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Architectural Design of Large Hotel and Energy Used for Internal Space Thermal Control

Dr Bin Su, School of Architecture and Architecture Landscape, UNITEC Institute of Technology
Private Bag 92025, Auckland NZ, Telephone: 0064 9 8154321 ext. 7847, bsu@unitec.ac.nz

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Introduction

Studies both in New Zealand and internationally have suggested that the best place to consider building energy efficiency is during the design of the building, not when the building has been completed and is in operation. Large hotels are the big energy users, and are thus likely to gain the greatest benefits from improved energy efficiency (Isaacs 1996). A hotel mainly uses its energy on water heating, space heating, refrigeration, space cooling, cooking, lighting and other building services. Comparing with the energy used for others the energy used for the internal space thermal control (internal space heating and cooling) is more closely related to the hotel building itself. This study mainly investigated the relationships between the large hotel building design and the energy used for the hotel space heating and cooling. To minimize the influence of the difference of hotel facilities and climates, the research is based on the monthly energy consumption data (in a same whole year period of time) of a number of four and five star large hotels (more than 100 guest rooms) using central air conditioning system in the Auckland CBD and the design details of the hotel buildings. The energy consumption data is from the energy survey. Energy survey forms were sent to 11 large hotels, which have central air conditioning systems. 8 hotels had responded to the survey and 7 hotel's were suitable for the research.

Summary of Energy Usage of the 7 Large Hotels in Auckland

Historic surveys showed that the energy use per bedroom per year of large hotels (>100 rooms) in New Zealand have the widest range from very high (50678 kWh/room/year) to very low values (2075 kWh/room/year). The average value is 22371 kWh/room/year (Isaacs 1996). The range of the energy use per bedroom per year of the 7 large hotels in Auckland for this study was from 24832 kWh/room/year to 16221 kWh/bedroom/year. The average energy used in the 7 large hotels (22425 kWh/room/year) is very close to the average value of energy use of the large hotels in New Zealand (22371 kWh/room/year). Figure 1 shows the monthly mean energy used per room per night in the 7 large hotels in Auckland. Figure 2 shows the monthly mean energy used per m^3 per night in the 7 large hotels in Auckland. In Figure 2 the energy used per m^3 per night is calculated according to the actual space used in each month not including the volume of the vacant hotel rooms' space. To compare the energy used in the 7 hotels, Figure 1 and Figure 2 show different pictures.

The mean energy used per room per night in a hotel (e.g. the hotel 1) is lower than the other hotels but the mean energy used per m^3 per night could be higher than the other hotels. Using different units to compare the energy used in different hotels the results can be different.

The question is what unit is appropriate to be used to present or compare the energy consumptions or the energy efficiency related to the different hotel building designs, especially to compare the energy used for internal space heating and cooling. The national and international energy surveys for the hotel sector commonly used kWh/room/year as the units to present the energy used in the hotels. The mean energy data use per room in the national energy survey can be used to show the general profile of energy used in hotel business. The mean energy used for the space heating and cooling per unit of the volume actually used in the hotel (not including the volume of the vacant rooms) is more appropriately used for the comparison of building design.

Figure 1

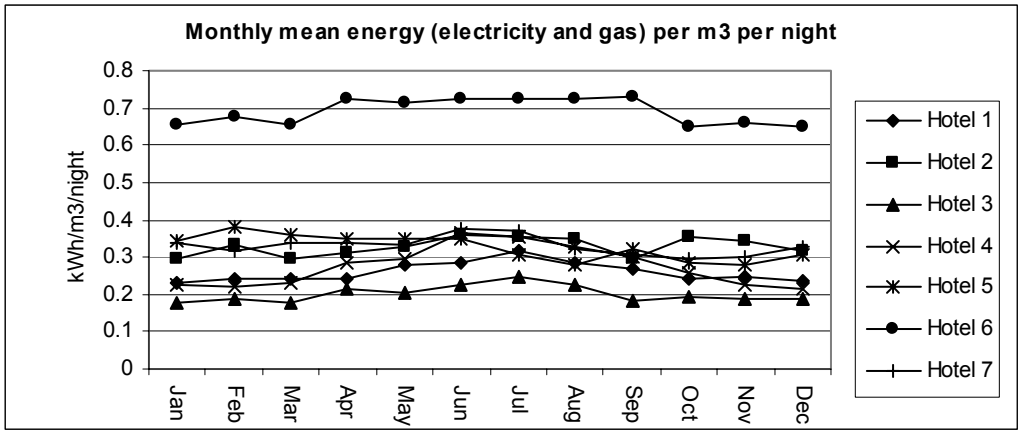
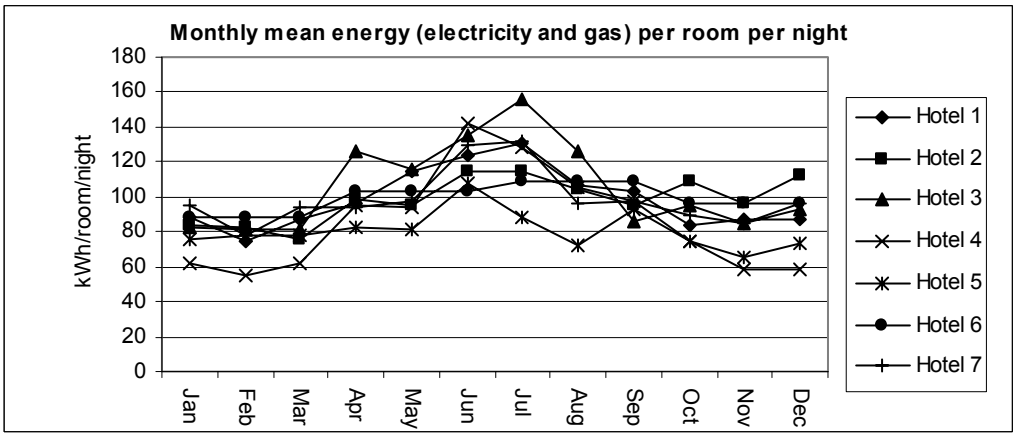


Figure 2



Calculation of the Energy Used for the Space Heating and Cooling

For the hotel with a central air conditioning system, the space heating is commonly supplied by the gas boiler and the gas boiler also supplies the hot water for the whole hotel. The space cooling is supplied by the cooling tower. It is difficult to identify how much energy is used for the space heating and cooling according to energy

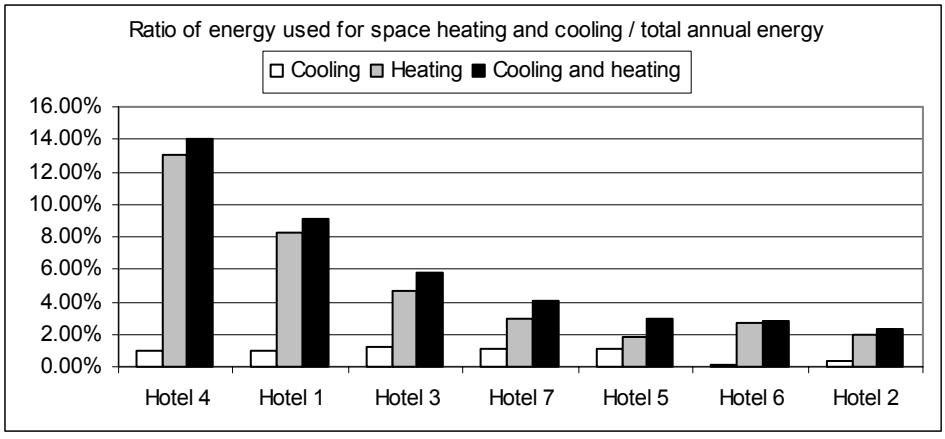
consumption data from the meters in the current central air conditioning system and it is time consuming and expensive to install the meters on the existing central air conditioning systems to obtain the actual energy consumption data of the space heating and cooling.

For the comparison of the energy uses for thermal control related to the different hotel building designs, the approximate values of the space heating and cooling energy were calculated according to the monthly electricity and gas consumption data, the monthly occupancy data and the building design data of the 7 large hotels. The accuracy of the thermal control energy from the calculation cannot be compared with the value from the meter but it can be used to indicate the profile of the energy used for the space heating and cooling in a hotel and to compare different designs of the hotel buildings.

The method to approximately calculate the energy used for the space cooling is based on the difference of the mean electricity used in per m^3 of the actual hotel internal space being used (not including the vacant rooms' space) per night between the likely cooling months (December, January and February) and the months without cooling or unlikely using a lot of energy for the space cooling (such as March, April, August and November). The method to approximately calculate the energy used for the space heating is based on the difference of the mean gas (or electricity if electricity heater is used in the central air conditioning system) used in per m^3 of the actual hotel internal space being used (not including the vacant rooms' space) per night between the likely heating months (from May to September) and the months without heating or unlikely using a lot of heating energy (such as March, April, August and November).

Figure 3 shows the ratios of the energy used for the space heating and cooling and the total annual energy used in the 7 large hotels. The energy used for the space heating is the major portion of the energy used for total internal space thermal control. In Auckland the large hotel building design should focus more on reducing the space heating energy to save the total energy for internal space thermal control.

Figure 3



Relationships between Building Design and Energy for Thermal Control

The building design data used for investigating the relationships between the building design and the energy used for internal space thermal control is as following:

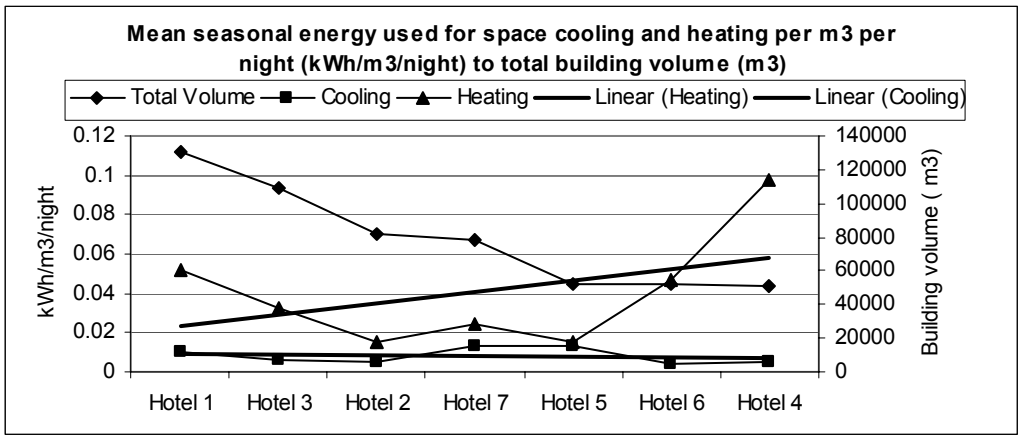
- Ratio of surface area / building volume
- Ratio of total opening area / total wall area
- Ratio of total roof area / total floor area
- Ratio of total area of North, East, West side walls / building volume
- Ratio of total room volume / building volume
- Building volume
- Building height

The energy data used for the study is the mean energy used for the space heating and cooling in per m^3 of the actual hotel internal space being used (not including the vacant rooms' space) per night in the heating and cooling seasons. The unit of mean energy used for the space heating and cooling is kWh/m^3/night.

Building Volume

The range of the volumes of the 7 hotel buildings is from 15178 m^3 to 41736 m^3. The trend of energy used for the space heating increases with the decrease of the building volume. The trend line of energy used for the space cooling keeps flat with the decrease of the building volumes (see Figure 4).

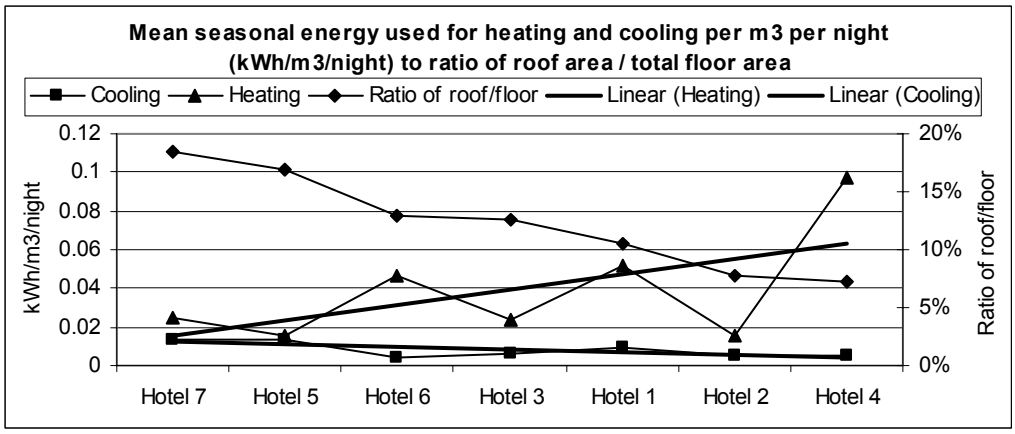
Figure 4



Ratio of Roof Area / Total Floor Area

The ratios of roof area / total floor area of the hotels are in the range of 7% to 18% (see Figure 5). The trend of the mean energy used for the space heating increases with the decrease of ratio of roof area / total floor area. The mean energy used for the space heating strongly responds to the decrease of ratio of roof area / total floor area. A small ratio of roof/floor is good for saving the heating energy. The trend of the mean energy used for the space cooling decreases with the decrease of the ratio of roof/floor.

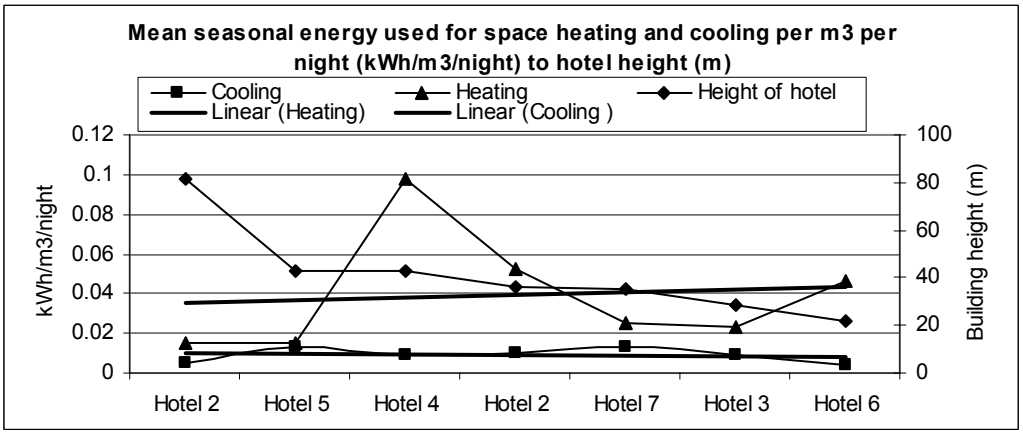
Figure 5



Building Height

The range of the heights of the 7 hotel buildings is from 22 m to 81 m (see Figure 6). The trend of the mean energy used for the space heating slightly increases with the decrease of the building height. The trend of the mean energy used for the space cooling slightly decreases with the decrease of the building heights. Comparing with the ratio of roof area / total floor area, the trends of mean energy used for heating and cooling do not strongly respond to the change of building height.

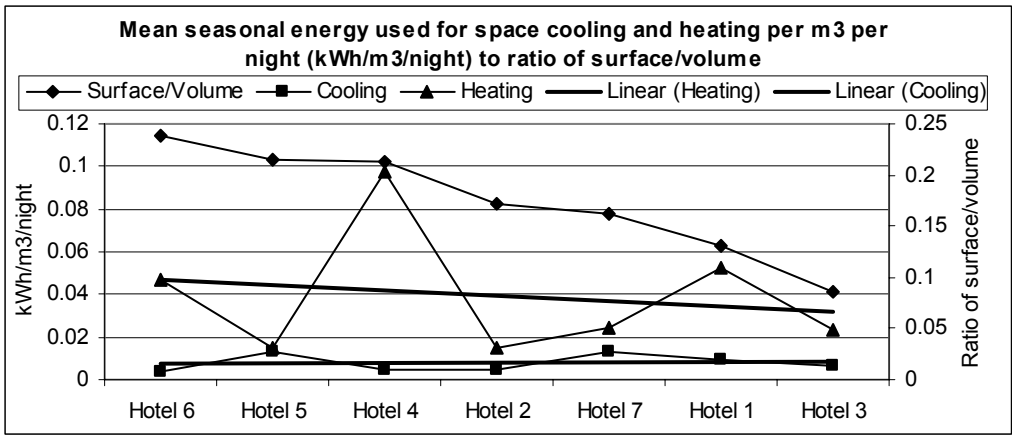
Figure 7



Ration of Building Surface Area / Building Volume

The trend of mean energy used for the space heating in the hotels decreases with the decrease of the ratios of surface/volume. The trend line of mean energy used for the space cooling keeps flat with the decrease of the ratios of surface/volume (see Figure 7). The ratios of surface/volume of the 7 hotels are in the range of 0.09 to 0.24. Chinese Building Standard JGJ26-95 requires that the ratio of surface/volume of the multi-storey residential building with the permanent heating is 0.3 or less for saving the energy for the space heating (Liu 2000). The ratios of the 7 hotels are all under 0.3.

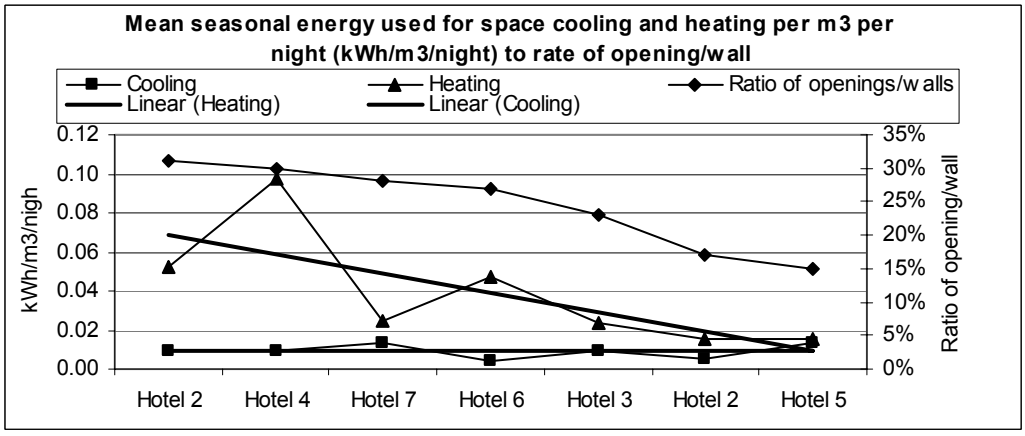
Figure 7



Ratio of Total Opening Area / Total Wall Area

The ratios of total opening area / total wall area of the hotels are in the range of 15% to 31% (see Figure 8). The trend of mean energy used for the space heating in the hotels decreases with the decrease of the ratios of total opening area / total wall area. The change of energy used for the space heating in the hotels strongly responds to the change of the ratios of opening/wall of the hotels. Generally a small ratio of opening/wall is good for saving the heating energy. The mean energy used for cooling does not change with the decrease of the ratio of opening/wall.

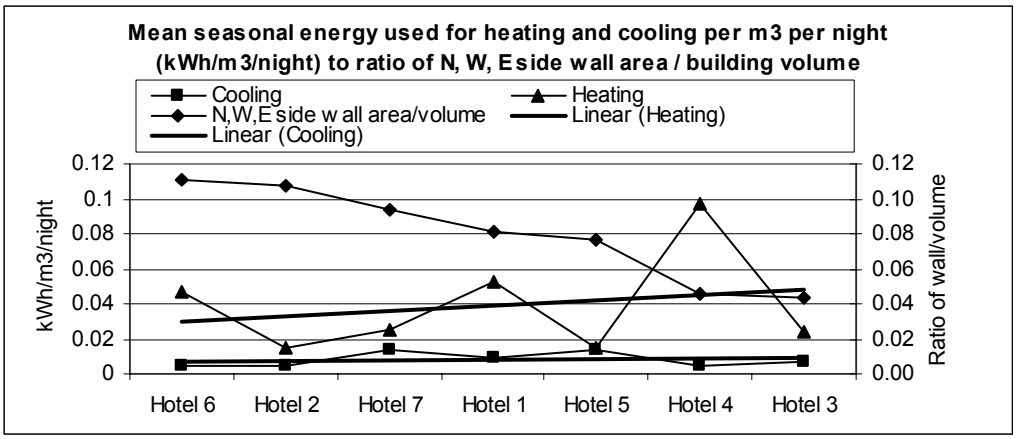
Figure 8



Ratio of Total Area of North, West and East Walls / Building Volume

The ratios of total area of North, West and East walls / building volume of the hotels are in the range of 0.04 to 0.11 (see Figure 9). The mean energy used for heating increases with the decrease of the ratios of total area of North, West and East walls / building volume of the buildings. The more area of walls was exposed to the sun; the less the energy was used for the space heating in the hotel. The mean energy used for the space cooling does not change with the decrease of the ratios of total area of North, West and East walls / building volume.

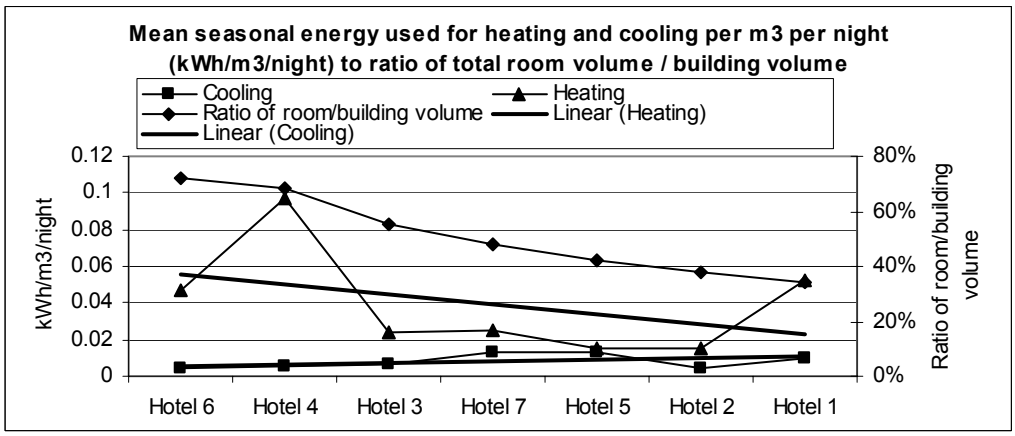
Figure 9



Ratio of Total Room Volume / Building Volume

The ratios of total room volume / building volume of the 7 large hotels are in the range of 34% to 72% (see figure 10). The mean energy used for the space heating decreases with the decrease of the ratios of total room volume / building volume. The mean energy used for the space cooling slightly increases with the decrease of the ratios of total room volume / building volume.

Figure 10



Conclusion

The energy used for the space heating is the major portion of the total energy used for internal space thermal control. This study shows the trend of the energy used for the space heating in the large hotels more strongly responded to the change of the building designs to compare with the energy used for the space cooling. In Auckland the large hotel building design should focus more on reducing the space heating energy to save the total energy for internal space thermal control.

It is difficult to study the relationships between the existing building design and the energy used for the internal space thermal control without available energy consumption data for the space heating and cooling in the buildings. This is because the energy used for the space heating and cooling cannot be directly identified through the energy consumption data recorded by the meters in the current central air

conditioning systems. It is also time consuming and expensive to install the meters on the existing central air conditioning systems in the buildings to obtain the actual energy consumption data for the space heating and cooling. Using the monthly energy consumption data of electricity and gas, the occupancy data and the building design data to calculate approximate energy data for the space heating and cooling can be an option for the studies to compare the different building designs related to the energy used for the space heating and cooling.

Larger energy used for the internal space thermal control in the large hotels does not necessarily result from poor energy management or inefficient equipment. It may be due to the hotel building design. Architects should also take a greater responsibility and leadership for hotel energy efficiency especially for the energy used for the internal space thermal control.

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