

What is the relationship between the distribution of parking facilities and the local traffic in Kwun Tong, Hong Kong?

Personal code: [REDACTED]

Word Count: XXXX



Commented [AC1]: Consider changing to "To what extent does the distribution of parking facilities interplay with local traffic in Kwun Tong, Hong Kong?"

Commented [AC2R1]: Maybe not

Commented [AC3]: Update!!!

1 Table of Contents

1	Table of Contents	2
1.1	Word Count Breakdown	3
1.2	List of figures and maps	4
2	Introduction	5
2.1	Abstract	5
2.2	Literature Review	5
3	Geographical Context	7
4	Hypothesis	9
5	Methodology	10
5.1	Accessibility	11
5.1.1	The Gaussian-based two-step floating catchment method (Ga2SFCA)	11
5.1.2	Quantification of demand	14
5.1.3	Quantification of supply	16
5.1.4	Measurement of distance between locations	17
5.1.5	Service and catchment distance	18
5.1.6	Sampling method	18
5.2	Traffic congestion	19
5.2.1	Time-occupancy	19
5.2.2	Flow	20
5.3	Precautions for surveying	21
5.4	Hypothesis Testing	21
5.4.1	Spearman Rank Correlation Coefficient (SRCC)	21
5.4.2	Student's T-test	22
6	Data Analysis	23
6.1	Macroscopic Trend	23
6.1.1	Heteroscedasticity	24
6.2	Qualitative Analyses	25

6.2.1	Role of land use in traffic congestion	26
6.2.2	External physical factors and limitations	30
6.2.3	Pedestrian interruption of traffic flow	Error! Bookmark not defined.
6.2.4	Inefficient road design	Error! Bookmark not defined.
7	Evaluation	34
7.1	Methodology	34
7.1.1	Unsuitability of selecting a set service catchment distance	34
7.1.2	Region-wide insufficiency of parking spaces	34
7.1.3	Assumption of equal parking fees across all car parks	34
7.1.4	Selection of distance-decay function	35
7.1.5	Measurement of Traffic congestion	35
7.2	Study Area	35
8	Conclusion	37
9	Bibliography	38
10	Appendix	38

1.1 Word Count Breakdown

Excludes maps, graphs, figures, infographics, diagrams, calculations, formulae, equations, tables, footnotes, headings, citations, and in-text citations.

2.1	
2.2	
3	
4	
5	
5.1.1	
5.1.2	
5.1.3	
5.1.4	
5.1.5	
5.1.6	
5.1.7	
5.2	
5.2.1	

5.2.2	
5.3	
5.4	
5.4.1	
5.4.2	
6	
6.1	
6.1.1	
6.2	
6.2.1	
6.2.2	
6.2.3	
6.2.4	
7	
Total	

1.2 List of figures and maps

To be added.

Commented [AC4]: UPDATE!!!

Commented [AC5]: Export as TXT + treat in VSCode.

2 Introduction

2.1 Abstract ← not necessary

Since the industrialisation of Hong Kong (HK), the territory has observed a steady increase in car ownership, while the growth rate of the number of parking spaces has decreased (“Transport Department”, 2021), resulting in a shortage in parking supply. With HK being one of the busiest freight and container hubs (“HKTDC Research”, 2021) and being one of the most densely populated areas (“Census and Statistics Department”, 2021), the development of an efficient transportation system is paramount to the long-term sustainability of the logistics industry. With the vehicular speed in urban areas declining (“Legislative Council Secretariat”, 2014), traffic congestion decreases the throughput of products and services, exacerbates air pollution, and worsens the quality of life (QoL) of citizens (Arnott and Small, 1994). Therefore, this investigation aims to provide a more solid understanding of the relationship between the spatial distribution of parking spaces and the local traffic in urban areas of HK, so to build a more resilient and sustainable transport system.

2.2 Literature Review

According to the Traffic Advisory Committee (2014), traffic congestion is one of the most important urban issues in HK. Many researchers have compared traffic congestion to fluid dynamics, outlining the three fundamental components, including flow, the number of vehicles passing through a point per unit time; speed, the distance covered per unit time; and density, the number of vehicles occupying a road segment per unit distance (Salter, 1976; Gaddam and Rao, 2018). Although multiple attempts have been made to relate speed and density (Greenshields, 1935; Drake et al., 1967; Wang et al., 2010), it has been widely accepted that traffic congestion is characterised by high density and low speeds (Bovy and Saloman, 2002).

It has historically been trivial to quantify traffic congestion (Aftabuzzaman, 2007). One of the methods developed is the Roadway Congestion Index (RCI), the ratio between the mean time delayed and the theoretical free-flow travel time (Schrank et al., 1994). Although the measure is widely implemented in the U.S., researchers have argued that the measure is inapplicable to public transport heavy cities (Levinson and Lomax, 1996), which is the case for HK as 90% of the population uses public transport (“Legislative Council Secretariat”, 2016). Another measure adopted by the U.K. and Japan is the volume-to-capacity (V/C) ratio, which is calculated by the quotient of the measured traffic volume and the maximum design volume and are often classified into different traffic behaviour categories (Lindley, 1987). Despite the measure offering great scalability, since fundamental parameters are not accounted for, some researchers have criticised using V/C as a measure of traffic congestion (Gordon et al., 1997; Hamad and Kikuchi, 2002). With a variety of different measures developed, researchers have

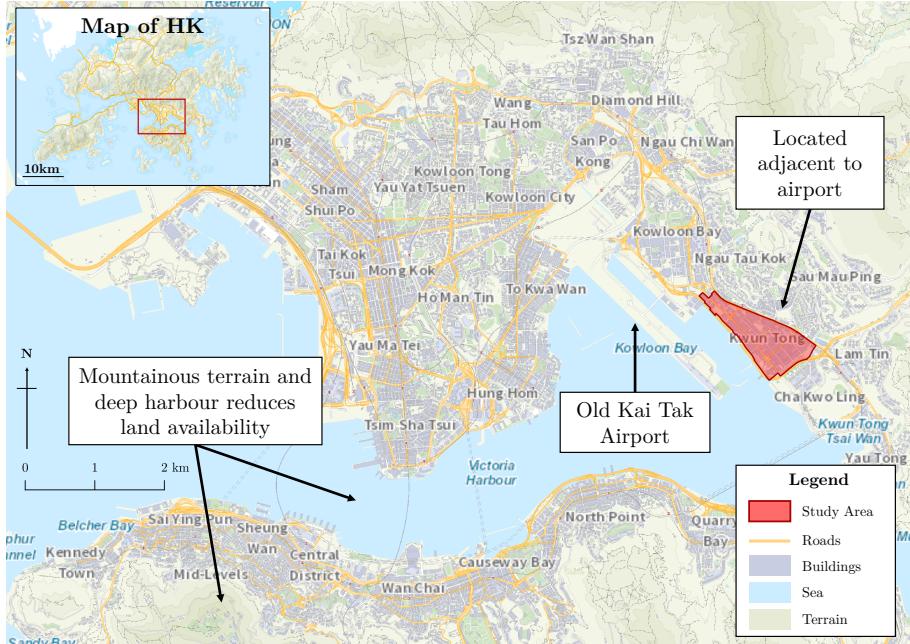
Commented [AC6]: Remove if WC exceeded. Extra detail that is not developed.

argued that the direct measurement of traffic speed is arguably the simplest, least biased, and most representative method of quantifying traffic congestion (Wardrop, 1952; Ye et al, 2006; Cvetek, 2021). Speed can be measured directly with cameras or estimated from time-occupancy, the percentage of time occupied by a vehicle, from inductive loop detectors or manually (Ulberg and McCormack, 1988; Arasan and Dhivya, 2009).

The distribution of services is often expressed by the extent to which geographical features are clustered or evenly spread out. Because drivers have the incentive to park at locations closest to their destination (Parmar et al., 2020), insufficient off-street parking spaces often cause drivers to resort to kerbside illegal parking, reducing the road capacity and increasing road accident risks (Tong et al., 2004). On the other hand, an overabundance of parking space can also cause drivers to cruise around the area in search of lower costs, resulting in a lower vehicular speed and the occupation of road space (Shoup, 2006). Therefore, multiple parking strategies and models have been developed to ensure an evenly distributed level of service, such as the Second Parking Demand Study in HK (Wong et al., 2000; Lau et al., 2005).

The distribution of facilities can be measured using the Nearest Neighbour Index (NNI), which is the ratio between the observed and expected mean Euclidean distances (Pinder and Witherick, 1972). Although the index provides an excellent general outlook on the inequity of services, the assumption that facilities are fully interconnected with no friction of distance is highly unreasonable (Wang and Lou; 2005). With the need of pinpointing regions with inadequate supply of facilities on a microscopic level increasing, researchers have developed the two-step floating catchment area method (2SFCA), which involves summing up distance-decayed supply-to-demand ratios (SDR) surrounding the survey point (Wang and Luo, 2004). Since 2SFCA incorporates both the aspatial utilisation of the service and the spatial demographic patterns, 2SFCA can effectively represent the real-life preferences of users and therefore has gained widespread interest in applications such as the measurement of accessibility in healthcare services (McGrail, 2012; Chen and Jia, 2019).

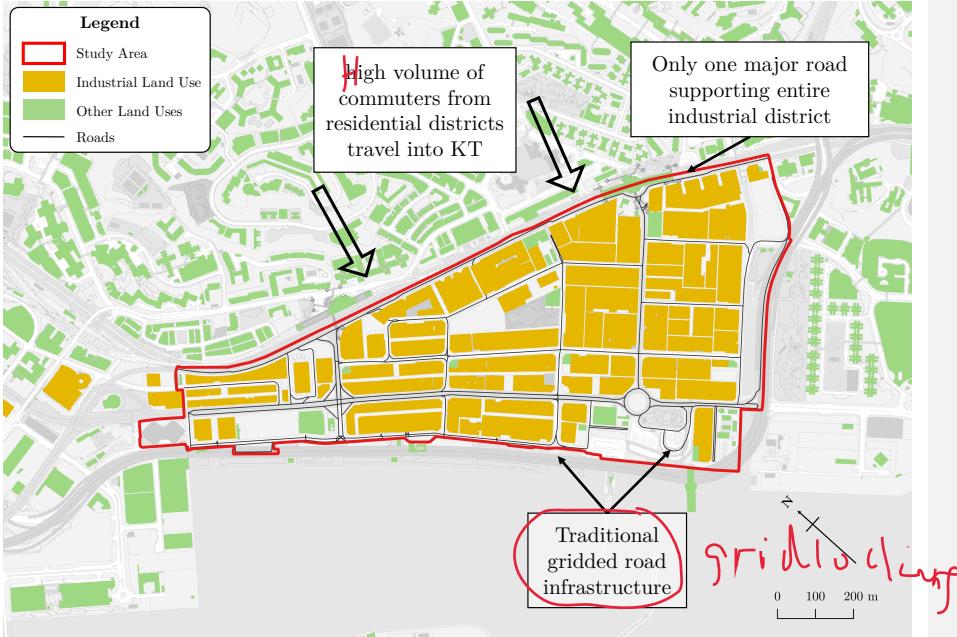
3 Geographical Context



Map 1. The location of the study area with reference to HK. (Hong Kong Geodata Store, 2021)

Due to the unique mountainous geography of HK, with land availability being highly contested, land developers often construct tall buildings to maximise their profit. As a result, due to the densely populated nature of HK, the demand for transport services is exceptionally high, causing severe traffic congestion.

In the early 1950s, to fulfil the growing industrial needs, Kwun Tong (KT) has been designated as the first industrial zone of HK (Kwun Tong District Council, 2015). As KT is within close proximity to the then-airport (see Map 1), it allowed raw materials to be rapidly imported and products to be efficiently exported, generating large volumes of traffic (Lai and Dwyer, 1965).



Map 2. The road infrastructure and land use of the study area. (Hong Kong Geodata Store, 2021)

To boost economic productivity, KT has been designated as a satellite city (Scott, 1982), where industrial zones and residential areas are segregated from each other. Although distinct functional zones can increase the QoL in residential neighbourhoods and allow industrial activities to be centralised, high volumes of cross-commuting can occur during peak hours, resulting in heavy traffic stresses (Merrilees et al., 2013). Furthermore, due to the traditional gridded road layout, the high amount of traffic junctions and intersections causes traffic flow to be frequently interrupted. Coupled with the fact that the area has the highest population density across all districts of HK (“Census and Statistics Department”, 2016), KT is renowned for its heavily congested traffic, with bus journey speeds as low as 1.32km/h during peak hours (Tse and Wong, 2021).

4 Hypothesis

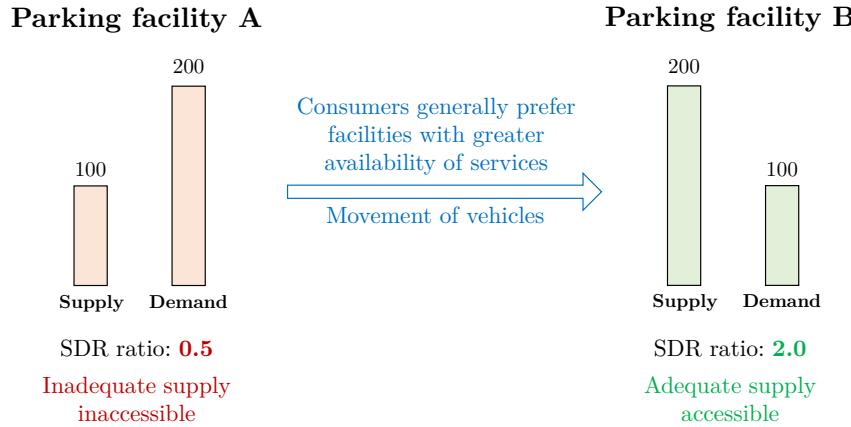


Figure 1. Demonstration of the movement of vehicles to areas with greater parking accessibility.

As shown above, where there is an imbalance in SDR, drivers tend to move towards areas with greater supply in parking spaces. While it is commonly believed that areas with an adequate supply of parking facilities can alleviate traffic congestion, researchers have found that the excess of parking supply can instead worsen traffic congestion. The reason for this phenomenon goes by that with a wide spectrum of parking spaces available, drivers are willing to constantly circle the area in search of better parking prices (Millard-Ball et al., 2020). Since cruising behaviour often involves frequent lane-changing and abrupt changes in vehicle acceleration, it essentially forms a mobile stream of slow-moving traffic queue, thereby worsening traffic congestion (Zhu et al., 2020). Conversely, in areas with inadequate parking supply, drivers are less likely to bid for lower parking costs at the expense of losing the opportunity to park, therefore reducing cruising and leading to smoother traffic (Shoup, 2006).

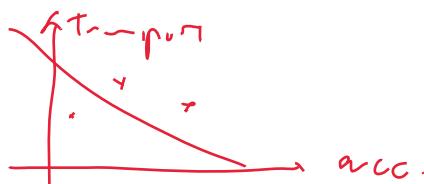
Commented [AC7]: For hypothesis changing: highlight distinction between cruising / searching for parking.

The following set of hypotheses will be tested:

Null Hypothesis (H_0) There is no correlation between the relative magnitude of traffic congestion and the accessibility to parking spaces.

Alternate Hypothesis (H_1) There is a correlation between the relative magnitude of traffic congestion and accessibility to parking spaces.

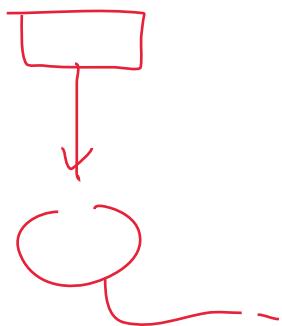
Commented [AC8]: Changed.



5 Methodology

To assess the correlation between the independent and dependent variables, the accessibility will be first computed by processing the locations of all roads, buildings, and parking facilities through a modified version of Ga2SFCA method with QGIS¹ and Python². An on-site survey will then be performed to measure the traffic congestion. Finally, both variables will be compared to validate H_1 using the Spearman Rank Correlation Coefficient (SRCC).

Commented [AC9]: Add flowchart!



¹ An open-source geographic information system (GIS) software, available at: <https://www.qgis.org>

² A general-purpose programming language, available at: <https://www.python.org>

5.1 Accessibility

5.1.1 The Gaussian-based two-step floating catchment method (Ga2SFCA)

As explored in the hypothesis, since the utilisation of parking services is heavily influenced by the SDR of the location, the accessibility A_i can be expressed by:

$$A_i = \sum_j \frac{S_j}{D_j} \quad (5.1.1.1)$$

where:

A_i Accessibility to parking facilities at location i

S_j Supply of parking facility j

D_j Demand of parking facility j

However, the supposition that every parking facility has an equal probability of being selected is inherently untrue. Because transport incurs some form of cost such as time, drivers often have to overcome the friction of distance using additional resources, consequently, the attractiveness of a facility is attenuated at increasing distances (Huff and Jenks, 1968).

The distance-decay effect is often accounted by multiplying the attractiveness by some monotonically decreasing distance-decay function, with the most commonly used being Gaussian-based (Dai, 2010; Luo and Whippo, 2012; Tao et al., 2020):

$$f(d, d_0) = \begin{cases} \frac{e^{-\frac{1}{2}(\frac{d}{d_0})^2}}{1 - e^{-\frac{1}{2}}} & \{d \leq d_0\} \\ 0 & \{d > d_0\} \end{cases} \quad (5.1.1.2)$$

where:

d Distance between location and facility

d_0 Maximum catchment distance

Since the demand of a parking facility follows distance-decay effects:

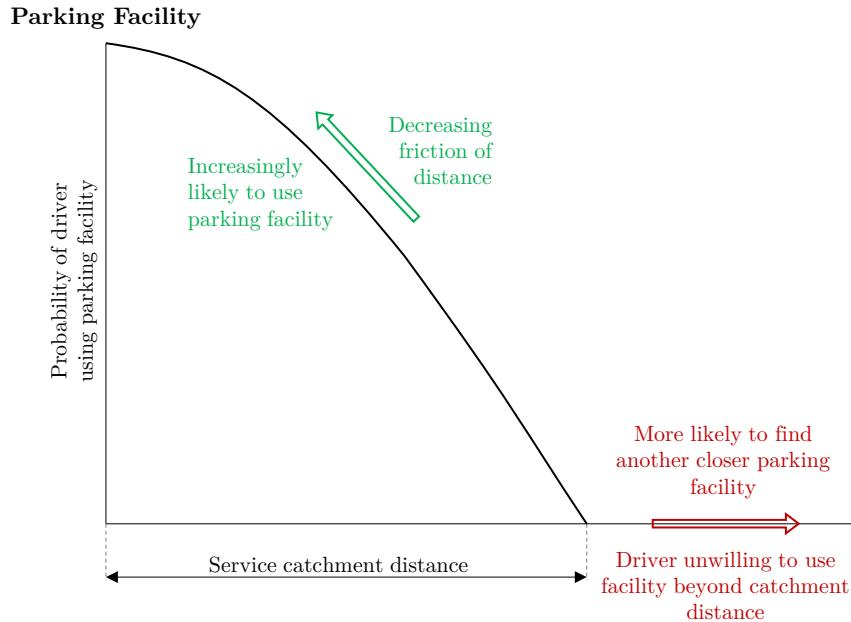


Figure 3. Demonstration of the distance-decay effects on the supply of parking facilities.

The effective supply is often adjusted with the distance-decay function (Wang et al., 2021), hence Equation 5.1.1.1 can be better represented by:

$$A_i = \sum_j \frac{S_j f(d_{ij}, d_i)}{D_j} \quad (5.1.1.3)$$

where:

- A_i Accessibility to parking facilities at location i
- S_j Supply of parking facility j
- f Distance-decay function, as defined in Equation 5.1.1.2
- d_{ij} Distance between location i and parking facility j
- d_i Service catchment distance of location i , by driving
- D_j Demand of parking facility j

Since the distance-decay effect also applies to the demand:

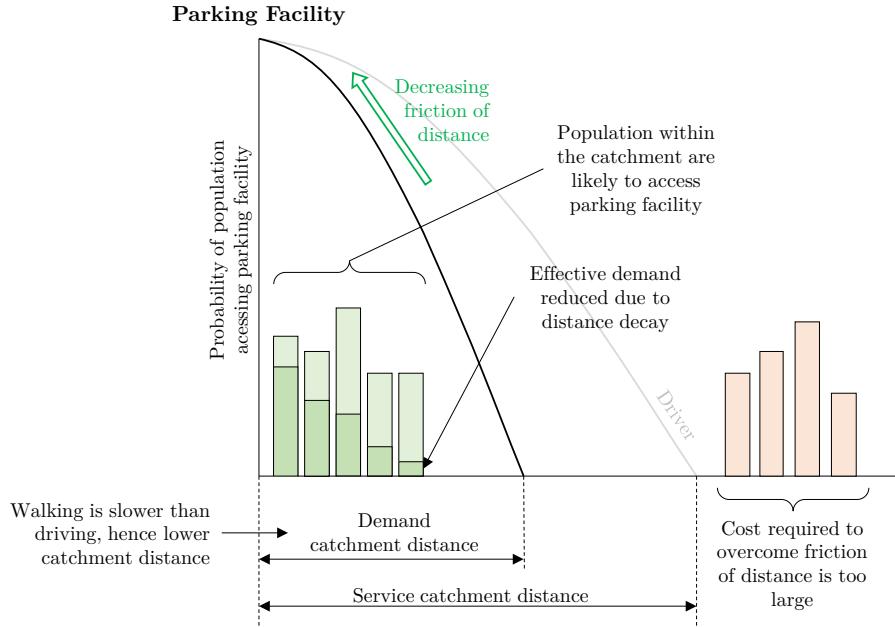


Figure 4. Demonstration of the distance-decay effects on the demand of demand nodes.

This yields the final equation of Ga2SFCA, accounting for both the aspatial utilisation and spatial distance-decay effects (Wang et al., 2021):

$$A_i = \sum_j \frac{S_j f(d_{ij}, d_i)}{\sum_k D_k f(d_{jk}, d_j)} \quad (5.1.1.4)$$

where:

- A_i Accessibility to parking facilities at location i
- S_j Supply of parking facility j
- f Distance-decay function, as defined in Equation 5.1.1.2
- d_{ij} Distance between location i and parking facility j
- d_i Service catchment distance of location i , by driving
- D_k Demand at demand node k
- d_{jk} Distance between parking facility j and demand node k
- d_j Demand catchment distance of parking facility j , by walking

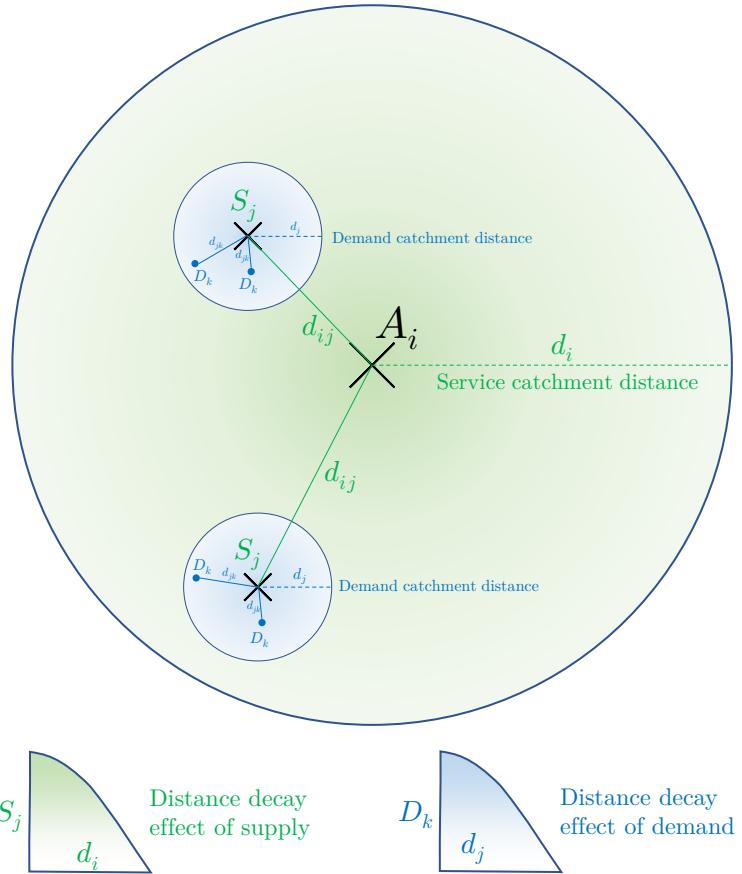
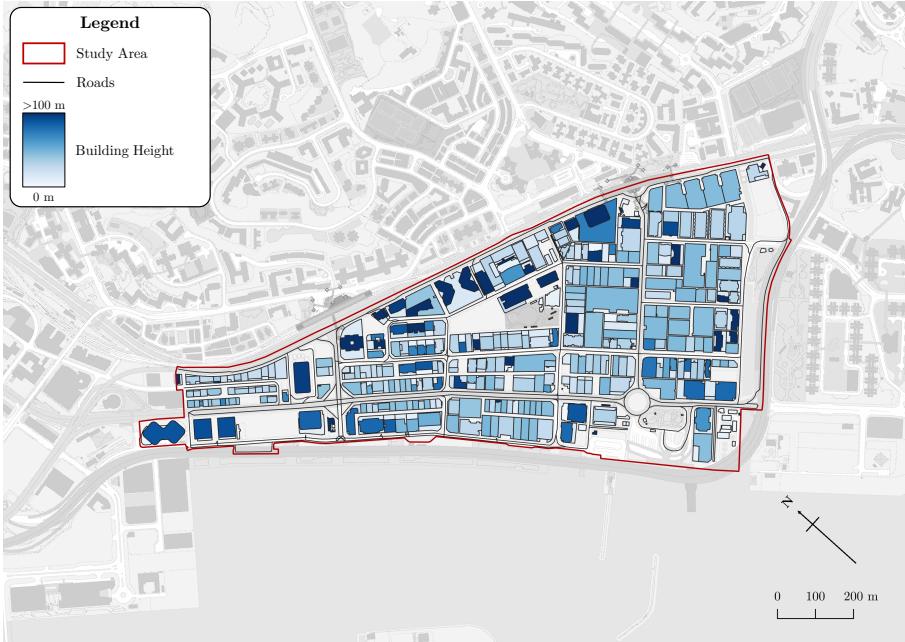


Figure 5. Visual representation of the modified Ga2SFCA method.

5.1.2 Quantification of demand

$$A_i = \sum_j \frac{S_j f(d_{ij}, d_i)}{\sum_k D_k f(d_{jk}, d_j)} \quad (5.1.1.4)$$

To obtain the demand (D_k), buildings are first extracted using QGIS from a digital map downloaded through the government's HKMS2.0 portal ("Lands Department", 2021):



Map 3. All buildings and their heights. (Hong Kong Geodata Store, 2021; Lands Department, 2021)³

Since the demand is closely correlated to the gross floor area (GFA) of a building, the relative demand is:

$$D_k \propto GFA = A_{floor} \left[\frac{h_{rooftop} - h_{base}}{\bar{h}_{ceiling}} \right] \quad (5.1.2.1)$$

where:

$h_{rooftop}$ Height of the roof of the building (mPD⁴)

h_{base} Height of the base of the building (mPD⁴)

$\bar{h}_{ceiling}$ Average ceiling-to-ceiling height of a building, which is 3.0m (Cheung, 2019)

A_{floor} Area of each floor (m²)

← explained!

³ The list of all buildings and their GFAs are listed in the Appendix.

⁴ mPD refers to the number of metres above the Hong Kong Principal Datum (HKPD), which is a standardised Ordnance Datum similar to the measure of "metres above sea level" (AMSL)

5.1.3 Quantification of supply

$$A_i = \sum_j \frac{S_j f(d_{ij}, d_i)}{\sum_k D_k f(d_{jk}, d_j)} \quad (5.1.1.4)$$

Since the exact number of parking spaces is not publicly available, the supply (S_j) is often estimated using parking standards which are a set of specifications newly constructed buildings must follow (Wang and Liu, 2014). According to the HK Planning Standards and Guidelines (HKPSG), the recommended number of parking spaces (N) for business-use buildings (“OU/B”) are (Planning Department, 2021):

$$S_j \approx N = \begin{cases} \left\lfloor \frac{\text{GFA}}{675} \right\rfloor & \{n \in I \cap O'\} \\ \left\lfloor \frac{\text{GFA}}{175} \right\rfloor & \{n \in O, \text{GFA} \leq 15000\} \\ \left\lfloor \frac{\text{GFA}}{175} + \frac{\text{GFA} - 15000}{250} \right\rfloor & \{n \in O, \text{GFA} > 15000\} \end{cases} \quad (5.1.3.1)$$

where:

GFA Gross floor area of the building (m^2), which is obtained from Section 5.1.2

n Specific land use of the buildings, type: ‘I’ (industrial use) and/or ‘O’ (office use)



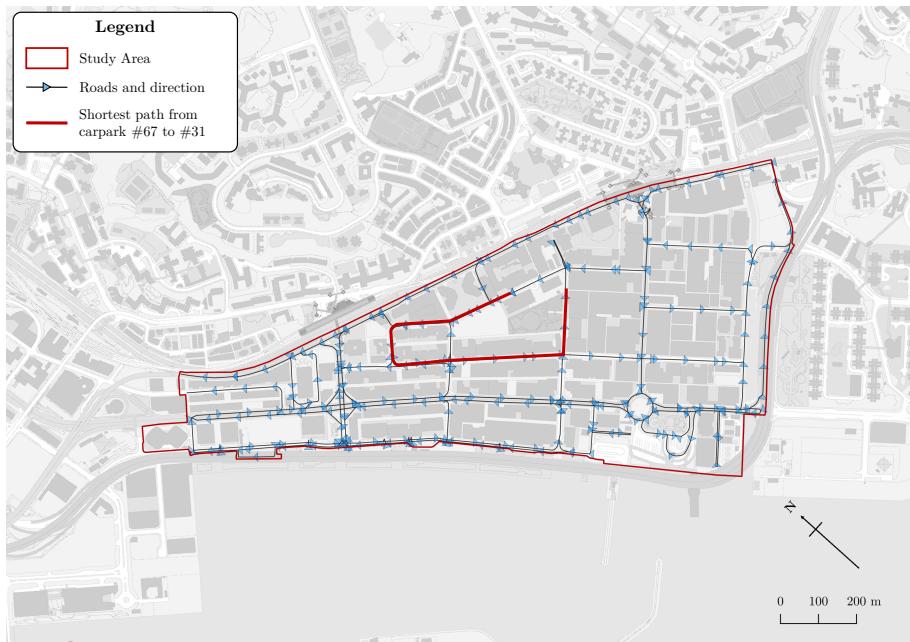
Map 4. Distribution of parking facilities and their amounts within the study area. (Hong Kong Geodata Store, 2021; Lands Department, 2021)

To obtain the supply S_j , a digital “Road Network (2nd generation)” dataset is downloaded (“Lands Department”, 2021) and combined with GFAs of the corresponding building, the list of parking facilities is extracted using QGIS⁵.

5.1.4 Measurement of distance between locations

$$A_i = \sum_j \frac{S_j f(\mathbf{d}_{ij}, d_i)}{\sum_k D_k f(\mathbf{d}_{jk}, d_j)} \quad (5.1.1.4)$$

To obtain an accurate distance between two points, a weighted directed graph is generated. By using Dijkstra's algorithm, the shortest distance between two nodes could be found:



Map 5. A demonstration of finding the shortest distance from carpark #67 to carpark #31 using Dijkstra's algorithm. (Hong Kong Geodata Store, 2021; Lands Department, 2021)

With Dijkstra's algorithm, two sets of origin-to-destination (OD) distance matrices are generated using QNEAT3⁶ in QGIS:

1. Between each survey location i and parking facility j (d_{ij})
2. Between each parking facility j and demand node k (d_{jk})

⁵ The list of parking facilities can be found in the Appendix.

⁶ An open-source QGIS plugin for network analysis, available at: <https://github.com/root676/QNEAT3>.

5.1.5 Service and catchment distance

$$A_i = \sum_j \frac{S_j f(d_{ij}, \mathbf{d}_i)}{\sum_k D_k f(d_{jk}, \mathbf{d}_j)} \quad (5.1.1.4)$$

The catchment distances via driving (d_j) and walking (d_i) is:

$$d_i = v_i t_i = \frac{21.6 \text{ km h}^{-1}}{3.6 \text{ km h}^{-1} \text{ s m}^{-1}} \times 2.7 \text{ min} \times 60 \text{ s min}^{-1} = 972 \text{ m} \quad (5.1.5.1)$$

$$d_j = v_j t_j = \frac{62.7 \text{ m min}^{-1}}{60 \text{ s min}^{-1}} \times 2.9 \text{ min} \times 60 \text{ s min}^{-1} = 181.83 \text{ m} \quad (5.1.5.2)$$

where:

- d_i Service catchment distance of location i , by driving
- v_i Average velocity of vehicles (Transport Department, 2021)
- t_i Average search time of vehicles (Lau et al., 2005)
- d_j Population catchment distance of demand node j , by walking
- v_j Average velocity of pedestrians in KT (Master Alliance Ltd., 2021)
- t_j Average search time of pedestrians (Lau et al., 2005)

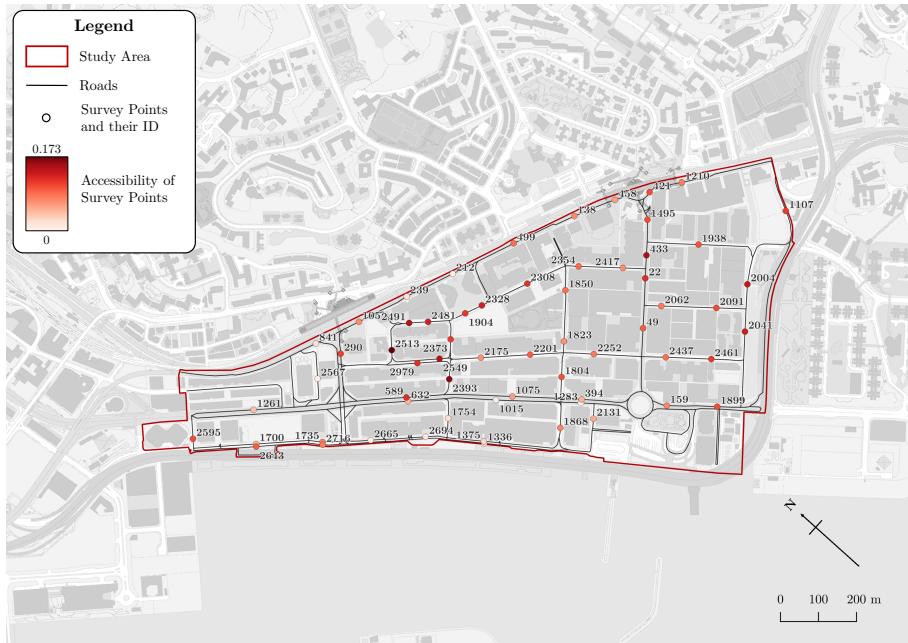
5.1.6 Sampling method

To maximise data representativeness and to reduce the time needed to collect samples, stratified sampling is used, where each major road segment is sampled 1-2 times. The following constraints are set to maximise data accuracy:

- should be as evenly distributed as possible *← 1 line.*
- should not be located at/within proximity to intersections/roundabouts, as vehicle speed is almost always lower than expected due to safety considerations

62 sample points across the study area have been selected, of which can be found in the Appendix and Map 5.

Commented [AC10]: Awkward wording, illustrate with diagram!



Map 6. The distribution of selected sample points and their accessibility index A_i . (Hong Kong Geodata Store, 2021; Lands Department, 2021)

Commented [AC11]: Improve visualisation!

5.2 Traffic congestion

With traffic speed being an excellent proxy indicator for traffic congestion, it can be estimated by the formula (Kidando et al., 2017):

$$v \propto \frac{O}{q} \quad (5.2.1)$$

where:

- | | |
|-----|--|
| O | Time-occupancy, percentage time occupied by a vehicle (<i>dimensionless</i>) |
| q | Flow of traffic (vehicles per hour) |

A web application is developed to collect both parameters.

5.2.1 Time-occupancy

Time-occupancy is defined as:

$$O_i = \frac{\sum_i t_i}{T} \quad (5.2.1.1)$$

which is the ratio between the sum of time measurements when the line-of-sight is occupied by the vehicle (t_v) and the total time (T).

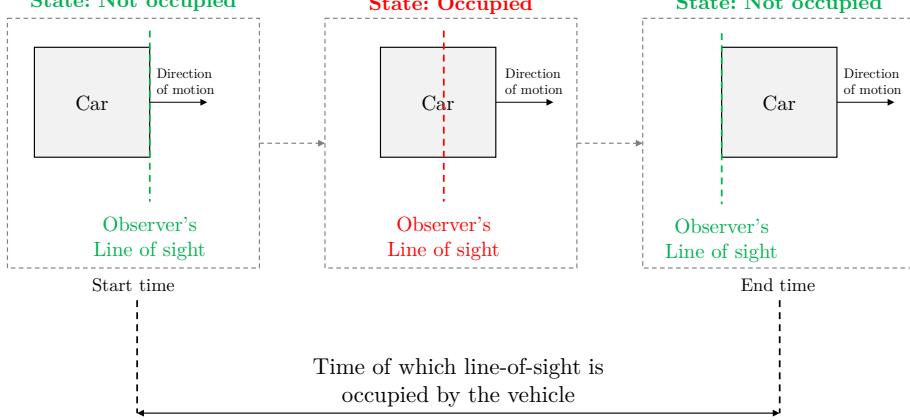


Figure 6. Visual representation of how time-occupancy is calculated.

The web interface is designed to operate on a touch-enabled smartphone⁷, which will save touch measurements in a JSON file⁸ containing timestamps that describe the occupancy at that instant:

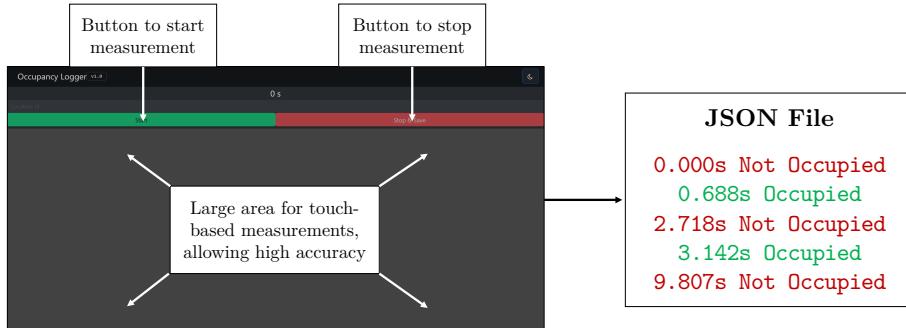


Figure 7. The interface of the logging tool and its output.

Commented [AC12]: Mention instrumental uncertainty of 1ms in fig

5.2.2 Flow

Since flow is defined as:

$$q = \frac{N}{T} \quad (5.2.2.1)$$

The number of vehicles (N) can be derived by counting the number of “Occupied” states in Figure 7⁹.

⁷ The interface is mainly written in JS. Source code: <https://github.com/cathaypacific8747/occupancy-logger>.

⁸ A commonly used standardised machine-readable text-based format for representing data.

⁹ The Python code used to derive the time-occupancy and flow from the original JSON file can be found in the Appendix.

5.3 Precautions for surveying

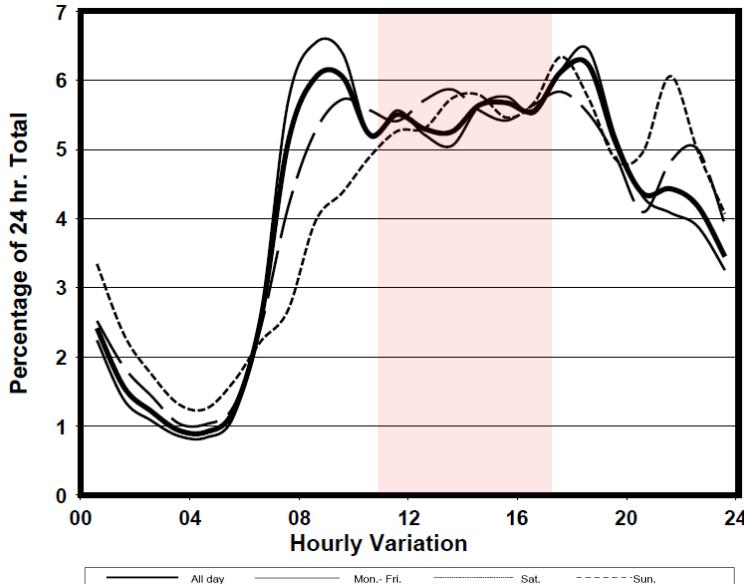


Figure 8. Graph of daily and weekly traffic changes at Station #3012 (Transport Department, 2021).

To reduce data fluctuations, surveying shall be performed from 10:00-16:00 because the traffic flow is rather stable, has a sufficiently large volume, and is the time when industrial activities are the most active (Labour Department, 2013). The surveying shall be completed on a single day to reduce the effect of unpredictable events (such as weather) on the rate of traffic generation.

5.4 Hypothesis Testing

5.4.1 Spearman Rank Correlation Coefficient (SRCC)

An SRCC test is used to determine the magnitude of two variables. The SRCC is insensitive to outliers and produces highly accurate measures of correlation especially for nonlinear relationships (Lovie, 1995). It is given by:

$$R = 1 - \frac{6 \sum d^2}{n^3 - n} \quad (5.4.1.1)$$

Commented [AC13]: Add map to show geographical location!

Commented [AC14]: Improve illustration!

Commented [AC15]: Move explanation to graph if time allows

where $d = r(x) - r(y)$, as detailed below:

Accessibility, x	Rank of $x, r(x)$	Relative speed, y	Rank of $y, r(y)$	If ranks are equal, take the average	
				Difference, d	d^2
0.001698	0	5487	5	-5	25
0.003340	1	4380	3.5	-2.5	6.25
0.008747	2	4380	3.5	-1.5	2.25
0.016384	3	1252	2	1	1
0.019683	4	343	1	3	9
				Sum, Σd^2	43.5

Figure 9. A table for calculating $\sum d^2$ from the accessibility (x) and relative speed (y).

Commented [AC16]: change graph so it doesn't match with IA too closely

Perfect negative $\xleftarrow{-1} R \xrightarrow{1}$ Perfect positive correlation

Figure 10. A general interpretation of the correlation based on the SRCC.

5.4.2 Student's T-test

To check whether the SPCC obtained is statistically significant enough to reject H_0 , the t -value must first be found:

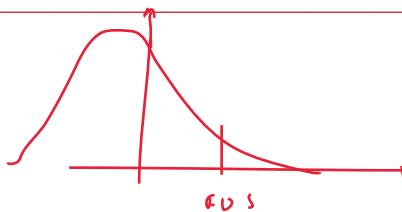
$$t = R \sqrt{\frac{n-2}{1-R^2}} \quad (5.4.2.1)$$

The statistical significance can be found by obtaining the one-tailed p -value:

$$p = \int_t^\infty f(u) du \quad (5.4.2.2)$$

where f is the probability density function and t the t -value. When $p < 0.05$, H_0 can be rejected.

Commented [AC17]: Use graph from IA to show pdf and emphasise on 95% confidence level.



6 Data Analysis

To better highlight the correlation between both variables and to aid with the identification of outliers, a scatter graph with a linear line of best fit is used. In addition, a bivariate dot map is used to visualise the geospatial patterns of both variables.

6.1 Macroscopic Trend

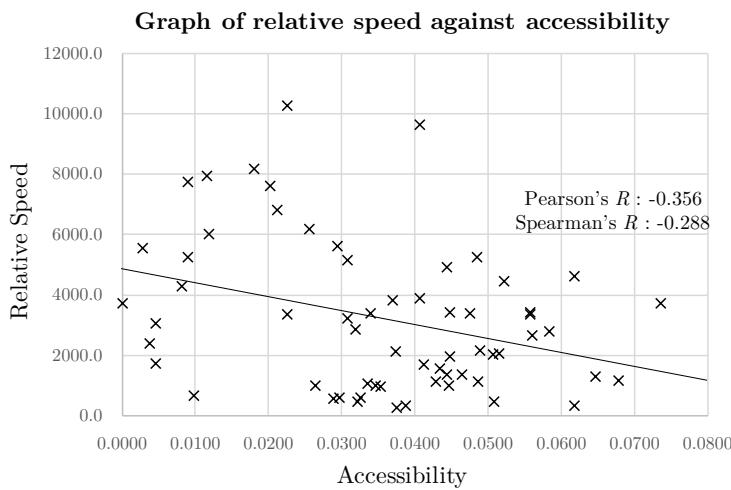


Figure 6.1. A scatter graph showing the relationship between relative speed against accessibility.

Parameter Name	Symbol	Value
Number of data points	n	62
Spearman's Rank Correlation Coefficient (SRCC)	R	-0.288
t -value	t	2.327
p -value	p	0.0116
Null hypothesis rejected?		Yes, as $p < 0.05$

Table 6.1. Statistics regarding the Spearman's rank correlation testing.

As the SRCC is -0.288 , there is a very weak negative correlation between the speed and accessibility. As discussed in the methodology, since low vehicle speeds are a common characteristic of severe traffic congestion, and that the p -value is below the accepted value, the correlation is statistically significant enough to reject H_0 .

However, it should be noted that while H_1 has been accepted statistically, the poor reliability of the correlation cannot be used to definitively conclude that parking accessibility is the *only causation* of traffic congestion (Coleman et al., 2015), and additional qualitative justification is required to describe the relationship between the two variables.

Commented [AC18]: Bold to emphasise findings?

6.1.1 Heteroscedasticity

In regression analyses, it is assumed that dependent variables are homoscedastic, meaning a constant variance (σ^2).

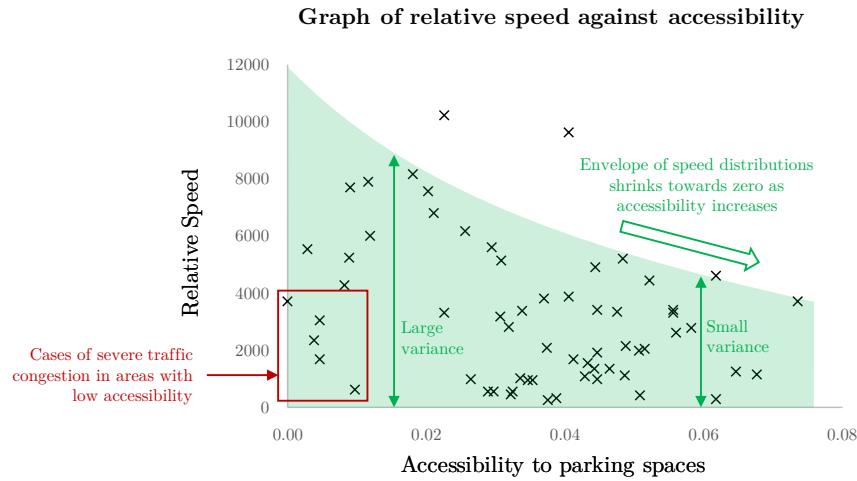


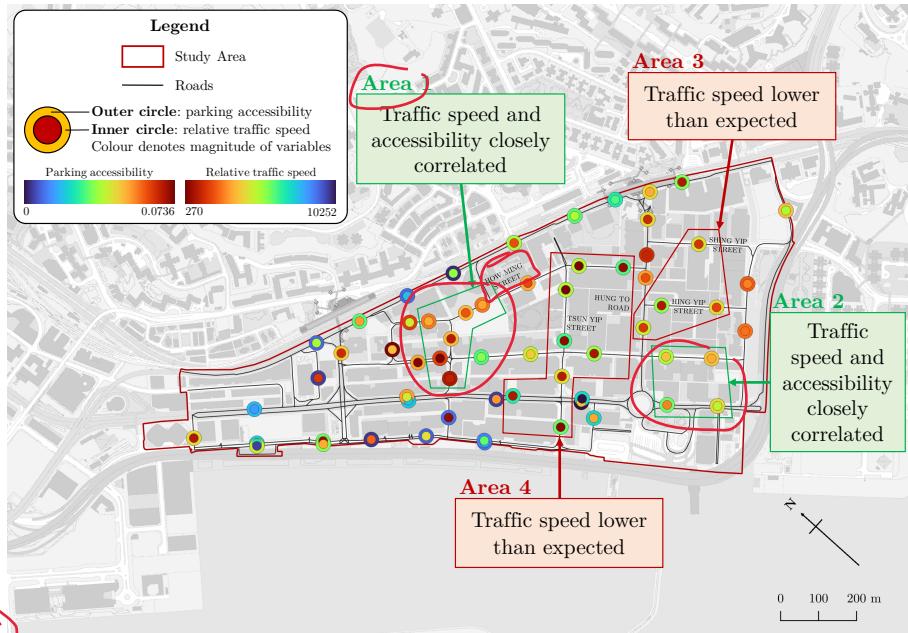
Figure 6.2. Demonstration of how heteroscedasticity can contradict the acceptance of H_1 .

However, the above shows that the variance of speed is unequal. As Goldberger (1964) suggests, heteroscedastic data can cause Type I errors in hypotheses testing, where H_0 is falsely rejected.

If H_1 is accepted, it would mean that it is improbable to experience severe traffic congestion in areas with low parking accessibility. However, this statement is inaccurate because such phenomenon occurred multiple times. It would therefore be more accurate to interpret the data by the statement: "there may be a greater probability of experiencing less traffic congestion in areas with low parking accessibility".

Commented [AC19]: Add table to show Type I/II errors.

6.2 Qualitative Analyses



Map 6.1. A bivariate dot map showing the accessibility and speed of survey locations. (Hong Kong Geodata Store, 2021; Lands Department, 2021)

The map above shows the spatial distribution of survey locations and the extent of each variable. If the colour of the inner circle is roughly equal to the outer circle, both variables are closely correlated; whereas if the colours are starkly different, it can suggest a mismatch in the predicted speed.

As an example, severe traffic congestion in Area 1 has been correctly predicted, as it is within close proximity to abundant parking spaces in carparks #65 and #66. Some areas with less severe traffic congestion have also been correctly predicted, especially in Area 2 where parking availability is limited along an arterial road that travels out of KT.

However, there are some notable large-sized areas where the severity of traffic congestion is often underestimated, which is seen to propagate down the entire road. This happens in Area 3, which seems as if a traffic queue has developed and extended along Tsun Yip Street, as well as Area 4, which also seems to exhibit the same effect in the loops formed by Hing Yip Street and Shing Yip Street. This phenomenon appears to echo with the argument made in Section 6.1.1, where areas of low parking accessibility appear to experience unusually severe traffic congestion. Therefore, given that there are strong macroscopic anomalies and spatially distinct regions where traffic flow seems to be obstructed by external factors, the following sections will aim to uncover potential reasons for this phenomenon.

Commented [AC20]: Show this in the map directly and delete.

Commented [AC21]: Show on map!

Commented [AC22]: Migrate to annotation form on map

Commented [AC23]: Simplify!

Commented [AC24R23]: Focus more on the positives!!!

6.2.1 Role of land use in traffic congestion

Commented [AC25]: 597 words

While it has been assumed that vehicles will always unload goods and people at parking facilities, on-site observations reveal that vehicles often stop at locations that causes inconvenience to other road users:

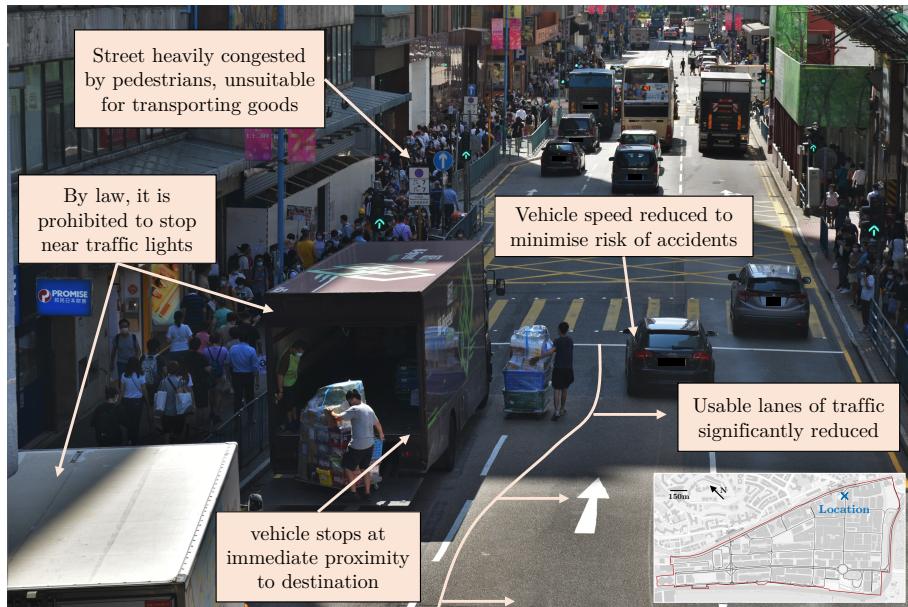


Figure 6.3. Demonstration of industrial vehicles obstructing traffic flow. (841349,819187^{EPSG:2326})

This behaviour can be attributed to the fact that the area is heavily industrial, where there is great demand for the import of raw materials and export of manufactured products, leading to high volumes of medium goods vehicles (MGV). Because heavy goods are unsuitable for long-distance travel by foot and combined with the lack of movable space in pavements, incoming trucks often unload goods within immediate proximity to their destination to maximise convenience. With logistical efficiency a key to the economic success of an industrial company, drivers are unlikely to spend the additional time and cost to search and use a dedicated parking facility. Therefore, it can be said that in industrial districts, the assumption that drivers will take into account of parking accessibility when unloading goods is invalid.

In addition, the result of unloading goods in a moving stream of traffic reduces the effective number of lanes, forming a bottleneck that worsens traffic congestion. Furthermore, by obstructing the vision of traffic lights (see Figure 6.3), it further reduces the cognitive ability for drivers to determine the traffic signal and hence causes reduces vehicular speed and increases sporadic accelerations, overall introducing congestion.

The phenomenon of industrial-based vehicles not using parking facilities can also be observed by illegal and double parking:

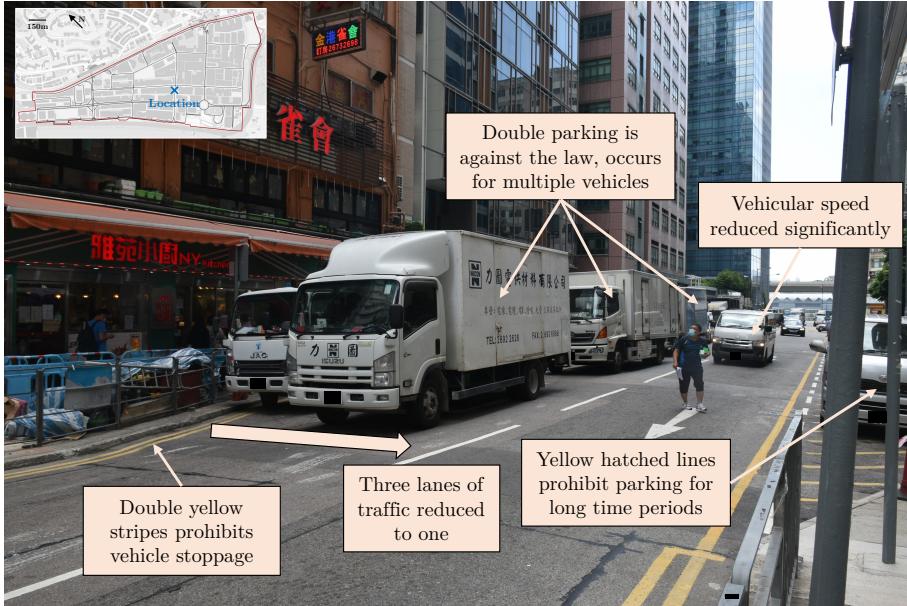


Figure 6.4. Photo of MGVs violating multiple parking restrictions. (“Cap 374C”, 2021; 840899,819090^{EPSG:2326})

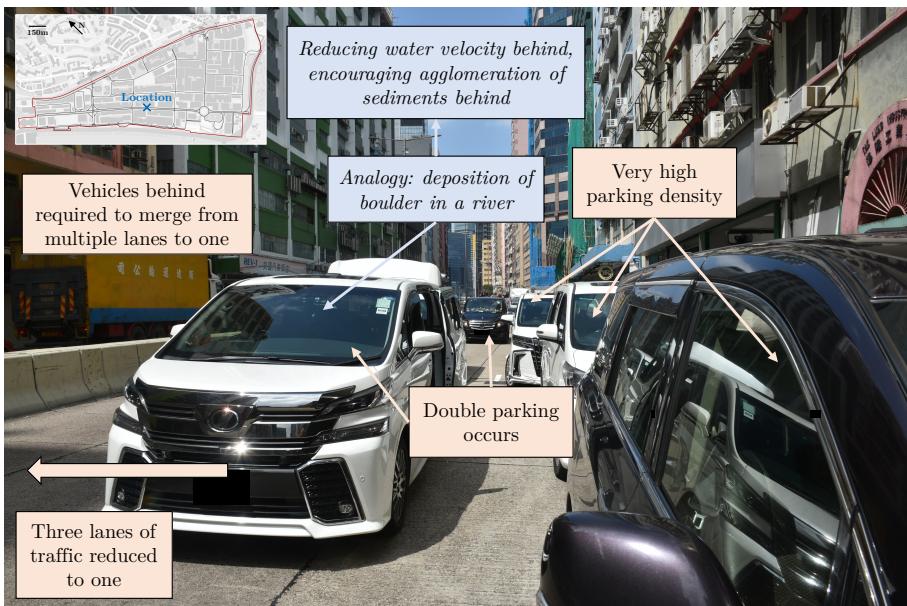


Figure 6.5. Demonstration of how double parking can encourage further double parking and worsen traffic congestion. (“Cap 374C”, 2021; 840727,819155^{EPSG:2326})

As seen above, a multitude of parking restrictions has been violated. To explain the cause, drivers often perform a risk assessment to determine whether they are willing to neglect traffic restrictions to trade for convenience.

When the probability of receiving a fine is lower than the operational costs incurred from encircling the area, the desire for parking illegally will be increased. Because industrial vehicles have a strong motive to maximise profit by increasing the throughput of supplies and materials and to ensure the stability of the supply chain, journeys relating to logistics are often time-sensitive. The driver's preference is therefore strongly influenced to minimise movement over avoiding fines, hence leading to the common occurrence of illegal parking (Nurul Habib et al., 2011).

Other than vehicle stoppage inducing traffic congestion, delivery workers of industrial vehicles also exacerbate traffic congestion:

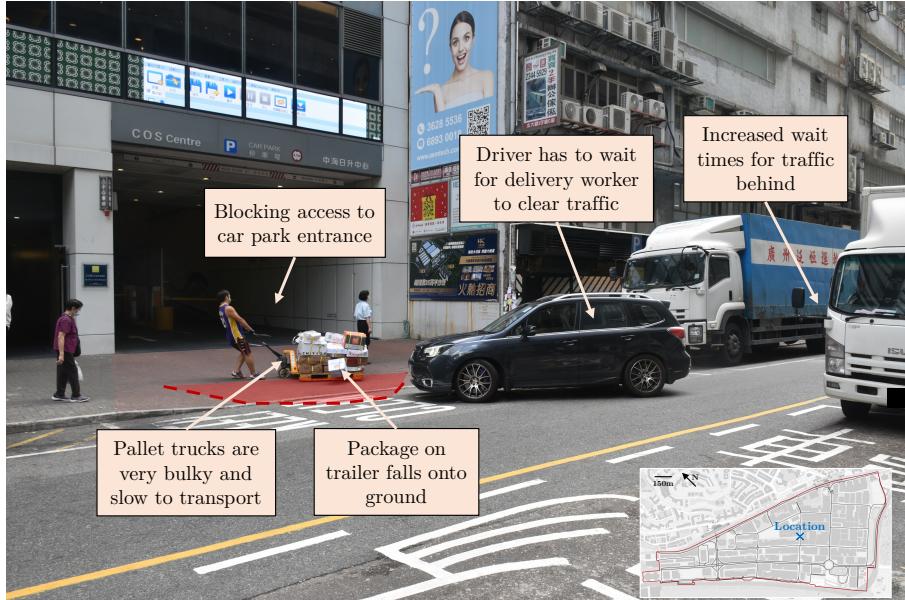


Figure 6.6. Photo of delivery workers blocking the entrance to a car park. (840967,819144^{EPSG:2326})

Because delivery workers often transport a large number of bulky goods with trailers to shorten delivery times, their movement speed is often very slow. Combined with the fact that KT is a highly concentrated industrial district, this phenomenon occurs region-wide:

Commented [AC26]: Add terminology with
10.1177/1541931218621320

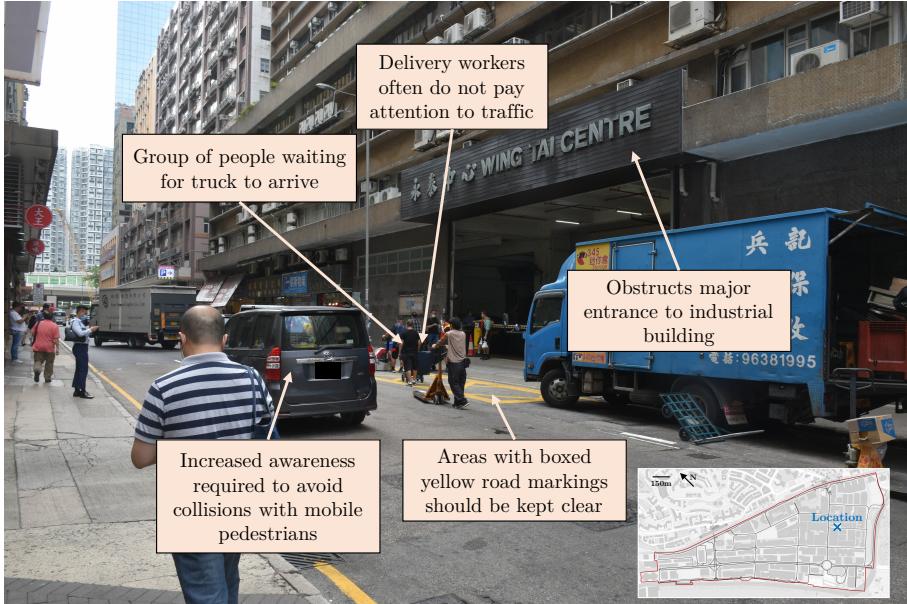


Figure 6.7. Photo of a group of delivery workers congregating, indirectly reducing traffic speed.
(841204,818978^{EPSG:2326})

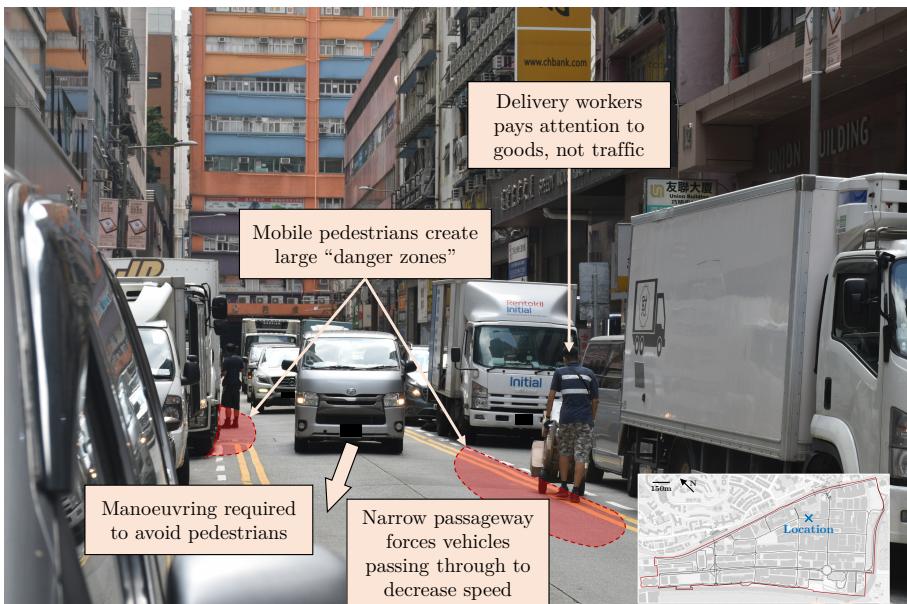


Figure 6.8. Demonstration of how mobile pedestrians cause drivers to slow down significantly.
(841140,819200^{EPSG:2326})

Overall, because KT is predominantly composed of industrial buildings, vehicles involved in industrial activities do not have the necessity or benefit of finding or using a parking facility, therefore resorting to illegal parking, and contributing to traffic congestion.

Conversely, vehicles that serve other land-use types such as commercial and retail purposes instead have a strong and regular will of patronising a parking facility. For example, because people engaged in shopping activities have a limited personal budget, there is a strong incentive to avoid illegal parking (Mingardo and van Meerkirk, 2012). Similarly, because white-collar workers engaged in office activities only ever work at a single location, the attractiveness of repeatedly utilizing the same parking facility is enormous. The usage of parking facilities can be even further increased by parking vouchers, monthly-reserved parking packages or employer subsidies (Lam et al., 1998).

Therefore, given that the nature and goal of industrial activities are fundamentally different from other activities, varying both in budget and obligation of using parking facilities, it can be argued that land use strongly governs the severity of traffic congestion, much more so than parking accessibility.

6.2.2 External physical factors and limitations

Commented [AC27]: Word count: XXX

Other than land-use effects, there are several factors that further cause vehicles to ignore their accessibility to parking spaces, and rather choose to stop at their immediate location. One of which is the deliberate obstruction of on-street parking spaces with barricades:

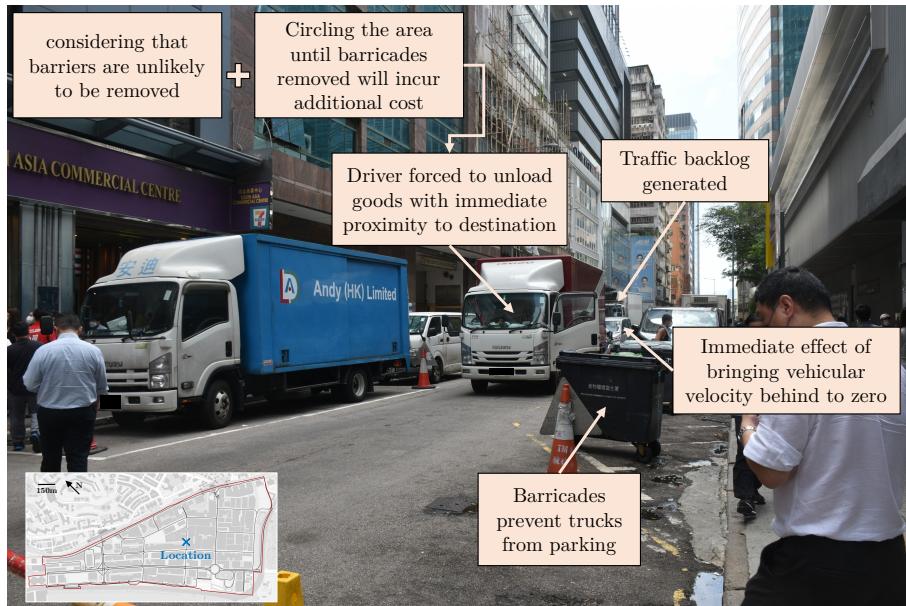


Figure 6.9. Photo of an HGV being forced to unload goods due to barricades obstructing the alighting zone. (841140,819200^{EPSG:2326})



Figure 6.10. Photo of how physical barricades indirectly obstruct traffic flow and worsen traffic congestion. (841058,819220^{EPSG:2326})

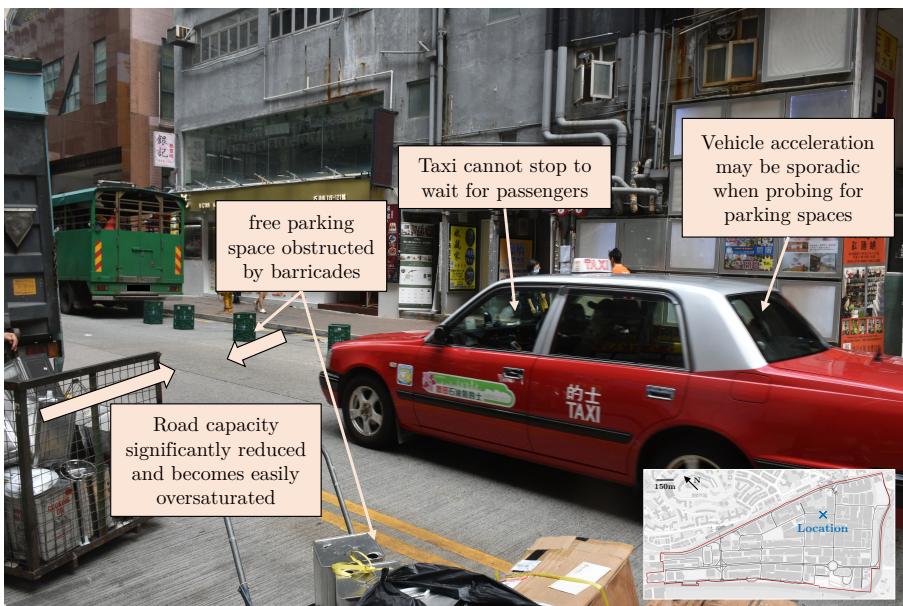
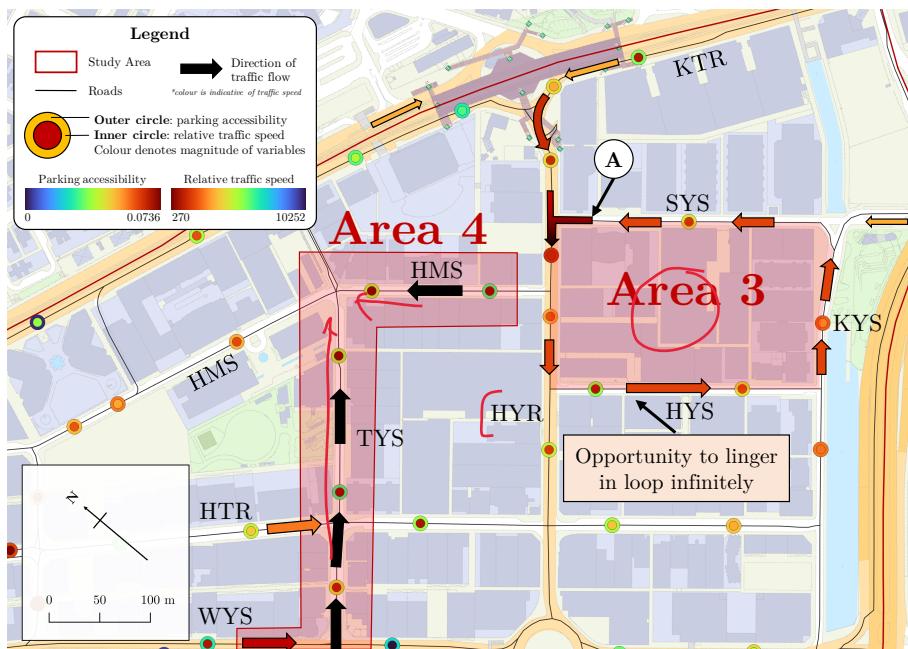


Figure 6.11. Demonstration of how physical barricades impede the normal operations of a taxi. (841058,819220^{EPSG:2326})

From the above, the fact that such barricades (rubbish bins, trolleys, and light cartons) are highly mobile suggests that they are used for pre-reservation purposes, which causes incoming traffic to be forced to stop at the only available lane. According to Li et al. (2019), sudden traffic halts can propagate quickly downstream and across street grids, hence explaining why the entire length of TYS is unusually congested.

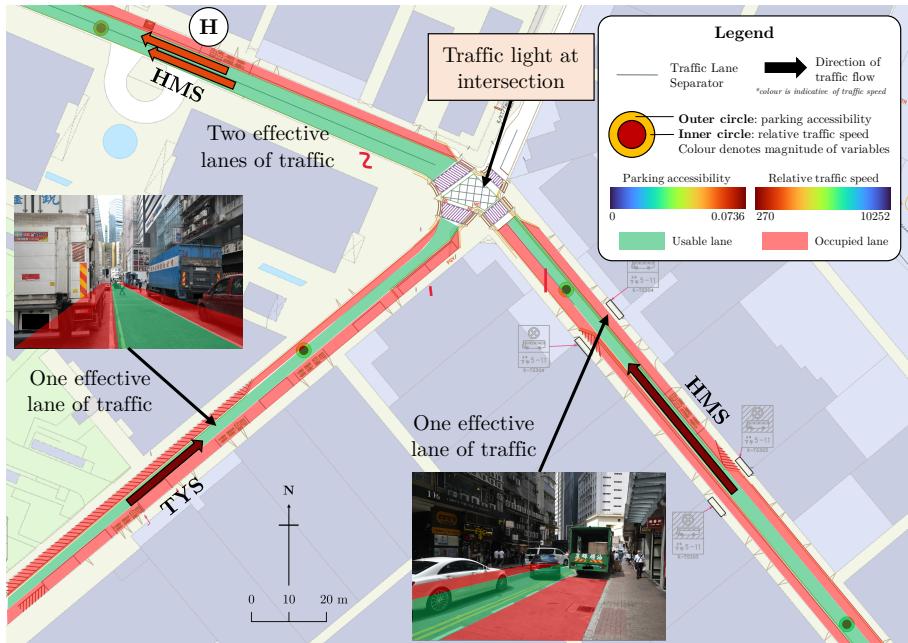
Although the law specifically prohibits the obstruction of parking spaces ("Cap 374C", 2021), for one to willingly violate regulations just to secure a parking spot reflects that parking availability is extremely scarce and competitive among road users. Because there is a region-wide insufficiency of parking space, it is inaccurate to conclude that "supply imbalances of parking facilities cause traffic congestion", because all parking facilities are observed to have close-to-zero supply.

Furthermore, KT is the oldest industrial district in HK. Given the road layout have remained largely unchanged with the traffic flow continuously increasing (Traffic Department, 2021), several routing issues with the current road layout have been identified:



Map 6.2. Map of the two most visually distinct over-congested regions. (Hong Kong Geodata Store, 2021; Lands Department, 2021)

In Area 3 above, it has been observed that SYS, HYR, HYS and KYS forms a closed anti-clockwise loop of traffic. This enables drivers to encircle the area infinitely, and combined by the increasing traffic from KTR, the traffic stress is very high. In Area 4, TYS and HMS appears to have severe traffic congestion, seemingly because they merge into one lane. Below is a closer view of the location:



Map 6.3. Map of the intersection between How Ming Street and Tsun Yip Street. (Hong Kong Geodata Store, 2021; Lands Department, 2021)

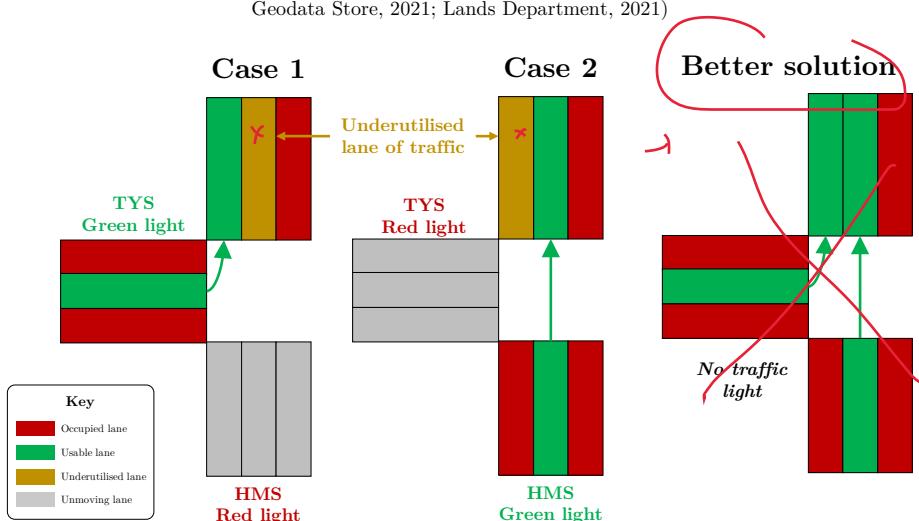


Figure 6.11. Demonstration of how one lane is always underutilised due to the traffic light and a possible solution to the issue.

As demonstrated above, because of the misconfiguration of traffic light signals, the potential traffic volume at this intersection is reduced by 50%, explaining why both TYS and HMS experience the unusual level of traffic congestion.

Overall, it has been demonstrated that in KT, the overall scarcity of parking spaces and the physical limitations in the road design can cause chronic traffic congestion. This provides additional justifications for drivers to park illegally, further making the argument of parking accessibility being the sole variable to traffic congestion invalid.

watered market

7 Conclusion

8 Evaluation

Although H_0 has been rejected, many errors and assumptions are violated, making the claim questionable.

8.1 Methodology

Fundamentally, the choice of 2SFCA may be flawed. Although it has gained much support from geographers, 2SFCA has only been proposed recently in the 2000s (ref), making results unproven and potentially unreliable. Furthermore, the majority of the existing literature used 2SFCA to assess the equity of healthcare and educational services on a nation-wide scale where distance-decay effects are significant, but never on such a microscopic street-scale level.

Additional points to talk about:

8.1.1 Unsuitability of selecting a set service catchment distance

8.1.2 Region-wide insufficiency of parking spaces

While the hypothesis states that traffic congestion occurs

- The hypothesis states that traffic congestion occurs when there is an excess of supply of parking spaces, but in fact from the survey 93.3% of respondents believe there is insufficient demand, which is contradictory → hypothesis should be re-evaluated
- “congestion is more likely to happen when cruising for parking happens” – in fact from observation there were almost no trucks cruising for parking, they just park whenever they could
- rather, industrial vehicles are less likely to cruise because they

land use specificity, Assumption of equal parking fees across all car parks

- Did not take in account of more expensive car parks, for example, Millennium City is considerably higher (~\$60/hr?), in fact according to survey 54.3% still think prices are too high, hence causing them to double park
- (variable catchment distance 2SFCA) V2SFCA should also be used because commercial/business centres have a much larger catchment distance

- Possible incorporate land use zoning + combine traffic generation/degeneration rates from TPDM 2019!

CAR DENSITY

8.1.3 Selection of distance-decay function

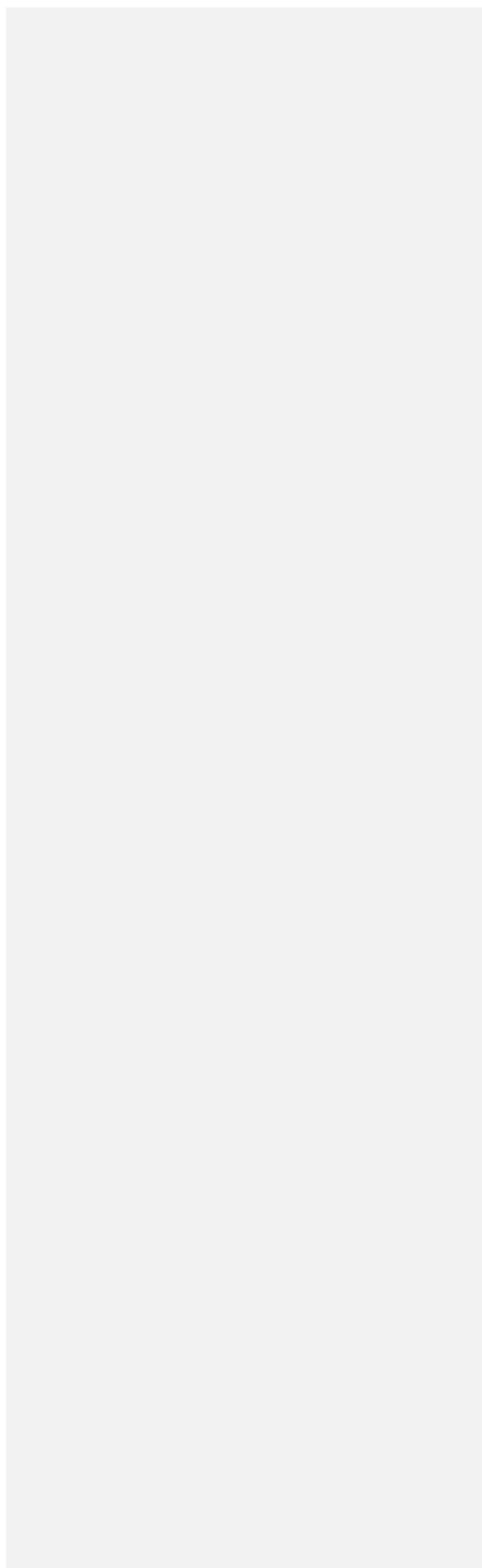
- “Consumers are likely to patronize a facility in their immediate proximity in lieu of equalizing the visit possibility within an arbitrary distance”, so the flat peak is not really realistic
- Inverse distance (POW20, $d^{-1.5}$) is thought to be superior to the Guassian functions according to 10.1080/13658816.2019.1591415, should've used that

8.1.4 Measurement of Traffic congestion

- Lane-switching causes measurements to be really awkward and sometimes vehicles can suddenly stop at the lane you're measuring and results go off → improvement = measure traffic data for all lanes if possible
- Lane selection is inconsistent – flawed representation. Since HK is left hand drive city, drivers unload people and goods on the leftmost lane, causing interruptions of traffic flow on the left, uneven distribution especially at Kwun Tong Rd. → improvement = measure traffic data for all lanes if possible
- Traffic lights can run for 2 minutes and if timed incorrectly can lead to large result differences
- Can be more accurate by incorporating vehicle detection, so vehicle length is known and hence more accurate speed measurements

8.2 Study Area

- Perhaps the choice of KT is unsuitable – given the fact that industrial vehicles and industrial-purposed vehicles are highly likely to patronise a facility in the immediate proximity, the large catchment distances are not reflected in real-world conditions, hence rendering the methodology inaccurate.
- Study area should be more commercially/retail oriented, where drivers *actually* have the incentive to park far from their destination, for example, Mong Kok, because they can't afford to keep the car illegally parked
- On-street parking spaces &
- Should not have chosen KT because of its *renowned* traffic congestion, difference is probably going to be insignificant, so it's best to go to an area where there are actual differences to start with
- Macroscopically the parking space availability is severely lacking (90% of respondents say so), not whether there is a spatial imbalance of parking space. 54.9% believes parking prices are expensive, say they are willing to park for HKD11-20/hr



FACTORS AFFECTING ACCURACY

- Land use plays extremely important role in governing whether illegal parking *exists*
 - o Industrial activities (strong incentive to park illegally)
 - o Commercial activities (reserved parking spaces + regular work schedules)
 - o Shopping activities (more to explore!!!)
- Time of day governs which type of activities are dominant
- private carparks + on-street parking spaces are ignored (only 28.2% are open to the public¹⁰): traffic congestion underestimated.
- model ignores parking cost – in fact many respondents feel like its too expensive to begin with
- familiarity to study area also determines the drivers' potential of cruising.
- Lane selection is inconsistent

FURTHER EXTENSIONS

- Compulsivity of activities -> There are no non-compulsory activities in industrial areas, so scope of study is limited.
- Land use homogeneity -> should include mixed residential/commercial to cover different types of activities, MM2SFCA should be used
- Absolute parking space availability -> macroscopically KT is *overall* lacking spaces (90% respondents say so), not worth to investigate because there are no significant spatial imbalances in parking accessibilities to start with, combined by heavy propagative nature -> overall insignificant.
 - o Can expand on the fact that not including parking spaces overall lead to underestimation on the homogeneity of parking distribution.
- V2SFCA??????

9 Conclusion

To be completed

¹⁰ https://www.td.gov.hk/en/transport_in_hong_kong/parking/carparks/index.html

10 Bibliography

Initial: <https://zbib.org/e02b7bd727f64727801bae0bb2dbe0bf>
backup 1: <https://zbib.org/d5f2865e0ba547eba78a8fb6d719ec83>
backup 2: <https://zbib.org/125fccaa2d514778948d96dd6b20c17b>
backup 3: <https://zbib.org/395823387e164c68a110caf69022bc73>
backup 4: <https://zbib.org/75fc386c329d45b4a7438875d1d9f021>
backup 5: <https://zbib.org/275ba48fa0ff479599f1b61216e4be61>

11 Appendix

Things to be added:

- Code
- TABLE: All buildings
- TABLE: survey points + spearman rank