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COMPARISON OF LIFE CYCLE COST OF CENTRALIZED AND SPLIT AIR CONDITIONING SYSTEMS

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Central and split systems are the two most common air conditioning (AC) systems used in residential applications. Central system employs one large unit to produce and distribute conditioned air through a system of ductwork. On the other hand, the split system, employs several small ACs. Each AC consisted of outdoor and indoor units to produce conditioned air directly to the designed area. Each system has distinct strengths and weaknesses. Depending on the structure of cooling area and operating schedule, the performance of each system will be different. The aim of this paper is to examine the impact of various parameters such as operating schedule and building characteristics to the performance of central and split AC systems over the 25 years of their operation. The life cycle analysis (LCA) considered essential factors which have significant impact on the energy consumption and both initial and operating costs of the two systems. All required sections of life cycle analysis are included according to the relevant Australian Standards. The results indicated that under standard operating conditions, central system is more economical and energy efficient than split system. However, when the flexibility in operation of split system is considered, there was a significant reduction in its operating cost, which was below that of central system. Overall, total life cycle cost of split system was slightly lower than central system. Also, considering the usage flexibility and the comfort of users, it appears that the split system is more suitable than the central AC system for residential buildings.

Keywords: Heating, Cooling, Residential buildings, Sustainability, Initial cost, Operating cost, Life cycle cost.

1 INTRODUCTION

Air conditioning is an essential part of both residential and commercial buildings. This would be the case especially in the light of impending climate changes. Climate change is expected to increase extreme weather conditions in the future. This makes all the more important for buildings to have air conditioning systems which can provide warm or cold air when required. The objective of the air conditioning is to maintain the inside the building air temperature at around 24°C.

This study mainly focuses on the residential buildings air conditioning. Air conditioning requirements for residential buildings is generally met either by centralised or split system. Both systems have their own strengths and weaknesses. Central system was proven in many previous studies (Gheewala and Nielsen 2003,

Yang *et al.* 2001) to have better efficiency in operation than split systems. In central system one single AC unit is employed to provide conditioned air. The unit is connected with a system of ductwork to deliver conditioned air to the designated areas (rooms). The position where the unit is installed greatly affects the design of duct system. The centre of the building is normally taken as the best position to locate the central unit where minimal length of duct is required to run the duct to designated rooms. The unit is usually placed on the ceiling area and hence it is called 'rooftop unit'. On the other hand, a split system can cover a smaller area than the central system, normally one unit per room. A split system consisted of an outdoor and indoor unit. Refrigerant is transferred between these two units to receive and release heat into or out of a building depending on the operating mode.

A building model was developed using Archicad software (https://myarchicad.com/). The model was assigned with a construction set comprising a particular types of external wall, roof, ground floor and windows. More details are given in Ho (2013). Operating cost of the AC systems was simulated for the building using Bentley Hevacomp software (https://www.bentley.com/en/products/brands/hevacomp).

2 INSTALLATION, MAINTENANCE AND DISPOSAL COSTS

The initial installation costs for both central and split systems were estimated by taking into account the market value of various components, which are given in Table 1. Central system was found to be slightly expensive due to the high installation cost associated with the ducting. The assumptions involved in estimating the maintenance cost and the estimated costs for both central and split systems are given in Table 2. Also, Table 2 shows the estimated disposal costs after the life period of 25 years.

Table 1. Initial installation cost of both the systems.

Items	Central system	Split system
Initial installation cost	$9,237 (this included installation of the main air conditioning unit plus the associated ducting)	$8,792 (this included installation of 7 split systems)

3 OPERATION COST

To estimate the operation costs for both the air-conditioning systems two scenarios were developed reflecting the operation of AC systems in residential building in real life (Ho 2013):

- Scenario 1 was aimed to represent typical AC usage schedule in a general family, for example: from 9am to 5pm all members have to leave the house for work and school, hence the system is off. When all members are at home, ACs in selected areas are operated to suit particular activities such as having dinner or go to bed.
- Scenario 2 was developed to reflect the operation flexibility of split system to increase the overall efficiency of HVAC operation. In scenario 2 it was assumed that one bedroom is used as guest room and hence, requires no

cooling need during the week. The guest room will be utilised in the weekend and will be operated on the same schedule with other bedrooms. Operation of AC in other room was also modified. This scenario particularly applied for split system as each system could be operated individually.

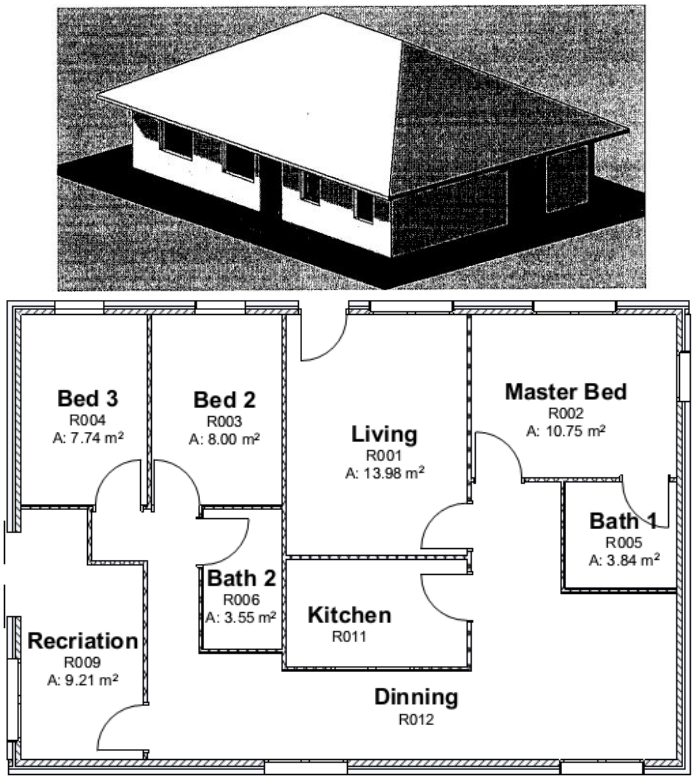

Figure 1. General plan and 3D view of the building considered for simulation.

Table 2. Maintenance and disposal cost of central and split system.

Maintenance	
General tasks	
Refrigerant check; Temperature check; Function check	
Central system	**Split system**

• Return filter replacing
• External condenser coil cleaning
 	
Unit cost: $ 250 per system
Total annual cost: $ 250
	• Outdoor unit cleaning
	• Indoor unit cleaning
	  ○ Filters cleaning
	  ○ Indoor evaporator coils cleaning
	Unit cost: $ 80 per unit
	Total annual cost: $ 560

Disposal	
Central system, including • Duct disconnection • Refrigerant removal • Unit removal Unit cost: $ 450 per system Total cost: $ 450	Split system, including • Pipe disconnection • Refrigerant removal • Unit removal Unit cost: $ 120 per unit Total cost: $ 840

Annual operating cost for both air conditioning systems were estimated using Bentley Hevacomp software. The results are shown in Figure 2. As explained earlier, while the Scenario 1 was applied for both central and split air conditioning systems, Scenario 2 was applied only for split air conditioning system. An inflation rate of 3 per cent was used to calculate future operating cost base on the first year cost (Trading Economics 2013).

4 NET PRESENT VALUE (NPV)

Using the economic parameters listed Table 3, net present values over 25 years operating life of the air-conditioning systems were computed. The results are shown in Figure 3. As shown in the figure, under standard operating conditions (Scenario 1), the central air conditioning system works out to be cheaper over the 25 years of the operating life. However, when the flexibility of the operating split air conditioner (Scenario 2) is considered, the split air conditioning system works out to be cheaper. In addition to the economic benefits associated with the split air conditioner over the operating life of 25 years, it provides superior comfort for the users as the level of air conditioning can be set individually for each room. On the other hand the temperature settings under the central air conditioning system can only be set as per the zones which may not provide the ability to adjust the temperature at room level. Thus the comfort at the room level is not guaranteed.

Table 3. Input data for life cycle analysis simulation.

Parameter	Value
Annual inflation rate	3 %
Period of analysis	25 years
Electricity price	$0.30/ kWh
NPV discounted rate	5 %

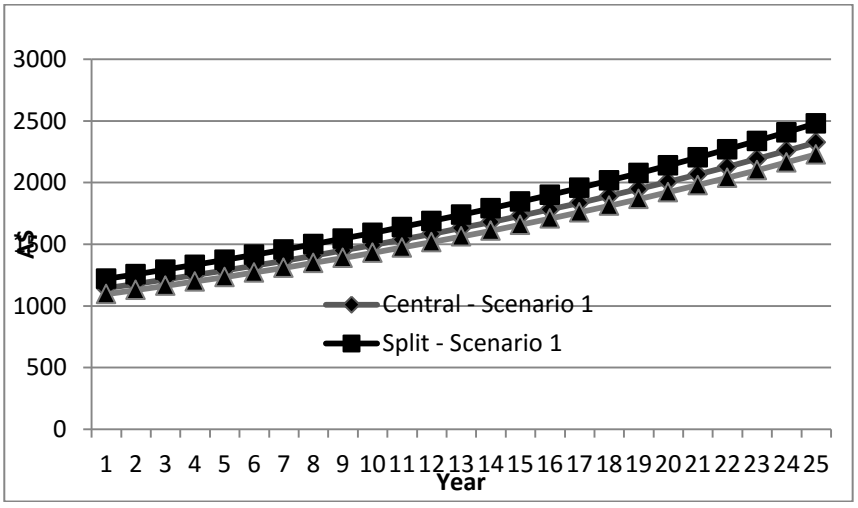

Figure 2. Annual operating cost of central and split systems over 25 years of life.

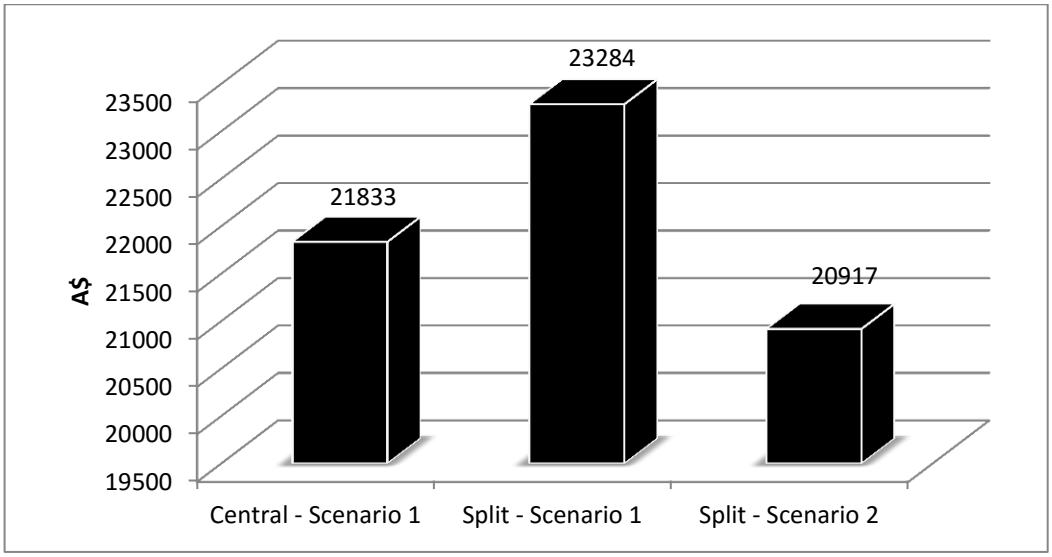

Figure 3. Total operating NPV in 25 years life cycle of central and split system.

5 CONCLUSIONS

This paper compares the overall cost over 25 years period between central and split air conditioning (AC) systems. Central system provides conditioned air by zone and appears to have effective airflow management. However, this type of AC system requires long installation time and higher initial cost. Moreover, zoning does not allow control of conditioned air at room level which can become a source of energy wastage if there is any room belong to the zone but is not required to be conditioned. Also, central AC systems do not provide for user flexibility. Split system has the ability to control conditioned air at room level and hence, can achieve better energy efficiency. However, single split requires one set of indoor and outdoor units for each room to be conditioned which may be time-consuming and costly for maintenance. Operation of split system is less efficient than central system.

Both central and split systems have distinct characteristics that can affect the associated cost in various stages in their life cycle. Central system which the requirement of ductwork for supply and return system has its initial cost varies significantly according to the number of zones, the building structure and the size of cooling area. On the other hand, initial cost of split system seems to be immune with change of building structure and the size of cooling area. Initial cost of split system only changes at a moderate rate when there is change in the number of rooms which usually requires purchase of additional AC units. Operational stage is where central system shows its strength over split system. Simulations in annual and life cycle perspectives show that central system operates more effective and economical than split system in the same scenario.

A 25 years life cycle cost analysis shows that in a long term consideration, split system is a more suitable HVAC system to be chosen. The inefficiency in operation is outweighed by the low initial cost and flexibility in operation which makes life cycle cost of split system more economical than central system.

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References

Gheewala, S. H. & Nielsen, P. H., Central and individual air-conditioning systems - A comparison of environmental impacts and resource consumption in a life cycle perspective. *International Journal of Sustainable Development and World Ecology,* 10**,** 149-155, 2003.

Ho, K. D., Life cycle analysis of different residential air-conditioning systems. Honours thesis, University of Western Sydney, Austrlia, 2013.

Trading Economics, *Australia Inflation Rate* [Online]. Retrieved from http://www.tradingeconomics.com/australia/inflation-cpi on September 13, 2013.

Yang, H., Burnett, J., Lau, K. & Lu, L., Comparing central and split air-conditioning systems. *ASHRAE Journal*, 43, 36, 2001.