Comparative Study on Implementing Home Air Conditioning for Passenger Carriages in the Indonesian Railway

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ABSTRACT

Passenger comfort is important in railway transport system. The train operator company in Indonesia would like to increase passenger comfort by installing home air conditioning into all existing carriages of the economy train. The air conditioning is expected to give better passenger convince. Therefore, the aims of this research are to know the cooling load and compare characteristic between home Air Conditioning (AC) and train AC. The cooling load calculation is analyzed using Cooling Load Temperature Difference (CLTD)/Solar Cooling Load (SCL)/Cooling Load Factor (CLF) method. Comparison between both home air conditioning and train air conditioning are discussed to identify the benefits and drawbacks of each type. The total heat that needs to be removed from a passenger carriage with home AC is 104,334 Btu/h, while the total cooling capacity of home AC is 75,000 Btu/h. The passenger carriages with train AC have cooling capacity 119,100 Btu/h to remove heat 11,5290 Btu/h. The Energy Efficiency Ratio (EER) value of most home AC is higher than train AC, installation time of home AC is shorter than train AC, total cost for 20 years period of home AC is more than train AC. There is no guarantee for home AC, so everything that happens to it will become the full responsibility of train operator company. The train AC control system is more effective than the home AC. No fresh air is permitted to circulate within the home AC system hence, the same air is repeatedly processed in the system. Implementing home air conditioning in the existing passenger carriages is worthwhile for short time period in the goal to increase and improve the level of service provided by giving better comfortability to the passenger.

Keywords: Air conditioning, cooling load, passenger carriage, CLTD/SCL/CLF.

1 INTRODUCTION

Indonesia is a developing country that is trying to build a better railway system. The Government, as rail infrastructure owner is continuing to build new rail infrastructure to develop railway links to increase railway routes. Additionally, train operating companies has attempted to increase the level of service by upgrading the train facilities. Indonesia as a tropical country with a mostly hot climate during the whole year highly requires air conditioning on the trains. Not all trains in Indonesian railway have air conditioning. The majority of the older passenger carriages do not have air conditioning. To cope with this problem, the train operating company of Indonesian railway provided home air conditioning to increase passenger satisfaction and comfort ability.

The train operating companies decided to use home air conditioning in the passenger train because of it is easier and faster to install. Subsequently, carriages do not need to stay in the workshop for a long time, as the installation can be done in the train depot. The train operating companies argue that using home air conditioning is cheaper than using train air conditioning, so the cost to build and maintain the air conditioning is reduced.

Factually, the home air conditioning is not designed to be used in the railway carriages; it is designed for static places like homes or buildings rather than for moving objects. Therefore there could be risks as a consequence of placing home air conditioning on the train. Before train operating company implemented home air conditioning on the train, there was no initial

study conducted or engineering design made to cope with this plan. Therefore, it is important to conduct research on the implementation of home air conditioning on passenger carriages to find out how they perform and assess any associated risks or effects that might occur.

The main objective of this paper is to give suggestion to Indonesian Government to allow or not related to implementing home air conditioning in the train. There are several aims to achieve the objective of this research, i.e. to calculate the amount of heat that needs to be removed from the passenger carriage with full loaded, to compare the performance of home air conditioning and train air conditioning, and to identify the risks that could happen on implementing home air conditioning in the train.

2 LITERATURE REVIEW

2.1 Air Conditioning

According to ASHRAE (2016), the first functional definition of air conditioning was created by Wilson (1908). The definition was claimed by Willis Carrier, "father of air conditioning" as follow:

a) Maintain suitable humidity in a vehicle or a room.
b) Supply a constant and adequate of ventilation.
c) Release surplus humidity in the air during certain seasons.
d) Remove micro-organism from the air efficiently such as dust, soot, and other foreign bodies.
e) Cool indoor air efficiently during certain seasons.
f) Equipment that is not cost-prohibitive in purchase or maintenance.

The air conditioning also is known as HVAC & R. This is an abbreviation of Heating, Ventilating, Air Conditioning, and Refrigerating. All these individual component processes were developed before a complete concept of air conditioning.

2.2 Mechanism of Air Conditioning

Every air conditioner has got a compressor inside. The compressor function is to compress and pump the refrigerant gas. When the compressor compresses refrigerant gas, it produces heat. To dissolve this heat, compressed refrigerant is pumped to the condenser coils where a fan blows the heat out to the outer atmosphere. Refrigerant gas transforms into the liquid form during this process. Then, the liquid refrigerant is pumped to expansion valve. The expansion valve has a temperature sensor connected that works in correlation with thermostat settings. Then, the expansion valve releases the appropriate amount of refrigerant to the evaporator that consists of cooling

coils. In this process, the liquid refrigerant becomes gas form. The transformation from a liquid into gas state due to expansion causes cooling because energy is absorbed by the surrounding. A fan blow air passes through fins that attached to coils. The air becomes cooler and spread to the room. The gaseous refrigerant in cooling coils then go to the compressor and compressed once again. The cycle keeps continuing unless the compressor is shut down (Talal, 2016).
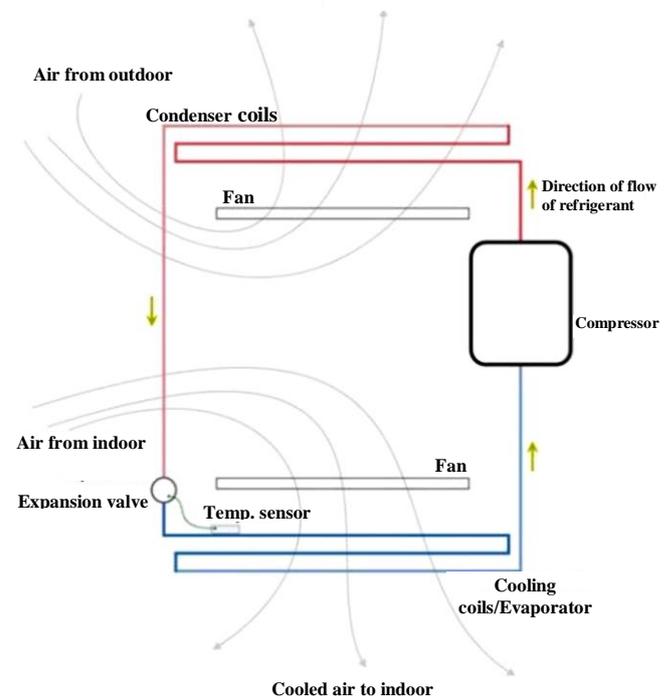

Figure 1. Principle Mechanism of Air Conditioning (Talal, 2016).

2.3 Classification of Air Conditioning

Air conditioners have several types that can be used for different applications. To choose the right type of air conditioners depends on several factors such as the size of the area is to be cooled, and total heat generated inside the enclosed area. The common commercial types of an air conditioner according to Khaemani (2016), as follow:

a) Window air conditioner.
b) Split air conditioner.
c) Packaged air conditioner.
d) Central air conditioning system.

2.4 Train Air Conditioning

Train Air Conditioning can be defined as air conditioners that designed for rail vehicle to altering the air inside the vehicle to meet the required condition. The objective is to create comfort ability for the passenger during the journey.

2.5 General Comfort Considerations

Based on ASHRAE Standard 55, Thermal Environmental Conditions for Human Occupancy may be referenced to determine the train interior thermal environmental factors that will provide environmental condition acceptable to a majority of the passengers.

Simion, et al. (2016) explained about factors that influence the thermal comfort inside of vehicles and categorized the factors into two, i.e. :

a) Personal factors, characteristics of the occupants included activity level and clothing insulation level.
b) Measurable or environmental factors, conditions of the thermal environment included air velocity, air temperature, mean radiant temperature, and relative humidity.

All factors above have complex effects on the passenger's heat balance directly. They must be considered to gain conditions that will be perceived as comfortable by a majority of passengers (Prasetio, 2017).

3 METHODOLOGY

This paper was mostly based on the web study to find information and data that will be needed to address the problem. If possible, the interview will be held with staff from the train operating company and train manufacturer in Indonesia. A cooling load calculation will be provided using CLTD/SC/CLF method. The performance of the air conditioning will be calculated based on the specification of the air conditioning. Characteristic for both types of air conditioning will be compared to know the advantages and disadvantages. From the analysis, the main conclusion will be decided worth or not to use home air conditioning for passenger carriages.

4 THEORETICAL BACKGROUND

4.1 Cooling Load

The cooling load is calculated using CLTD/SCL/CLF method. Bhatia (2016) explained that LLTD, SCL, and SCL method include the effect of conductive heat gain through opaque exterior surfaces and thermal storage in converting radiant heat gain to the cooling load.

Cooling load calculations for air conditioning system design are mainly used to determine the volume flow rate of the air system as well as the coil and refrigeration load of the equipment. It is also to size the HVAC&R equipment and to provide the inputs to

the system for energy use calculations in order to select optimal design alternatives (Wang, 2001). Cooling load usually can be classified into two categories, namely external and internal.

4.2 External Cooling Loads

External loads consist of two types of heat transfer. The first one is conduction through the walls, roof, and windows. The second one is heat transfer by radiation through fenestration on windows glass and floor. Both of them are sensible heat transfers. The sensible heat transfer means the energy added to space by conduction, convection and/or radiation.

4.2.1 Heat gain due to conduction

Basic equations used to calculate heat gained by conduction is as follows (ASHRAE, 1997; 2014; 2016).

$$Q = U \times A \times (CLTD) \qquad (1)$$

where Q is cooling load or heat gain (kcal/h), U is heat transfer coefficient for wall, window, roof (kcal/h m^2 ^0C), A is area of exterior wall, window, or roof (m^2), and $CLTD$ is cooling load temperature difference (^0C).

4.2.2 Heat gain due to radiation

a) Solar load through glass

$$Q = A \times (SC) \times (SCL) \qquad (2)$$

where SC is shading coefficient, and SCL is solar cooling load factor of glass without interior shade or with shade (kcal/h m^2).

b) Solar load through floor

$$Q = U \times A \times (T_a - T_{rc}) \qquad (3)$$

where T_a is the temperature in adjacent space (^0C), and T_{rc} is inside design temperature in conditioned space (^0C).

If adjacent space or temperature is not suitable, use outdoor air temperature less 3^0C. The design temperature in conditioned space assumed constant 25^0C.

4.3 External Cooling Loads

4.3.1 Heat gain from the passenger

Cooling load that gained from the passenger consist of two parts which are sensible heat and latent heat (ASHRAE, 1997; 2014; 2016).

$$Q_{Sensible} = N \times (Q_S) \times (CLF) \qquad (4)$$

$$Q_{Latent} = N \times (Q_L) \qquad (5)$$

where N is number of passengers, Q_S is sensible heat gain from occupancy (kcal/h), Q_L is latent heat gain from occupancy (kcal/h), and CLF is cooling load factor, hour time of occupancy.

4.3.2 Heat gain from the lights

$$Q_{el} = 3.41 \times W \times F_{ul} \times F_{sa} \times (CLF) \qquad (6)$$

where W is power input from electrical lighting plans or lighting load data, F_{ul} is lighting use factor, as appropriate, F_{sa} is special allowance factor, as appropriate, and CLF is cooling load factor.

4.4 Total Heat to be Removed

Besides external cooling load and internal cooling load, the total heat gain should consider the ventilation and infiltration.

4.4.1 Passenger carriage with train AC

Train AC usually installed on the coaches by train manufacturer company when the coaches are built. The carriages with train AC are designed with better insulation, so there is no infiltration air from outside. However, passenger train needs fresh air to make them feel more comfortable. Therefore, train AC unit has fresh air intake to blow the fresh air into the carriages.

$$Q_{Sensible} = 1.23 \times q \times (T_o - T_i) \qquad (7)$$

$$Q_{Latent} = 3010 \times q \times (W_o - W_i) \qquad (8)$$

where T_i is inside air temperature (°C), W_o is outside air humidity (kg water/kg dry air), and W_i is inside air humidity (kg water/kg dry air).

4.4.2 Passenger carriage with home AC

The infiltration can be defined as air flow into the compartment through door open and leakage of partition. Unfortunately, the coach on the economy train does not have an automatic door. The door is manual handling that needs to be operated by people to open and close it. The door open condition time will vary depending on the passenger flow and attitude. Some irresponsible passengers that open the door does not close the door after through it. Therefore assumption has to be made for the heat gain from infiltration. The proposed value for infiltration is 20% of total heat gain.

Total heat gain = External cooling load + Internal cooling load   (9)

Infiltration = 20% × Total heat gain   (10)

4.5 Cost analysis

The cost analysis is consisting of two parts which are: initial cost and maintenance cost. The lifespan of home AC is assumed only 3 months while the train AC is designed for 20 years. Maintenance of home AC needs to be done every week, while for train AC every 6 months and overhaul every 4 years.

Initial cost = (price + installation) × unit   (11)

Maintenance cost = maintenance × frequency × unit (12)

Overhaul cost = overhaul × frequency × unit   (13)

4.6 Performance of Air Conditioning

4.6.1 Energy Efficiency Ratio

Each tool, as well as air conditioning, has an own measure of efficiency which is called the Energy Efficiency Ratio (EER). The EER for air conditioning can be calculated by dividing the average cooling capacity of the unit with the average power input of the unit.

4.6.2 Energy Consumption

The energy consumption is total power within time periods. While total power is power input multiplied by power factor. Energy consumption is usually measured in kilowatt-hours (kWh).

Energy consumption = Power × Power Factor × Time (14)

The operation of the train can be assumed 14 hours a day. Assumption needs to be made for power factor of home AC which is 0.8. While power factor for train AC can be calculated using Equation 15.

$$\text{Power factor} = \frac{P}{\sqrt{3} \times V \times I} \qquad (15)$$

where P is power input (Watt), V is voltage (Volt), and I is current (Ampere).

4.7 Risk identification

Risk = Probability × Impact   (16)

Probability is how often the things happen. The impact is how big the result or effect of the things that happen. Classification of the risk can be seen in Table 1.

Table 1. Risk level classification

Level of risk	Condition
Low	There is no significant impact which means does not decrease the passenger satisfying and do not disturb the train operation.
Medium	There is a value impact to the passenger. Create dissatisfied of passenger and disturb the train operation, but there are no injuries people.
High	There is a big impact to the passenger and train operating company. Creates accident that disturbs the train operation that needs rescheduling. There is injuries people and broken of infrastructure and rolling stock.

5 AIR CONDITIONING IN INDONESIAN RAILWAY

In Indonesia which has a tropical climate, the train air conditioning usually only have the ability to cooling the air temperature without heating capability. There is a train manufacturer in Indonesia which called PT Industri Kereta Api that produces rail vehicle mostly for the domestic market. For the air conditioning part, PT Industri Kereta Api has cooperation with one of train air conditioning manufacturer that already spread its products around the world. One type of air conditioning that produces by one company and mostly used in passenger carriages in Indonesia is RPU-6035V. Train air conditioner that commonly used on the passenger train in Indonesia is RPU-6035V with quantity two units in each carriage. The specification of this air conditioner can be seen in Table 2.

Table 2. Railway air conditioning type RPU-6035V specification (Toshiba, 2011)

Item		Performance
AC Main circuit	Voltage	3 phase 380V AC
	Frequency	50 Hz
Air conditioning capacity		17.5 kW or more (15,000 kcal/h)
Air flow rate	Circulation	35 m^3/min/unit
	Return	27 m^3/min/unit
	Fresh	8.0 m^3/min/unit
Total operation current		15.34 A
Total input power		7.84 kW
Refrigerant	R-407C	1.5 kg/cycle

Train AC consists of several components that connected and collaborated to provide comfort air condition in the coach. Difference type of train AC could have slightly different component. However, the mechanism is still same. The main component of train AC roof mounted can be list below.

a) Compressor.
b) Condenser.
c) Evaporator.
d) Gauge panel.
e) Filter-Dryer.
f) Refrigerant.
g) Fresh air filters and returns air filter.
h) Temperature sensors and room temperature thermostat.

5.1 Home Air Conditioning for Passenger Carriages

Implementation of home air conditioning for passenger carriages in Indonesian railway started in 2012. The first train uses this kind of air conditioning is KA Sibinuang route Padang – Pariaman in West Sumatera. In the middle of 2013, PT KAI intends to install home air conditioning into all existing intercity train. PT KAI decides the type of home air conditioning used in passenger carriages in Indonesia be 1.5 PK with total six units for each coach. Typical specification of this air conditioning is shown in Table 3.

Table 3. Specification of typical home air conditioning (Panasonic, 2015)

Item		Performance	Unit
Cooling capacity	EER	12,500 - 12,700	Btu/h
		3.66 – 3.73	kW
Electricity	Voltage	10.4 – 10.2	Btu/h W
	Current	220 – 240	V
	Power	1,200 - ,250	W
Moisture removal		2.2	L/h
		4.6	Pt/h
Air flow		11.1	ft^3/min
		392	ft^3/min
Weight	Indoor	9	kg
	Outdoor	25	kg

5.2 Installation

5.2.1 Indoor part

Indoor part is one part of home air conditioning located in the room that needs to be conditioned. The indoor part is also called as cool part because the warm air inner room turns cool. There is two scheme of installation indoor part of home AC depending on the shape of the roof platform, such as flat, or curve one.

5.2.2 Outdoor part

The installation of home air conditioning can be done in the train depot. At the first time installation of air

conditioning, there is no guidance to put the outdoor part. Some of the depots even locate the outdoor part at one of the carriage doors and shut off that door. This condition will decrease mobility of the passenger to enter or exit the carriage because one of the doors is forbidden. PT KAI decided to remove this scheme and move the outdoor parts in a better location. Then the idea is to put the outdoor part of air conditioning on under the frame. The outdoor units are placed in the bracket, and the brackets are screwed or welded under frames.

6 RESULTS AND DISCUSSIONS

6.1 Cooling Load Calculation

a) External Cooling Load

External cooling load = Heat gain from conduction + Solar load

$$= 5,576.87 + 5,162.64$$

$$= 10,739.51 \text{ k-Cal/h}$$

$$= 42,635.85 \text{ Btu/h}$$

b) Internal Cooling Loads

Internal cooling load $= Q_{Sensible} + Q_{Latent} + Q_{el}$

$$= 6,374.84 + 4,240 + 546.17$$

$$= 11,161.01 \text{ k-Cal/h}$$

$$= 44,309.21 \text{ Btu/h}$$

c) Total Heat to be Remove

Beside external cooling load and internal cooling load, the total heat gain should consider the ventilation and infiltration.

Passenger coach with train AC

Total heat = External cooling load + Internal cooling load + $Q_{Ventilation}$

$$= 10,739.51 + 11,161.01 + 7,139.65$$

$$= 29,040.17 \text{ k-Cal/h}$$

$$= 115,289.47 \text{ Btu/h} \approx 115,290 \text{ Btu/h}$$

Passenger carriage with home AC

Total heat gain = External cooling load + Internal cooling load

$$= 10,739.51 + 11,161.01$$

$$= 21,900.52 \text{ k-Cal/h}$$

Infiltration = 20% x Total heat gain

$$= 0.2 \text{ x } 21,900.52$$

$$= 4,380.1 \text{ kcal/h}$$

Total heat to be removed = Total heat gain + Infiltration

$$= 21,900.52 + 4,380.1$$

$$= 26,280.62 \text{ kcal/h}$$

$$= 104,334.07 \text{ Btu/h}$$

$$\approx 104,334 \text{ Btu/h}$$

6.2 Cooling Capacity and Cost

Comparison of cooling performance and cost for each type of air conditioning can be seen in Table 4. It shows that changing the home AC unit with higher cooling capacity can remove the amount of heat.

Table 4. Cooling performance and cost

	Railway AC	Existing home AC 1.5 PK	Home AC 2 PK	Home AC 2.5 PK
Quantity	2	6	6	6
Cooling capacity each unit (Btu/h)	59,550	12,500	18,800	24,200
Total cooling capacity (Btu/h)	119,100	75,000	112,800	145,200
Total heat to be removed (Btu/h)	115,290	104,334	104,334	104,334

Based on calculation, the home AC 2 PK which has cooling capacity 18,800 Btu/h was already enough, because the capacity minus heat of home AC 2 PK is slightly higher than train AC. However, in implementation the train AC with 15,000 kcal/h will be replaced with 18,000 kcal/h so, the capacity minus heat will be higher than before. Another fact, the home AC implemented only for old carriages. Considering the old carriages, there is a possibility that actual cooling load is higher than calculation. Therefore, it is recommended to replace the existing home AC 1.5 PK with home AC 2.5 PK.

Table 4 also shows that the total cost in 20 years times period of home AC and train AC is hugely different. The cost of home AC is actually more expensive than

the train AC. However, in short period, the cost of train AC more expensive than home AC. Replace the existing home AC 1.5 PK with home AC 2.5 PK will increase production cost charged to the train operator company. However, slightly increase of cost will increase the home AC performance significantly. Another benefit of use home AC, when one unit of the AC is broken the remaining unit of AC still provide enough cooling capacity to conditioning the air.

6.3 Performance of Air Conditioning

6.3.1 Energy Efficiency Ratio

Table 5 shows that higher cooling capacity of air conditioning needs higher power input to operate it. Air conditioning which has a higher value of cooling capacity and power input will have less EER value. It means that the air conditioning with high cooling capacity is not efficient as AC with lower cooling capacity. It also shows that the home AC is more efficient of energy than the train AC.

Table 5. Energy efficiency ratio of air conditioning

	Existing home AC 1.5 PK (6 unit)	Home AC 2 PK (6 unit)	Home AC 2.5 PK (6 unit)	Train AC (2 unit)
Cooling capacity (Btu/h)	75,000	112,800	145,200	119,100
Power input (W)	7,200	11,700	15,900	15,680
E.E.R. (Btu/h W)	10.42	9.64	9.13	7.60

6.3.2 Energy Consumption

Table 6 shows that energy consumption of home air conditioning 1.5 PK, 2 PK, and 2.5 PK are increase along with increasing cooling activity. It means that higher cooling activity will spend more energy consumption. In the implementation, it will need bigger generator to supply enough electricity for air conditioning operation.

Table 6. Energy consumption of air conditioning per day at 14 hours

	Existing home AC 1.5 PK (6 unit)	Home AC 2 PK (6 unit)	Home AC 2.5 PK (6 unit)	Train AC (2 unit)
Energy (kWh)	80.64	131.04	178.08	171.23
Cooling activity (Btu)	1,050,000	1,579,200	2,032,800	1,667,400

The interesting part of Table 6 is about energy consumption of home air conditioning 2.5 PK and train air conditioning which are equal, but the cooling action of home air conditioning is higher than train air conditioning. It means that the home AC has less energy consumption than train AC. Less energy consumption will affect in less fuel consumption used for generator to supply electricity.

6.4 Qualitative Analysis

There are several things need to consider to choose type of air conditioning. These things including installation, lifespan, guarantee, controlling, air circulation, maintenance, and inspection. It becomes important factors that influence the investment of air conditioning and need to be analyzed.

6.5 Installation

Installation of home AC can be done in the depot with short of time and light equipment because the work is relatively simple. The roof structure does not need to change in order to add the air conditioning unit, no installation of the automatic door. To completely install home AC, for one coach, it needs a time less than two weeks. With this short time, the process of installation does not disturb the train operation.

Installation of train air conditioning into existing train carriage will take longer time because the complexity of the jobs that need to be done. The structure of the roof must be changed to attach the air conditioning, need installation of automatic door movement, and sealing all parts of the coach. This work cannot be completed in the depot because of the lack of equipment. The work can be held on workshop or train manufacturer with a complete equipment and heavy tools to doing heavy jobs. Estimated time to install the train AC is two months. The longer time to install AC will have the possibility to disturb the train operation.

6.6 Lifespan

The train air conditioning has expected lifespan around 20 years. While for the home air conditioning, the lifespan varies depending on the maintenance and inspection. The lifespan of home air conditioning is predicted only three months less than one year. The lifespan will affect the whole cost of the air conditioning. The train AC with long lifespan has huge initial cost, and need a long time before replacing it with the new AC. While home AC has low initial cost but with a short lifespan that will need rapid change during the operation of the train and makes the whole cost will bigger. That is the reason

there is an opportunity that the whole cost of the home AC could be slightly higher than the train AC.

6.7 Guarantee

The home air conditioning actually has a guarantee from the manufacturer. However, since the home air conditioning cannot implemented in the right way, the guarantee automatically broke and cannot be used. So, the train operator company has full responsibility for everything happened to home AC.

6.8 Maintenance and Inspection

Maintenance is an activity to keep the condition of machine or equipment so, it still can operate well. The home AC needs to be maintained more often than the train air conditioning. Some of parts of the home AC are located in under frame of the coach that will be dirty faster than another component in other location.

Inspection is an activity to check or identify the condition of our stuff. Inspection for home air conditioning is important because actually, it does not design for the train. The frequent inspection will be better to identify any possibility of malfunction that could happen with home AC. As soon as any unusual things happen and already identified, the solution to handle the problem can be arranged.

6.9 Controlling

The home air conditioning must be controlled individually to turn on or turn off the AC. As well as for setting the indoor temperature, need to be done one by one. While the train air conditioning is easier to control because it was centralize controlling. It is much simpler to turn on the AC and set the temperature. The train air conditioning has sensor and thermostat that controls the temperature continuously and warn if something unusual condition happens.

6.10 Air Circulation

Train air conditioning system has fresh air intake which means there is always fresh air join the AC circulation. The fresh air flowing into carriages in a certain amount depends on the train AC design. Unfortunately, the home air conditioning does not have a fresh air intake. So, the air circulation in the coach always uses the same air. In the small room with a lot of people like carriage, no fresh air for circulation could have bad effect on the passenger health.

6.11 Comparison of Air Conditioning

The comparison between home air conditioning and train air conditioning can be explained in Table 7. It

shows comparison of train AC with home AC in several types. Train AC has advantages and drawbacks, while home AC also has their own advantages and drawbacks. Compare with existing home AC, the train AC has superiority in cooling capacity, lifespan, manufacturer guarantee, central controlling, fresh air circulation, less maintenance, and inspection. While existing home AC has excess in power consumption, fast installation, and less initial cost.

Back to the main goal, the train operator company adding air conditioning system in the old passenger carriages is to increase the level of services. However, the installation of air conditioning is restricted by the time. This means that, although the train operator company has limited rolling stock, the installation should not disturb the train operation schedule so, fastest time installation is needed. Another restricted is the lifespan of the old carriages that will reach their limit in several years in front, so, spend a lot of money in investment to use air conditioning with long lifespan could be wasted decision. Because of this reason, even the train AC has more superiority than home AC, the train operator company choose to use home AC for their old passenger carriages. However, the cooling capacity of existing home AC is less than train AC and not enough to remove the heat in the coach. Therefore, it is recommended for train operator company to replace the existing home AC 1.5 PK with home AC 2.5 PK.

6.12 Risks Identification

According to the analysis result, risk level that may occur for each event is shown in Table 8. Maintenance and inspection are important to reduce the risks of implementing home AC in the passenger carriages. Both of them is responsibility of train operating company to keep the train service that satisfy the passenger and provide safety for the people. The train operating company must have maintenance and inspection program. Unfortunately after few years implementation of home air conditioning, the train operating company does not do the maintenance and inspection appropriately. It make the outdoor parts becomes rusty and dusty. This condition will affect the performance of home air conditioning. It is important to conduct the maintenance in the right way follow the schedule and procedure. Therefore, it is recommended for the train operating company to enhance their maintenance and inspection program.

Table 7. Comparison of home AC and train AC

Parameter	Existing home AC 1.5 PK	Home AC 2 PK	Recommended home AC 2.5 PK	Train AC
Quantity of AC	6 unit	6 unit	6 unit	2 unit
Cooling capacity each unit	12,500 Btu/h	18,800 Btu/h	24,200 Btu/h	59,550 Btu/h
Total cooling capacity	75,000 Btu/h	112,800 Btu/h	145,200 Btu/h	119,100 Btu/h
EER	10.42 Btu/h/ W	9.64 Btu/h/ W	9.13 Btu/h/ W	7.60 Btu/h/W
Total power input	7,200 W	11,700 W	15,900 W	15,680 W
Energy consumption per day (14 h)	80.64 kWh	131.04 kWh	178.08 kWh	171.23 kWh
Installation time	Short			Long
Installation place	Depot			Workshop or train manufacture
Total cost 20 years	3,456 Million IDR	3,936 Million IDR	4,896 Million IDR	1,206 Million IDR
Lifespan	Short			Long
Guarantee	No			Manufacturer
Maintenance and inspection	Often			Periodic
Controlling	Individual			Centralize
Air circulation	No fresh air			Fresh air intake

Table 8. Risk level of the event that could be occur

Event	Level of risk		
	Low	Medium	High
Fail component of indoor part due to vibration		√	
Outdoor part fall down due to vibration			√
Flying ballast	√		
Dust and rust	√		

7 CONCLUSIONS

7.1 Findings

From the analysis on implementing home air conditioning in passenger carriage, there are some important findings as follow.

a) Base on calculation, the cooling load for existing passenger carriages economy train is 104,334 Btu/h. While the home air conditioning has total cooling capacity only 75,000 Btu/h. The home AC cannot handle the cooling needed of the carriages. That is the reason why the passengers still feel warm.

b) Energy efficiency ratio for home AC is higher than train AC. It means home AC is more efficient than train AC. Simply explains for this is that with equal power consumption, the home AC produce cooling capacity higher than train AC.

c) Installation of home AC needs shorter time which is less than two weeks and can be done in the depot. While train AC installation needs longer time estimated which is two months and can be completed in the workshop or train manufacturer. Longer installation of AC can disturb the train

operation and will take few years to install it in all existing economy train.

d) Total cost for 20 years period of home AC is more than train AC, namely 3,456 Million IDR for 1.5 PK; 3,936 Million IDR for 2 PK, and 4,896 Million IDR for 2.5 PK. While the train AC cost about 1,206 Million IDR. It was a big difference cost for 20 years times period. If time period is shorter, the cost of home AC is less than train AC.

e) Guarantee for home AC was scorched since the AC installed on the rail vehicle because the home AC was not designated for moving an object with much vibration. If something happens to the home AC, then the train operator take full responsibility.

f) The home AC needs maintenance and inspection more often than the train AC. Often maintenance is important to maintain the performance of the air conditioning and make the lifespan longer. Often inspection is required to identify the possibility of faulty or problem that could occur. This activity will increase the cost of maintenance and inspection that spend by train operator.

g) There is no fresh air intake in the home AC system. It means that the same air in the compartment is used continuously. This condition can create uncomfortable for some passenger.

h) The risk that could be occurs especially for outdoor parts that located under frame that will become rusty and dusty and possibly of falling down due to a lot of vibration. The connections between outdoor brackets and under frame are important to prevent the outdoor from falling down.

Based on findings that already explained in above, there can be concluded that home AC superior to train AC only in construction and initial cost. Implementation of home air conditioning in the

passenger carriages is worth only for existing rolling stock in short time period, to increase the level of service and give better comfort ability to the passenger. However, several adjustments are required to achieve better performance.

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