Maintenance Practices and Energy Performance of Hotel Buildings

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ABSTRACT

An attempt was made to explore the maintenance practices and energy performance in hotel buildings through a novel questionnaire survey in the hotels sector and detailed case studies in a representative hotel. An energy performance index and daily load profiles of different types of energy use in relation to outdoor temperature and hotel occupancy rates are identified. Allocation of resources and outgoing of expenditures on maintenance are examined and reported. The needs of multi-skilling for individuals of the maintenance team and computerized maintenance management systems (CMMS) in hotels are discussed. Some key factors underpinning the formulation of a maintenance program and decisions on the utilization of in-house technicians or outsource contractors are identified. A self-assessed scheme was set up and conducted in individual hotels by the chief engineers. The findings would be helpful to maintenance personnel in developing appropriate maintenance strategies for better system availability and efficient energy use in hotels.

INTRODUCTION

Proper operation of a hotel relies on the availability of the engineering systems to provide air conditioning, water supply, lighting, transportation, laundry, and kitchen services. As hotels are operative for 24-hour operation all year round, the maintenance of the engineering systems is a complex process, and its effectiveness will directly affect the quality of hotel service, food, and beverage.

An equipment failure might not cause an immediate loss of business, but it would eventually project on the established reputation and that in turn could affect business. Hence, development of an appropriate maintenance strategy is becoming more important, as greater reliance is placed on it to maintain high system availability and achieve satisfactory environmental conditions for the occupants. Maintenance management plays a dominant role in improving energy efficiency and keeping the total costs optimal.

The costs of operating and maintaining the engineering systems, in particular the in-house manpower, out-source contractors, energy consumption, and equipment deterioration, must be properly monitored and controlled. To reduce the costs, proper operation procedures and effective maintenance are crucial.

This article reports an investigation of the current maintenance practices in association with the energy performance of engineering systems in hotels in Hong Kong. Allocation of maintenance resources, operation and maintenance expenditures, and some key factors required for maintenance decision-making are identified. A self-assessment scheme is established to enable individual hotels to assess maintenance performance and develop maintenance strategy for satisfactory system availability and energy efficiency.

QUANTITATIVE APPROACH

To establish an understanding of current maintenance practices and energy performance in hotels, a novel questionnaire was designed to identify qualitative information from hotel chief engineers. After explanation of the survey's objectives in meetings with the chief engineers, the study was fully supported by members of the Hong Kong Hotels Association.

There are six sections, A to F, in the questionnaire. The first section contains the hotel data covering the age, class, number of guest rooms and kitchens, total gross/guest room floor area, and other facilities provided in hotels. Section B and C deal with energy consumption and maintenance expenditure spent in supporting the hotel business. Information of maintenance resource allocation can be obtained from Section

D. Section E concerns the current maintenance practices regarding the need of a multi-skilling, computerized maintenance management system (CMMS), and others. It also identifies the factors and to what extent they are weighed by the chief engineers for the development of maintenance strategy and decision of in-house or outsourcing labor force for maintenance and retrofitting tasks. Finally, a self-assessment scheme enabling an effective evaluation of the maintenance management in individual hotels is provided in Section F.

There were 81 hotels in the city based on the hotels directory [1], of which 26 participated in the survey, giving an overall response rate of 32.1 percent across the local hospitality industry. Individual chief engineers of the hotels were interviewed for clarification of unclear replies on the questionnaire returns. Apart from the survey, in-depth case studies were also conducted in a representative prestigious hotel. This is a micro-oriented approach to find out more detailed information, which is difficult to obtain from the questionnaires. For instance, maintenance resources spent on different engineering systems and daily energy use profiles, occupancy rate, and number of food covers were studied. Figure 1 shows the daily energy profile of the representative hotel and outdoor temperature. The profile of electricity consumption closely follows the pattern of daily mean outdoor temperature. This implies that operational control schemes such as chilled water supply temperature reset and free cooling at mild weather conditions would help save energy. Changes of occupancy rate and number of food covers served, however, have no noticeable effect on energy consumption, implying that there is a lack of operational procedures in room keeping and cooking processes for energy saving.

Among the 26 hotels studied, there are seven 3-star, eight 4-star and eleven 5-star hotels. The years of construction range from 1950 to 2000. Other attributes of the hotels are: gross floor area between 6,000 to 72,820 m^2; guest room floor area between 4,909 to 44,450 m^2; number of guest rooms between 158 to 736; and number of kitchens between 1 to 11.

Overall, the guest room floor occupies 69 percent of the gross floor area, with an average size of 46.3 m^2 for each guest room. Statistical details for individual class of hotel are shown in Table 1. The averaged ratio of guest room floor area to gross floor area for 3-star hotels is higher than the others because the former have fewer facilities of laundry, swimming pool, shopping arcade, sauna and restaurant. Those are also energy intensive areas.

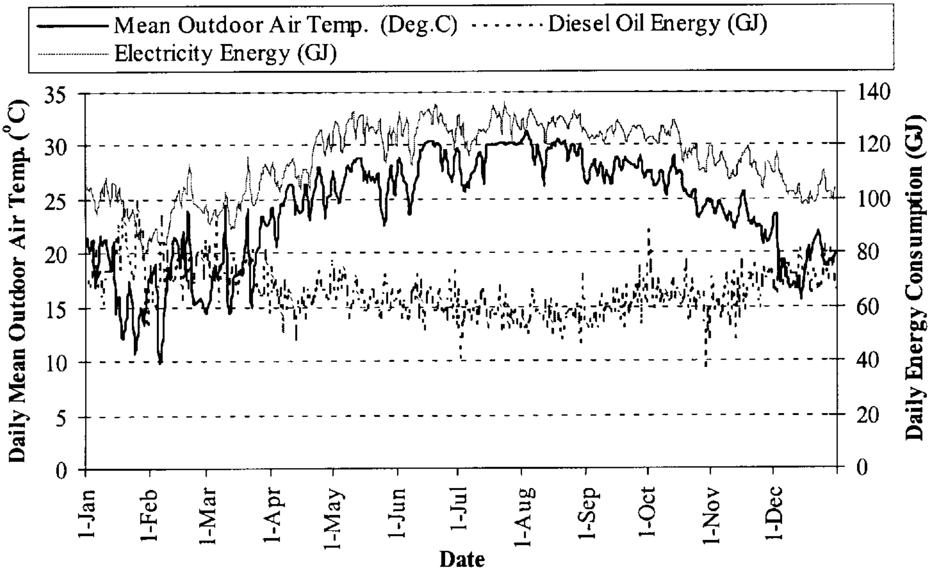

Figure 1. Profiles of Daily Energy Consumption and Outdoor Temperature

RELATION BETWEEN MAINTENANCE AND ENERGY PERFORMANCE

Energy management is recognized as a function associated with an effective maintenance management to operate the systems at optimum efficiency. Thumann [2] reported that 8 to 12.5 percent of reduction in energy consumption could be achieved through improved operation and maintenance activities. Thus, energy use intensity can be used as a performance indicator of maintenance [3].

Generally, there are three types of energy supply in hotels, including gas, electricity, and diesel oil. Gas is supplied to kitchens and electricity is used for most equipment and appliances. Diesel oil is used mainly in boilers for supplying steam to laundry and calorifiers, but some hotels consume gas or electricity for steam, heating, and hot water supply.

By analyzing the electricity energy data in hotels, it is found that unit price for each kilowatt-hour varies in a wide range from 0.71 to 0.9 HK$ (1 US$ = 7.8 HK$). Since the majority of energy consumption in hotels is electricity, as indicated in Table 2, constituting

Table 1. Statistical Details of Floor Area in the Hotels Studied

Class of Hotel	Guestroom Floor Area : Gross Floor Area				Size of Individual Guestroom (m^2)			
	Max.	Min.	Average	Standard Deviation	Max.	Min.	Average	Standard Deviation
3-Star	0.82	0.60	0.72	0.08	34.9	23.4	29.9	4.3
4-Star	0.84	0.52	0.67	0.13	65.2	28.9	46.2	15.2
5-Star	0.82	0.61	0.68	0.07	79.8	46.4	58.7	10.9
Overall	0.84	0.52	0.69	0.1	79.8	23.4	46.3	16

Table 2. Statistical Results of Energy Use in the Hotels Studied

Class of Hotel	Ratio of Electricity to Total Energy Use				Energy Performance Index ($GJ/m^2/yr$)			
	Max.	Min.	Average	Standard Deviation	Max.	Min.	Average	Standard Deviation
3-Star	0.90	0.64	0.76	0.08	2.39	1.65	1.85	0.25
4-Star	0.97	0.57	0.80	0.16	2.04	0.96	1.58	0.41
5-Star	0.91	0.44	0.64	0.13	2.71	1.51	2.06	0.41
Overall	0.97	0.44	0.72	0.14	2.71	0.96	1.87	0.41

72 percent of the total in the average, the management should pay more attention to this issue for cost control. Optimum start schedules for high loading systems, such as chillers, show potential cost savings by limiting the maximum demand charge. Power factor correction can also reduce the maximum demand charge due to lower apparent power in kilovolt-amperes. Individual hotels should determine an electricity tariff suitable for its demand conditions. For example, demand over 3,000 kVA can apply for supply under large power tariff, resulting in lower unit price. Like many other buildings [4], the opportunity of using thermal storage for cooling has not been utilized to cut the maximum demand charge in the hotels studied, whereas off-peak electricity tariff is yet to be implemented by the local power companies.

Energy efficiency of hotel buildings can be compared in terms of the energy performance index (EPI), which is the normalized total energy consumption per gross floor area ($GJ/m^2/yr$). Among the hotels studied, EPI spreads from 0.96 to 2.71 $GJ/m^2/yr$, with an average of 1.87 $GJ/m^2/yr$. Results for different classes of hotels are summarized in Table 2.

Maintenance cost index (MCI) and energy cost index (ECI), that account for the annual total costs weighted per gross floor area ($HK\$/m^2/yr$), are useful for analysis of the engineering overheads. The former comprises the costs of in-house labor, materials, tools, and all outsourcing maintenance works, whereas the latter represents the costs of all energy resources. Results of MCI and percentage breakdown of the maintenance costs of the hotels studied are summarized in Table 3. On average, MCI is 336 $HK\$/m^2/yr$, involving 43 percent for in-house labor force, 22 percent for in-house materials and tools, and 35 percent for contracted-out maintenance and retrofitting works.

It is indicated by the statistical results that MCI is larger in high-class hotels in which more effort and resources are put into maintaining the engineering systems to satisfy the higher customers' expectations. As seen in Figure 2, values of ECI spread around an average of approximately 350 $HK\$/m^2/yr$. Although the range of MCI is wide, two-thirds of the hotels studied have similar MCI, between 201 to 400 $HK\$/m^2/yr$. The higher MCI in some hotels is due to major system breakdown problems or because of capital-intensive retrofitting works carried out in the reporting period.

It is of interest to know about the relative amount of maintenance

Table 3. Maintenance Cost Index and Breakdown of the Maintenance Cost

Class of Hotel	Maintenance Cost Index (HK$/m²/yr)				Maintenance Cost Breakdown (%)		
	Max.	Min.	Average	Standard Deviation	In-house Labor	In-house Materials/Tools	Contracted-Out Works
3-Star	403	162	276	88	59	17	24
4-Star	400	180	311	116	30	18	52
5-Star	585	244	379	112	39	26	35
Overall	585	162	336	110	43	22	35

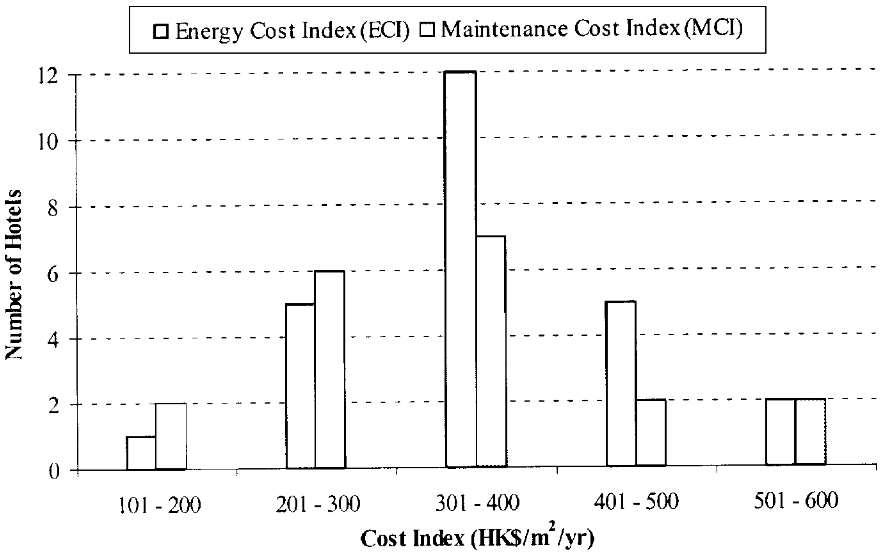

Figure 2. Normalized Energy Cost and Maintenance Cost Index

cost and energy cost. Based on the hotels studied, the maintenance cost rises along with the amount of energy consumption. This is shown in Figure 3. Surprisingly, the trends of both maintenance and energy costs with increasing amount of energy consumption are almost parallel. From these two trend lines of the hotels studied, the expected maintenance cost per joule of energy consumption is always marginally less than the expected energy cost per joule.

An implication of the above trends of maintenance and energy cost is that effective maintenance can lead to efficient plant operation and lower energy consumption. Dividing MCI by ECI will produce a maintenance performance indicator, which can be called the maintenance intensity signature (MIS). It carries an average value of 0.93 for the hotels studied. This will be useful to indicate how changes in maintenance would reduce energy consumption if strategies of optimizing the total expenditure on maintenance resources and energy could be developed. Sometimes, increasing MIS may be due to more resources spent on retrofitting works to improve system performance, and that is a positive action to achieve energy efficiency.

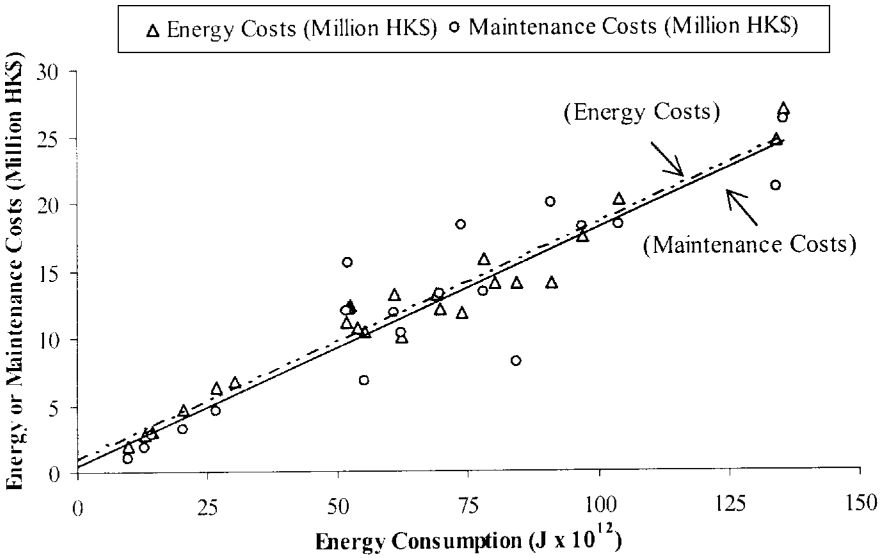

Figure 3. Energy and Maintenance Costs vs. Energy Consumption

MAINTENANCE RESOURCE ALLOCATION

In hotel practice, engineering employees are required to work in shifts (three shifts a day). On average, 67 percent of the total manpower is spent doing tasks in the day shift, including administration and maintenance works, and this arrangement can minimize disturbance to the hotel occupants, as most of them do not stay in hotels in the daytime. Fifteen percent and 9 percent are allocated in the mid-day shift and the night shift respectively, for handling equipment failures and emergency calls, during which almost no preventive maintenance is conducted. The remaining 9 percent account for employees on leave or holiday.

Based on the survey findings, the number of engineering employees in individual hotels is between 4 and 38, who handle 570 to 22,563 equipment failures in a year. The average ratio of guest rooms to employees is 24.2, and the ratio tends to be smaller for the higher class of hotels. This is summarized in Table 4. The ratio of the total number of failures to guest rooms, on the other hand, tends to be larger for the higher class of hotels because of their more comprehensive facilities and services. These two ratios are quantitative indicators that can be used in defining hotel categories and evaluating maintenance performance.

Table 4. Ratios of Number of Staffs and Failures to Guestrooms

Class of	Ratio of Number of Guestrooms to Staffs				Ratio of Number of Failures to Guestrooms			
Hotel	Max.	Min.	Average	Standard Deviation	Max.	Min.	Average	Standard Deviation
3-Star	48.5	16.6	31.7	10.2	15.9	1.9	8.9	5.7
4-Star	44.0	19.1	24.9	8.3	33.9	7.0	17.6	11.4
5-Star	28.6	11.4	18.9	4.7	50.9	3.6	19.2	15.1
Overall	48.5	11.4	24.2	9.0	50.9	1.9	15.4	12.2

Maintenance activities in hotels can be classified into four main categories: routine, corrective, preventive, and emergency. Routine maintenance refers to the daily activities with repetitive nature, such as taking meter readings, lubricating, monitoring, start-up, and shut-down. Corrective maintenance works are scheduled or unscheduled activities to restore the equipment to as-built functions. Preventive maintenance includes scheduled activities of inspection, adjustment, replacement, and overhaul to prevent system breakdown and extend its useful life. Emergency maintenance refers to immediate actions to avoid further equipment damage and adverse consequences, such as loss of business.

The relative portions of the above four types of maintenance activities in the hotels studied are shown in Figure 4. The findings indicated that there were as much as 30 percent of the maintenance resources spent on routine maintenance. Nevertheless, the maintenance personnel often took an attitude of overlooking routine maintenance as something insignificant. They were not aware that routine maintenance and preventive maintenance, if properly carried out, would effectively reduce system breakdown. If there is no clear maintenance policy, resources spent on routine maintenance may be wasted. System operating parameters should be monitored and compared against the criteria, and follow-up actions have to be taken for non-compliance or equipment failures.

One measurement of the maintenance effectiveness is the ratio of preventive maintenance to corrective maintenance actions in terms of man-hours use, called the preventive maintenance ratio (PMR). In a report of power plants, this ratio ranged from one to two [5]. It is expected that the PMR of hotels will not be as high as that for power plants, as the latter require a much higher reliability. In the hotels stud-

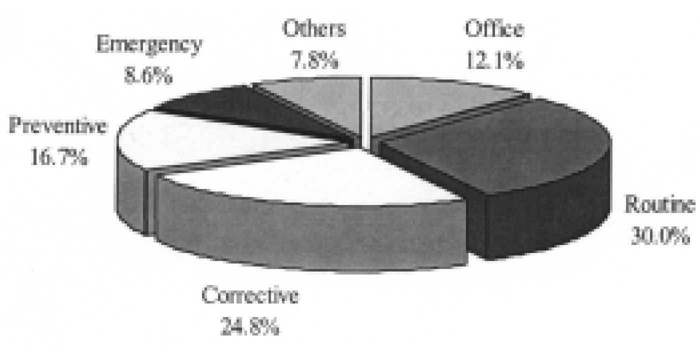

Figure 4. Percentage Breakdown of Maintenance Activities

ied the average ratio is 0.67, implying that the maintenance workforce is tied up with corrective work, which is commonly observed in hotels. For long-term improvement, the management must turn their attention from corrective maintenance to preventive maintenance. As the preventive maintenance program gradually matures, the ratio should increase if the engineering systems maintained are healthy.

To understand more about the in-house labor force spent on the maintenance of the engineering systems, including air-conditioning (HVAC), electrical and lighting (EL), plumbing and drainage (P&D), mechanical equipment (ME), and building and decoration (B&D), a total of 43,500 work orders issued in a year in the representative hotel were collected and analyzed. Approximately 54,300 man-hours were used to cover all the engineering systems, office works and others, such as supervisory works, inventory control and non-maintenance works. The related percentage breakdown is illustrated in Figure 5. Over 37 percent of the total manpower was spent on the air-conditioning, electrical and lighting systems.

MAINTENANCE PRACTICES

Development of the maintenance strategy and program is a process that involves the consideration of a variety of factors before making decisions. Questions in Section E of the questionnaire were designed to determine the status of maintenance-related factors. A five point numeric scale was used to indicate perception of the respondents on various factors, with ‘1’ for strongly disagreed or insignificant through ‘5’ for strongly agreed or significant.

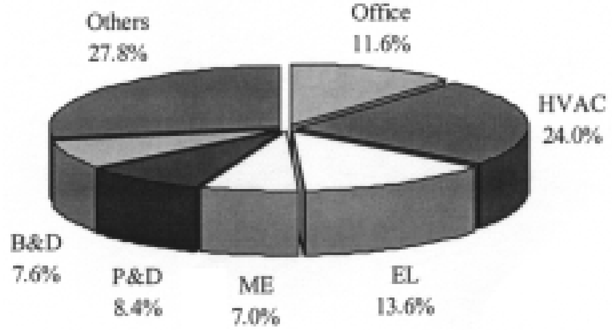

Figure 5. Apportionment of Manpower Used for Maintenance

Multi-skilling

Multi-skilling is a form of working which seeks to enhance staff strength through proper training. Multi-skilled staff are capable of individually undertaking a wider range of tasks, increasing flexibility in allocation of day-to-day labor force to tasks. Better utilization of their capabilities can improve the maintenance performance and quality of services. 81 percent of the respondents have deployed multi-skilling in their hotels. A question was designed to see if hotels gained benefits from the scheme of multi-skilling, and the average score was 4.1, implying that benefits were assured.

As indicated in Table 5, financial constraint is not a major barrier to the deployment of multi-skilling in hotels, though multi-skilled technicians usually have higher salary. What bothers the chief engineers is the problem arising from the attitude of front-line operators who often desire to do mono-skilled tasks and less work. Mono-skilled workers are normally less capable of achieving energy saving because of inadequate knowledge of the system. This can be solved by providing internal training to drill for better skill, accountability, and motivation. Safety, time, and ability of individuals are the constraints that have to be considered.

Computerized Maintenance Management Systems (CMMS)

Maintenance activities in hotels, including handling of work orders, compiling equipment histories, retrieving information, managing resources, and keeping stock inventories, can be accomplished more efficiently with the aid of a computerized maintenance management system (CMMS). CMMS has been utilized in 31 percent of the hotels studied. A question was designed in the questionnaire to investigate if the hotels gained benefits from the use of CMMS, and the average score is 3.6 out of the five-point scale. From discussion with some chief engineers, there were two major restrictions in the use of CMMS. First, a lot of time and manpower was necessary for collecting and inputting the data. Second, CMMS has a limited ability to generate detailed analysis reports or graphs that they needed, for example, the change of failure frequency and energy consumption in relation to the resources spent on the maintenance activities. Other barriers to the deployment of CMMS in hotels are shown in Table 6. It is noted that most of the front-line maintenance personnel are not able to use CMMS because they are handicapped in the English software language.

CMMS would allow the maintenance team to store and retrieve a

Table 5. Barriers to the Deployment of Multi-skilling Work Force

Description	Percentage of respondents for each scale					Average Score
	1	2	3	4	5	
Maintenance front-line operator dissatisfaction at doing more tasks	3.8	19.2	23.1	30.8	23.1	3.50
Time constraint on providing adequate internal training	11.5	11.5	26.9	30.8	19.2	3.35
Shortage of manpower to promote and monitor multi-skilling	7.7	11.5	38.5	26.9	15.4	3.31
Financial constraint on supporting multi-skilling	11.5	30.8	38.5	7.7	11.5	2.77

Table 6. Barriers to the Deployment of CMMS in Hotels

Description	Percentage of respondents for each scale					Average
	1	2	3	4	5	Score
Most front-line maintenance personnel can hardly read English	11.5	7.7	11.5	34.6	34.6	3.73
Most front-line maintenance personnel are incapable of using computer	3.8	19.2	23.1	34.6	19.2	3.46
Financial constraint on providing software and/or LAN-based computer system	19.2	11.5	23.1	15.4	30.8	3.27
Little support by top management	19.2	15.4	26.9	23.1	15.4	3.00
Incompatible with existing software used in hotel	19.2	11.5	38.5	15.4	15.4	2.96

vast quantity of information efficiently. One of the benefits of CMMS is the historical database that can be built up, from which the parameters for maintenance decision making, such as mean time between failure and mean time to repair, can be determined. It would also enable the chief engineer to identify trends of system status, develop an energy management scheme, determine a suitable time for overhaul or replacement, and automatically trigger the maintenance work orders according to the preventive maintenance schedules. The CMMS has to be capable of enabling the engineers to perform system analysis and formulate measures to improve system performance, for example, formulating and implementing a chilled-water temperature reset scheme for energy efficiency. Otherwise, the manpower required for the CMMS would not be justified.

Development of Maintenance Strategy and Program

Maintenance strategy sets the direction of maintenance management, whereas the maintenance program is a comprehensive schedule of maintenance works carried out in a specified period of time. Both involve a high level of decision making. In Table 7, the average scores indicate the significance of some key factors of concern to management prior to the development of maintenance strategy and program.

According to the findings, health, safety, energy consumption, and guest expectations are the main considerations for maintenance decision making, and they are equally significant with an average score of 4.12. Health and safety have become a fundamental requirement for business success; both depend on good maintenance practices to avoid hazards in the buildings or workplaces. Regarding energy consumption, the results reflect that the management is willing to make every effort to improve the maintenance management for energy savings. They also understand that customer perception of quality is determined by a number of factors relating to services, food, facilities, and indoor environment. For these reasons, a sound maintenance strategy should be developed and implemented to keep the engineering systems reliable, safe, and energy efficient, satisfying customer needs and expectations.

The equipment histories were valuable data, but responses from the chief engineers indicate that these data were seldom utilized. They appreciated that historical data analysis would provide useful information to the management for performance monitoring or maintenance

Table 7. Influential Factors of Decision-making for Maintenance Management

Consideration Factors	Average Score	Consideration Factors	Average Score
Health and safety	4.12	Reliability of system	3.77
Energy consumption	4.12	Criticality of system	3.65
Guest expectation	4.12	System life cycle	3.65
Degree of influence on business activities	3.96	Annual budget	3.58
Environmental impact	3.85	Feedback from other department heads	3.42
Hotel policy, objectives and targets	3.85	Manufacturers' recommendations	3.38
Maintenance resources (e.g. labor, materials, tools, workshops, etc.)	3.81	Equipment history records (e.g. failure mode, frequency and cause, etc.)	3.31
Legal requirements	3.77		

decision-making, but little effort was made on this aspect in the current practices.

In-house versus Outsourcing Maintenance

Maintenance works may be undertaken by in-house technicians, out-source contractors, or combination of both. There is no general rule for a desirable ratio of in-house to contracted-out labor force on which the management will decide based on availability of resources and a number of other factors. These factors and their weightings perceived by the chief engineers are summarized in Table 8.

Limited skill of the in-house technicians in specialized disciplines, as weighed by the chief engineers, was the most significant factor driving the management to employ outsourcing labor for some maintenance and retrofitting works. Time constraints was another significant factor, having an average score of 4.19. Since the main income of the hotels is from the rent of guest rooms and the provision of food and beverage services, including restaurants and banquet halls, longer downtime of critical equipment and functional areas will lead to a serious loss of business. As a result, the management has to carefully compare the working time needed by the outsourcing contractors with the in-house staffs. In general, specialized contractors are better equipped and have flexible manpower that will ensure the tasks are completed on time.

Another influential factor with high weighting is the statutory requirement. It is stipulated in local regulations that some activities, such as maintenance of fire protection systems, lifts and escalators, must be carried out by authorized contractors. Once again, the results show that the management makes little attempt to use the historical information in making a decision.

MAINTENANCE MANAGEMENT AUDITS

Maintenance management audit is a systematic approach to evaluate the current maintenance performance and identify necessary actions for improvement. There are alternative auditing schemes for evaluating the performance of the management, operation and maintenance [6,7]. Based on these alternatives, a workable self-assessed scheme is set up and applied for the maintenance management audits in hotels in this

Table 8. Influential Factors of Considering In-house vs. Outsourcing Maintenance

Consideration Factors	Average Score	Consideration Factors	Average Score
Skills of in-house technicians	4.23	Degree of system complexity	3.92
Time constraint	4.19	Financial constraint	3.88
Statutory requirements	4.15	Technical support from manufacturers	3.85
Availability of in-house labor force	3.96	Use of proprietary units and parts	3.73
Use of special tools and instruments	3.96	Historical information	3.35

study. The scheme comprises 40 questions and covers four principal aspects: maintenance policy, planning, implementation, and monitoring. It is designed to be simple to follow, requiring the participants to answer 'yes', 'partial' or 'no' for each question, with a score of '2', '1' or '0' respectively. Then a total score leads to five grades of excellent, good, satisfactory, marginal, and unsatisfactory, representing the overall effectiveness of the maintenance management. The audit results of the hotels studied are summarized in Table 9.

Table 9. Results of Maintenance Management Audits

Score Range	*Grade*	*% of Hotels Studied Achieving This Grade*
71 - 80	Excellent	11.5
58 - 70	Good	30.8
42 - 57	Satisfactory	46.2
26 - 41	Marginal	11.5
0 - 25	Unsatisfactory	0

The self-assessment scheme is designed to enable users to learn their strengths and weaknesses in the maintenance management. Common weaknesses of the hotels studied were identified, including no mission statement on the target maintenance performance, no established procedures for identifying variances between planned and actual maintenance activities, no clear policy for balance of engineering workload, no time budget specified for accomplishment of maintenance work orders, and no proper description of the work and material involved in the work orders. Individual hotel's scores in the maintenance management audit are compared with its normalized number of failure occurrences. This is shown in Figure 6. The regression line indicates that a hotel with high frequency of failure occurrence per m^2 floor area comes up with a low score in the audit. This suggests that the score obtained in using the self-assessment scheme is a good indicator of maintenance effectiveness.

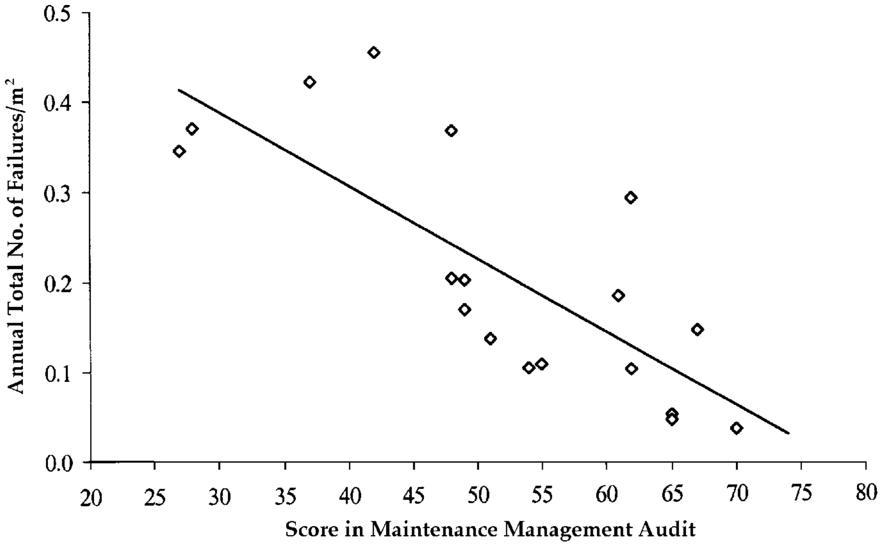

Figure 6. A Plot of Number of Failures vs. Score in Audit

CONCLUSIONS

Accommodation, food, and beverage services are the primary provisions and sources of revenue in hotels. Availability of the engineering systems is essential for support of hospitality business. The overall objective of maintenance management is to reduce the operation and maintenance costs while retaining the system availability and satisfying the users' expectations. Thus, through the maintenance management audit to constantly monitor, evaluate, and improve the maintenance works, reduction of running costs as well as system downtime can be achieved.

Energy performance index (EPI), energy cost index (ECI) and maintenance cost index (MCI) were compiled from the findings of questionnaire survey, interviews and detailed case studies. These can be utilized as benchmarks for evaluating the performance of energy use and for budget planning. The results also indicate a direct relationship between energy and maintenance costs in hotels.

The maintenance resource allocation for the different maintenance activities and engineering systems were investigated and reported. Key influential factors of decision-making by the chief engineers, in respect of maintenance program, deployment of multi-skilling work force, use of computerized maintenance management system, in-house and outsourcing maintenance, were identified. Health, safety, energy consumption, and customer expectation are the principal elements considered by most chief engineers prior to the development of a maintenance strategy and program. The key factors that influence the management to decide on the use of in-house or contracted-out labor are the skills of in-house technicians, time constraints, statutory requirements, and cost effectiveness. 81 percent of the hotels studied have deployed a scheme of multi-skilling work force, whereas only 31 percent have adopted a computerized maintenance management system. Outsourcing maintenance and multi-skilling work force are the trends. However, much effort has to be made before the hotels can benefit from the use of computerized systems for maintenance management.

The findings presented in this article are intended to provide the hotel management with a view of the current maintenance practices and energy performance in hotels, which would be useful for developing maintenance program to improve system availability and energy efficiency.

Acknowledgments

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