Big Data Approach as an Institutional Innovation to Tackle Hong Kong's Illegal Subdivided Unit Problem

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Abstract: While applications of big data have been extensively studied, discussion is mostly made from the perspectives of computer science, Internet services, and informatics. Alternatively, this article takes the big data approach as an institutional innovation and uses the problem of illegal subdivided units (ISUs) in Hong Kong as a case study. High transaction costs incurred in identification of suspected ISUs and associated enforcement actions lead to a proliferation of ISUs in the city. We posit that the deployment of big data analytics can lower these transaction costs, enabling the government to tackle the problem of illegal accommodations. We propose a framework for big data collection, analysis, and feedback. As the findings of a structured questionnaire survey reveal, building professionals believed that the proposed framework could reduce transaction costs of ISU identification. Yet, concerns associated with the big data approach like privacy and predictive policing were also raised by the professionals.

1. Introduction

"Big data" is a poor term, lacking a universally agreed definition [1,2]. It is "an all-encompassing term for any collection of data that is very large or complex, and therefore difficult to analyze using conventional data-processing applications" [3]. Some others defined big data as "data that can no longer be captured, stored, managed and analyzed using conventional methods" [4]. Big data has been commonly characterized by its huge volume, high velocity, diverse variety, high complexity, and fine-grained resolution [2,5]. Nonetheless, the definition of what constitutes big data should be relative to our abilities to process it [6]. As a matter of fact, big data should not be limited to data that is so big and exceeds our capacity to handle, search and aggregate it [1]. Instead, it represents a new landscape of the data ecosystem. Big data should comprise a wide spectrum of data sets with varying characteristics [5].

Big data is everywhere, though we may not realize its existence immediately. The big data approach is a novel way to combine digital data sets from different sectors, including governments and businesses, and apply analytic techniques to extract or mine hidden information in the data sets [7]. For example, big data analytics can facilitate advanced decision making which is essential for better-informed policy making [8]. In the arena of urban management, the use of big data analytics can transform mega-cities into resilient smart cities [9,10]. While applications of big data in urban management have been widely explored and discussed in the literature, most of the research has concentrated on technical and legal issues. Perspectives of informatics, computer science and Internet services dominate the big data literature. Big data has been often regarded as a kind of information

technology. No previous attempt has been made to frame big data application as an institutional change or innovation. In fact, big data can be a social technology for better urban management. Using the case of enforcement against illegal subdivided units (ISUs) in Hong Kong, we illustrate in this article that the high transaction costs incurred in various stages of public enforcement lead to the enforcement failure. For more effective control of ISUs in the city, we propose a big data approach, which can significantly reduce the costs of identifying ISUs in the existing building stock of Hong Kong. The results of a structured questionnaire survey conducted in Hong Kong generally support the feasibility of the proposed approach. Yet, the respondents have some concerns about the application of big data in fighting ISUs.

This article is organized as follows. First, the ISU problem in Hong Kong is overviewed and relevant literature on the applications of big data approach in urban management is reviewed. What comes next is the outline of the research design. Then, the failure of the public authority in halting ISUs is analyzed from the perspective of transaction cost economics. Afterwards, an alternative approach, which is built upon big data analytics to facilitate ISU enforcement, is detailed. The results of the empirical study are presented and discussed before the article is concluded. An agenda for further research is suggested at the end of the article.

2. Issue and Literature Review

In this section, the subject issue of the research is briefly discussed. It is then followed by a review of literature relevant to the research.

2.1. The Rise of Subdivided Units

In Hong Kong, some people have no choice but to live in transient accommodation in subdivided units as a result of multiple forces like protracted waiting time for public rental housing and highly unaffordable rentals of private housing. Here, the term 'subdivided unit' (*tongfang*) refers to accommodation that was originally designed for single-family occupation and has "been subdivided into two or more smaller units for rental" [11]. It was estimated that, as at 30 April 2013, about 2.4% of the total population in Hong Kong or 171,300 persons lived in 66,900 micro units produced by flat subdivision [11]. The number of quarters that are subdivided amounted 18,800 [11]. However, these estimations did not cover those subdivided units in industrial buildings, residential buildings constructed before 1988, and village houses. Therefore, the number of micro units in Hong Kong is expected to far exceed the official figure. The number of micro units created through flat subdivision was estimated again in 2015; the new estimate jumped to 88,800 [12]. As shown in Table 1, the estimated population living in sub-divided rose from 171,300 in 2013 to 199,900 in 2015.

Table 1. Estimates of the number of subdivided units in Hong Kong [11–13]

Estimated Figure	2013 Estimate	2014 Estimate	2015 Estimate
Number of quarters with micro units	18,800	24,600	25,200
Number of micro units	66,900	86,400	88,800
Number of households living in micro units	66,900	85,500	87,600
Number of persons living in micro units	171,300	195,000	199,900
Average area of micro unit per capital (m^2)	Unavailable	5.7	5.8

The typical sizes of these micro units range from 70 ft^2 to 120 ft^2. Relatively smaller micro units are commonly known as 'coffin homes'. Most of the micro units have an independent toilet and a few come with a kitchen as well. The general living conditions of the subdivided units are rough. Residents in subdivided units complain of different problems associated with their living environment, such as water seepage and concrete spalling [11]. Flat subdivision can create potential death traps and the cramped living environment in subdivided units triggers many social conflicts among residents [14]. A review of the news reports in local newspapers reveals that there were at least 40 incidents of fire

within subdivided units in Hong Kong during 1 January 2010 to 30 June 2017. These incidents resulted in 9 deaths and 72 injuries. In the Policy Address 2015, it was emphasized that the safety problems associated with subdivided units should be addressed without further delay. Moreover, some works point out that living in a subdivided unit could impose long-term impacts on the residents' physical and mental health [15,16].

2.2. Illegality of Subdivided Units

Many subdivided units are essentially unauthorized building works (UBWs). In Hong Kong, the *Buildings Ordinance* (Chapter 123 of the *Laws of Hong Kong*) and its subsidiary legislations such as *Building (Planning) Regulations* and *Building (Construction) Regulations* form the statutory framework of building control. The building control regime covers all building works, ranging from demolition, new building construction to alterations carried out in existing buildings. According to the *Buildings Ordinance*, the Director of Building—i.e., the head executive of the Buildings Department—serves as the Building Authority and the Buildings Department executes and enforces the provisions in the *Buildings Ordinance*. To make sure that the minimum acceptable standards are met in the design and execution of a building work, prior approval and consent granted by the Building Authority are necessary before the work can be carried, unless the work is exempted from this requirement by the ordinance [17–19]. Building works carried out in contravention with this requirement are generally referred to "UBWs" [20]. The creation of micro units in existing buildings commonly involves the subdivision of a dwelling unit or flat into two or more smaller, individual units. As Figure 1 illustrates, the related building works typically comprise setting up of new bathrooms/toilets, modification of existing drainage and plumbing systems for the new bathrooms/toilets, thickening of floor screeding to house the diverted or new drains, demolition of original nonstructural partitions and erection of new nonstructural partitions.
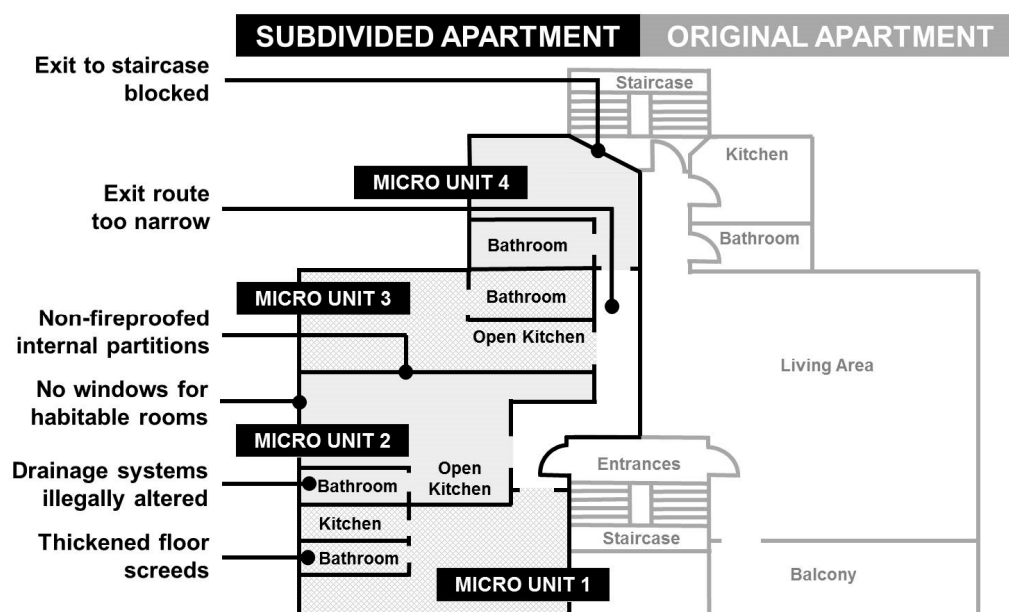

Figure 1. Common illegal alterations made in flat subdivision.

In fact, many of these building works are 'minor works' in nature. They can be performed in the absence of the Building Authority's prior approval and consent. However, the property owners and qualified contractors have to follow a set of simplified statutory procedures (e.g., notification of commencement of works and certification of completion of works) under the Minor Works Control System with regard to the undertaking of minor works. The Minor Works Control System is a relatively

new part of the building control system in Hong Kong. Its idea was first incepted in the late 1990s. After decade-long discussions and legislation, the system finally came into effect in December 2010. Under the current Minor Works Control System, there are three classes of minor works which are classified according to their scale, nature, complexity and potential safety risk. Table 2 summarizes the streamlined submission requirements of different classes of minor works. Yet, minor works undertaken without following the statutory procedures are still taken as UBWs.

Table 2. Classification of minor works [21]

	Class I	Class II	Class III
Degree of complexity and risk	High	Medium	Low
Number of items	44	40	42
Example	Making an opening to staircase enclosure	Repair of a column or beam	Erection of drying rack
Persons required to prepare and sign prescribed plans	Prescribed building professional and prescribed registered contractor	Prescribed registered contractor	Prescribed registered contractor
Document submission before work commencement	Minimum 7 days before work commencement	Minimum 7 days before work commencement	Not required
Document submission after work completion	Within 14 days after work completion	Within 14 days after work completion	Within 14 days after work completion

In addition, many flat subdivision works are illegal in nature because the products do not comply with the building regulations. For example, those new rooms produced as a result of flat subdivision very often do not have windows or have inadequate window areas so the statutory requirements regarding the provision of ventilation and lighting cannot be fulfilled. The partitions separating different occupancies in a subdivided flat are supposed to be fire-resistant according to the requirements laid down in the *Building (Construction) Regulations*. However, most of these partitions in real-life cases are not fire-resistant. As for subdivided units in industrial buildings, they are all illegal for their nonconformance with the *Buildings Ordinance* and statutory land-use zoning.

2.3. Government Efforts to Fight against ISUs

To a certain extent, the contemporary illegal micro units evolve from other types of illegal accommodations like caged homes, which have existed in Hong Kong for over 50 years [22,23]. Since 1994, caged homes have been controlled through a licensing regime under the *Bedspace Apartments Ordinance* (Chapter 447 of the *Laws of Hong Kong*) and the number of caged homes in the territory has been dropping. However, ISUs and cage homes are different in some ways. First, building works are usually involved in the former but not the latter. Second, the leasing subjects in the ISU case are micro units while bedspaces are rented in the case of cage homes. Third, the *Bedspace Apartments Ordinance* does not apply to ISUs. Therefore, other measures to deal with the ISU problem are needed. In response to the ISU problem in the territory, the Hong Kong Special Administrative Region (HKSAR) Government has taken a multipronged approach.

On the community education side, the Buildings Department has produced television advertisements and publications to promote the Minor Works Control System as a proper pathway to do alterations in a flat. The Buildings Department has also distributed numerous pamphlets to educate the public on the deathtraps in subdivided flats and their prevention [24]. Furthermore, the Buildings Department launched various public education programs. For example, the website www.careyourbuilding.bd.gov.hk came into use in 2013 to disseminate useful information and promote building safety to the general public. Building Safety Certificate Courses were also organized for property owners and homeowner associations.

Apart from community education, the HKSAR Government has also attempted to deal with the ISU problem through the existing building control system. Under the *Buildings Ordinance*, knowingly failing to appoint a prescribed building professional and/or a prescribed registered contractor to carry out a minor work is an offence. The person who arranges for the minor work without making prescribed appointments is liable to a maximum fine of HK$100,000 upon conviction. If the illegal flat subdivision is not a minor work in nature, the person commits an offence if he or she carries out the work without going through the submission process for the Building Authority's prior approval and consent properly. Imprisonment for two years and a fine of HK$400,000 are imposed on the offender who is found guilty [25]. In case of a continuing offence, a further fine of HK$20,000 is imposed for each day during which the law violation persists [25].

The Building Authority may serve a statutory order, which is usually known as a reinstatement order, mandating the offending property owner to rectify the violations by a specified deadline. The order may be registered against the title of the property in the Land Registry. As per the *Buildings Ordinance*, it is a serious offence if one person fails to comply with a statutory reinstatement order without any reasonable excuse. Upon conviction, the offender is subject to a fine of HK$200,000 and one year's imprisonment as the maximum penalty [25]. There is also a further fine of HK$20,000 per day for any continuing violation [25]. In case the property owner concerned refuses to carry out the required rectification works, the Building Authority may also engage a government contractor to rectify the contraventions directly. The costs incurred together with supervision charge will then be recovered from the property owner [25].

The Buildings Department investigates the cases involving UBWs associated with subdivided units after receiving reports or complaints about subdivided units. Suitable enforcement actions will then be taken in accordance with the prevailing UBW enforcement policy [26]. In addition, the Buildings Department has launched large-scale operations since April 2011 to identify, inspect and enforce against ISUs [27]. Heavy emphasis has been placed on the means of evacuation from the buildings in these operations. Once irregularities are identified, the Buildings Department will take necessary enforcement actions. Table 3 summarizes the number of target buildings and buildings actually inspected during the period between 2011 and 2016. Up to 31 December 2016, around 9000 subdivided flats have been inspected during these large-scale operations since April 2011. At least 1900 statutory orders were issued and 439 prosecutions were instigated. As mentioned above, in spite of the government actions, the number of ISUs did not go down in the past years [11–13]. The decreasing trends of the number of target buildings and number of buildings actually inspected from 2014 to 2016 actually reflected the difficulties of ISU enforcement and limited resources of the Buildings Department for coping with the ISU problem. In order not to give the general public any false expectation, the HKSAR Government consecutively lowered the enforcement targets.

Table 3. Statistics of large-scale operations targeting ISUs

Year	Number of Target Buildings to be Inspected [1]	Number of Buildings Actually Inspected [1]
2011	150	116
2012	200	369
2013	200	300
2014	330	308
2015	330	210
2016	100	100

[1] The figures were compiled based on the information contained in the Controlling Officer's Reports (Head 82–Buildings Department) in the government budgets of various years.

2.4. Applications of Big Data in Urban Management

In view of the unresolved problem of ISU proliferation in Hong Kong, we propose a big data approach to facilitate the public enforcement. In point of fact, 'big data' is now a buzzword in

many different disciplines, ranging from business management and public administration to public health though there is still a lot of noises and misunderstandings about the use of big data [28]. Many governments have committed to make use of big data to develop their smart cities [29,30]. Big data can improve organizational efficiency, operational effectiveness, and decision-making [31]. It can also enhance productivity [32,33]. The application of big data and associated analytics also significantly improves government services in different arenas.

Big data has been regarded as an important source of insights into urban management. It allows better understanding of urban problems and provides actionable and sustainable solutions [34]. Governments have employed big data in many different areas in urban management and planning—e.g., land-use planning [3], land administration [35,36], and traffic operations [37,38]. For example, a big data approach was proposed to ease the problem of illegal parking in Goyang City, South Korea [16]. In American cities such as Chicago, Los Angeles, and Manchester, big data was employed to predict where crime would take place before it occurred [39,40]. This helped policing agencies to decide smartly the places for their officers to patrol. Evidence shows that crime rates could be lowered with the same manpower input upon the application of big data analytics. From above, it is clear that data-driven urban management is becoming a global trend [35,41]. Big data has a high potential to facilitate urban management efforts aimed at tackling city problems [42].

3. Research Design

The current research has five stages and its design is graphically illustrated in Figure 2. First of all, under the broad umbrella of big data applications in urban management, a specific issue was picked for in-depth investigation. ISU enforcement in Hong Kong was chosen eventually because we expected that the big data approach could have promising implications in this aspect though its application was still at the conception stage. Background information about the issue of ISU proliferation in Hong Kong and what the HKSAR Government had done to cope with the issue was overviewed. In the second stage, relevant literature about the applications of big data analytics in urban management was reviewed. Besides, the literature review covered previous works that explained failures of public enforcements. What comes next is the theorization of research issue. In this research, the transaction cost theory in the discipline of institutional economics was adopted to explain why HKSAR Government's efforts in combating ISUs were in vain. An alternative approach drawn upon the transaction cost theory was then proposed.
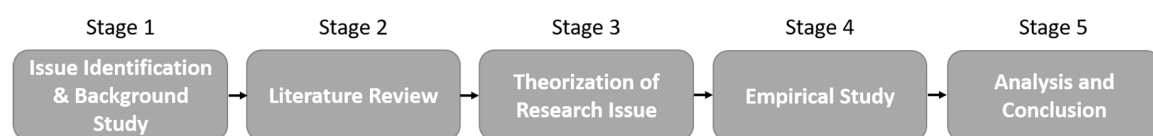
Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Issue Identification & Background Study	Literature Review	Theorization of Research Issue	Empirical Study	Analysis and Conclusion

Figure 2. Research design.

In Stage 4, the feasibility of the proposed approach was evaluated. Nonetheless, it was impossible to obtain any real-life data to evaluate if the proposed approach could really trim down the number of ISUs in Hong Kong because the proposed approach was yet implemented at the time when the research was conducted. Therefore, views of local building professionals (e.g., architects, building surveyors, builders, fire engineers, structural engineers, and property and facility managers) towards the proposed approach were collected through a semi-structured questionnaire survey which was conducted in the period between January 2018 and March 2018. To achieve a balanced sample with building professionals from different disciplines, purposive sampling was adopted for selecting the invitees. A total of 120 building professionals with a profound understanding of Hong Kong's ISU issue were chosen. An invitation letter was sent to each of these 120 professionals to complete an online questionnaire. A follow-up invitation was sent to the selected professionals if we had not received any replies from them within one month after the first invitation. Eventually, 88 invitees (73.3%)

completed the questionnaire fully. The profile of the invitees and respondents is shown in Table 4. The questionnaire was predesigned to comprise three parts. The first part asked the respondent to rate the feasibility of the proposed big data approach with reference to technical practicality and political acceptability (i.e., whether the proposal would be received by relevant policy stakeholders). The respondent was required to give a rating to these two aspects using a four-point scale, with 1 = very low; 2 = low, 3 = high, and 4 = very high. The second part concerns whether the proposed approach could reduce transaction costs incurred in different stages of ISU enforcement. A four-point Likert scale (with 1 = strongly disagree; 2 = disagree; 3 = agree and 4 = strongly agree) was employed to indicate respondent's degree of agreement (or disagreement) with the argument that the proposed big data approach would help reduce the transaction costs of ISU enforcement. The last part contained an open-ended question, asking respondents to raise their concerns about the proposed big data approach. Before the official survey started, the questionnaire had been pretested and modified by taking the testers' comments and suggestions into account. In the last stage of the research, the findings of the survey were analyzed and interpreted. Implications were drawn based on the analysis results.

Table 4. Profiles of the survey invitees and respondents

Characteristic		Invitees		Respondents	
		Number	%	Number	%
Gender	Male	87	72.5%	67	76.1%
	Female	33	27.5%	21	23.9%
Profession	Architect	21	17.5%	16	18.2%
	Building surveyor	24	20.0%	19	21.6%
	Builder	17	14.2%	12	13.6%
	Fire engineer	16	13.3%	9	10.2%
	Structural engineer	22	18.3%	13	14.8%
	Property & facility manager	20	16.7%	19	21.6%
Professional experience	10 years or less	33	27.5%	24	27.3%
	11–20 years	34	28.3%	25	28.4%
	21–30 years	30	25.0%	22	25.0%
	More than 30 years	23	19.2%	17	19.3%
Working sector	Public sector	72	60.0%	46	52.3%
	Private sector	48	40.0%	42	47.7%

4. Transaction Cost Model of ISU Enforcement

In this section, the failure of government interventions in curbing ISU problem in Hong Kong was explained from the perspective of institutional economics. In view of such failure, we put forward an institutional innovation.

4.1. High Transaction Costs of Government's Enforcement

In spite of the efforts of the HKSAR Government in fighting against ISUs, the ISU problem in the city still remains very serious. The failure of government's enforcement actions can be explained from the angle of institutional economics. Institutional economics supplements classical economics with the concepts of institutions and transaction costs [43–45]. Institutions are the game rules in a society, shaping the contexts for economic behavior [44]. Institutions come in different forms, including formal rules (e.g., laws and constitutions) and informal rules (e.g., societal norms and customs) [46]. On the other hand, transaction costs are the costs of making and enforcing agreements, which also include the rules such as laws and regulations. The costs of searching and information collection are also important transaction costs in many different institutional settings [47–49]. In the building control system, transaction costs are incurred in the law making and law enforcement processes. This research focusses on the law enforcement process only.

As Figure 3 shows, there are several stages in a law enforcement process against ISUs and different enforcement costs are involved in these stages. For example, at the start of the enforcement exercise, the public officials in the Buildings Department need to figure out which properties in the existing building stock have been subdivided unlawfully. Then, the public officials have to collect sufficient evidence for subsequent enforcement actions, such as the issuance of statutory reinstatement orders or direct prosecutions. These two initial stages of the enforcement exercise involve prohibitively high transaction costs, leading to law enforcement incapacity.
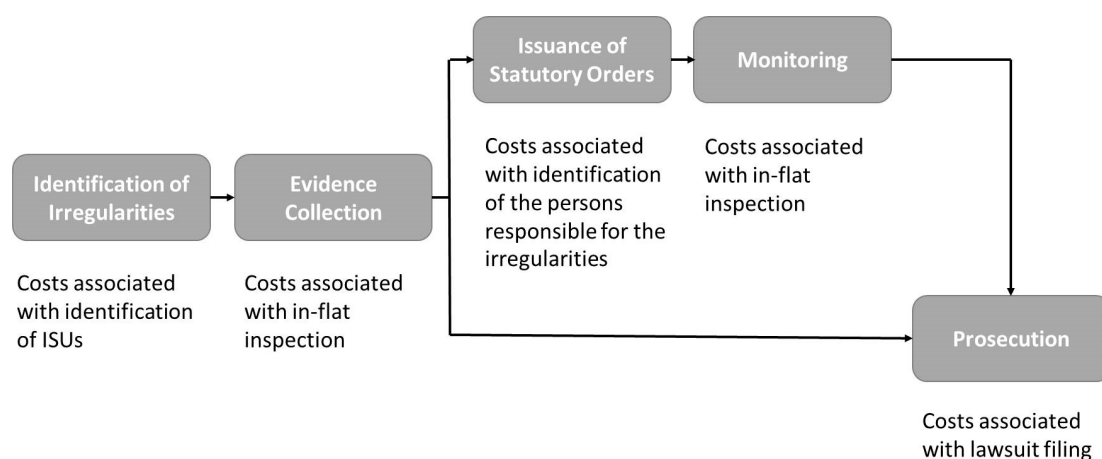

Figure 3. Transaction costs incurred in different stages of ISU enforcement.

Unlike other types of UBWs, such as flower racks and metal cages erected on the external walls of buildings, ISU works are undertaken inside a flat so their presence is not so readily observable from the outside. Several years ago, public officials relied on some noticeable signs to identify ISUs in a building. These signs included multiple doorbells, mailboxes, and water meters installed for a single flat or dwelling unit, as illustrated in Figure 4. Through learning from previous enforcement experience, landlords and renters of ISUs are getting smarter. Households of different micro units within an ISU now share the same doorbell, mailbox, and water meter, hiding the existence of the ISU from outsiders. Therefore, it becomes more and more difficult for the public officials to identify ISUs without entering a premise.

In practice, the officials of the Buildings Department inspect a property or properties in a building for suspected ISUs either because the building is targeted in a large-scale operation or the department receives complaints from the public. In the first scenario, the Buildings Department picks a sample of target buildings based on a number of criteria, such as building age and building management regime (e.g., formation of incorporated owners and appointment of third-party management agent). However, these criteria may not be good predictors for the level of ISU proliferation in a building. Older, unmanaged buildings do not necessarily have more ISUs. Erroneous shortlisting may result in inefficient use of public resources. More importantly, there is a need for the public officials to enter the properties in the targeted building for inspection. Otherwise, the public officials cannot ascertain whether the properties have been illegally subdivided for subsequent actions.

In the second scenario, although the suspected ISU has been spotted by a member of the public, the government officials still need to collect sufficient hard facts or evidence on the existence of ISUs (e.g., number and dimensions of the illegal micro units and types of UBWs carried out for flat subdivision) for further enforcement actions. In other words, for both scenarios, getting access to the property interior is crucial. Nonetheless, the ISU residents, in most cases, deny the access of public officials to the subdivided flats because they do not want to risk losing their current relatively affordable accommodation.

Figure 4. Multiple electricity meters as a signal of flat subdivision.

On the other hand, Section 2.2 of the *Buildings Ordinance* stipulates that the power of entry or breaking into the premises or upon land by the Building Authority in the presence of a police officer is restricted to emergency situations only. To further facilitate in-flat inspection of suspected ISUs, the *Buildings (Amendment) Ordinance 2011* introduced a new measure to empower the Building Authority to apply to the court for a warrant for entry into the interior of individual premises for inspection or other enforcement actions. Before the issuance of the warrant, a magistrate must be satisfied by information on oath that:

1.　There are reasonable grounds for suspecting any of the following matters:

   - building works have been or are being carried out to the premises or land in contravention of any provision of the Buildings Ordinance;
   - the use of the premises or land has contravened any provision of the Buildings Ordinance;
   - the premises have been, or the land has been, rendered dangerous, or the premises are, or the land is, liable to become dangerous;
   - the drains or sewers of the premises or land are in a defective or insanitary condition; or
   - a notice or order served under the Buildings Ordinance has not been complied with;

2.　The Building Authority has made attempted entry on at least two different days; and
3.　A notice of intention to apply for a warrant has been served on the owner or occupier of the premises.

In spite of the facilitation of in-flat inspection through law amendment, transaction costs for in-flat inspections for ISUs are still very high. The Buildings Department officials need to visit the property suspected of having illegal subdivisions twice before applying to the court for an entry warrant.

Moreover, to substantiate their warrant application, they have to provide sufficient evidence to the court that there are UBWs in the subject property. As discussed above, the task of evidence collection in ISU enforcement is a really thorny issue. From the above, it is clear that the existing enforcement system in Hong Kong fails to stop the ISU problem due to the prohibitively high transaction costs of searching and information collection.

4.2. Institutional Innovation for ISU Enforcement with the Use of Big Data Analytics

In order to make ISU enforcement in Hong Kong more effective, we propose that the ISU search can be facilitated with the use of big data analytics. Big data has been used in many cities for combating different urban problems, such as crime, illegal parking, and traffic congestion [5,37,38,50,51]. In some cities, the local governments also employed big data to fight against substandard housing. For example, big data is used to register and track each housing-related complaint in New York City [52]. The data collected are then analyzed to point out those properties with the highest chances of code violation. In the past, building inspectors used their personal experience or gust feelings to prioritize cases for follow-up. Nevertheless, this mode resulted in a low enforcement efficiency as the inspectors could not find property conditions adverse enough to warrant a vacate order in 87% of the cases. Later, the employment of big data analysis brought about a fivefold improvement in the building inspectors' efficiency. Prioritizing inspections based upon the results of big data analysis, building inspectors served vacate orders on over 70% of the properties they inspected. In New South Wales of Australia, the state government harnesses big data to blitz Sydney's illegal boarding houses [53]. Data from the utility bills, electoral rolls, and other sources are collected and used to find where there is an unusual increase in the number of residents.

The same idea can be applied to the identification of the ISUs in the existing building stock in Hong Kong. The big data approach proposed in this article has five key stages, as shown in Figure 5. In Stage 1, information required to address the ISU problem and data necessary to derive the required information are identified. In the case of an ISU search, the information required is the level of risk of a property or building with ISU proliferation. To derive such information, useful data such as monthly utility consumption of each property or building are needed. If a property is subdivided to create more micro units, the total number of occupants in the property is expected to rise. In normal situations, utility consumption increases with the number of occupants. Consequently, it can be the first alert of a subdivided unit if a dwelling unit has a much higher monthly consumption of water, gas, and electricity than a similar standard unit. Abnormal rises in the utility bills can indicate the illegal subdivision of a dwelling unit. To facilitate the subsequent comparative analysis, both historical and current data should be obtained.
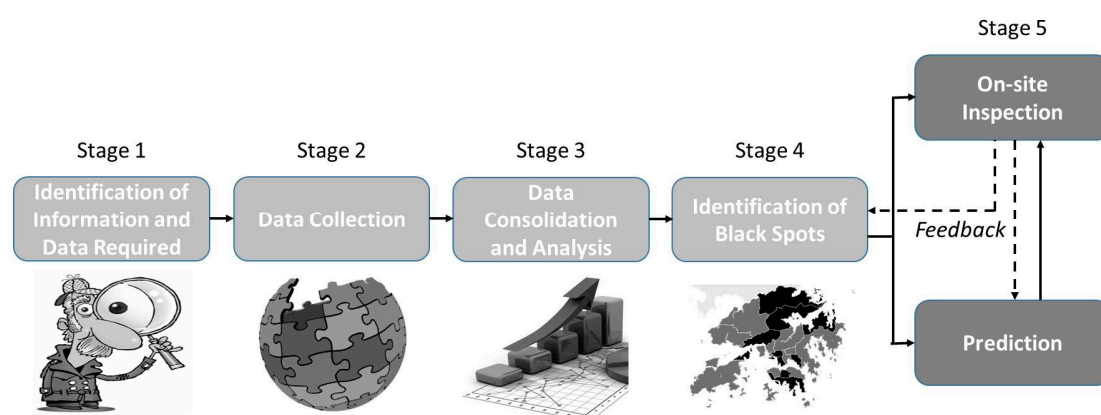

Figure 5. Five stages of the proposed big data approach.

Apart from the utility consumption, other information, such as the number of complaints or reports about water seepage in a building, may also give public officials some hints about the existence of ISUs in the building. In most cases, the conversion of a lawful flat into illegal micro units involves the installation of new toilets or bathrooms and alterations to existing pipework. All these works may increase the chances of water leakage from the pipes and water seepage through walls and slabs. Accordingly, it is reasonable to expect that a dramatic rise in the number of water seepage reports in a building is a good indication of ISU proliferation in that building.

Stage 2 is the collection of the required data. Utility consumption and usage is usually reflected in the utility bills. In this regard, the data required can be collected from various utility providers (e.g., Water Supplies Department, CLP Power Hong Kong Limited (Hong Kong, China), HK Electric Investments Limited (Hong Kong, China) and Hong Kong and China Gas Company Limited (Hong Kong, China)). As for the number of reports about water seepage, the data can be collected from the Joint Offices for Investigation of Water Seepage Complaints. We assume that monthly records of water, electricity, and town gas bills and water-seepage reports of all dwelling units in Hong Kong in a three-year moving window are necessary for a meaningful analysis for identifying problematic properties. Given that there are around 1,174,628 dwelling units in private housing in the city at as the end of 2017 [54], the dataset for analyses in the subsequent stage will have at least 211,433,040 entries (1,174,628 buildings × 12 months × 3 years × 5 columns) in the spreadsheet.

In Stage 3, the data collected in Stage 2 are consolidated and analyzed. In the data analysis, both cross-sectional and longitudinal comparisons can be made. In the cross-sectional analysis, utility bills of similar properties (e.g., properties of similar ages and sizes) are compared. Those properties with monthly or quarterly utility bills far exceeding the average figures are screened out. Similarly, properties with abnormally high number of water-seepage reports are identified. In the longitudinal analysis, the quarterly utility bills of the same property in different time periods are compared after adjusting for the seasonal factors. An abrupt, significant increase in utility bills may indicate potential illegal flat subdivision in the property. Apart from the unit-based analysis, data from the same building can be aggregated such that the big data analysis can be conducted on a building basis. In addition to utility bills, numbers of water-seepage reports can be deployed in the building-based analysis.

In Stage 4, properties or buildings at higher risk of illegal subdivision are identified based on the analysis results in Stage 3. These high-risk premises will become the black spots that warrant the government's priority enforcement actions. In Stage 5, the inspectors of the Buildings Department investigate those black spots to see if ISUs exist or not. There is a feedback loop such that the inspection results can be taken as an input, which helps the government improve black spot identification. For instance, the government can learn by trial and error what the optimal differential threshold for the utility bills should be. At the same time, the big data analytics can be further extended to enable predictive analysis. Predictive analysis can be a powerful tool for law enforcement or crime prevention. The public authorities can apprehend law-breakers based on foreknowledge of their future misdeeds. For instance, by looking into the characteristics of buildings with higher risks of ISU proliferation, the public authorities can identify a set of determinants. These determinants can be used to predict which buildings will be riskier and will warrant more attention in the future. Again, the accuracy of the prediction can be improved through the feedback mechanism.

The proposed big data approach is a kind of institutional innovation that aims to reduce the transaction costs incurred in the early stages of ISU enforcement by the public authorities. By analyzing the big data, the HKSAR Government can identify the ISU black spots on a property basis and a building basis with significantly reduced information costs. The property-based identification helps the Buildings Department to locate the properties that have very probably been subdivided illegally. This trims down the search costs for ISU enforcement. Moreover, based on the findings of building-based identification, the Buildings Department can have a more informed selection of target buildings for large-scale operations, directing the limited public resources to the neediest buildings.

In addition, the valuable information of abnormal utility consumption is a piece of evidence that the Building Authority can use for substantiating its applications to the court for entry warrants.

5. Research Findings and Discussion

5.1. Feasibility of the Proposed Big Data Approach

As Table 5 demonstrates, over 70% of the respondents in the survey rated the technical practicality of the proposed big data approach high or very high. Around 80% opined that the political acceptability of the proposed approach was high or very high. The mean scores for technical practicality and political acceptability were 2.97 and 3.11, respectively. They were both significantly greater than 2.5 which was the mid-value of the scale ($p < 0.01$). Therefore, the survey results reveal a strong collective view that the proposed big data approach is technically and politically feasible. The perceived high level of technical practicality might be ascribed to the fact that data about utility consumption in dwelling units and water-seepage reports was already easily available or obtainable in Hong Kong. There should be no need for the government to establish any new protocol for data collection. On the other hand, the proposed approach was considered politically acceptable probably because no introduction of new law or legislative amendment was envisaged. Moreover, it was believed that with the application of big data analytics, identification of ISUs would not cause any gratuitous nuisances to the building occupants.

Table 5. Respondents' responses regarding feasibility of the proposed big data approach

Response	Technical Practicality		Political Acceptability	
	Number	%	Number	%
Very high (4)	28	31.8%	32	36.4%
High (3)	35	39.8%	38	43.2%
Low (2)	19	21.6%	14	15.9%
Very low (1)	6	6.8%	4	4.5%
Total	88	100.0%	88	100.0%

Chi-squared tests were conducted to probe if the responses were dependent on the respondents' backgrounds. Gender was found to have significant impacts on both technical practicality and political acceptability ratings ($p < 0.10$). Technical practicality rating was found to be contingent on profession ($p < 0.10$) while there was no significant relationship between political acceptability rating and profession. As far as professional experience is concerned, it had no significant impact on technical practicality and political acceptability ratings. On the other hand, the sector in which a respondent was working was found to bear a significant association with the political acceptability rating ($p < 0.05$) but no impact on the technical practicality rating.

5.2. Transaction Cost Implications

Respondents' views towards transaction cost implications of the proposed big data approach varied across different stages of ISU enforcement. Over 80% of the respondents agreed or strongly agreed that the proposed approach could reduce the transaction costs incurred in the identification of ISUs. The proportion dropped to around 60% for in-flat inspection and further to around 30% for identification of persons responsible for the irregularities and lawsuit filing. Table 6 summarizes the mean scores of the respondents' responses. The mean scores for identification of ISUs and in-flat inspection were 3.14 and 2.74, respectively. They were both significantly greater than the mid-value of 2.5 ($p < 0.10$ at least), implying that respondents generally believed in the high potential of the use of big data in trimming down the transaction costs incurred in these two aspects of ISU enforcement. Conversely, the mean scores for identification of responsible persons and lawsuit filing were significantly less than the mid-value of 2.5 ($p < 0.01$). That means the respondents negated the

argument that the proposed big data approach could reduce the transaction costs incurred in the identification of persons responsible for the irregularities and lawsuit filing. These findings generally confirm our expectations. With the use of big data analytics, dwelling units with high potentials of being illegally subdivided can be identified more easily. With reference to the case in New York City discussed in Section 4.2, this protocol helps the government officials prioritize their enforcement actions, and thus enhance the overall enforcement efficiency. Although in-flat inspection is still indispensable in the process of ISU enforcement, the transaction costs incurred can be reduced with the aid of big data analytics. Signs spotted in big data analysis like abrupt upsurges in utility bills can be used as evidence for applying to the court for an entry warrant, lowering the costs of evidence collection.

Table 6. Perceived transaction cost implications of the proposed big data approach

Transaction Cost	Mean Score
Identification of ISUs	3.14
In-flat inspection	2.73
Identification of responsible persons	2.07
Lawsuit filing	1.99

Based on the survey results presented above, we need to admit that the proposed big data approach might not be able to reduce the transaction costs incurred in all stages of ISU enforcement. Yet, the survey findings still give a strong indication that the use of big data have can moderate the problems associated with high costs of identification of ISUs and in-flat inspection in the early stages of ISU enforcement. Overall, the opinions of the surveyed professionals support that the proposed big data approach is an institutional innovation which helps the government lower transaction costs of ISU enforcement.

5.3. Concerns about the Application of Big Data Approach

Uses of big data are always accompanied by challenges. The respondents raised some concerns with the proposed application of big data in fighting ISUs in Hong Kong; 36 respondents (40.9%) opined that big data could pose high privacy risks. In fact, the same concern has been named by many other studies [1,55,56]. Using big data may clash with the principle of data minimization for privacy protection, blurring the boundary between personal and non-personal data [7]. Privacy issues can constrain the use of big data, even for government administration and services. Collecting and manipulating sensitive data is a contentious topic of interest to many communities outside and inside the government [31]. It is probable that government departments are not willing to share data that they regard proprietary with other public agencies. The same applies to the private organizations. These organizations in competitive markets tend to use their big data internally and are reluctant to give access to outsiders for different reasons, such as loss of competitive advantage and potential public-relation disasters [3]. Even if the utility providers agree to share their data with the Buildings Department, whether it is lawful under the current privacy law in Hong Kong to use property-based utility consumption data for risk assessment is questionable. Utility usage is closely related to one's lifestyle, which is a private matter. To a large extent, the property-based utility bills may reflect one's lifestyle. Therefore, there can be privacy concerns associated with the employment of property-based data. We anticipate that the use of aggregate figures like building-based utility consumption is less problematic and attracts fewer criticisms.

Given that data for crime prevention or detection is generally exempted from the protection of privacy law, one possible way to get around the potential privacy issue is to treat the investigation of illegal flat subdivision as criminal investigation. A special taskforce or authority can be setup within the government and empowered to collect the private data from the utility companies or related government departments for ISU investigation. Analogous to the police force, the taskforce or authority uses the 'potentially sensitive' data for the public interest, i.e., ensuring public safety. That is

why the access and use of the utility usage data is not subject to the protection of the privacy law. In spite its legitimate right to collect and use the sensitive data, the authority can make it clear that it will observe important data protection principles concerning data collection, data use, data security, and openness in order to lessen the worries of the general public.

Moreover, although the proposed big data approach enables prediction, predictive analysis results should be used in a very careful manner. Thirteen respondents (14.8%) alerted that ISU proliferation prediction might lead to problems. On one hand, predictive analysis may trigger or aggravate redlining [56]. On the other hand, even with non-sensitive data, predictive analysis may have stifling effects on certain types of buildings in the long run [55]. For example, older buildings will have the deck stacked against them even more so than before. This will encourage premature redevelopment of old but well-maintained buildings. It is perhaps debatable whether or not we should apply the principle 'innocent until proven guilty' to buildings in the ISU war. This concerns how the balance between public interest (say, public safety) and private interest is maintained.

Apart from the issues of data privacy and data discrimination discussed above, there are some relatively minor concerns regarding the proposed big data approach. For instance, five respondents (5.7%) worried about the inadequate analytical know-how in the Buildings Department to handle big data. A few respondents also alerted that credibility of the big data analytics might be undermined by dirty data. This issue could be caused by incorrect data linking, duplicate data, or input errors.

6. Conclusions and Agenda for Further Research

The era of big data is still underway. While more and more literature has been dedicated to the discussion of the employability of big data analytics in the field of urban management, big data is often regarded as an information technology rather than a social technology. Besides, no attempt has been made to analyze big data application from a transaction cost perspective. Using the case of ISU enforcement in Hong Kong, this article aimed to expound why the public authorities fail in addressing the ISU problem and to recommend an institutional change in the enforcement system. With an eye to lowering the costs of information search and collection, the public authorities, particularly the Buildings Department, can collect information regarding, for example, consumption of water, gas, and electricity. Sharp increases in utility usage and the number of water seepage cases can be clear indications of ISU proliferation in a building. Use of big data in this way helps the HKSAR Government predict the likelihood of ISU proliferation in different buildings. The public authorities can improve the efficiency of their actions by targeting those buildings with greater risks in large-scale operations based on the analysis results. Results of a survey on local building professionals confirmed that the use of big data in curbing the ISU problem in Hong Kong is practical and promising. Nonetheless, while there are enormous benefits from big data analytics, the use of big data is not free of problems. For instance, the associated privacy risks should never be overlooked. Therefore, it is necessary for the policymakers to strike a balance between public interest and privacy. Lastly, one should bear in mind that the value of big data does not lie in its size. Bigger data is not always better data. It is the methodological design that actually determines the quality of big data analytics.

This article makes three major contributions. First, it offers deeper theoretical insights into the failure of public enforcement actions in the arena of building control. Transaction cost economics, which has been accorded little attention by academics in the field, is employed for the explanation. Yiu and Yau's work in 2005 [19] was the first attempt to expound why UBWs proliferate in Hong Kong from the transaction cost perspective. They argued that poorly written laws resulted in ambiguities and increased the enforcement costs. Studying the information search and collection processes of the whole enforcement exercise, this article is an extension of their work. Second, the article discusses the application of big data analytics in building control. Again, this is an innovative idea, which may stimulate more research in the field in the future. Third, the big data approach advocated can inform policy making with regard to long-term management of building stock in Hong Kong and other

high-rise cities. Vigilant building stock management can ensure safety and health of the community and is thus critical for urban sustainability of a city [57].

On the other hand, the opinion survey reported in the current article indicates the views of the local building professionals only. It is necessary to collate the views of data scientists towards the practicality of the proposed big data approach. Moreover, a true validation of the proposed approach is needed. The effectiveness of the proposed big data approach cannot be evaluated at this moment because the approach has yet been put in place and there are some privacy concerns which hinder data sharing. Once the proposed approach is executed by the government, further research is warranted to investigate if the approach can really reduce the amount of man-hours incurred in the identification and enforcement against ISUs. Besides, it will be interesting to investigate how different stakeholders, particularly landlords and tenants of ISUs, respond to this new tactic to crack down on ISU proliferation when it is executed. It is expected that the number of ISUs should drop as a result of increased efficiency of irregularity identification. The empirical inquiry into the deterrent effects can further confirm the effectiveness of the proposed approach. Last but not least, the applicability of the big data approach in controlling other types of building illegality or informal settlements—such as urban villages, small property right housing, and illegal accommodations in industrial buildings—can be explored in the future.

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