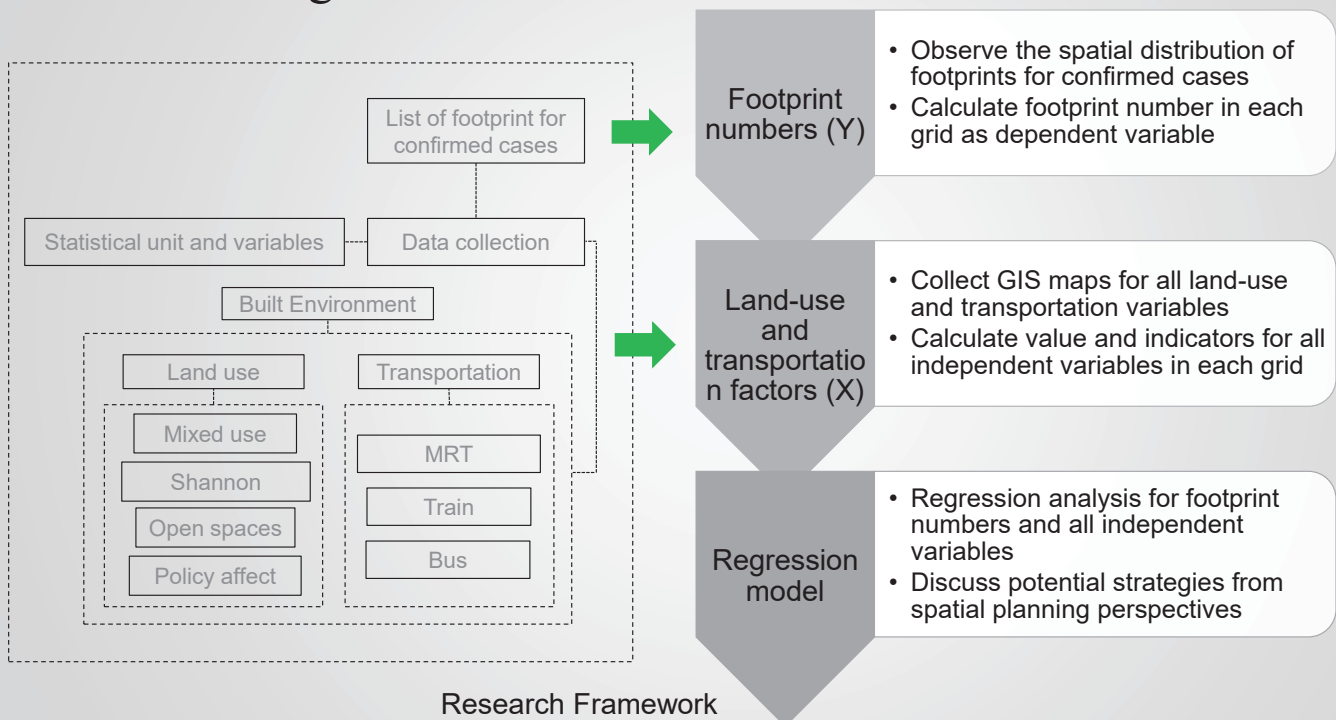
The COVID-19 policy effect in Taiwan

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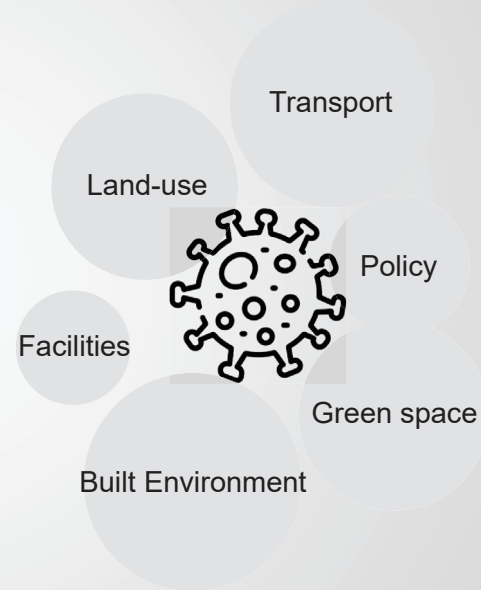
Research Design

Research Design



Methods and data source

- **Data Source**
 - Government Open Data—
 - The footprint of COVID-19 in Taichung from 2021/05 to 2021/08 (de-identification)
 - Construction and Planning Agency, Ministry of the Interior—
 - Land use survey and zoning maps in Taichung
 - Taichung Government, TRA, Open data and Open Street Map—
 - Stations and traffic (lines) volumes of MRT, Trains, and Bus data in Taichung
- **Methods**
 - Geographical Information System (GIS)
 - **Regression Analysis Model**
- **Spatial Analysis**
 - Spatial distribution pattern
 - Cross analysis of COVID-19 distribution pattern and spatial factors



Research Design

Variable definitions and calculation methods

	Code	Definition	Expected impact	Calculation	References	
Dependent variable	Y_FPP	The footprint numbers of the confirmed COVID-19 cases	x	The numbers of the confirmed cases footprint in each grid	(Nasiri, et al. 2021 ; Azadeh Lak, et al. 2021)	
Independent variables	Land-use	X_mixeduse	Mixed land-use type	+	Ratio of mixed-use category area to the built environment in each grid	(Xin Li, et al. 2020 ; Li, et al. 2020 ; Behram Wali, Lawrence D. Frank. 2021)
		X_openspaces	Open spaces	-	Ratio of open spaces category area to the built environment in each grid	(Boyeong Hong, et al. 2021)
		X_Shannon	Land-use diversity (Shannon index)	+	The diversity of the land use zoning in each grid	--
		X_built Env.	Area of built environment area	+	Area of built environment in each grid	--
	Policy	X_policy	Prohibited land-use area due to the epidemic prevention policy	-	Ratio of policy-impact category area to the built environment in each grid	--
	Transportation	X_MRT	MRT station amount	+	MRT station amount in each grid	(Xin Li, et al. 2020 ; Shuang Ma, et al. 2021 ; Azadeh Lak, et al. 2021)
		X_train_s	Train station and line amount	+	Total train station amount and line amount within neighborhood grids	
		X_bus_v	Bus station and line amount	+	Total bus station and volume (line) in each grid	

Results (temporal)

Results— Footprint points and grids

Table.3 The descriptive statistics of COVID-19 footprint point

Mean	Median	Mode	Standard Deviation	variance	Number
1.62	1	1	1.20	1.44	171
Kurtosis	Skewness	Range	Minimum	Maximum	Sum
18.34	3.59	9	1	10	277

- 703 Footprint points from 119 COVID-19 confirmed cases
- Select **171 grids** of **500x500 m²** that have at least one footprint for statistical analysis.

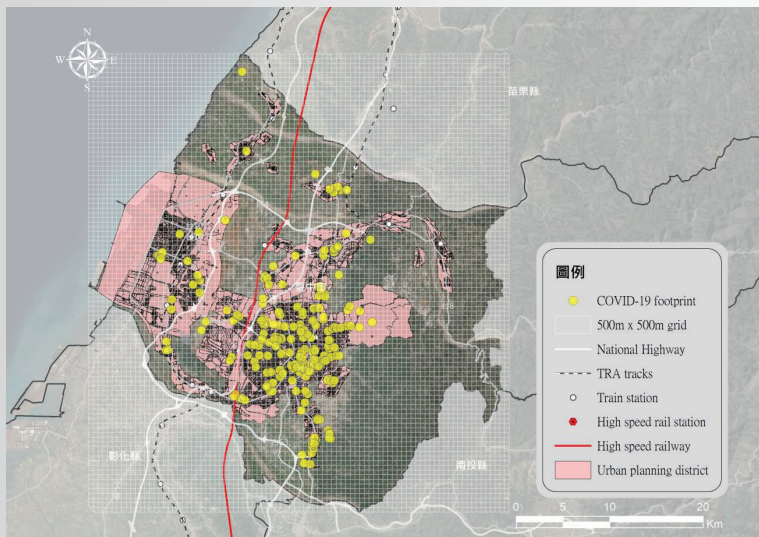


Fig. COVID-19 footprint points

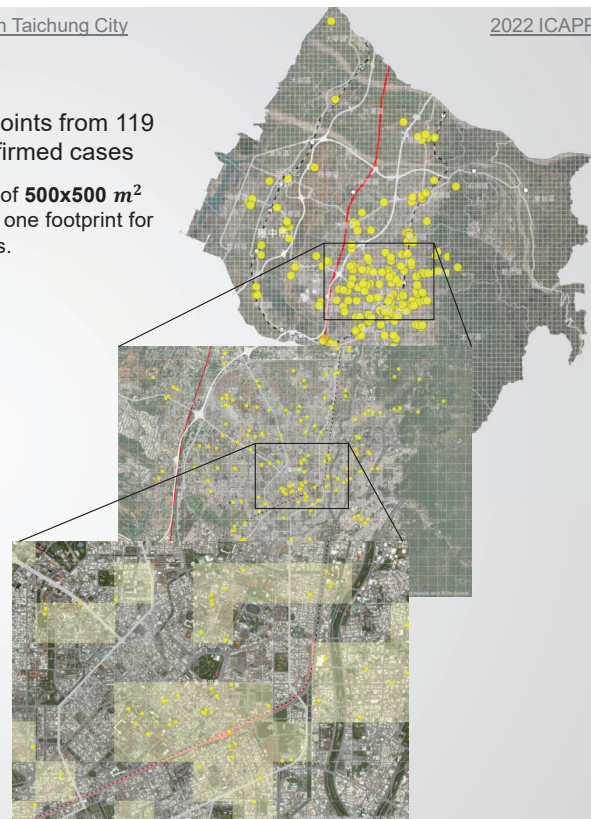


Fig.13 Example location

Results— Mixed land-use area

- Mixed land-use area presents positive correlation with footprint numbers

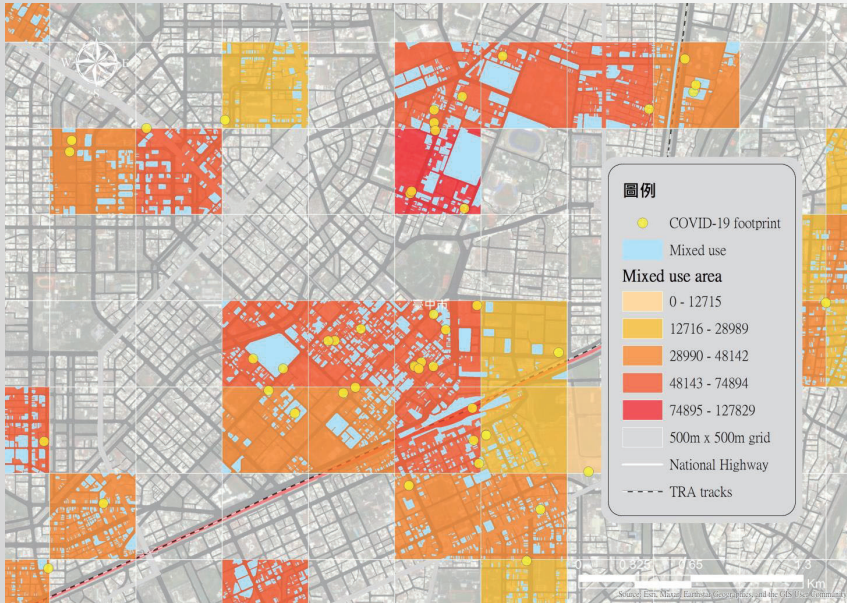


Fig. Mixed use area

Mixed use

- Mixed land-use may increase activity complexity and potential for cross-infection.
- A special phenomena in Taiwan.

Table.4 The descriptive statistics of mixed use

Mean	Median	Mode	Standard Deviation	Variance	Number
0.16	0.14	0	0.14	0.02	171
Kurtosis	Skewness	Range	Minimum	Maximum	Sum
7.24	2.19	0.88	0	0.88	28.13

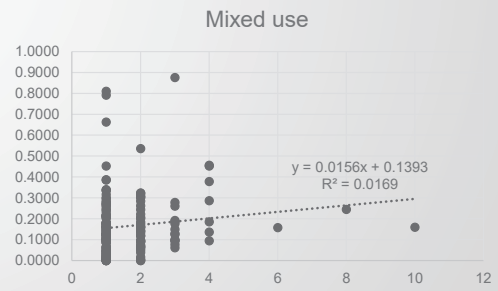


Fig.15 Mixed use scatter diagram

Results— Shannon index for land-use diversity

- The correlation between land use diversity and the footprint is not significant.

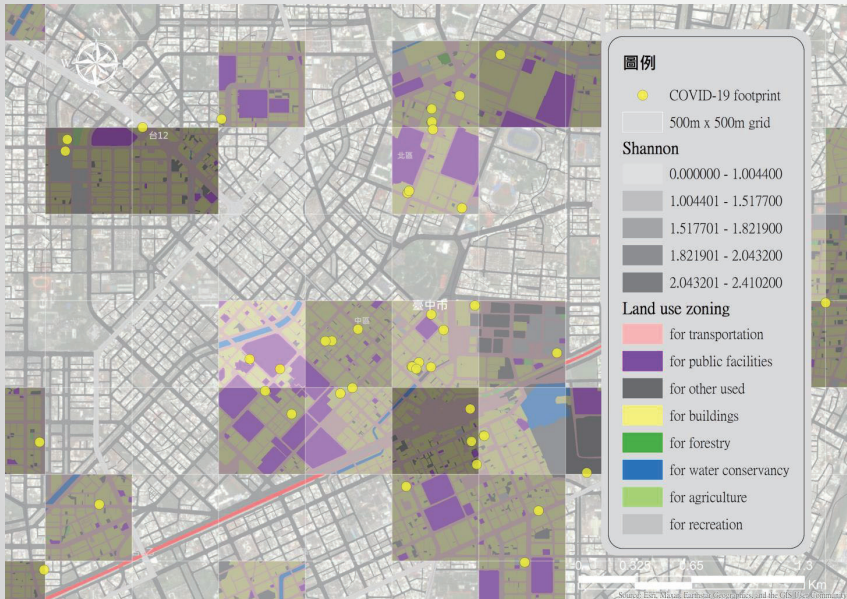


Fig. Land use zoning area

Shannon index

- More different land-se in the grid, provide more function to the neighborhood.

Table.6 The descriptive statistics of Shannon

Mean	Median	Mode	Standard Deviation	variance	Number
1.66	1.76	--	0.4	0.16	171
Kurtosis	Skewness	Range	Minimum	Maximum	Sum
2.44	-1.33	2.41	0	2.41	284.21

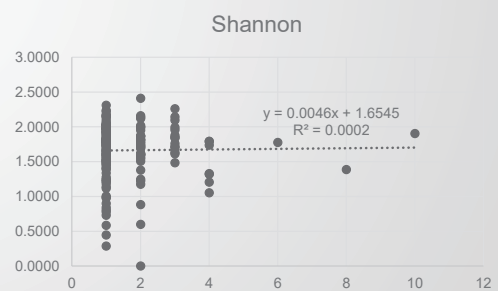


Fig.19 Shannon scatter diagram

Results— Open spaces area

- Open spaces area present slightly negative correlation with low R².

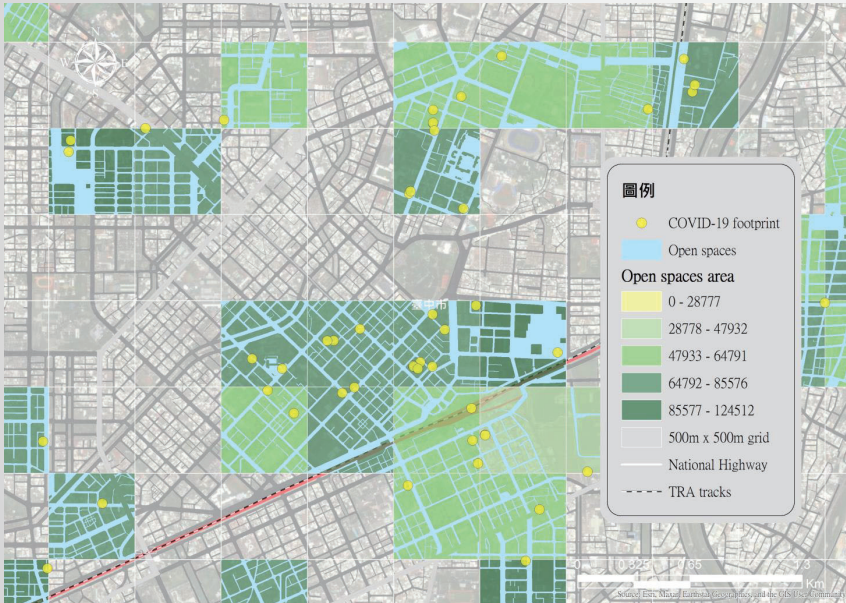


Fig. Open spaces area

- Open spaces
 - Where people could easily gain social distance.
 - Activities are not likely to be prohibited.

Table.5 The descriptive statistics of open spaces

Mean	Median	Mode	Standard Deviation	variance	Number
0.29	0.27	--	0.14	0.02	171
Kurtosis	Skewness	Range	Minimum	Maximum	Sum
5.80	1.89	0.94	0	0.94	49.95

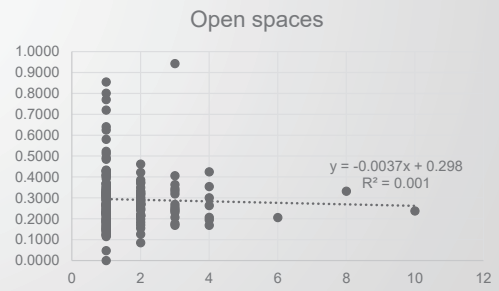


Fig.17 Open spaces scatter diagram

Results— Area of land-use which impacted by epidemic prevention policy

- The correlation between policy-impacted land-use and the footprint is **slightly positive** with low R²

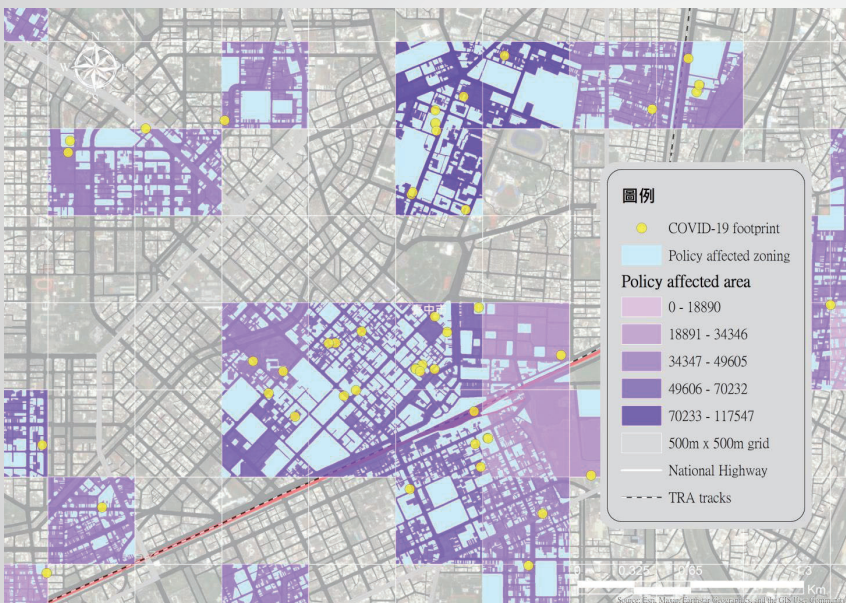


Fig. Policy-impact area

- Policy-impact
 - The epidemic prevention policies could reduce the activity intensity or reduce the opportunities for people to gathered.

Table.7 The descriptive statistics of policy-impact

Mean	Median	Mode	Standard Deviation	variance	Number
3.84	3.85	--	2.03	4.11	171
Kurtosis	Skewness	Range	Minimum	Maximum	Sum
0.74	0.44	11.75	0	11.75	656.63

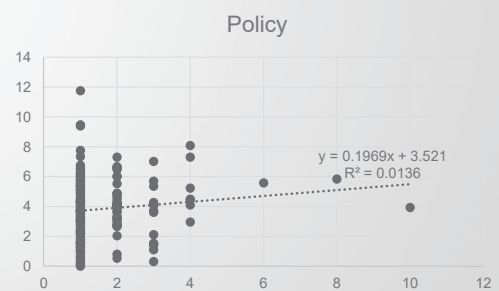


Fig.21 Policy-impact scatter diagram

Results— Built environment

- The correlation between built environment area and the footprint numbers is positive with low R²

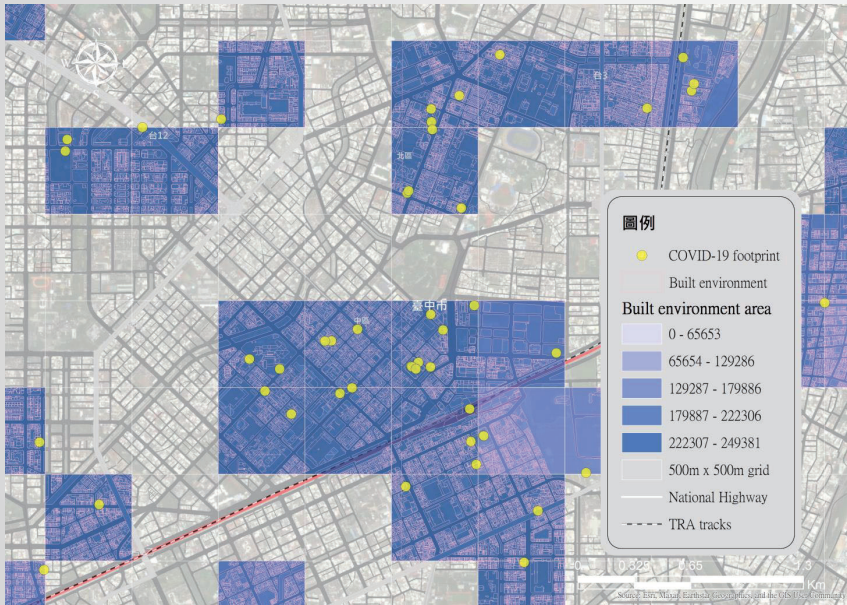


Fig. Built environment area

Built environment

- Built environment are the main area where people work or shop everyday.

Table.8 The descriptive statistics of built environment

Mean	Median	Mode	Standard Deviation	variance	Number
18.55	20.89	--	5.93	35.13	171
Kurtosis	Skewness	Range	Minimum	Maximum	Sum
0.6	-1.12	24.94	0	24.94	3172.66

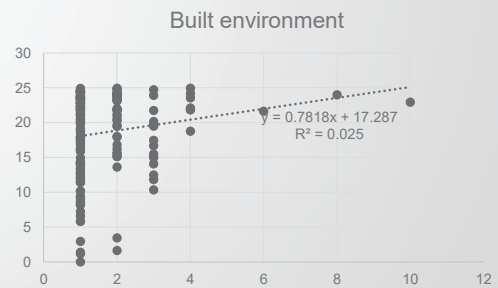


Fig.23 Built environment scatter diagram

Results— Train station and line amount

- The correlation between train station and the footprint were non-significant.

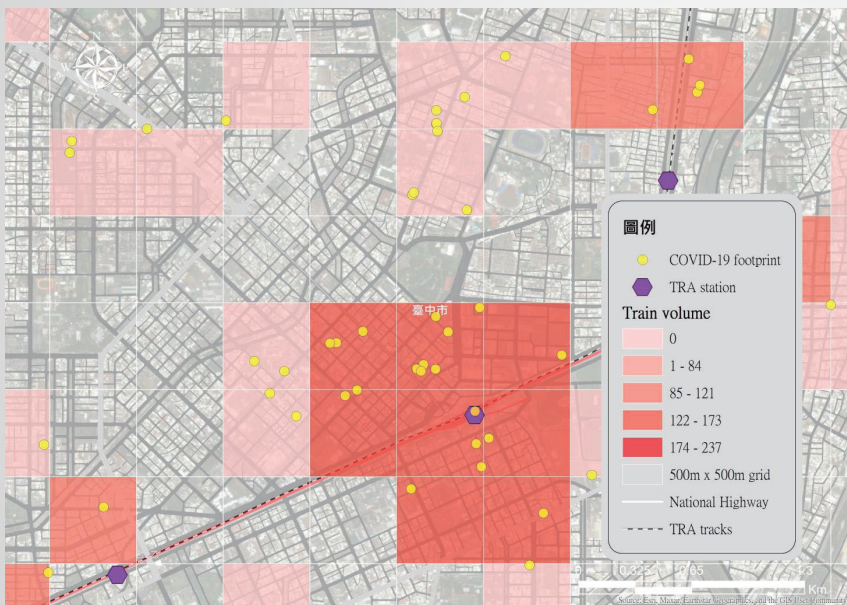


Fig. Train station and volume

Train station and volume

- Trains are the main transportation for people between the county.
- The area around train stations has more footprint.

Table.9 The descriptive statistics of train station

Mean	Median	Mode	Standard Deviation	variance	Number
0.18	0	0	0.43	0.18	171
Kurtosis	Skewness	Range	Minimum	Maximum	Sum
4.85	2.32	2	0	2	31

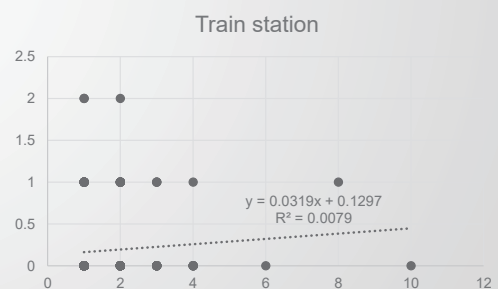


Fig.25 Train station scatter diagram

Results— Bus station and volume

- Bus volume presents positive correlation with footprint numbers



Fig. Bus station and volume

- Bus station and volume
 - Bus stations makes the more mobility in the neighborhood.
 - Frequent contact via transportation can exacerbated the epidemic in the area.

Table.10 The descriptive statistics of bus volume

Mean	Median	Mode	Standard Deviation	variance	Number
35.44	20	0	47.15	2223.3	171
Kurtosis	Skewness	Range	Minimum	Maximum	Sum
11.97	3.01	304	0	304	6061

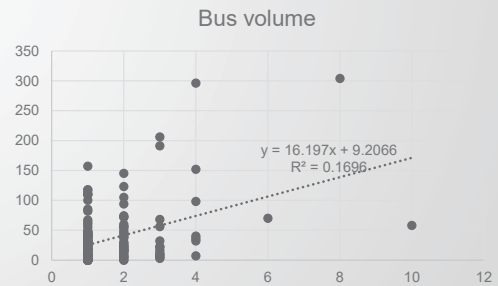


Fig.27 Bus volume scatter diagram

Results—Correlation and Collinearity of Explanatory Variables

- Correlation analysis
 - Except for built environment and policy, there is no significant collinearity between independent variables.

Correlation of explanatory variables

	Y_AFF	X_mixeduse	X_openspaces	X_shannon	X_policy	X_BE	X_train_s	X_bus_v
Y_AFF	1							
X_mixeduse	0.130	1						
X_openspaces	-0.032	0.441	1					
X_shannon	0.014	0.071	-0.041	1				
X_policy	0.116	0.391	-0.192	0.128	1			
X_BE	0.158	0.270	-0.246	0.130	0.702	1		
X_train_s	0.089	0.123	-0.126	-0.061	0.136	0.146	1	
X_bus_v	0.412	0.231	-0.045	0.033	0.405	0.385	0.172	1

Results

- Regression model
 - Compared to other variables, mixed land-use and bus volume has a higher explanation ability.
 - R^2 0.18. There are still some other variables we should consider.

Table.12 Regression model test

	Test1	Test2	Test3	Test4	Test5	Test6	Final test
	係數(t)	係數(t)	係數(t)	係數(t)	係數(t)	係數(t)	係數(t)
截距	1.2260(2.15)	1.4308(2.71)	1.1707(2.70)	1.4372(3.56)	1.1876(4.16)	1.4325(3.53)	1.4230(2.69)
X_mixeduse	1.2847(1.49)	0.9318(1.17)	0.5276(0.82)	0.9325(1.18)	0.5287(0.82)	0.9205(1.16)	0.9194(1.15)
X_openspaces	-0.7252(-0.84)	-0.6914(-0.87)	--	-0.6920(-0.87)	--	-0.6787(-0.85)	-0.6778(-0.85)
X_Shannon	0.0159(0.07)	0.0042(0.02)	0.0112(0.05)	--	--	--	0.0061(0.03)
X_policy	-0.0282(-0.41)	-0.0883(-1.37)	-0.0754(-1.21)	-0.0883(-1.38)	-0.0752(-1.21)	-0.0881(-1.37)	-0.0881(-1.37)
X_BE	0.0094(0.38)	0.0102(0.49)	0.0135(0.66)	0.0102(0.49)	0.0135(0.67)	0.0102(0.49)	0.0101(0.49)
X_train_s	0.0947(0.43)	--	--	--	--	0.0166(0.08)	0.0171(0.08)
X_train_v	--	0.0000(-0.02)	0.0002(0.10)	0.0000(-0.02)	0.0002(0.10)	--	--
X_bus_s	0.1204(1.78)**	--	--	--	--	--	--
X_bus_v	--	0.0108(5.27)**	0.0107(5.24)**	0.0108(5.29)**	0.0107(5.26)**	0.0108(5.35)**	0.0108(5.33)**
X_tmrt_s	-0.9365(-1.32)	--	--	--	--	--	--
R ²	0.0660	0.1820	0.1782	0.1820	0.1782	0.1821	0.1821

* : 表示相關性在0.1層級上顯著

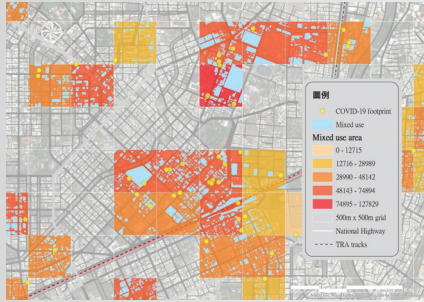
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Discussion with COVID-19

- Land-use diversity and mixed land-use policy
- Development density and TOD policy
- Public transportation with different influence
- Open spaces in urban area

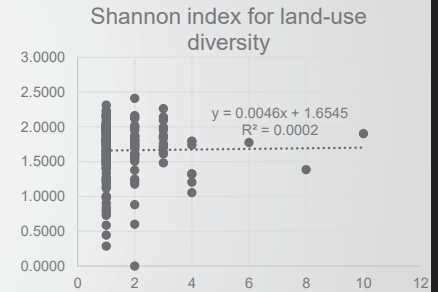
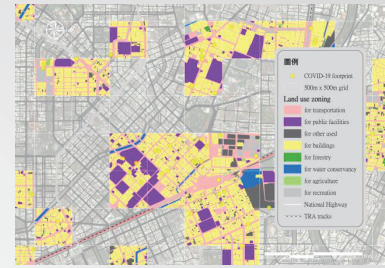
Discussion

- Land-use diversity and mixed land-use policy



- There is no adequate evidence to prove that land-use diversity will increase footprint numbers and affected risk in Taichung.
- Mixed land-use policy significantly increase footprint numbers.
- Coefficient of elasticity

$$E(Y_i \cdot mixeduse) \equiv \frac{\Delta\% \delta Y_i}{\Delta\% \delta mixeduse_i} = 0.81 \%$$



- Decrease 1% mixed land-use area may decrease 0.8% footprint numbers
- Direction of potential strategies to built up a safer urban environment to epidemic diseases.



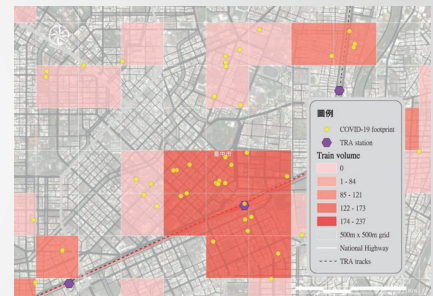
Discussion

- Public transportation with different influence on footprint numbers

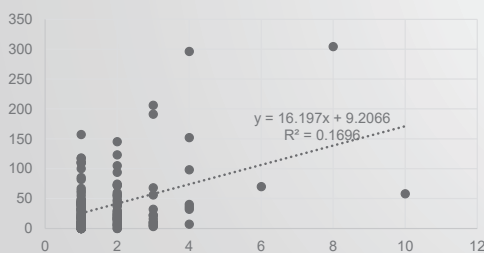


- Train system in Taichung is an transfer tool for citizens and stations is usually not a destination for a trip. Therefore, There is no significant correlation with footprint numbers.
- However, bus station and line volume significantly increase footprint numbers.
- Coefficient of elasticity

$$E(Y_i \cdot bus) \equiv \frac{\Delta\% \delta Y_i}{\Delta\% \delta bus_i} = 0.20 \%$$



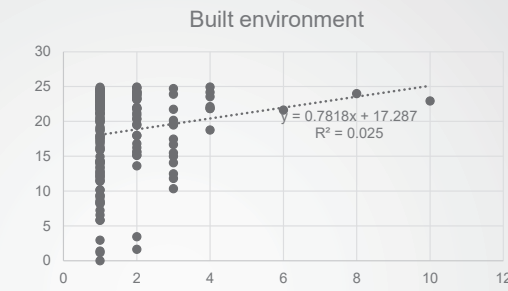
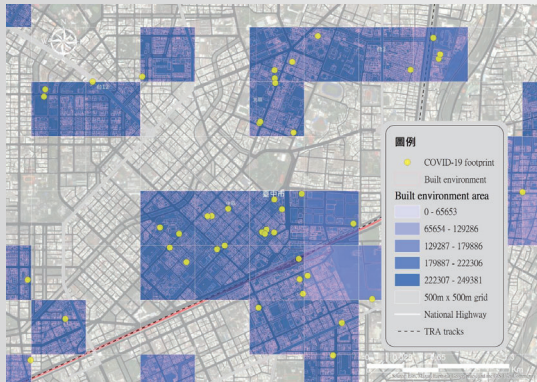
Bus line volume



- Decrease 1 % bus line volume may decrease 0.2 % footprint numbers
- Epidemic prevent policy with spatial heterogeneity can help us to focus on high risk area.

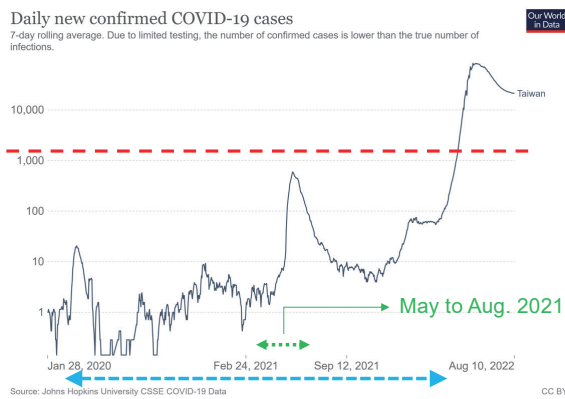
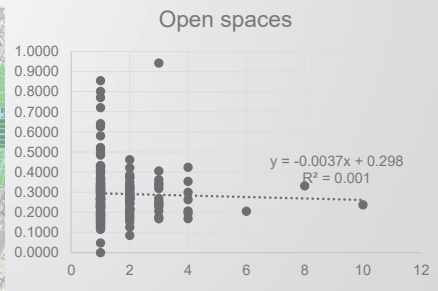
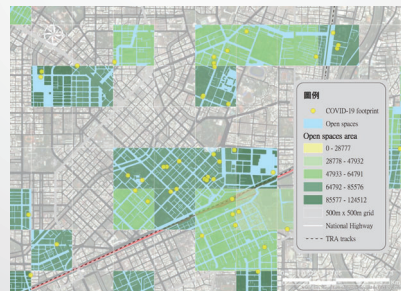
Discussion

- Development density and TOD policy



- Open spaces in urban area

- We have **no adequate evidence to prove the correlation for development density and open spaces to footprint numbers** at present in Taichung.
- Still need more footprint data, effort, and vertical approach to understand **development density and intensity**.



Conclusion Remarks

- If global epidemic disease (COVID-19) is an once-time attack to us, we can get used to it and survive. But **if it becomes a "new normal" to our society, we need to reconsider our urban and spatial planning policy** and help to adjust urban structure to a safer and easier environment to fight with the disease.
- Release more COVID-19 footprint data for urban and spatial researchers.** They will help to **propose COVID-19 prevention policy with spatial heterogeneity and rethinking open spaces, mixed land-use, and TOD policy.**