

# Understanding Illegal Waste Dumping Behaviours with Multi-Source Big Data: Visualized Evidences from Hong Kong

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**Abstract:** Illegal dumping refers to the unauthorised disposal of waste in public or private land, which impacts on the surrounding environment. In literature, many studies on minor offences focused on qualitative methods such as questionnaire surveys, of which the findings might be confined to social expectation bias, small sample size, questionnaire design and limited applicability. This study aims at understanding illegal dumping behaviour records in the big picture of urban big data from multiple sources, including demography, geography, economy, and household. We georeferenced the penalty records from January 2014 to June 2019 in Hong Kong and connected them to other data sources. We found that old urban areas were more prone to fly-tipping of building debris and half of the districts most stricken with fly-tipping of waste predominantly comprising renovation waste had a higher proportion of population residing in owner-occupied properties. The levels of income and education were found to have no direct impact on the tendency to commit illegal dumping behaviours. The findings in this paper, therefore, provide directions for the government in formulating policies to fight against illegal dumping.

**Keywords:** Illegal dumping; waste management; behaviour analysis; big data; Hong Kong

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## 1 Introduction

20 Illegal dumping, also known as fly-tipping, refers to the illegal disposal of waste in public areas or private land which often involves arbitrary dumping from trucks [1]. Commonly found in urban areas with convenient vehicular access, illegal dumping not only causes nuisance to residents nearby and poses threat to their health, but can also  
25 undermine the environment in various ways [2], including but not limited to air, soil and water pollution [3] as well as destruction of wildlife habitat [4].

Apart from causing damage to the surrounding environment, illegal dumping is a criminal offence which is enforceable by various government departments, with the vast majority of enforcement actions undertaken by the Environmental Protection Department (“EPD”) through the issuance of Fixed Penalty Notices (“FPN(s)”) to  
30 offenders.

In order to alleviate the problem of illegal dumping, the EPD had begun to install Closed-Circuit Televisions (“CCTVs”) in blackspots of offences since 2010 [5]. However, up to early 2016, only 12 CCTVs had been installed [6]. In face of the aggravating situation, the EPD had significantly increased the number of CCTVs to 50  
35 during the period from March 2016 to March 2018. During the same period, the Food and Environmental Hygiene Department (“FEHD”) had stepped in to assist the EPD in fighting against illegal dumping by installing 6 CCTVs [1]. By June 2019, the total number of CCTVs being installed by EPD and FEHD had escalated to 80 and 118 respectively [7, 8].

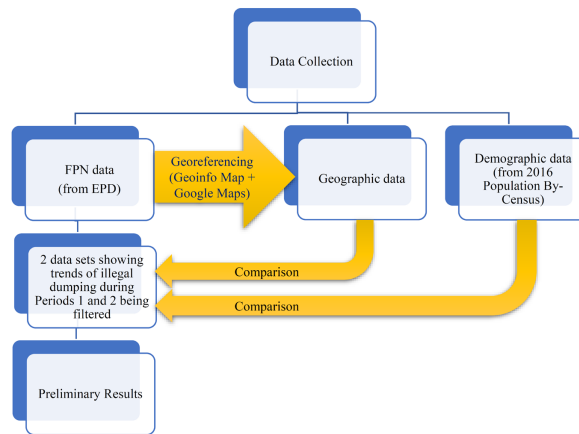
40 Although a myriad of studies had already been conducted on waste management, academic research on illegal dumping behaviour in Hong Kong is still at its infant stage. This study which serves to explore the patterns of fly-tipping activities in Hong Kong is divided into 4 sections. Firstly, a brief overview of the methods of research is presented in Section 2, followed by preliminary analyses of “big data” on illegal  
45 dumping offences in Hong Kong in Section 3. Thereafter, a discussion on how this study can be improved is presented in Section 4 and finally a conclusion is drawn in Section 5.

Big data is commonly known for its “5Vs”, namely, volume, variety, velocity, veracity and value. Volume means large in amount; variety stands for that big data can  
50 either be structured, unstructured, semi-structured or a combination of at least 2 of them [9]; velocity means the high speed of data generation; veracity refers to the significance of the quality of big data on the results of research [10]; value indicates the value of the hidden patterns recognized from big data analyses [11].

In comparison to the traditional method of questionnaire survey which had been  
55 widely applied to the analyses of less serious offences such as software piracy and purchase of counterfeit products, the results generated from big data analyses are capable of giving a more objective and accurate picture of the subject matter being studied which can in turn minimise the potential issues of poor generalisability and low reliability associated with self-report data in questionnaire surveys.

## 60 2 Research Methods

A big data approach was adopted in this study with the methods of research being summarised in Figure 1 below.



**Figure 1. Structure of Research**

65 As demonstrated in Figure 1, three types of data were obtained for the purpose of  
 conducting this research. Firstly, the data sets on fly-tipping were first collected from  
 the government. The anonymous FPN data covering 917 illegal dumping offences  
 happened between 1 January 2014 and 30 June 2019 (both days inclusive) in all 18  
 70 districts in Hong Kong was provided by the EPD. Each FPN record includes the date  
 of offence, type of waste, detailed description of the relevant waste, the district and the  
 exact location of offence. Next, the demographic data sets were obtained from the  
 results of Hong Kong’s “2016 Population By-census” conducted by the government  
 [12]. Thirdly, the geographic data sets were generated from georeferencing the FPN  
 data, the process of which will be further elaborated in the next paragraph.

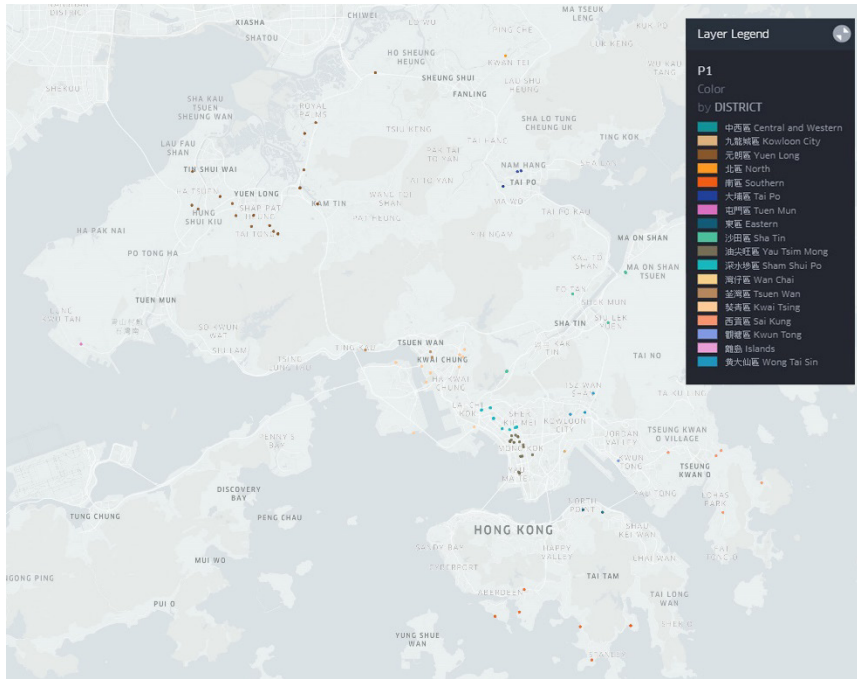
75 All the data sets on fly-tipping were integrated to the WGS84 (World Geodetic  
 System 1984) latitude-longitude system. The FPN data was first georeferenced using  
 the exact locations identified from the GeoInfo Map developed by the government and  
 Google Maps services. The shapes and locations of districts, buildings and populations  
 were also converted from local coordinates HKGS80 (Hong Kong 1980 Grid System)  
 80 to WGS84.

To compare the trends of illegal dumping behaviours between the initial stage with  
 nearly no CCTVs and the later stage where more CCTVs had been installed to track  
 fly-tipping activities, two comparative FPN data sets were filtered - the first set “P1”  
 covering 24 months from 1 January 2014 to 31 December 2015 (Period 1); the other  
 85 being “P2” which covers the 24 months from 1 July 2017 to 30 June 2019 (Period 2).  
 The demographic and geographic data was compared against the FPN data being  
 filtered to explore whether there is any correlation between demographic factors (e.g.  
 income and education levels) and tendency to commit illegal dumping. The preliminary  
 results are presented in the following section.

## 90 **3 Preliminary Results**

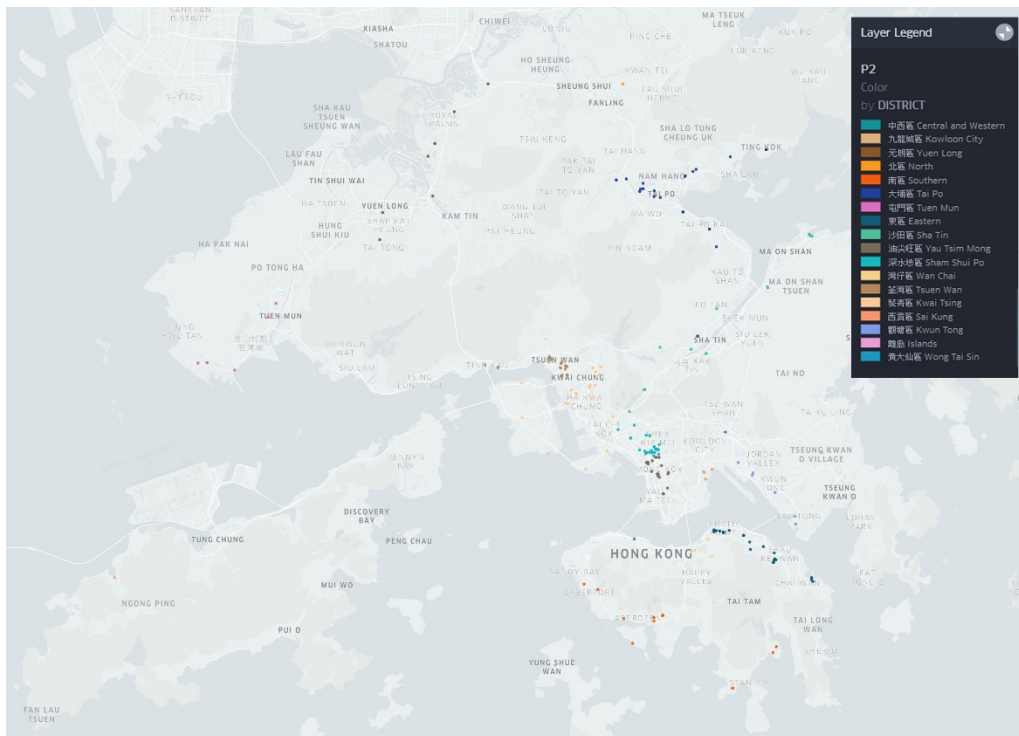
### **3.1 General Overview**

Figures 2(a) and (b) below provide an overview of the distributions of FPNs issued  
 during Periods 1 and 2 respectively. In Period 1, a total of 250 FPNs had been issued.  
 With 42 FPNs being issued, Shatin ranked the first in terms of the number of illegal  
 95 dumping offences which was followed by Sham Shui Po and Yuen Long (each had 34  
 offences) as well as Kwai Tsing and Yau Tsim Mong (each had 24 offences). As for  
 Period 2, the total number of FPNs being issued was 422. Illegal dumping activities  
 remain highly concentrated in Shatin (42 offences), Kwai Tsing (99 offences), Sham  
 Shui Po (52 offences) and Yau Tsim Mong (33 offences).



100

**Figure 2(a). Data Set “P1” being visualized in a map showing the locations of FPNs in Hong Kong during Period 1: 250 FPNs with nearly no CCTVs from January 2014 to December 2015.**



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**Figure 2(b). Data Set “P2” being visualized in a map showing the locations of FPNs in Hong Kong during Period 2: 422 FPNs with nearly 200 CCTVs from July 2017 to June 2019.**

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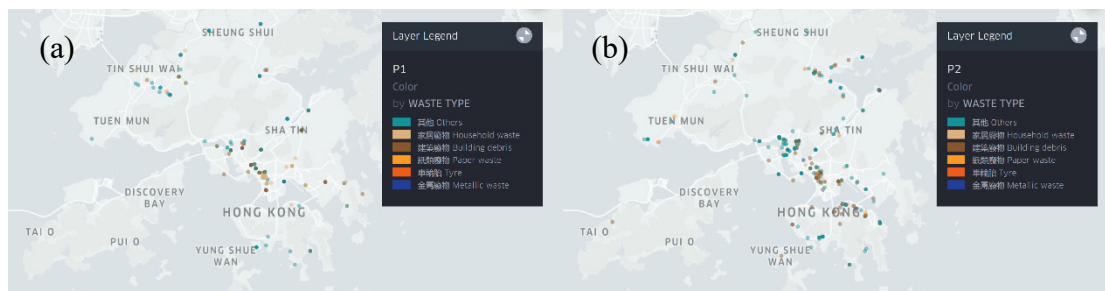
Overall, the total number of FPNs had escalated by nearly 70%, from 125 per year to 211 per year. Kwai Tsing which had experienced increase in the number of fly-tipping activities by more than four times had replaced Shatin as the district most seriously affected by illegal dumping. Sham Shui Po had also undergone more than 50%

115 increase in the number of offences. However, the number of offences in Yuen Long had considerably reduced from over 30 to only 8. It is also important to note that certain districts where the issue of fly-tipping was not that rampant during Period 1 had aggravated at an unprecedented pace. Examples of such districts include Tai Po (from 10 to 30 offences), Tsuen Wan (from 3 to 35 offences), the Eastern District (from 2 to 41 offences) and the Southern District (from 15 to 36 offences).

120 It is also worth to mention that Kwai Tsing was also the district with the lowest median monthly income and second-lowest percentage (15.9%) of population aged 15 or above attaining the education level of bachelor's degree or above whereas Sham Shui Po falls within the lower quartile in terms of median monthly income [12].

### 3.2 Analyses in the Context of Different Types of Waste

125 In the data set provided by the EPD, the waste involved in the illegal dumping offences had been divided into six categories, namely, building debris, household waste, paper waste, tyres, metallic waste as well as others. Indeed, the vast majority of waste under the category of “others” were waste generated from renovation works which include pipes, plastic, packaging materials, canvas, bamboo sticks, broken glass, carton boxes, containers, furniture, waste metal, rocks, carpets as well as wooden frames, boards and bars. Only a small proportion of waste being categorised as “others” were commercial and industrial wastes. A comparison of the distribution of the 6 categories of illegal dumping offences in Hong Kong between Periods 1 and 2 is presented in Figure 3 below.



135 **Figure 3. Comparison of the distribution of 6 categories of FPNs (criterion of classification: waste type) in Hong Kong. (a) Distribution during Period 1; (b) Distribution during Period 2.**

#### 3.2.1 Waste Type – Building Debris

140 By the end of Period 1, there were 48 offences arising from illegal dumping of building debris. With 17 offences, Sham Shui Po was the district most seriously threatened by fly-tipping during that period, followed by Kwai Tsing (10 offences), Shatin and Sai Kung (each had 5 offences) as well as Yau Tsim Mong (4 offences). Nearly half of the districts (8 districts) had no offence and almost one-third of the districts (5 districts) had only one or two offences.

145 It had been observed that the total number of offences had escalated by nearly 90% to 90 during Period 2. Kwai Tsing (16 offences) had replaced Sham Shui Po as the district most stricken with illegal dumping of building debris. With no offence during Period 1 but the number of offences being escalated to 14 by the end of Period 2, the Eastern District had become the second most affected district, followed by Sham Shui Po (12 offences), Tai Po (9 offences) and Shatin (7 offences). It is worth noting that the number of offences in Tai Po was only 2 during Period 1, which indicates that fly-

150

tipping in that district had worsened. The number of districts with no offences reported had declined to 4 whereas nearly one-third (5 districts) had 3 or less offences.

155 In contrast to the waste being categorised as “others” which predominantly  
comprised renovation waste, building debris in this study refers to the waste generated  
from construction sites. Although fly-tipping of building debris had replaced household  
waste as the second most common type of offence during Period 2, it was not as serious  
as fly-tipping of waste under the category of “others” which will be further discussed  
160 in Section 3.2.6. One probable explanation is that Hong Kong is a highly developed  
city with limited land supply without much room for new construction projects.  
Together with the support of the government’s public policies of “Revitalisation of  
Industrial Buildings” and “Operation Building Bright”, the type of project that had been  
prevailing in recent years was renovation work rather than construction of new  
165 buildings. The findings that Kwai Tsing, the Eastern District and Sham Shui Po were  
the three districts most stricken with illegal dumping of building debris are consistent  
with the fact that all three districts are under urban decay with an urgent need of  
redevelopment. Kwai Tsing was segregated from Tsuen Wan, one of the earliest  
developed new towns in Hong Kong, in the mid-1980s. It is also commonly known that  
170 North Point which is an important component part of the Eastern District is one of the  
earliest developed areas in Hong Kong whereas Sham Shui Po is an inner city district.

### 3.2.2 Waste Type – Household Waste

There was a total of 50 offences relating to illegal dumping of household waste by the  
end of Period 1. With 17 offences, Yau Tsim Mong was the district most seriously  
175 affected by fly-tipping, followed by Yuen Long (10 offences), Sai Kung (5 offences)  
as well as Shatin and Wong Tai Sin (each had 4 offences).

During Period 2, the total number of offences had increased by nearly 25% to 62.  
With 20 offences, Yau Tsim Mong remained as the district most succumb to fly-tipping.  
It is also worth noting that the issue of fly-tipping in the Eastern District had aggravated  
180 at an unprecedented pace as reflected by a drastic increase in the number of offences  
from 1 in Period 1 to 13 by the end of Period 2, thereby causing the Eastern District to  
rank second in terms of illegal dumping of household waste. With the number of  
offences being increased to 8, Sham Shui Po had become the third most affected district.  
Shatin which remained as the district ranking the fourth in terms of the number of  
185 offences had 6 offences, followed by Tsuen Wan (5 offences). In contrast to Yau Tsim  
Mong and Shatin where fly-tipping continued to prevail, such problem had significantly  
improved in Yuen Long with only 1 offence being observed and no offence happened  
in both Sai Kung and Wong Tai Sin.

Among the 5 districts most affected by fly-tipping of household waste, although 2  
190 of them (i.e. the Eastern District and Shatin) ranked top four in terms of the total number  
of domestic households, with only 126,540 households, Yau Tsim Mong which was the  
most stricken with illegal dumping fell within the lower-middle quartile in this aspect  
[12]. Therefore, no correlation between the number of households and tendency to  
commit fly-tipping of household waste existed.

195 Similar to the case of number of households, there was no correlation between the  
median domestic household income and tendency to commit illegal dumping of  
household waste. This can be reflected by the fact that except Sham Shui Po which had  
the lowest median domestic household income, the levels of median monthly domestic  
household income of the other 4 districts most seriously affected by the issue were not



200 that low. It is worth to note that the Eastern District even ranked fifth in terms of the level of median monthly domestic household income [12].

No correlation between the median monthly income level and likelihood of committing fly-tipping had been observed. Except Sham Shui Po which fell within the lower quartile, the median monthly income level of districts most succumb to illegal dumping during Period 2 were not that low. The Eastern District, Tsuen Wan and Shatin even fell within the top one-third in this regard [12].

205 It is worth to mention that education level was not a factor affecting the tendency to commit illegal dumping. 3 out of the 5 districts most affected by the problem were within the first half in this regard, with the Eastern District and Yau Tsim Mong (i.e. the 2 districts with the largest number of offences) ranking fourth and fifth respectively in terms of the proportion of population who were degree holders [12].

### 3.2.3 Waste Type – Paper Waste

215 Among the 7 offences of illegal dumping of paper waste during Period 1, both Kwai Tsing and Sham Shui Po had 2 cases being fined whereas the remaining three offences happened in Kwun Tong, Wong Tai Sin and Sai Kung respectively. As for Period 2, there had been an escalating increase in the total number of offences by more than 4 times to 29. During that period, with a significant increase in the number of offences to 12, Sham Shui Po had become the district most seriously affected by fly-tipping of paper waste, followed by Kwai Tsing (5 offences) and the Eastern District (5 offences). 220 Offences had also been reported in Tsuen Wan (3 offences), Kowloon City (1 offence), the Southern District (2 offences) and Tuen Mun (1 offence). In comparison to the categories of building debris, household waste and “others” which will be elaborated in Section 3.2.6, fly-tipping of paper waste is a relatively minor issue in Hong Kong.

### 3.2.4 Waste Type – Metallic Waste

225 Only 3 offences of illegal dumping of metallic waste had been fined during Period 1 which happened in Yuen Long, Kwai Tsing and Kowloon City respectively. The total number of offences had increased to 12 by the end of Period 2, with Kwai Tsing being the district most severely stricken with the issue (6 offences), followed by Sham Shui Po and Tsuen Wan (each had 2 offences) as well as Yau Tsim Mong and the Eastern 230 District (each had 1 offence). Compared with other types of waste, illegal dumping of metallic waste is the second least serious issue in Hong Kong.

### 3.2.5 Waste Type - Tyres

235 There was only 1 offence in relation to the dumping of tyres during Period 1 which took place in Yuen Long. During Period 2, there were altogether 3 offences which happened in Shatin, Kwai Tsing and Tuen Mun respectively. The illegal dumping of tyres is among the least serious problem in Hong Kong.

### 3.2.6 Waste Type - Others

240 During Period 1, with a total of 141 offences, illegal dumping of waste under the category of “others” had become the most rampant fly-tipping activity. In terms of the number of offences, Shatin was the district most stricken with fly-tipping (33 offences),

followed by Yuen Long (20 offences), the North District (17 offences), Kowloon City (15 offences), the Southern District (14 offences) and Sham Shui Po (12 offences). Contrastingly, the remaining two-thirds of districts only had a few or even no illegal dumping activities during the same period.

245 The number of offences had drastically increased by around 60% to 226 during  
Period 2. With the number of offences being escalated by more than 6 times from only  
10 during Period 1 to 67 by the end of Period 2, Kwai Tsing had become the district  
most seriously affected by fly-tipping. With the number of offences being more than  
250 doubled to 32, the Southern District ranked second in terms of the total number of  
offences during Period 2, followed by Shatin (28 offences), Tsuen Wan (20 offences),  
Tai Po (19 offences) and Sham Shui Po (18 offences). It had also been observed that  
the number of offences in the North District had significantly dropped from 17 during  
Period 1 to only 1 by the end of Period 2. The number of offences in the Eastern District  
and Tuen Mun had jumped from only 1 during Period 1 to 8 and 7 respectively by the  
255 end of Period 2. Similar to the case of Period 1, the remaining majority of districts had  
nearly no offences.

It is worth to mention that there is no correlation between education level and  
tendency to commit fly-tipping in relation to this category of waste. Among the 6  
260 districts most vulnerable to fly-tipping, except Kwai Tsing which was the district with  
the second lowest proportion of population possessing at least a bachelor's degree, the  
percentages of population with degree level or above in the remaining districts were  
not that low, with the Southern District ranking the eighth in terms of the percentage of  
population with degree level or above and the other 4 districts falling within the upper  
two-thirds in this regard [12].

265 No correction had been observed between the median monthly income level and  
the likelihood of committing offences concerning this category of waste. This can be  
attributed to the fact that except Kwai Tsing and Sham Shui Po, both of which fell  
within the lower quartile in terms of their median monthly income levels, none of the  
remaining 4 districts most stricken with fly-tipping ranked below the lower-middle  
270 quartile in this regard. It is worth mentioning that Shatin and Tsuen Wan, i.e. the  
districts with the third and fourth largest number of offences, ranked fourth (i.e. fell  
within the upper quartile) in terms of the levels of median monthly income [12].

Similarly, there was no correlation between median household monthly income  
level and commission of fly-tipping. This can be reflected by the fact that except Kwai  
275 Tsing and Sham Shui Po which had fallen into the lower quartile in terms of the level  
of median household monthly income, all the remaining 4 districts most succumb to  
illegal dumping fell within the top half in this aspect [12].

Among the 6 districts most severely threatened by illegal dumping, half of them  
(i.e. Tai Po, Shatin and Tsuen Wan) ranked the top 6 in terms of the percentage of  
280 households residing in owner-occupied properties [12]. Compared with tenants, it is  
commonly understood that owners have a greater incentive to improve their living  
environment through renovation. Together with the fact that the vast majority of  
offences under this category of "others" were related to the illegal dumping of waste  
generated from renovation works, a possible explanation for the high concentration of  
285 fly-tipping in these 3 districts is the greater demand for renovation works arising from  
a higher proportion of home-owners in those districts.

## 4 Discussion

By employing the 6 categories of waste delineated by the data provider without any  
modification, this study does have certain limitations. As previously discussed, the



290 category of “others” mainly included renovation waste with a small proportion being  
commercial and industrial waste. Indeed, to improve the comprehensiveness of the  
study, the types of waste can be reorganised into 4 categories including renovation  
waste, building debris, household waste and “others” which include commercial waste,  
295 industrial waste, paper waste, metallic waste as well as tyres. More detailed statistics  
on the number of new construction projects as well as the schemes of “Revitalisation  
of Industrial Buildings” and “Operation Building Bright” in each district should be  
obtained from the relevant authorities to facilitate in-depth analyses of illegal dumping  
of building debris and renovation waste in certain areas. Finally, it is recommended that  
300 information on the distribution of CCTVs should be obtained from the EPD and FEHD  
for the purpose of assessing the effectiveness of CCTVs on curbing illegal dumping. It  
is anticipated that by undertaking the aforesaid measures to improve the method of  
analysing the big data provided by the EPD, more representative results which might  
play a role in the formulation of policy recommendations can be generated.

## 5 Conclusion

305 Admittedly, most previous studies on minor offences with the vast majority of which  
concerning software piracy and purchase of counterfeit products had adopted the  
conventional approach of questionnaire survey. However, the reliability and  
generalisability of self-report data obtained from questionnaire surveys are highly  
questionable. Therefore, there has been a shift from such traditional method to the use  
310 of big data analytics in academic research in recent years. It is worth noting that the  
application of the big data approach to research on waste management is still at an  
infant stage as reflected by the limited literature available. By adopting a big data  
approach, this study serves to bridge the research gap not addressed by previous studies  
on illegal dumping behaviour in Hong Kong.

315 This study had generated new knowledge in relation to the pattern of illegal  
dumping behaviour in Hong Kong. Firstly, old urban areas were more vulnerable to  
fly-tipping of building debris. Secondly, the dumping of paper waste, metallic waste  
and tyres were relatively minor issues in Hong Kong. Thirdly, in relation to fly-tipping  
of waste under the category of “others” which primarily consisted of renovation waste,  
320 it was observed that 3 districts with a higher percentage of population residing in owner-  
occupied properties had a larger number of offences. It is worth noting that this type of  
offence was also the most rampant during both Periods 1 and 2. Fourthly, it was found  
that education level, monthly income level, monthly domestic household income level  
as well as the number of households in a district (in the case of household waste) had  
325 no impact on the likelihood of commission of fly-tipping. It is also worth to mention  
that there had been an increase in the total number of offences at an unprecedented pace  
despite the joint efforts of the EPD and FEHD in installing CCTVs at blackspots.

The findings of this study suggest that future enforcement actions should target at  
old urban areas and districts with higher proportion of residents living in owner-  
330 occupied properties. Another important implication is that given the lack of impact of  
demographic factors such as education and income levels on the tendency to commit  
all 6 categories of illegal dumping offences, there is a lack of awareness of the need to  
protect the environment by disposing waste at proper waste reception facilities operated  
by the government among the public in general. Therefore, education programmes  
335 targeting at all walks of life should be placed at the top of the agenda in alleviating the  
issue in the long run. The collective efforts of the government, the general public as  
well as the academia will certainly be indispensable throughout such process.

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