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INVESTIGATING THE ENERGY PERFORMANCE AND MAINTENANCE RESOURCES OF QUALITY HOTELS IN HONG KONG

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ABSTRACT

Purpose: The study reported in this article aimed to identify the relations between the resources used for maintaining hotels and their energy uses.

Background: Past studies have researched into either the energy side or the maintenance aspect of some existing hotels. Analyses focussing on the empirical relation between maintenance resources and energy performance of hotels remain unavailable.

Approach: Detailed and reliable data were obtained through face-to-face interviews with the senior maintenance staff of 20 quality hotels in Hong Kong. Descriptive statistics and benchmarking curves of the hotels' energy consumptions and maintenance resources were worked out. Correlation analyses were made between the energy consumptions and the maintenance resources.

Results: The energy use of the hotels was dominated by electricity consumption. Generally the cost for implementing capital projects outweighed the cost for hiring maintenance staff or executing repair and maintenance works. Hotels with greater investment in capital projects used less energy, which highlighted the link between energy performance and works done for improving the energy efficiencies of hotel facilities.

Practical Implications: Benchmarks and benchmarking charts were established for use in evaluating energy performance and maintenance effectiveness of hotels.

Research Implications/limitations: Future studies may use a similar methodology to investigate the energy performance and maintenance resources of hotels or other types of buildings elsewhere. The present study findings were based on a sample of 20 hotels. More representative findings would be obtained when more samples are included in the analysis.

Originality/value: An original and useful finding was the existence of connection between energy performance of hotels and resources used for carrying out capital projects to improve the condition of their facilities.

Keywords: Benchmark, Energy use, Hong Kong, Hotel, Maintenance

1 INTRODUCTION

The global energy consumption has continued to rise. The use of energy in urban areas, especially those developed with a high density of commercial buildings, has become progressively intensive. This has led to various environmental issues, particularly the growth of greenhouse gas emission, which is central to the global warming problem.

Hong Kong, a developed city in Asia, is famous for its overcrowded high-rise buildings. Being a popular tourist destination, it received over 48.6 million visitors in 2012, among them over 23.7 million were overnight visitors and their average length of stay was 3.5 nights (Tourism Commission, 2013). Accommodating these visitors were many sizable hotels built with quality facilities; they include not only engineering installations such as chiller, boiler, lift, and lighting but also leisure facilities like swimming pool, sauna, gym equipment, and so on.

According to the government's statistics (Electrical and Mechanical Services Department, 2012), the biggest share (42%) of the total energy use of Hong Kong was due to the commercial sector. Hotels belong to the commercial segments that used 63,962 TJ (Terajoule; 1 TJ = 10^{12} J) in 2010, a substantial increase from 40,255 TJ in 2000. Therefore it is necessary to optimize or minimize the energy use of the hotels in order to help reduce the growth of energy consumption of Hong Kong.

The energy use of hotels is dependent on a multitude of factors over their building life cycle, including designed efficiency of their facilities; installation workmanship and hence constructed quality of the facilities; whether the facilities have been properly tested and commissioned before use; and how well the facilities are operated and maintained. It is well-recognized that the energy use as well as occupancy cost during the operation and maintenance stage of a building life cycle prevail over the costs of the other stages (Evans et al., 1998). Yet little has been done to research into the relation between energy performance and maintenance effectiveness of hotels. Aimed at contributing knowledge to this area, a study was carried out, as reported in this article.

In the next section, a review of the past research works that are relevant to the present study is presented. Section 3 describes the theory based on which the objective of the study was formulated and the methodology used for data collection and analysis of the data collected. The analysed findings are reported in section 4, which include benchmarks of the energy consumptions and maintenance resources of the hotels studied, and correlations between various parameters of the consumptions and resources. Lastly, section 5 summarises the conclusions drawn from the study results and the future works needed.

2 PAST RELEVANT STUDIES

Over the years, numerous research studies have been carried out to study the energy use of buildings, including many that were focused on hotel buildings. In studying the efficiency of hotels, some research works (e.g. Barros, 2005; Neves and Lourenco, 2008) investigated parameters such as business performance (e.g. revenue, return on investment), management or administrative expenses (e.g. labour cost, front-of-the-house hours). In view of the limited findings about operation and maintenance (O&M) costs of hotels, Lai and Yik (2008) carried out a benchmarking study based on 10 luxury hotels in Hong Kong, which unveiled that large amounts of resources were used for maintenance and that energy cost was the greatest O&M expenditure of the hotels.

Among the major costs-in-use of buildings, energy consumption has attracted the most attention. In Hong Kong, Deng and Burnett (2002) investigated the energy use of 16 quality hotels, which was found to be dominated by electricity consumption. The study of Bohdanowicz and Martinac (2007), which covered a sample of 184 Hilton International and Scandic hotels in Europe, investigated the utilizations of energy and water in the hotels. Based on a survey of 29 quality hotels in Singapore, Rajagopalan et al. (2009) found that the average total energy use intensity of the hotels was 427 kWh/m^2. In Taiwan, the study of Wang (2012) collected the data of 200 hotels and revealed that on average electricity consumption accounted for 84% of their total energy use.

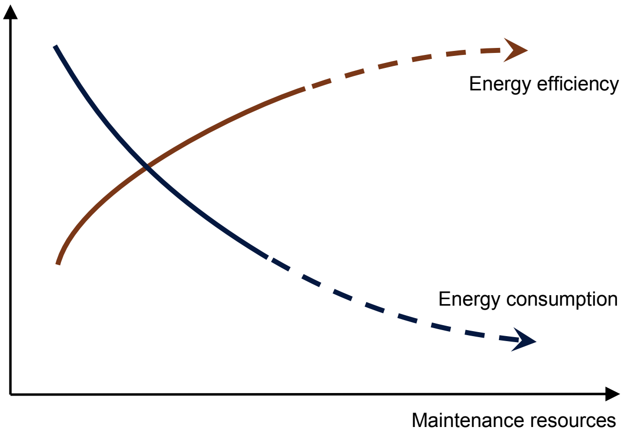
In recent years, studies that probed into the maintenance performance of hotels have emerged. Particularly, the study of Lai and Yik (2012a), conducted based on the computerized maintenance management data of a 618-room hotel, identified the existence of a significant correlation between equipment downtime and amount of maintenance work orders, and developed a range of performance curves for assessing maintenance performance of hotel engineering facilities. Meanwhile, it was found that the work efficiency of the hotel's maintenance workforce declined with increasing utilization levels of the workers (Lai and Yik, 2012b). Furthermore, Lai (2013) introduced a model that enabled analysing maintenance data according to the period, place, and physical installation ("3P") of the maintenance works. The analyses carried out in that study showed that the maintenance works for the hotel were highly correlated with their demands but had little correlations with the input manpower.

The above studies had delved into either the energy side or the maintenance aspect of some existing hotels. The work of Chan et al. (2003) was among the limited studies that attempted to explore both the maintenance practices and energy performance of hotels. Performance-based models that can link built asset maintenance with the strategic performance of buildings, however, have yet to be developed (Jones and Sharp, 2007). Not long ago, three case studies – a college district, a laboratory building, and a medical center were carried out in the North America (Lewis et al., 2011), which showed the existence of an interdependent link between energy use and maintenance management of the buildings. To date, analyses focusing on the empirical relation between energy performance and input maintenance resources of quality hotels remain unavailable. In order to help in bridging this knowledge gap, a study was initiated.

3 APPROACH

The premise based on which the study was formulated is that the energy performance of hotel buildings is linked with the level of maintenance of the buildings. Theoretically, a higher level of maintenance resources input for a building would allow more and better maintenance work to be carried out, thus enabling the energy-consuming facilities of the building to perform more efficiently, using less energy. Figure 1 conceptualises this idea.

Figure 1: Conceptual relations between maintenance resources and energy consumption/efficiency



Identification of the energy performance of a building can be made by referring to the amounts of utilities the building consumed. Resources used for maintaining a building include those needed to hire maintenance staff, execute routine repair and maintenance work, and implement some capital projects to improve the conditions of the existing facilities. Such utilities and costs data are sensitive and, as experienced before, they were difficult to obtain (Lai et al., 2008). Therefore, individual face-to-face interviews, which assure the confidentiality of the identities of the hotels and the interviewees, were adopted to collect the data needed. In order to identify the utilities consumptions of the hotels and their maintenance resources, a data template was designed. The types of data collected covered: star rating; building age; gross floor area; number of guestrooms; occupancy rate; annual costs of maintenance staff, repair and maintenance work, and capital project; and annual consumptions of utilities including electricity, diesel oil, town gas, and water. The maintenance costs include all those required for the builder's works (e.g. façade, roof, ground) and building services installations (e.g. electrical, air-conditioning, fire, piped services) in the hotels.

The template was provided to the interviewees in advance so as to allow them sufficient time to gather the necessary data. During the interviews, the interviewer explained the coverage of the various categories of data requested. In cases where such coverage was found to be different from that of the data the interviewees provided, minor revisions were made at the time of the interviews. For revisions that were too substantial to be made within the limited interview periods and for data that could not be made available during the interviews, follow-up contacts were made with the interviewees to supplement the outstanding data. Afterwards, the data collected were organized and checked for completeness and any abnormality. For incomplete data and those detected as unreasonable, clarifications were sought from the respective interviewees, before the data were consolidated for analysis.

The analysis was started with figuring out the descriptive statistics of the data, including those about the characteristics of the hotels, and their utilities consumptions and amounts of maintenance resources input. Then, the data were processed to generate benchmarking curves for the various kinds of utilities consumptions and maintenance resources. Finally, the correlations between different parameters of energy consumption and maintenance cost were tested in an attempt to identify the relation between the energy performance of the hotels and their maintenance resources.

4 RESULTS

4.1 Characteristics of the hotels

20 interviewees who were senior engineering staff (e.g. Director of Engineering, Chief Engineer) of the hotels provided useful data for the study. All the hotels were of high quality: 11 were 5-star hotels and 9 were rated as 4-star. There was no new hotel in the sample; the hotel buildings were on average close to 17 years old (standard deviation: S.D. = 9.3), with their mean gross floor area exceeding 41,000m^2 (Table 1). Collectively there were 10,529 guestrooms in the hotels and the maximum occupancy rate among them was as high as 94%.

Table 1: Characteristics of the hotels

	Mean	Min.	Max.	S.D.
Star rating	-	4	5	-
Building age (year)	16.9	2	34	9.3
Floor area (m^2)	41,401	14,975	65,024	14,359
Guestroom (nos.)	526	113	884	174
Occupancy rate (%)	84.8	65.0	94.0	7.3

The energy use of the hotels was enormous, amounting to a yearly total of over 1,419 TJ. The annual maximum electricity consumption among the samples was up to 109,101 GJ (Gigajoule; 1 GJ = 10^9 J), which was more than double of the mean consumption level (Table 2). The consumptions of town gas spread over a wide range, from 500 GJ to 55,317 GJ. Diesel oil was not used in all but nine of the hotels; the largest annual consumption among them was 40,007 GJ. Besides, the annual total amount of water consumed by the hotels was 3,256,867 m^3, or 309 m^3 per room.

Table 2: Annual utilities consumptions of the hotels

	Mean	Min.	Max.	S.D.
Electricity (GJ)	50,197	15,259	109,101	22,605
Town gas (GJ)	11,908	500	55,317	11,984
Diesel oil (GJ)	8,892	0	40,007	13,586
Water (m^3)	162,843	43,305	297,000	61,334

Given that the hotels were large in scale, and high in quality, considerable amounts of resources were deployed to maintain their operations. The relevant cost data of a sampled hotel and the capital project cost data of four others, which the respective hotel owners were reluctant to disclose, were not made available for analysis. Despite this restraint, statistics of the various kinds of maintenance resources, namely repair and maintenance, capital project, maintenance staff, and their overall total, were figured out. Table 3 shows the calculation results and the numbers of samples (*n*) based on which the results were obtained.

The annual cost for providing repair and maintenance works per hotel, on average, was over HK$8.2 million. The counterpart for financing capital projects of the hotels, including improvement and refurbishment works, was even larger - exceeding HK$11.1 million. Whereas the average amount of maintenance staff payroll was much less than those of the preceding two kinds of resources, the minimum level of the payroll was actually the highest among the three categories.

Table 3: Annual maintenance resources of the hotels

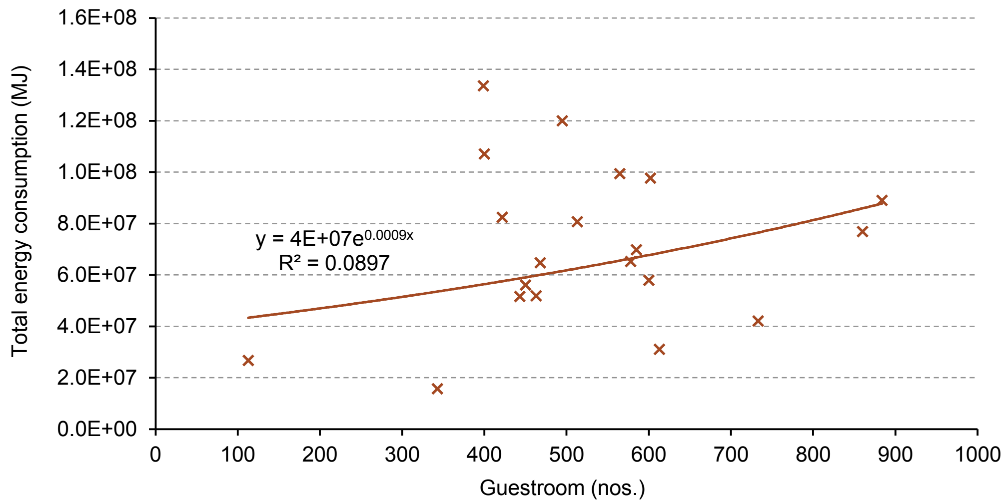
	Mean	Min.	Max.	S.D.
Repair & maintenance (HK$) [*n* = 19]	8,255,100	1,698,857	18,414,369	4,884,890
Capital project (HK$) [*n* = 15]	11,126,478	1,191,000	23,000,000	7,502,980
Maintenance staff (HK$) [*n* = 19]	5,692,214	2,469,018	8,845,669	1,917,371
Total (HK$) [*n* = 15]	44,117,196	12,253,324	62,898,628	12,745,538

4.2 Normalisation and benchmarking charts

Normally a bigger hotel would be equipped with more facilities and hence require more energy to operate, and vice versa. Since the sizes of the hotels were not identical, it is not meaningful to evaluate their performance by making direct comparisons between their levels of energy consumptions and maintenance resources. In order to enable fair comparisons to be made on the performance parameters, it is necessary to normalise their values with respect to the scale of the hotel buildings.

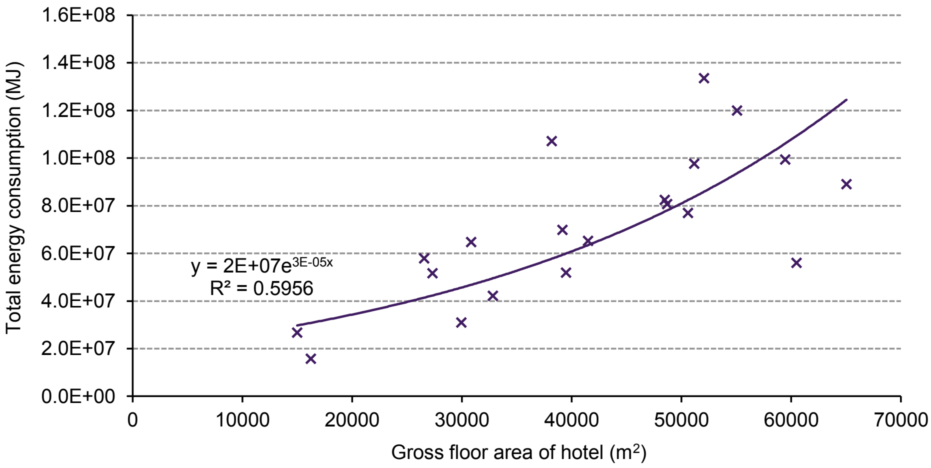
Drawn upon the experience gained from an earlier study (Lai et al., 2008) where some trials were conducted to identify an appropriate normalisation factor for some commercial buildings, an initial attempt was made in the current study to investigate if the levels of energy consumption were dependent on the number of hotel guestrooms. As the scatter plot in Figure 2 shows, the total energy consumptions of the hotels generally increased with the number of their guestrooms. But the former varied widely at the middle range of guestrooms. The *R*-squared value of the trend line was small, reflecting a low goodness of fit. These observations suggest that number of guestrooms is not good for normalising the total energy consumptions of the hotels.

Figure 2: Relation between total energy consumption and number of guestrooms



A further trial was made by plotting the total energy consumptions against the gross floor areas of the hotels, as shown in Figure 3. It showed that the energy consumptions increased exponentially with the floor areas, and the *R*-squared value of the trend line was close to 0.6, which was much higher than that of the first trial. Thus, gross floor area can be regarded as a better normalisation factor than number of guestrooms.

Figure 3: Relation between total energy consumption and floor area



In the ensuing analyses, the various kinds of annual energy and water consumptions of the hotels were normalised by their respective gross floor areas. The normalised figures were grouped into bin values and the corresponding cumulative frequencies were plotted to generate some benchmarking charts. Ranging between 811.4 MJ/m^2 to 2,173.2 MJ/m^2, the normalised electricity consumptions of the hotels, on average, was 1,223.7 MJ/m^2 and their cumulative frequencies were as depicted in Figure 4(a). Diesel oil was used in nine of the hotels; its maximum consumption level, at 801.2 MJ/m^2, was much lower than the counterpart of electricity. While the use of town gas was as common as that of electricity, its consumption levels, with an average value being 311.9 MJ/m^2, were much lower. Figure 4(d) further shows the cumulative frequency distribution of the normalised water consumptions of the hotels. Unlike the wide-ranging energy consumptions, the variations in the water consumptions were confined to between 2.39 m^3/m^2 and 7.04 m^3/m^2.

Following the way in which the above benchmarking charts were developed, the recourses deployed for maintaining the hotels were normalised by their respective gross floor areas. Such normalised values, including those for repair and maintenance cost, capital project cost, maintenance staff cost, as well as the total maintenance cost, were plotted as shown in Figure 5.

With its minimum value being HK$66.9/m^2, the annual amount of repair and maintenance cost reached a maxium value of HK$908.2/m^2. The 50th percentile, for instance, was approximately HK$170/m^2 (Figure 5(a)). The ranges of the captical project costs and the repair and mainteannce costs were of the same order of magnitude, but the 50th percentile of the former costs was much higher, at around HK$275/m^2 (Figure 5(b)). Comparatively, the amounts of maintenacne staff cost were significantly smaller, ranging between HK$83.6/m^2 and HK$287.2/m^2 (Figure 5(c)). Overall, the total maintenance cost of more than 80% of the hotels exceeded HK$1,200/m^2 (Figure 5(d)).

4.3 Correlation analyses

To test whether the energy use of the hotels was linked with their physical/operational characteristics, a series of correlation analyses, involving the calculation of the Pearson product-moment correlation coefficient (*r*), was carried out. Table 4 summarised the calculation results as well as the significance values, where *n* is the number of samples used in the calculation.

Figure 4: Benchmarking charts for utilities consumptions

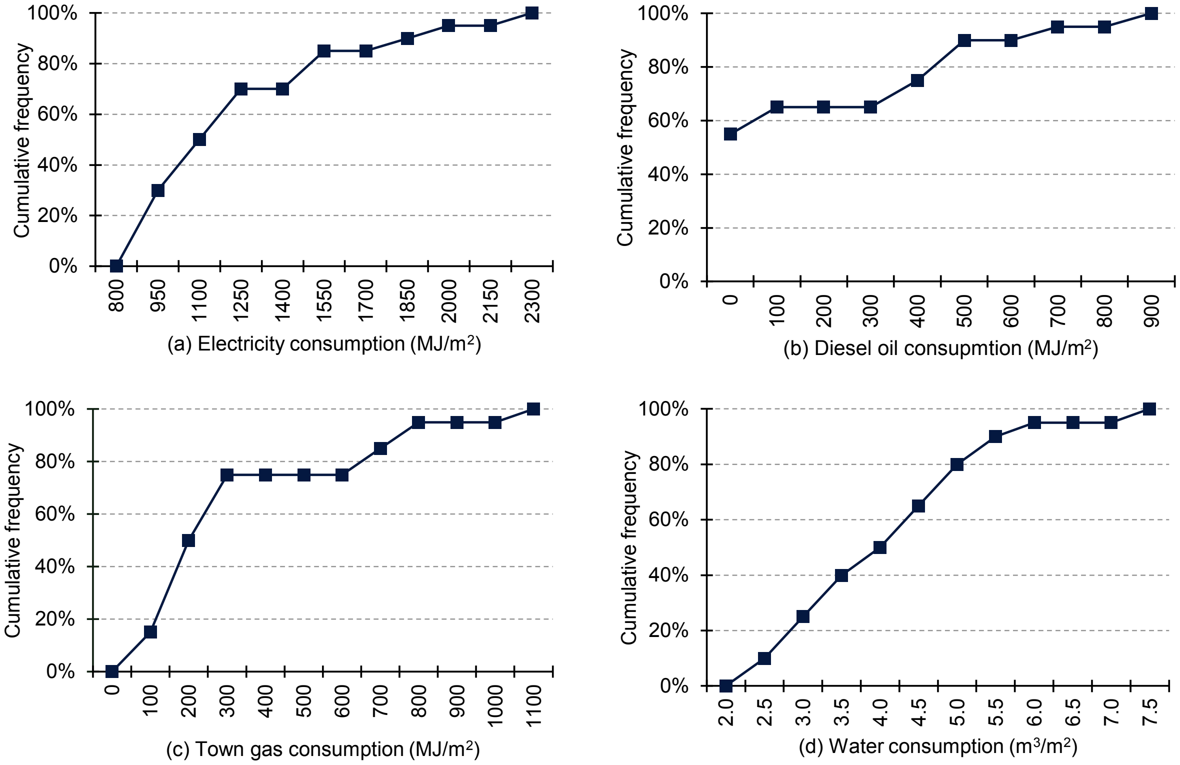


Figure 5: Benchmarking charts for maintenance resources

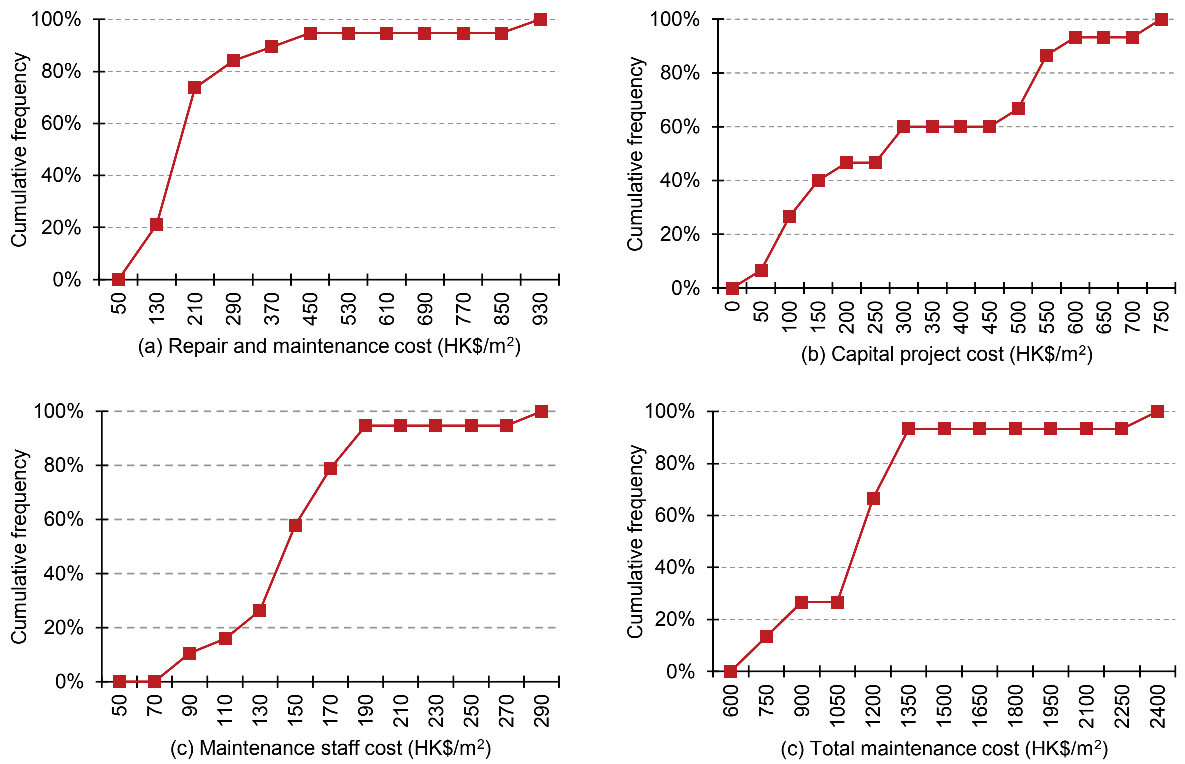


Table 4: Correlations between total energy use and characteristics of the hotels

Parameter	*n*	Pearson coefficient, *r*	Sig.
Age (years)	20	0.0574	0.8099
GFA (m^2)	20	0.7280	0.0002**
Guestroom (nos.)	20	0.1759	0.4581
Occupancy (%)	20	-0.3846	0.0940

** correlation is significant at the 0.01 level (2-tailed).

Obviously, gross floor area was found to have a strongly positive correlation with the total energy use of the hotels ($r = 0.7280$; sig. 0.0002), meaning that the bigger the hotel building, the more energy was used. This result is in line with the finding shown in Figure 3. On the other hand, there were no significant correlations between the hotels' total energy use and the remaining parameters. As revealed earlier, number of guestroom was not a good normalisation factor so the absence of significant correlation between this parameter and the total energy use is not unexpected.

As for the age of the buildings, it had no significant correlation with the total energy use. This may be because improvement works for hotels, which cover replacement of energy-inefficient facilities, are typically implemented on a cyclical basis (Lai and Yik, 2012a). Older hotels provided with sufficient improvement works might not be less energy efficient than the newer ones. Whereas it is reasonable to hypothesize that a greater occupancy rate (i.e. higher user density) of the hotels would result in more energy use, the analysis result does not support this hypothesis. Similar to the case of Lai and Yik (2012b), the occupancy rates covered in the analysis, ranging between 65% and 94%, were not wide enough. This is a probable reason for the non-existence of correlation between the total energy use and the occupancy rate.

Further tests were made to investigate if any correlation existed between the total energy use and the maintenance resources used by the hotels. As the results in Table 5 show, there was no significant correlation between the total energy use and the repair and maintenance cost. The same conclusion can be drawn from the findings for the capital project cost and the total maintenance cost. Nevertheless, a moderate, positive correlation was found between the total energy use and the maintenance staff cost ($r = 0.6248$; sig. 0.0042). This implies that more maintenance manpower was required for hotels that consumed more energy.

In order to find out whether a more intensive input of resources for maintaining the facilities would upkeep their energy efficiencies, thereby minimizing their energy uses, it is necessary to investigate the correlations between the total energy use of the hotel buildings and their normalized maintenance resources. To this end, the Pearson's *r* was computed between the total energy use and each of the maintenance cost categories listed in Table 3. Common to all the categories, they were negatively correlated with the total energy use of the hotels (Table 6). In other words, a lower energy consumption level was associated with a higher intensity of maintenance resources input. Although such correlations for the repair and maintenance cost and the maintenance staff cost were not statistically significant, the correlations for the capital project cost and the total maintenance cost were significant at the 0.05 level.

Table 5: Correlations between total energy use and maintenance resources

Parameter	*n*	Pearson coefficient, *r*	Sig.
Repair and maintenance cost ($)	19	0.3863	0.1023
Capital project cost ($)	15	-0.3318	0.2269
Maintenance staff cost ($)	19	0.6248	0.0042**
Total maintenance cost ($)	15	0.0865	0.7592

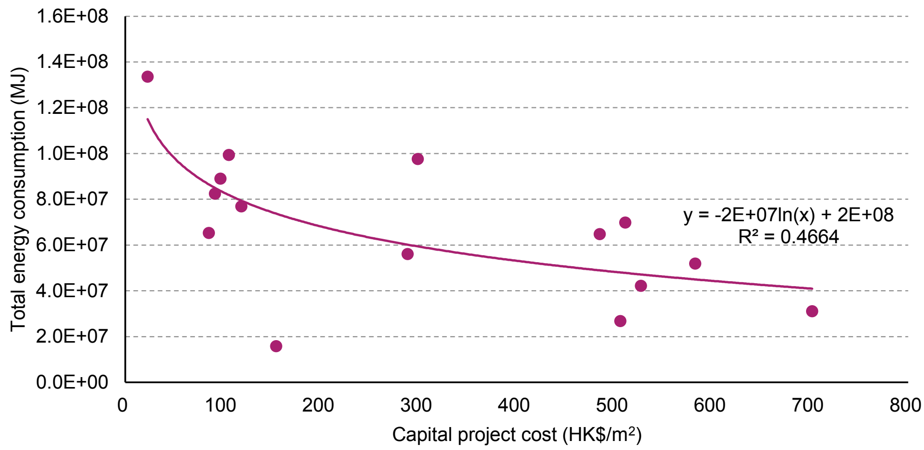
** correlation is significant at the 0.01 level (2-tailed).

Table 6: Correlations between total energy use and normalised maintenance resources

Parameter	*n*	Pearson coefficient, *r*	Sig.
Repair and maintenance cost ($/m^2)	19	-0.1693	0.4884
Capital project cost ($/m^2)	15	-0.5930	0.0198*
Maintenance staff cost ($/m^2)	19	-0.3130	0.1920
Total maintenance cost ($/m^2)	15	-0.5550	0.0317*

* correlation is significant at the 0.05 level (2-tailed).

Figure 6: Relation between total energy use and capital project cost



In light of the comparatively high Pearson's *r* value associated with the capital project cost, a graphical representation of the relation between the total energy consumptions and the capital project costs was prepared, as shown in Figure 6. It is clear that the hotels consumed less total energy with increase in funding for their capital projects, and the decline in energy use followed a logarithmic pattern. This finding suggests that when more intensive investment was made for implementing projects such as replacement of energy-inefficient facilities or improvement of their energy efficiencies, less energy was used by the hotels. Further increase in capital project investment, nonetheless, could only lead to diminishing reduction of energy consumption.

5 CONCLUSION

The study is among the limited research that attempted to investigate the link between energy performance and resources used for maintaining hotel buildings. It showed that among the various energy uses, electricity consumption dominated. The various maintenance resources of the hotels were enormous, with the cost for implementing capital projects being generally more than the cost for hiring maintenance staff or executing repair and maintenance works.

Instead of number of guestrooms, gross floor area was found to be a better parameter for normalising the total energy consumptions of the hotels. Based on the normalised energy and water consumption levels of the hotels, cumulative distribution curves were constructed for benchmarking purposes. Likewise, a set of benchmarking curves was established using the normalised data of the various kinds of maintenance resources. These benchmarking tools can facilitate practitioners to compare and evaluate the energy performance as well as the maintenance effectiveness of similar types of hotels.

Gross floor area, representing the scale of hotels, was the only characteristic parameter exhibiting a strong correlation with the total energy use of the hotels. Generally the larger the hotels, the more resources were needed for hiring maintenance staff. A salient finding from the correlation analyses was that hotels with greater investment in capital projects were less demanding in their total energy use. This highlights the link between energy performance and maintenance works undertaken for improving the condition of hotel facilities.

Further work is needed to examine the effects of factors such as grade, age, and occupancy rate on the maintenance resources as well as energy performance of the hotels. The approach adopted in the study may be taken to investigate the relation between energy performance and maintenance resources of hotels or other types of buildings elsewhere.

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