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The value of building safety: A hedonic price approach

Theoretical and empirical studies on how building performance is valued by the property market abound in the literature. Some of them investigate changes in property prices after building renovation, but little has been done on pricing the safety performance of buildings. This article presents a study that explores whether residential properties in safer buildings command higher market values in Hong Kong. Hong Kong is a good laboratory for this study because building failures can pose a serious threat in such a densely populated high-rise environment. The study measures the safety performance of a building by the weighted number of unauthorised building works (UBWs) on the external walls of the buildings. By their nature, UBWs are building works that are constructed without prior approval and consent from the government. A hedonic price model is developed to assess the market value of building safety. For the model estimation, apart from the property transaction data, the number of unauthorised appendages (i.e., UBWs attached to the building facades) in each building studied is obtained through a building survey. Based on the analysis results, several hypotheses built upon the theories of self-protection and self-insurance are tested.

Keywords: building safety, hedonic pricing model, self-protection, self-insurance, unauthorised building works

1 Introduction

"A safe home is a good home", as the saying goes. Safety is defined by the World Health Organization (1998: 6) as "a state in which hazards and conditions leading to physical, psychological or material harm are controlled in order to preserve the health and well-being of individuals and the community". From an etymological perspective, safety is about the wholeness of physical life. This is because *salvus* and *solwos*, the Latin and Proto-Indo-European antecedents of word *safe*, mean 'uninjured and healthy' and 'whole', respectively (Nilsen et al., 2004). Therefore, it is sensible for Alton Thygerson (1977) and Thomas Hunter (1992) to define safety as a state free from hazard or danger. With reference to these definitions, Yung Yau, Daniel Ho and Kwong-Wing Chau (2008: 503) interpreted building safety as "the achievement of a building in safeguarding its occupants and the general public from the harms originated [sic] from the built environment, which in turn reduces injuries and deaths". To perform its function, a building should be safe in many senses. For example, a building should be structurally stable and fire-resistant, and the escape routes free from any obstructions.

In order to ensure the safety of the building stock, governments usually adopt three approaches. The first approach is building inspection, which makes sure the safety level of all buildings in a city meets the minimum acceptable standards through strict monitoring and enforcement of building codes or regulations (Crook & Hughes, 2001). For instance, building authorities apply penalties for properties in disrepair and illegal building works (Hattis, 1981; Yiu & Yau, 2005). Subsidisation is a second means of state intervention. Grants and loans have been offered to property owners for improvements (including maintenance and rehabilitation) to their properties around the world (e.g., Whalley, 1988; Boyne et al., 1991; Scanlon, 2010; Yau et al., 2013). Third is a state-led redevelopment programme that aims to replace unsafe properties with safe ones (Yau, 2011; Ho et al., 2012; Kotze, 2013). In addition to these three approaches, market forces may help motivate property owners to keep their buildings safe (Yau, 2009). In theory, safer properties should have higher values, all other things being constant. There is a large volume of empirical literature on how an overall change in building performance or conditions (e.g., through refurbishment and renovation) is reflected in property price or rental level (Chau et al. 2003; Hui et al., 2008; Fortes & McCarthy, 2010) but little has been done specifically on pricing the safety performance of buildings. In this regard, this preliminary research explores whether residential properties in safer buildings command higher market values in Hong Kong. For the purpose of this study, the safety performance of a building is measured by the weighted number of unauthorised appendages on the external walls of the buildings. A hedonic price analysis is conducted to assess the market value of building safety. Based on the analysis results, three hypotheses built upon the theories of self-protection and self-insurance put forward by Isaac Ehrlich and Gary Becker (1972) are tested.

Hong Kong is a good laboratory for this study because it is a densely populated city where high-rise buildings are common. In such an environment, building failures can pose a serious threat (Yau, 2010). A number of terrifying building-related accidents occurred in the city in recent years, including the sudden collapse of a fifty-five-year-old apartment building in To Kwa Wan, Hong Kong that claimed four lives in January 2010 (Buildings Department, 2010). These accidents have vividly demonstrated the painful consequences of neglecting building safety. There are two major reasons why the safety performance of a building is proxied by the number of unauthorised appendages, which are essentially illegal or unauthorised building works (UBWs). First, the problem of UBW proliferation has attracted much public attention in Hong Kong, particularly because many top government officials and lawmakers found themselves embroiled in scandals involving illegal structures in 2011 and 2012 (Ma, 2011; Foo, 2012; Luk, 2012). Second, unauthorised appendages are the most easily observable among all types of UBWs.

2 Literature review

2.1 Building quality as a determinant of property value

Much evidence shows that building quality is positively correlated with occupants' satisfaction and quality of life (e.g., Moolla et al., 2011; Huston & Li, 2013; Sendi, 2013; Shrestha, 2013; Aigbavboa & Thwala, 2014; Tsenkova, 2014). In fact, building quality has been regarded as an important determinant of property value. Andrew Baum (1991, 1994) and Daniel Ho (2000) showed that commercial buildings of better quality brought higher returns to the owners. In the residential property sector, Peteke Feijten and Clara Mulder (2005) asserted that the quality of a dwelling can be ideally reflected in its value or price. In the broadest sense, the quality of a building embraces all the attributes related to the building. A survey of empirical literature (e.g., Mok, 1995; Mok et al., 1995; So et al., 1997; Tse et al., 1997; Tse & Love, 2000; Chau et al., 2001; Yau, Chau et al., 2008; Yau, 2009) suggests that, apart from time factors, the value of a residential property is determined by its structural characteristics (e.g., age and size), locational characteristics (e.g., floor level and accessibility to public transport) and external environment (e.g., view and proximity to parks). Nonetheless, previous studies tended to examine the impacts of building design and environmental factors on property prices. These factors are mostly intrinsic or are not easily adjustable by property owners, particularly after a property is in use. Building quality attributes such as building conditions and the presence of illegal structures, which are more easily adjustable or manageable by property owners, have not attracted much attention from researchers.

Similar to the design and environmental characteristics, building conditions have often been thought of as influencing property price. Without any empirical support, Scott Arens (1997) analytically argued that defective properties should be valued at a discount in view of the potential costs of remediation, higher vacancies and extra insurance premiums. John Kain and John Quigley (1970) empirically showed that properties in better condition were sold at higher prices. Similar findings were returned from other studies (Bourassa & Peng, 1999; Bulter, 1982; Jimenez, 1983). In addition, the presence of substandard structural items in a building was found to suppress property prices (Murdoch et al., 1993). In another stream of research, property value was shown to change with building condition as a result of an improvement project. For example, Kwong-Wing Chau, Andrew Leung, Chung-Yim Yiu and Siu-Kei Wong (2003) carried out a hedonic price analysis to study how a refurbishment project affected property value in Hong Kong. Their research showed an approximately 9% rise in property value brought about by refurbishment, implying that there was a significant positive relationship between building quality and property value. Another study in Hong Kong showed that building rehabilitation resulted in an average 35.6% enhancement of property value (Hui et al., 2008). In New Zealand, property price was also found to increase by 1 to 8% after home improvement (Fortes & McCarthy, 2010).

As a whole, although there are many empirical studies on the relationship between building quality and property value, most of them are not specifically related to the safety performance of buildings. The improvement projects investigated by Chau et al. (2003) and Hui et al. (2008) were associated with improving the safety, hygiene and aesthetic quality of buildings at the same time. These previous studies do not show whether the housing market values properties in a safer building at a premium.

2.2 Theories of self-insurance and self-protection

The price-safety connection of housing can be conceptualised based on the theories of self-insurance and self-protection as put forward by Ehrlich and Becker (1972). These two theories frame how rational individuals make choices among various actions when facing risks. Very often, individuals participate in an array of risky activities that may jeopardise their own safety (Blomquist, 2004). Driving a car and cycling are typical examples of such risky activities. By engaging in these activities, an individual may risk injury or property damage, and so he can take out insurance against potential losses. Alternatively, the individual may choose to drive a car or ride a bicycle slowly and carefully in order to reduce the chance of an accident, or recourse can be made in the form of protective measures such as seatbelts and bike helmets to reduce loss in the case of accident.

2.2.1 Choice among market insurance, self-insurance and self-protection

In their classic paper, Ehrlich and Becker (1972) devised a state-preference approach to explain an individual's choices and behaviour under uncertainty by combining the indifference curve and expected utility analyses. In their premise, there are two states of the world: good states (or well-endowed states) and bad states (or less well-endowed states). Examples of the bad states include fire, earthquakes and many other man-made or natural disasters. Facing a prospective loss in a bad state, an individual can either insure against the loss or take steps to lower the likelihood that the loss will occur. In this sense, individuals are required to determine their optimal expenditures on a set of alternative instruments; namely, market insurance, self-insurance and self-protection. In Ehrlich and Becker's language, self-insurance refers to effort to reduce the sizes of prospective losses from bad states, given the probability of distribution of the corresponding bad states. Self-protection, in contrast, refers to effort to reduce the probabilities of bad states given the magnitudes of the corresponding prospective losses.

In the characterisation by Ehrlich and Becker (1972), market-insurance and self-insurance are similar. They both aim to lower sizes of loss in bad states by transferring an individual's income from good states to bad states. By choosing not to insure through a market or to self-insure, the individual has to bear by himself the losses that arise from any bad states. Sometimes this is the only option available because instruments for market insurance and self-insurance are not available. Market insurance, if available, can be purchased at a price that is usually called the premium. What makes self-insurance different from market insurance is the absence of an insurance market for self-insurance. An explicit price for self-insurance therefore does not exist. Nonetheless, the price of self-insurance can be imputed to the costs incurred in self-insuring by the individual. Other than pricing, the mechanism of risk pooling also marks a significant difference between the two types of insurance. Risk is pooled across different individuals in market insurance but not in self-insurance. Unlike the two insurance options, self-protection does not involve any income transfer from good to bad states. It targets the reduction of the probabilities of bad states rather than lowering the sizes of loss in bad states.

In a world without insurance markets, individuals can only resort to self-insurance and self-protection to mitigate any prospective losses. If market insurance is available, it is a close substitute for self-insurance as long as the premium of market insurance is independent of the extent of self-insurance taken (Ehrlich & Becker, 1972). The take-up of self-insurance will drop with an increasing availability of market insurance with an actuarially fair price. For mitigating a "rare" or low-probability loss, market insurance is preferred to self-insurance because the premium of market insurance decreases with the probability of loss, whereas the costs incurred or the implicit prices of self-insurance do not (Ehrlich & Becker, 1972). In other words, to achieve the same level of reduction in the probability of a rare loss, the cost or the amount of effort paid for self-insurance generally exceeds the market insurance premium. Therefore, the low cost-effectiveness will discourage people from self-insuring against rare losses. In other words, self-insurance is subject to crowding out (Simmons et al., 2002). This view is empirically supported by Paul Fronstin and Alphonse Holtmann (1994). In contrast, market insurance and self-protection complement each other provided that the former is available in the market at an actuarially fair rate (Ehrlich & Becker, 1972). The rationale for this complementary relationship is straightforward. In order to reduce the risk of moral hazard, the premium of market insurance should reflect the amount of self-protection effort taken by individuals to reduce the probability of loss. Any effort of self-protection perceived to be effective is recompensed by the market in the form of a lower premium. Following this line of thought, the coverage of market insurance is not necessarily negatively correlated with the amount of effort paid for self-protection by individuals.

2.2.2 Self-insurance, self-protection and house value

Much empirical research has attempted to evaluate the market values of various self-insurance and self-protection measures. Some literature studied how self-insurance measures affected the prices of a wide range of services and products such as automobiles (Boulding & Purohit, 1996; Andersson, 2005). In the real estate market, self-insurance usually appears in the form of mitigation measures that reduce the losses of life and property in natural hazards. For example, housing in earthquake-prone areas can be designed and constructed to become earthquake-resistant. Using the contingent valuation method, Kenneth Willis and Ali Asgary (1997) found that the prices of earthquake-resistant houses in Iran were significantly higher than those for non-resistant houses. Furthermore, Kevin Simmons, Jamie Kruse and Douglas Smith (2002) estimated the market values for hurricane blinds for beachfront buildings on the Gulf Coast in the United States. On average, a premium of USD 4,000 was added to the value of a house equipped with hurricane blinds. Kevin Simmons and Daniel Sutter (2007) also showed that a tornado shelter increased the sale price of a home by approximately USD 4,200 in Oklahoma City.

As for self-protection, several hedonic studies examined the value of reducing the probability of a loss from a natural hazard by relocating out of harm's way. David Brookshire, Mark Thayer, John Tschirhart and William Schulze (1985) studied the housing markets of Los Angeles and San Francisco and showed that homes located outside earthquake-prone areas were sold at a premium. James Shilling, John Benjamin and C. F. Sirmans (1985) found that homes located outside a floodplain in Baton Rouge were sold at higher prices than those within the floodplain. Similar studies were conducted in other parts of the US (MacDonald et al., 1987; Donnelly, 1989; Speyrer & Ragas, 1991; Harrison et al., 2001; Bin et al., 2008; Posey, 2010) and their results confirmed the findings of Shilling et al. (1985). Findings in other studies also showed that self-protection mitigations were priced in property transactions. Prices of houses were higher when they were sited beyond the influence of potentially hazardous facilities such as nuclear plants (Gamble & Downing, 1982), chemical plants (Carroll et al., 1996), landfills (Nelson et al., 1992) and gas pipes (Kask & Maani, 1992). Sometimes the hazards associated with the living environment are not known until relevant information is disclosed by some other parties. It was shown by Richard Bernknopf, David Brookshire and Mark Thayer (1990) that the announcement of hazards regarding earthquake and volcanic activities in the Mammoth Lakes area in California depressed house prices in that area. Comparable results were obtained by Burrell Montz (1993), who focused on the disclosure of flooding risk in New Zealand. The house price differentials detected in these studies provide additional evidence for the values of self-protection mitigations in property markets.

Although there is much empirical research applying the theories of self-insurance and self-protection to property market, nearly all focused on "external" hazards, including natural hazards (e.g., floods, hurricanes and earthquakes) and technological hazards (e.g., nuclear plants and waste storage or treatment facilities). "Internal" hazards associated with a property such as the safety performance of a building (e.g., fire hazards and structural failures) have largely been ignored. Moreover, previous studies predominately focused on low-rises, particularly single-family houses; little research has examined high-rises such as apartment buildings.

Figure 1: Lightweight canopies, flower racks and drying rack (photo: Yung Yau).

Figure 2: Solid extension (photo: Yung Yau).

3 Hypotheses and analytical model

3.1 Proliferation of unauthorised appendages as a measure of building safety performance

To study how the safety performance of a building is valued by the property market, this research takes the degree of proliferation of unauthorised appendages in the building as the measurement of the safety performance of the building. Unauthorised appendages are commonly found in Hong Kong and include unauthorised cages, drying racks, flower racks, lightweight canopies, and air-conditioner support frames that are attached to the external walls of buildings. Figures 1–3 show some examples of unauthorised appendages in apartment buildings in the city. These building works are unauthorised because they were constructed without prior approval of the building plan or consent to start work per the requirements of the Buildings Ordinance (Ho et al., 2008). The degree of proliferation of unauthorised appendages is used as a proxy for building safety performance for both practical and academic reasons. Practically speaking, because they are attached on the external walls of a building, unauthorised appendages are very easily identified compared with other types of UBWs. In addition, unlike structural stability and fire safety, the evaluation of which usually involves sophisticated testing or assessment, the appraisal of unauthorised appendage proliferation in a building is straightforward and relatively less costly. Academically speaking, employing the degree of UBW proliferation as a measure of building safety performance can facilitate the valuation of self-protection mitigations and self-insurance mitigations in safeguarding a building's safety in the absence of any influence by market insurance. This is simply because property losses, personal injuries and deaths caused by UBWs are not covered by the property-all-risk or third-party-liability

Figure 3: Metal cages (photo: Yung Yau).

insurance policies for buildings in Hong Kong. Therefore, the effect of market insurance can be ignored as far as the study of unauthorised appendages is concerned.

For increasing the amount of usable space or amenities for building users, unauthorised appendages are relatively easier to construct compared to other types of UBWs (Ho et al., 2008). However, such UBWs jeopardise building safety because their structural soundness is uncertain and they affect approved building works on or near which they are built (Choy, 1998). Proliferation of unauthorised appendages may also adversely affect the fire safety of a building because UBWs block firemen's access to building facades. From the perspective of health risks, unauthorised appendages often block natural light and ventilation from entering the building. As added by Kenneth Chan (2000), protruding unauthorised structures might indirectly aggravate the problems of building decay because they make repairs and maintenance of external walls more difficult. When an unauthorised appendage fails, it may cause casualties, property losses and social costs (e.g., hospitalisation and legal costs). In fact, fatal accidents involving UBWs are not uncommon in Hong Kong. There were twenty-one deaths and 135 injuries inflicted by UBW-related accidents in Hong Kong between January 1990 and December 2002 (Leung & Yiu, 2004). Several court judgments have established that all co-owners of a multi-owned building are liable for the casualties and property losses caused by failures of unauthorised appendages on the building.

Unauthorised appendages pose safety hazards of various degrees for building occupants and the public. Some are more harmful than others. From the public authority's perspective, unauthorised appendages that are more hazardous should be given more attention. The Buildings Department (2005) categorised unauthorised appendages under two categories: actionable and non-actionable UBWs. The former were thought to be an imminent danger to occupants and the public, and so they should warrant priority removal. According to the Buildings Department (2005), these high-risk unauthorised appendages included:

a. Cages, flower racks, structures or canopies of solid construction on the external walls, re-entrants, and lightwells, irrespective of the extent of their projection;
b. Dilapidated canopies and advertisement signs on the external walls, re-entrants and lightwells, irrespective of the extent of their projection;
c. Dilapidated or abandoned air-conditioning unit support frames, metal frames, chimney cages, flower racks, struc-

tures or canopies of solid construction on the external walls, re-entrants and lightwells, irrespective of the extent of their projection;

d. Lightweight canopies projecting more than 500 mm from the external wall;
e. Air-conditioning unit support frames projecting more than 600 mm from the external wall;
f. Structures on or attached to approved canopies, or attached to approved balconies;
g. Rooftop and flat roof structures with projections;
h. UBWs of two storeys or more; and
i. UBWs built on top of another UBW.

On the other hand, non-actionable unauthorised appendages were those posing a relatively limited degree of hazard to occupants and the public. Common examples of these are drying racks and lightweight canopies that project less than 500 mm from the external walls. Owing to the comparatively lower risks associated and the amenity offered to building users, these UBWs have been tolerated by the Buildings Department. Following the Buildings Department's (2005) dichotomy of unauthorised appendages, this study measures the degree of proliferation of unauthorised appendages by taking a weighted average of the numbers of actionable and non-actionable unauthorised appendages per dwelling unit in a building. Mathematically,

$$\text{Degree of profileration} = 1 \text{ x } N_{\text{non-actionable}} + 5 \text{ x } N_{\text{actionable}}$$

where $N_{\text{non-actionable}}$ and $N_{\text{actionable}}$ denote the numbers of non-actionable and actionable unauthorised appendages, respectively. A heavier weighting is placed on the number of actionable unauthorised appendages because of the higher risks associated with this type of UBW.

3.2 Hypotheses for empirical testing

Based on Ehrlich and Becker's (1972) theory of self-protection, if safety risks created by UBWs are not covered by market insurance, a rational individual should pay less to buy a property in a building with a higher degree of proliferation of unauthorised appendages because the probability of a building failure associated with unauthorised appendages is higher. Given the same degree of proliferation, according to Ehrlich and Becker's (1972) theory of self-insurance, a rational individual should pay less to buy a property in a building abutting one or more busy streets. This is because, when an unauthorised appendage fails and falls onto the street, the damage will be greater. Founded on these theoretical predictions, two hypotheses are developed for empirical testing in this study:

- Hypotheses 1: Properties in a building with a higher degree of proliferation of unauthorised appendages are sold at a discount, keeping other things constant.
- Hypotheses 2: Properties in a building with unauthorised appendages and abutting one or more busy streets are sold at a discount, keeping other things constant.

3.3 Analytical model

To test the two hypotheses above, an analytical model is broadly specified as follows:

$$PRICE = f(S, L, T, U)$$

In Equation 2, the sale price of a residential property, *PRICE*, is taken as a function (*f*) of four vectors of determinants; namely, *S*, *L*, *T* and *U*. The vector *S* contains structural characteristics of the property, including building age and floor area of the property. Vector *L* represents the locational factors of property, including the vertical location of the property in a building and the distance of the building from the nearest mass transit station. *T* is a vector of time dummies, which indicate the date of transaction (in month) of the property for controlling the time effects on property price. The focus of this study is placed on the vector *U*, which encompasses factors related to risks associated with the proliferation of unauthorised appendages.

The operationalised independent variables under various vectors are reported in Table 1. Because the specification of the analytical model is not known *a priori* in the absence of theoretical support, a semi-log functional form is used. This functional form is chosen for a practical reason because, when there is the possibility of an omitted variable bias, a semi-log model outperforms other functional forms (Cropper et al., 1988). Quadratic terms are also included in the model to address the non-monotonous effects of the continuous control variables on the dependent variable. The resultant hedonic price model established for this study to estimate the value of safety performance of a building is

$$\begin{aligned}\ln PRICE_{st} = {} & \alpha_0 + \alpha_1\, AGE_s + \alpha_2\, AGEs^2 + \alpha_3\, FLOOR_s + \alpha_4\, FLOORs^2 + \alpha_5\, AREA_s \\ & + \alpha_6\, AREA_s^{\,2} + \alpha_7\, MTRD_s + \alpha_8 MTRD_s^{\,2} + \beta_1\, UNAPPs \\ & + \beta_2\, UNAPP_s \times BSTREET_s + \sum_{t=1}^{T} \gamma_t\, TIME_{st} + \varepsilon\end{aligned}$$

where $PRICE_{st}$ denotes the transaction price of property *s* at time *t*; $TIME_{st}$ is a vector of monthly time dummies; *α*, *β* and γ are coefficients to be estimated; and ε is the stochastic term.

For the purpose of this study, a "busy street" is defined as a street with a high pedestrian flow or high traffic flow. More specifically, a street is classified as a busy street if it has four or more traffic lanes or if a street market or similar feature is

Table 1: Description of the independent variables used in the hedonic price model.

Symbol	Unit	Description
AGE_s	months	The age of the building, which equals the difference between the date of the issue of the occupancy permit and the date of the transaction
$FLOOR_s$		The floor level of the transacted property
$AREA_s$	square feet	The usable floor area of the transacted property
$MTRD_s$	metres	The distance between the transacted property and the nearest Mass Transit Railway (MTR) station
$UNAPP_s$		The weighted average of the numbers of actionable and non-actionable unauthorised appendages per dwelling unit in the building in which the transacted property is located
$BSTREET_s$		A dummy variable that equals 1 when the property is located in a building abutting one or more busy streets and zero if otherwise

Table 2: Summary of unauthorised appendage proliferation in the sixty-four developments.

Type of unauthorised appendage		Maximum	Mean	Minimum	Standard deviation
Actionable	Solid canopy	4	0.2	0	0.3
	Lightweight canopy (projecting more than 500 mm from external wall)	42	1.2	0	5.2
	Air-conditioner support frame (projecting more than 600 mm from external wall)	8	0.2	0	0.5
	Metal frame	27	1.5	0	4.6
	Metal cage	8	0.2	0	0.6
	Solid extension	1	0.1	0	0.1
	Flower rack	19	0.8	0	1.7
Non-actionable	Lightweight canopy (projecting not more than 500 mm from external wall)	189	9.5	0	17.2
	Air-conditioner support frame (projecting not more than 600 mm from external wall)	317	38.1	18	34.8
	Drying rack	287	16.4	34	21.2
Overall		542	178.4	19	129.0

found on the street. This characterisation delineates buildings that are more hazardous in the case of failure of any unauthorised appendage.

4 Data: Sources and descriptions

To estimate the empirical model, the transaction data of residential properties in sixty-four developments in Tai Po, Hong Kong were employed. This geographical area was selected because the building stock in the area was rather stable. There were not extensive development or redevelopment projects underway in the area in the past three years. In addition, buildings with different ages and configurations (e.g., single tenement blocks and high-rise apartment buildings) were available in the area. The data for property transactions between 1st July 2013 and 31st December 2013 were obtained from the Economic Property Research Centre. A study window of six months was chosen as a result of a balance between two different forces. On the one hand, a wider study window offers more data points for more meaningful model estimation. On the other hand, the degrees of unauthorised appendage proliferation in the subject buildings vary over time, which makes the empirical investigation more complicated. The longer the time horizon considered, the more likely the changes in degrees of unauthorised appendage proliferation.

It is assumed that the evaluated degrees of unauthorised appendage proliferation in the subject buildings held for the entire study period between 1st July 2013 and 31st December 2013, regardless of the dates of building inspections. Moreover, within the study window, there were no significant changes in the conditions of all the buildings selected. No large-scale refurbishment or rehabilitation works were undertaken for the buildings. Approved building plans of the sixty-four developments, retrieved from the Buildings Department, were

Table 3: Descriptive statistics of the continuous independent variables (n = 412).

Variable	Maximum	Mean	Minimum	Standard deviation
Transaction price (HKD million)	4.90	1.95	0.58	0.39
Flat size (square feet)	1,655.00	422.31	214.00	193.23
Floor level	26.00	9.98	1.00	5.13
Age (months)	534.00	343.14	199.00	62.14
Distance from MTR station (metres)	740.00	677.15	387.00	102.78
Weighted average of the numbers of actionable and non-actionable unauthorised appendages per dwelling unit	4.78	2.11	0.34	0.99

studied. Inspections were carried out on these buildings for identifying and counting unauthorised appendages. Table 2 summarises the statistics of unauthorised appendages in the sixty-four developments. Twenty-six developments out of sixty-four (40.6%) abutted at least one busy street. Within the study period, there were 412 transactions altogether. The descriptive statistics of the continuous independent variables are summarised in Table 3. Moreover, no significant correlations between the independent variables were spotted upon scrutiny of the correlation matrix of the dataset.

5 Analysis results and discussion

The estimation results of the hedonic price model, expressed in Equation 3, are shown in Table 4. The adjusted R^2 of the estimation was 0.59. The coefficients of *AGE* and AGE^2 were statistically significant at least at the 10% level, although their signs were different. With a negative coefficient for the first-order term and a positive coefficient for the second-order term, the effect of the variable *AGE* on property price decreased at a diminishing rate, but the rate of change was negligibly small. Conversely, opposite results for the effect of floor area on property price were returned from the hedonic price analysis. The coefficient of *AREA* was found to be positive, but negative for $AREA^2$, and both coefficients were statistically significant at the 1% level. Similarly, the diminishing trend in the positive relationship between floor area and property price was trivial. Regarding the coefficients of *FLOOR* and $FLOOR^2$, the former was found positive and statistically significant at the 5% level, with the latter being insignificant even at the 10% level. These findings confirmed the findings of my other hedonic price analyses (e.g., Mok, 1995; So et al., 1997; Yau et al., 2008), in which a significant positive relationship between floor level and property price was evidenced. As for the variables concerning the distance between the subject property and the nearest MTR station, only the first-order term was found to be statistically significant at the 10% level. The coefficient of *MTRD* was found to be negative, implying that properties with better accessibility were sold at a higher price.

Regarding the aim of this study, attention should be paid to the estimated coefficients of the variable *UNAPP* and interaction term *UNAPP* x *BSTREET*. The coefficient of the variable *UNAPP* (i.e., β_1) offers an indication of the impact of the degree of proliferation of unauthorised appendages in a building on the selling prices of dwelling units in the building. In other words, the estimated coefficient of the variable measures the value of self-insurance mitigation with regard to building safety, or buying a property in a building with less risk created by unauthorised appendages. The coefficient of the interaction term (i.e., β_2) measures the price differential between properties in a building with unauthorised appendages and facing one or more busy streets and those in a building with unauthorised appendages but not facing any busy street. The coefficient assesses the value of self-protection mitigation with regard to building safety, or buying a property in a building with smaller probable losses (e.g., property losses or injuries) in the case of an unauthorised appendage failure.

From the analysis results shown in Table 4, these two elements were found to have significant and negative effects on property price (at the 5% level at least). This means that, keeping other things constant, dwelling units in a building with a higher degree of proliferation of unauthorised appendages were sold at a discount and dwelling units in a building with unauthorised appendages and abutting one or more busy streets were sold at a discount. In other words, both hypotheses of the research were not rejected by the empirical findings. The results of the hedonic price analyses indicated that dwellings in buildings with a lower probability of loss were sold at a higher price, *ceteris paribus*. At the same time, the loss reduction feature of the buildings under investigation (i.e., located away from a busy street) was found to have a positive market value. These findings concurred with Ehrlich and Becker's (1972) prediction that, in the absence of market insurance, loss prevention and loss reduction mitigations were valued positively by the market.

In spite of its preliminary nature, this research has important findings that entail far-reaching policy implications. The anal-

Table 4: Estimation results of the hedonic price model.

Independent variable	Coefficient	*t*-statistic		
CONSTANT	−1.04	−4.12	***	
AGE	-3.13×10^{-3}	−2.20	**	
AGE^2	3.34×10^{-6}	1.93	*	
FLOOR	0.03	2.01	**	
$FLOOR^2$	-7.12×10^{-4}	−0.96		
AREA	2.11×10^{-3}	6.89	***	
$AREA^2$	-6.14×10^{-7}	−3.62	***	
MTRD	-3.30×10^{-4}	−1.95	*	
$MTRD^2$	1.03×10^{-6}	1.02		
UNAPP	−0.09	−2.07	**	
UNAPP × *BSTREET*	−0.02	−1.69	*	
Adjusted R^2	0.5852	Durbin–Watson statistic		1.49
F-statistic	14.72***	No. of observations		412
Dependent variable	ln *PRICE*			

Notes: (***), (**) and (*) denote the estimated coefficients of the variables and test statistics to be significant at the 1% level, 5% level and 10% level, respectively; The results for the time dummies were omitted, but are available upon request.

ysis results suggested that loss-prevention and loss-reduction measures with respect to failures of unauthorised appendages were rewarded by the housing market in the absence of market insurance. These findings basically support the use of market forces to motivate building owners to keep their buildings safe. Properties in safer buildings command a high value, and so a value league on building safety performance can be established. With an eye for higher property values, homeowners are incentivised to remove UBWs in their buildings and keep them UBW-free. Instead of coercion and subsidies, governments can institutionalise measures to facilitate a smooth exchange of information about safety performance of buildings among different players within the housing market. For example, governments can make the information about UBWs present in each building available to the public. By doing so, market players can benchmark the safety performance among buildings more readily and confidently. The benefits of reduction in the probability of loss and prevention of loss will be more likely fully priced in property transactions. This view is in line with the findings of Geoffrey Donovan, Patricia Champ and David Butry (2007) and Vanessa Daniel, Raymond Florax and Piet Rietveld (2009) that disclosure of safety risk to the public increased the price differentials between properties associated with different levels of risk.

On the other hand, the option of market insurance for loss reduction was omitted in the current research. When market insurance is available, the price differentials between properties in safer and not-so-safe buildings may depend on homebuyers' or building owners' decisions to take out a building-related insurance policy (e.g., property-all-risk or third-party liability insurance). If a homebuyer plans to take out insurance for a property after its acquisition, he or she is willing to pay more for a safer property (or, more precisely, a property with a lower likelihood of building-related accidents) in view of the lower insurance premium. In this regard, the monetary returns from loss-prevention measures regarding building safety will be more evident, or even increased, if building-related insurance is made compulsory for all residential buildings in a city.

6 Conclusion

This study was motivated by an urgent need to find ways to sustainably manage building stocks apart from law enforcement, subsidisation and state-led redevelopment. A market approach is a probable resort given that market players place a value on the safety performance of buildings. Although the feasibility of the market approach to promote other aspects of building quality such as environmental sustainability has been well researched (e.g., Yau et al., 2014), the economics of building safety have been largely ignored in the literature. In order to examine whether a market approach can motivate building owners to keep their buildings safe, this study evaluates the value of building safety performance in Hong Kong. Testable hypotheses were developed based on Ehrlich and Becker's (1972) theories of self-protection and self-insurance. For the research purpose, the safety performance of a residential building was measured by the degree or extent of proliferation of unauthorised appendages in the building. For hypothesis testing, a hedonic price analysis was conducted on a set of panel data that consists of property transactions in buildings with various degrees of unauthorised appendage proliferation and locational characteristics.

The analysis results showed that properties in more unsafe buildings were transacted at a discount, compared to those in relatively safer buildings. This exemplified the positive market value of loss-prevention effort. Moreover, given the same level of building safety, properties in a building abutting one or more busy streets were sold at a discount compared to those in a building not abutting any busy street. Loss-prevention mitigation is thus valued positively by the market in the absence of market insurance. As a whole, better safety performance of a building was found to command a positive value in Hong Kong's housing market.

This study is admittedly rather preliminary on account of its research limitations such as the small number of observations. However, the author hopes that this study can stimulate more empirical studies on the economics of building safety. The findings of such further research could offer very valuable insights to public administrators in formulating better-informed policies with regard to the sustainable management of building stock in different parts of the world. For example, testing the self-protection and self-insurance theories can be extended by investigating more types of UBWs. Some UBWs such as unauthorised appendages and alterations of load-bearing structures increase the chance of building failure, whereas some other UBWs such as installations of gates that obstruct escape routes increase the casualties (i.e., potential losses) in the case of fires and other emergencies.

Furthermore, other aspects of building safety such as fire safety and freedom from external safety hazards (e.g., location further from a petrol station) can be studied. Based on various mitigation measures embodied in either better building design and proper building management and maintenance, a loss-prevention index and loss reduction index can be developed. With the two indices or indicators, market insurance can be taken into account and various premises of Ehrlich and Becker (1972) can be tested. For instance, when market insurance for building safety (say, third-party liability insurance) is available, the market value of loss prevention (or self-protection) mitigations is theoretically expected to capture the capitalised value of the savings in market insurance premium. In addition, it is expected that self-insurance is subject to crowding out by market insurance available at actuarially fair prices.

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