ASSESSING THE HEALTH AND SAFETY PERFORMANCE OF RESIDENTIAL BUILDINGS IN HONG KONG

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Summary

Hong Kong is well known for its high population density and its highly compact living environment. With the outbreak of SARS in densely populated areas and the prolonged neglect of fire risk and structural safety in condominium buildings, it is necessary to understand the concept of sustainable cities in the light of building health and safety.

This paper applied an assessment model to evaluate the health and safety performance of residential buildings in Hong Kong. The model consists of a set of performance-based objectives and can be translated into a hierarchy of parameters concerning the quality of building design, building management, and the surrounding environment. The assessment results of 140 residential buildings in Hong Kong were presented and discussed.

To encourage more sustainable buildings at the community level, a method was also devised to integrate the assessment results into two simple and user-friendly performance indicators for public consumption, namely the Building Health and Hygiene Index (BHHI) and the Building Safety and Conditions Index (BSCI). These indices help inform the public of the health and safety risks of different buildings so that building owners, developers, and government bodies can make more informed and socially responsible decisions in the future.

1. Introduction

Hong Kong is rated as one of the most densely populated cities in the world, with 6.7 million people living in an area of 1,102 km^2. To accommodate this huge population in such a tiny place, a highly compact living environment characterized by high-rise condominium buildings has resulted. Recently, with the removal of airport height restrictions in most urban areas, residential buildings have been built taller than ever before. It is very common to find new residential buildings of over 50 storeys (e.g. Sorrento: 75 floors, Highcliff: 72 floors, The Harbourfront Landmark: 70 floors, The Summit: 65 floors, The Belcher's: 63 floors, Victoria Towers: 62 floors, and Island Resort: 60 floors). While this gives Hong Kong a unique skyscraper identity, such a compact environment poses important questions for the concept of sustainability, in particular for the objective of promoting human settlement development in Agenda 21 of the United Nations. On the positive side, developing high-rise high-density buildings is economically desirable because common facilities and services can be shared more effectively among co-owners or tenants. With regard to environmental protection, this can also help reduce urban sprawl. However, on the negative side, a high-density setting presents a serious threat to the health and safety status of residents. Previous research showed that overcrowding has led not only to social incoherence, but also to mental and physical health problems (Gove, *et al*., 1979). The outbreak of Severe Acute Respiratory Syndrome (SARS) in 2003 also made the public aware of the vulnerability of densely populated areas to communicable diseases (World Health Organization, 2003). Apart from health problems, aged condominium buildings often lack proper building management and maintenance, and thus pose tremendous safety hazards to both residents and passersby (Housing, Planning and Lands Bureau, 2004).

Since the condition of its buildings is an important indicator in the sustainability of a city, this paper aims to survey the health and safety performance of apartment buildings in Hong Kong based on a generic assessment framework. Health and safety were chosen as our focus because they are the fundamentals that underline the enjoyment of our living environment. Yet, they cannot be easily observed and evaluated. This paper, therefore, contributes to the revelation of hidden building information to the community, which, in turn, helps build a more sustainable city.

The paper is organized as follows. Section 2 presents the assessment framework with a set of assessment criteria. Section 3 describes the data and assessment procedures. Section 4 explains the derivation of performance indicators in the form of indices. Section 5 reports the assessment results. A conclusion is given in Section 6.

2. Assessment Framework

The assessment framework consists of a set of performance-based objectives that indicate whether a building is healthy and safe. It can be thought of as a three-tier system covering visions, strategic goals, and implementation. First, a vision defines the ultimate aim, sets the assessment principles, and delimits the scope of assessment. Given the resources we currently have, our framework focuses only on building health and safety, and is only intended to serve as an initial screening tool for mass assessments for the public rather than a detailed condition survey for each building. As such, the assessment scheme so derived would emphasize items that are accessible, measurable, and relevant to health and safety. Second, strategic goals define an environment's *generic attributes* that are conducive to health and safety (Figure 1). For health, the attributes include air, water, light, and noise (for details, see Ho, *et al*., 2004). For safety, they include fire risks, structural safety, falling risks, and specific hazards (for details, see Ho and Yau, 2004).

Finally, the third tier transforms the generic attributes into an assessment scheme with specific assessment items for implementation. Some examples of assessment items translated from the generic attributes are shown in Table 1. In fact, different schemes can be developed for places with different cultures and built forms. Based on the settings in Hong Kong, an assessment scheme comprising a hierarchy of *building factors*, which was concerned with "Design" (Architecture, Building Services, and External Environment) and "Management" (Operations & Maintenance and Building Management), was developed (Figure 2). The lower an item is located in the hierarchy, the more specific it is. For instance, under "Architecture", we have an item called "Windows," under which three building factors are assessed: 1) the window-to-floor area ratio, 2) the presence of a cross-ventilating window, and 3) the ventilation provision in common lift lobbies. Further details can be obtained from Ho, *et al*. (2004) and Ho and Yau (2004).

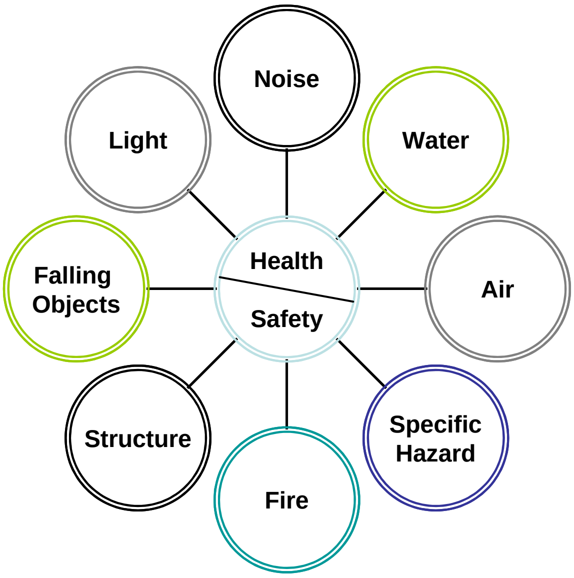


Figure 1 Generic attributes of a healthy and safe apartment building

Table 1 Examples of assessment items translated from the generic attributes

1. Light	2. Air	3. Fire	4. Structure
▪ Window size ▪ Size of external obstruction (e.g. adjacent building, advertisement sign) ▪ Proximity of external obstruction	▪ Window size ▪ Cross-ventilating windows ▪ Headroom ▪ Re-entrant shape ▪ Local air quality	▪ Compartment volume ▪ Travel distance ▪ Direct distance ▪ Provision of fire service installations ▪ Discharge value	▪ Cracks ▪ Spalling

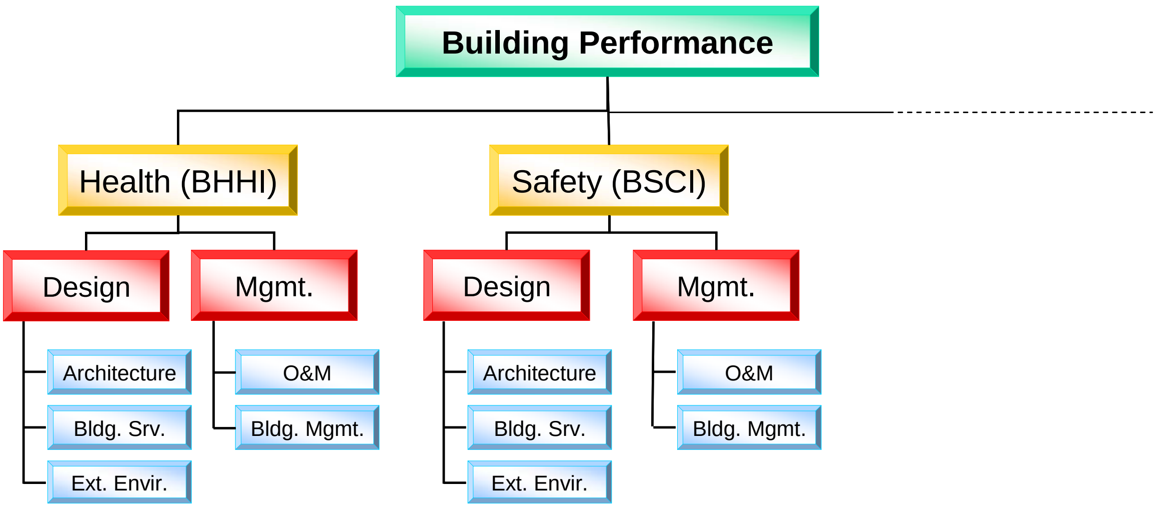


Figure 2 An assessment scheme comprising a hierarchy of building factors

3. Data and Assessment Procedures

There are about 38,000 multi-storey private buildings scattered all over Hong Kong. We opted to shortlist buildings for assessment from the Yau Ma Tei-Tsim Sha Tsui-Mongkok District (YTM), which is located on the southern part of the Kowloon Peninsula. The reasons for choosing YTM are twofold. First, building plans contain a lot of useful information required by our assessment scheme. Since YTM is one of the few districts in which building plans have been digitalized, focusing on YTM can greatly shorten the time for retrieving building plans from the government. The other reason is that there is a wide variety of residential buildings in YTM (e.g. post-war traditional Chinese low-rise buildings, single block buildings in congested sites, buildings with very large footprint areas, and relatively new building developments). Such a wide range of building types, ages, and management structures enables us to obtain a diversified sample to carry out further analysis.

The buildings in YTM were then stratified by the following criteria. First, the whole district of YTM was divided into six zones (Prince Edward, Mong Kok, Tai Kok Tsui, Yau Ma Tei, Jordan, and Tsim Sha Tsui). This ensures that our sampled buildings will spread around YTM with minimal locational biases. Second, buildings were sampled from each zone according to their development scale, building age, and management structure. This reduced potential bias towards a particular type of building (e.g. owner-managed or agent-managed buildings). Third, for each housing estate, at most one building was selected for assessment, as the performance of buildings within the same estate should be very similar in terms of their design and management. Finally, all pre-war buildings were excluded from the sample because most of these buildings do not have building plan records.

Assessments were carried out by trained assessors. Before assessments began, extensive training sessions were arranged to explain the assessment principles, the assessment items, and the detailed assessment procedures. This helped standardize the data collection method, and hence increased efficiency and consistency. As the assessments progressed, evaluation sessions were held to serve as a feedback mechanism for resolving any unexpected problems faced during data collection.

The assessment procedures can be summarized as three major tasks:

1) Desk Search

Most of the information required under “Design” in Figure 2 was acquired through desk searches. This includes: a) taking measurements from building plans (e.g. the window-to-floor area ratio and the size of a residential unit), b) searching for information on the web (e.g. population density and the Air Pollution Index), and c) analyzing street maps for items under “External Environment” (e.g. distance to adjacent buildings and road traffic). The data collected from the desk searches is publicly available, and therefore objective and verifiable.

2) On-site Assessment

Site visits are a necessary and essential part for verifying the actual health and safety conditions of a building. Photographs have to be taken during site visits for record purposes. All parameters to be measured or inspected on site were confined to common areas where owners or management agents have given us consent (e.g. podium, lobby, lift, staircase, and corridor) and the surrounding external environment. The interiors of flats, however important, were not assessed because access to individual flats was practically impossible. So, our scheme did not take the conditions of individual flats into account, except for those defects that affected the conditions of the exterior or common areas (e.g. concrete spalling).

3) Management Information

Inputs from owners’ organizations and/or property management companies were also required to evaluate their management practices in safeguarding health and safety. Interviews with owners/management staff were conducted to collect this information. If necessary, the owner or management staff was requested to provide documentary records (e.g. tenant survey records and monthly financial statements) for verification.

4. Derivation of Performance Indicators

After data was collected by the trained assessors, raw data was converted into a set of indicators (indices) that represent the health and safety performance of each building factor in Figure 2. The overall health performance of a building is given by the BHHI, while the overall safety performance is given by the BSCI. To obtain the performance of a particular building factor (rather than the whole building), the BHHI and BSCI were further broken down into sub-indices according to the hierarchy shown in Figure 2. Conversely, combining the BHHI and BSCI with other performance objectives (e.g. comfort) can form the Building Quality Index (BQI) at the top level. To compute all these index values, one simply needs to aggregate the ratings (F) and weightings (w) of all building factors under their respective arms:

$$I_k = \sum_{i=1}^{n} w_{ik} F_{ik} \quad (1)$$

where I_k is the performance indicator (e.g. BQI, BHHI and BSCI); w_i (i=1,2,…,n) denotes the non-negative weighting of the i^{th} building factor and all w_i's sum to unity; F_i denotes the (standardized) rating of the i^{th} building factor; and n is the total number of building factors.

The remaining question is how to determine w_is and F_is. Weightings represent the relative importance of a building factor in respect of health and safety. There are different kinds of multiple-criteria analysis techniques available, out of which the Analytic Hierarchy Process (AHP), developed by Saaty (1982),[1] was selected to calculate the weightings with a view to balancing the practicability and academic vigour of the multi-criteria decision making method. We conducted a survey in the form of a workshop, in which representatives from different professional bodies and universities were given brief instructions and questionnaires on their perceived importance of the building factors. The results of the workshop were used as weightings in Equation (1). (See Ho, *et al*., 2004 for the details of the workshop.)

To compute the rating, we needed to define a scale ranging from the best practice (rating = 1) to the worst practice (rating = 0). There are two scaling methods, one for discrete data and the other for continuous data. For continuous data, the best, average, and worst quality are determined by literature reviews or trade/regulatory standards. Taking the floor-to-floor height of a flat (a parameter under “Architecture”) as an example, we set the worst situation to 2.5m, which is the minimum headroom required by the current regulation. The average case is 2.8m, which is the median headroom in the sampling buildings. By linear interpolation, a full mark is awarded to buildings with headroom equal to or above 3.1m. Likewise, when the value falls between 2.5m and 3.1m, the score is calculated based on linear projection.

Discrete data is particularly useful for assessments of a qualitative nature. They can be dichotomous entries (e.g. presence or absence of a hopper drainage system) or multi-entries, as illustrated in Table 2. For example, a new or just replaced drainage system is rated as the best (rating = 1). At the other extreme, when the deterioration of the drain pipe is so severe that it is necessary to change the whole drain pipe immediately, a zero mark will be given. When only part of the drain pipe starts to rust and no particular length of pipe needs to be repaired, the pipe is graded as average (rating = 0.5). The interim ratings are then written out by comparison with the average and the extreme. It should be noted that apart from the brief description of the element, photos are also used to act as references for the ratings. This type of scaling makes judgments on both quantitative and qualitative criteria easier, and it works well even for inexperienced assessors (Schniedergans, *et al*., 1995).

Table 2 Rating scale for drainage conditions

Rating	**Description**
1	Good condition without obvious defects
0.75	Slightly rusty pipe, rusty blanket
0.5	Partly rusty pipe
0.25	Rusty pipe with vegetation growth
0	Choking and unsanitary condition, dripping pipe, busted pipe, unauthorized connection of pipe

5. Assessment Results

In YTM, about 200 buildings were sampled, of which 140 buildings received full assessments. As such, our discussion focuses only on these 140 buildings. As summarized in Table 3, the sample comprises buildings of varying physical characteristics, such as building age, flat size, and development scale. This wide coverage of building characteristics may allow us to extrapolate the results to other parts in Hong Kong in further research.

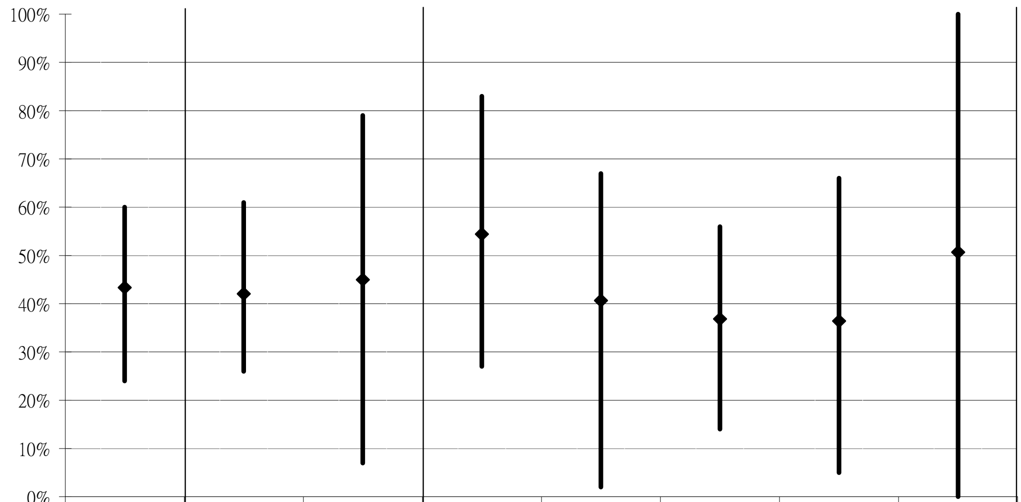
[1] See Schoemaker and Waid (1982) for a comparison of different approaches to determining weights.

Table 3 Physical characteristics of the sampled buildings

Characteristics	**Mean**	**Maximum**	**Minimum**	**Standard Deviation**
Age (Year)	30.9	50	3	11.8
Flat Size (m²)	51.4	142.4	10.1	18.5
No. of Storeys	11.9	28	3	5.8
No. of Flats	55.9	420	3	69.4

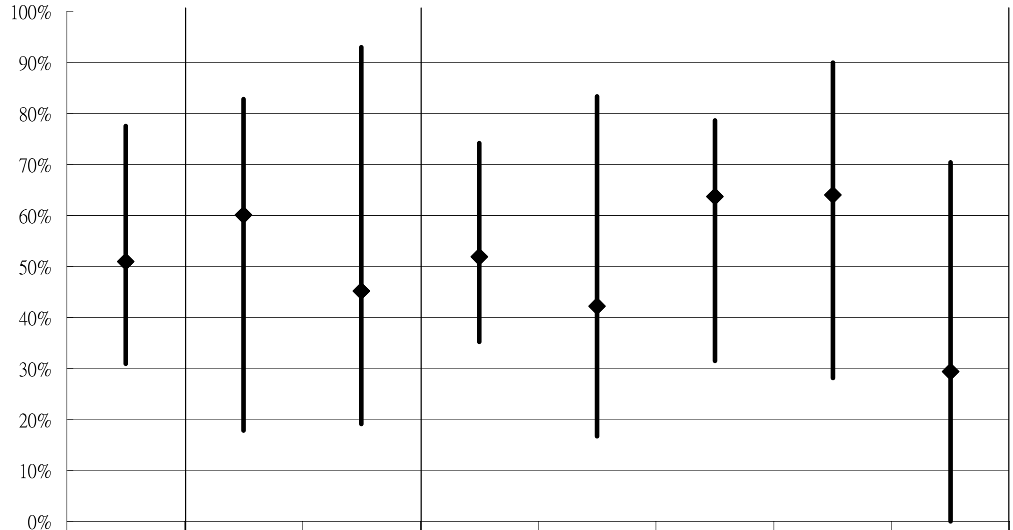
The assessment results for health and safety performances are reported in Figures 3 and 4, respectively. In each figure, eight performance indicators are shown, with each indicator representing the performance of each building factor in the three-level hierarchy in Figure 2. The first (leftmost) line in Figure 3 or 4 is the overall performance for health (BHHI) and safety (BSCI). Moving to the right, the second and the third ones depict the second-level performances, namely “Design” and “Management”. The remaining indicators reveal the performance of more specific building factors at the third level, which include “Architecture,” “Building Services,” “External Environment,” “Operations & Maintenance,” and “Building Management”. The index values (scores) have been normalized on a scale of 0 to 1, according to Equation (1), meaning that the lowest possible score for an index is 0, whereas the highest possible score is 100%.

Our findings showed that the average BHHI and BSCI are 43% and 51%, respectively, with the distribution of the BSCI slightly more dispersed than that of the BHHI. Moreover, from the weighting results, “Design” was slightly more important than “Management” in respect of health (54:46), but not so in respect of safety (40:60), although the difference in weightings between these two factors was apparently small. Since “Management” scores varied more widely than “Design” scores, most of the variations in the BHHI and BSCI were attributed to differences in building management systems rather than building designs. This is consistent with our intuition of Hong Kong, where building designs tend to be typical and standard, and where building management quality varies a lot. Further insight can be gained by looking at the third level results. In terms of weightings, “Operations and Maintenance” was the most important factor with regard to health and safety, accounting for 27% and 37% of weightings for the BHHI and BSCI, respectively. Yet, in terms of variations, “Building Management” was the most dispersed (especially for the BHHI, which spans from 0 to 1), thereby revealing the most vital area residents should look at in order to significantly improve the health and safety performance of their buildings. This includes establishing an effective owners’ organization, implementing facility management practices, and enhancing the level of emergency preparedness.



	BHHI	Design	Management	Architecture	Building Services	External Environment	Operation & Maintenance	Building Management
Weighting	100.0%	53.6%	46.4%	18.5%	19.3%	15.8%	27.1%	19.3%
Maximum	60.0%	61.0%	79.0%	83.0%	67.0%	56.0%	66.0%	100.0%
Minimum	24.0%	26.0%	7.0%	27.0%	2.0%	14.0%	5.0%	0.0%
◆ Mean	43.4%	42.1%	45.0%	54.4%	40.6%	36.8%	36.4%	50.7%

Figure 3 Health performance of the sampled buildings



	BSCI	Design	Management	Architecture	Building Services	External Environment	Operation & Maintenance	Building Management
Weighting	100.0%	40.2%	59.8%	23.1%	8.5%	8.6%	36.6%	23.2%
Maximum	77.5%	82.8%	93.0%	74.2%	83.3%	78.6%	90.0%	70.4%
Minimum	30.9%	17.8%	19.1%	35.2%	16.7%	31.5%	28.1%	0.0%
◆ Mean	50.9%	60.1%	45.2%	51.9%	42.2%	63.7%	64.0%	29.4%

Figure 4 Safety performance of the sampled buildings

6. Concluding Remarks

This paper has applied an assessment model to evaluate the health and safety performance of multi-storey residential buildings in Hong Kong. The model has been proven to be useful for the initial screening of a large number of buildings within a relatively short period of time. To encourage more sustainable buildings at the community level, a method has been devised to integrate the assessment results into two simple and user-friendly performance indicators for public consumption. One is the BHHI, and the other is the BSCI. These indices should inform the public of the health and safety risk of different buildings so that building owners, developers, and government bodies can make more informed and socially responsible decisions in the future. It is envisaged that further research can be conducted to investigate the relationship between building performance and extraneous factors such as building age, management structure, and development scale.

Acknowledgements

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