A LIFE-CYCLE COSTS STUDY OF A HOTEL BUILDING: A CASE-STUDY APPROACH

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ABSTRACT

It is common that the first cost is the main criterion when making choices between different systems. However, it is possible to demonstrate that a lower initial investment can turn out to be more costly from the whole life-cycle viewpoint. With life-cycle cost (LCC) calculations, it is possible to get better overview of the total cost. LC costs of typical systems (fan-coil, variable air volume and ventilated beams) were analyzed and compared in a case-study hotel building. Fan-coils are considered as a standard system for hotels to provide air conditioning. Disadvantages of fan-coil system are high maintenance costs and sound generation to the guest room. One new alternative is the ventilated beam system in hotels. The analysis shows that the ventilated beam system offers comfortable indoor environmental with competitive life-cycle costs. The LC cost of the system where is utilized air-water based ventilated beams in guest rooms was the lowest. Energy consumption and maintenance cost of the ventilated beam system is also lower than compared VAV and fan-coil systems.

KEYWORDS

Life-cycle costs, energy analysis, hotel building

INTRODUCTION

The building industry continues to see a growing interest in creating solutions that consider the priorities of indoor air quality and energy conservation. Additionally, there is obvious link with indoor climate and productivity. Recent studies have shown the link between indoor air quality to thermal comfort, productivity and health issues. Thus, it was possible to demonstrate that an investment to a better air-conditioning system is profitable already with very modest productivity improvements.

In hotels, high noise level has been reported to be one of the main problems in indoor environment quality (IEQ) [1]. Other pointed out problem is high ambient concentration of carbonyl compounds [2]. In indoor air, carbonyl compounds could be released from building materials, furniture, consumer products and through chemical reactions between indoor ozone and alkenes. Measured high concentration of pollutant indicates wrong selection of materials and insufficient ventilation for the actual emissions.

The need to consider the quality of the space is encompassed within the publication "Ventilation for Buildings – Performance requirements for ventilation and air conditioning systems" [3]. This sets a range of technical target values that need to be agreed between the designer and the client. Thus, end-users will become much more aware of what can be expected. During the design phase, the suitable air-conditioning system should be selected that maintains the set targets of IEQ in an energy efficient manner.

In the building process, it is still common that the first cost is the main consideration when making choices between different systems. A lower initial investment can turn out to be more costly from the whole life-cycle viewpoint if the operation costs and the influence on productivity of workers are not taken into account.

In this paper, the life-cycle cost of typical air-conditioning systems in the hotel environment are studied using a case-study approach. The case-study hotel building is located in Paris, France. This paper presents the main results of the conducted comprehensive life-cycle survey of a hotel building [4].

A CASE-STUDY HOTEL BUILDING

The building is located in Paris, France. The total area of the east-west oriented building is 6,715 m². In the building, there are 6 floors and altogether 300 guest rooms. The area of the guest room is 28 m^2 with a separate bathroom of 5 m^2.

The design room air temperatures are 24 °C in summer and 22 °C in winter. The average reservation ratio of the guest rooms is assumed to be 80 %. For the energy saving reason, the room temperatures are controlled based on the state of reservation and occupation:

- no reserved room: heating 16°C, cooling 27°C
- reserved room but no occupation: heating 19°C, cooling 23°C

The U-values of the building structures are:

- exterior wall 0.35 W/m²K
- triple glazed windows 2 W/m²K (no shades)

The heat loads consists of 2 persons, lighting and equipment loads in the guest room. The heat gain of the lighting is 10 W/m² and the equipment heat gain is 7 W/m² in the guest rooms

The analyzed air-conditioning systems are: A1) cooled beam with separate water radiators A2) cooled beam with integrated heating mode, B1) variable airflow rate (VAV) with water reheating, B2) variable airflow rate (VAV) with electrical reheating, C1) Fan-Coil (no condensation in the room unit) and C2) Fan-Coil (condensation). The supply and exhaust airflow rates are 22 L/s in the guest room. In the air-handling unit, there is no heat recovery system.

The cooling capacity of the systems is conducted with dynamic energy simulation software using the hourly weather data of the city of Paris. The calculated cooling capacities and the requested airflow rates are shown in Table 1.

Table 1. The requested cooling capacities and airflow rates of the analyzed systems.

Case	**Analyzed Air-Conditioning System**	**Occupied east oriented guest room**	**Occupied west oriented guest room**
A1	Cooled beam with water radiators	36.9 W/m²	40.4 W/m²
A2	Cooled beam (heating and cooling)	36.9 W/m²	40.4 W/m²
B1	VAV with water reheating	1.1 / 4.1 l/s per m²	1.1 / 4.5 l/s per m²
B2	VAV with electrical reheating	1.1 / 4.1 l/s per m²	1.1 / 4.5 l/s per m²
C1	Fan-coil unit (dry)	36.9 W/m²	40.4 W/m²
C2	Fan-coil unit (condensing)	52.8 W/m²	57.8 W/m²

RESULTS

Annual heating and cooling energy consumptions of the analysed air-conditioning systems are shown in Figure 1. The ventilated beam systems (case A1 and A2) have significantly lower consumption than the fan- coil (case B1 and B2) and VAV systems (case C1 and C2). Even when the cooling energy consumption of the variable airflow system (VAV) is lower than beam and fan coil systems, the total energy consumption of VAV is the highest of the analyzed systems. The reason for that is the highest heating energy consumption. Particularly, high consumption of the fan electricity increases significantly the total energy consumption of the fan-coil systems. The total consumptions of the fan-coil systems are only little bit lower level than VAV systems.

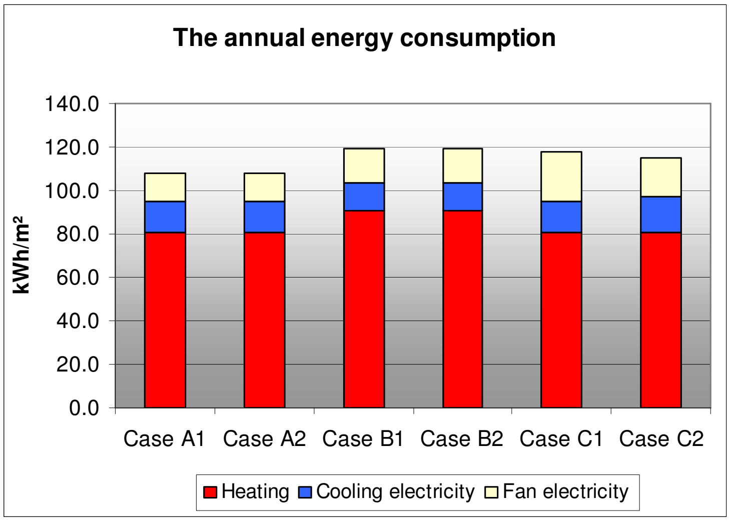

Figure 1. The annual energy consumption of the hotel building in Paris.

Taking into account the typical costs of heating energy (20 €/MWh) and electricity (53 €/MWh), the energy costs of the beam systems is about 10 % lower than the other systems, Fig. 2. It should be noted that fan electricity is playing a significant role in the breakdown of the energy costs and it is about the same level than the costs of the cooling energy.

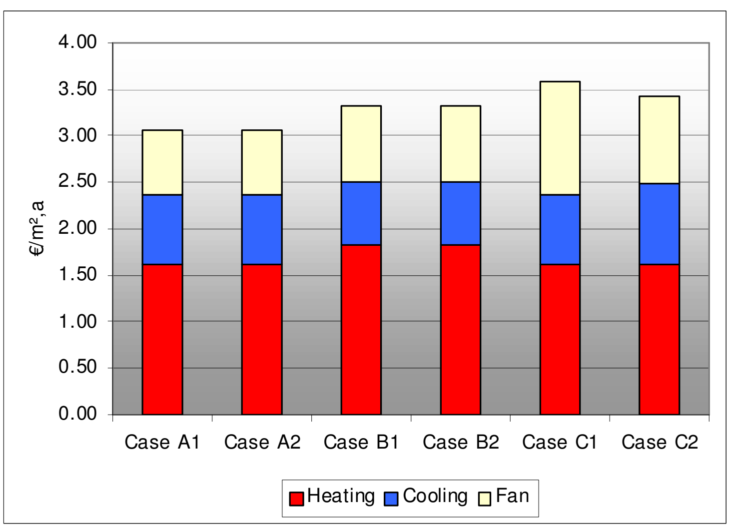

Figure 2. The annual energy costs of the hotel building in Paris.

Life-cycle costs (LCC) calculations were conducted for comparing technical systems. The LCC calculations included the investment, energy and maintenance costs. The components and systems included in the analysis covers:

- Central Air Handling, cooling and heating units
- Mechanical networks (ductwork, heating and cooling pipe work)
- Room equipment (cooling beams, fan-coils, VAV-units, water radiators, diffusers, grilles and valves)
- Building automation and electricity of the mechanical systems

The components included in the comparisons were limited to the components and costs, which vary between different technical solutions. However, the cost differences of central air handling units ductworks etc. that vary between different technical solutions are included in the comparisons.

The investment and maintenance cost calculations are carried out using software, which is supported by the statistical database. In the calculation method, preventive periodical maintenance including the labour and material costs is also taken into account. Calculations were conducted for a life cycle of 15 years. The net interest rate is set to be 7.0 %. The net present values are shown in Figure 3.

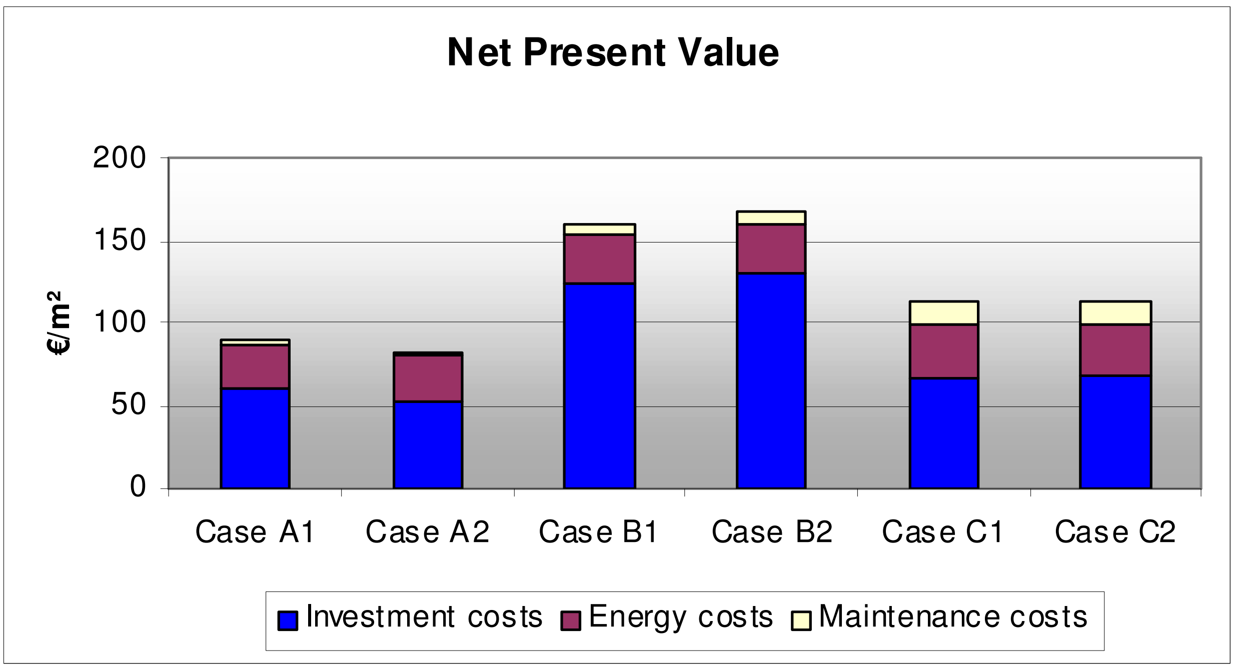

Figure 3. The net present value of the analyzed systems.

It should be noted that the investment cost signifies in the breakdown of the net present value. Independent of the system, investment costs is about 50 - 70 % of the total LC costs. Still, the energy consumption and maintenance are important factors to take into account during relatively quite short calculation period of 15 years.

From the analyzed systems, ventilated beam systems (A1 and A2) have the lowest net present value. The fan- coil systems (C1 and C2) have the second lowest costs. However, the net present value of the fan-coils system is about 35 % higher than the beam system. All-air VAV systems (C1 and C2) have significantly higher net present values than air-water concepts because of more expensive room units. Also, the air handling units and ductworks are much larger with all-air systems. The total net present value of the VAV is about 100 % higher than the ventilated beam system.

There is remarkable difference with the maintenance costs of the systems. The maintenance cost of the beam system (2.5 €/m^2) is much lower than with the compared fan coil (6.8 €/m^2) and VAV (15.9 €/m^2) systems.

CONCLUSION

LC costs of typical systems (fan-coil, variable air volume and ventilated beams) were analyzed and compared in a case-study hotel building. The investment cost signifies in the breakdown of the net present value. Still, the energy consumption and maintenance are important factors to take into account. Independent of the system, energy and maintenance costs are about 30 - 50 % of the total life-cycle costs. The life-cycle cost of the ventilated beam system was lower than the compared systems. The energy and maintenance costs of the ventilated beams is also lower than the fan coil and VAV systems.

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