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Air-conditioning in the cabins of passenger cars

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Abstract. The objective of this paper is to analyse the current state of the constructional design and operational conditions of air-conditioning device in passenger cars. The research was focused on the function of air-conditioning equipment of passenger cars Skoda and KIA in various modes of operation during the winter, spring and summer season at different levels of air conditioning (without air-conditioning, minimum, medium and maximum level). Air temperature, air humidity, globe temperature, CO_2 concentration, dust concentration and noise inside the cabin were measured. Solar radiation plays a big role to rise up temperature inside the cabin. It resulted in the higher values of globe temperature than temperature of the air. The results of the measurements showed that CO_2 values were significantly lower than 2,500 ppm at minimum air-conditioning, lower than 600 ppm at medium and lower than 500 ppm at maximum level of air-conditioning. For all vehicles, dust concentration was greater when it measured with the air conditioning switched off than with the air conditioning system turned on. The measurements confirmed that the total dust concentration was not more than 47 μg m^{-3}, PM_{10} lower than 28 μg m^{-3} and PM_1 lower than 27 μg m^{-3}. The noise levels ranged from 49.1 to 68.7 dB(A). The air-conditioning had very positive impact on the inside comfort in car cabins from all points of view during all periods of the year.

Key words: air humidity, carbon dioxide, drivers comfort, dust, noise, temperature.

INTRODUCTION

Drivers in all transport categories, in the course of their daily operations, are affected by microclimate, which is determined by air temperature, air velocity, relative humidity, carbon dioxide and thermal radiation. The objective of this research is to examine the microclimate value measured in the driver's cabins in the passenger cars. Microclimate in the driver's cabin significantly affects human thermal comfort; the cabin environment has an emphasis on thermal comfort not only for reasons of convenience, but also safety. It is necessary to ensure a suitable microclimate in the car cabin even in extreme operating conditions.

The recommended values of microclimate inside the cabin of the car, are according to publication Vlk (2003). The recommended values are as follows: air temperature 18–22 °C and relative humidity 40–60%; air velocity 0.1 m s^{-1} at 18 °C and 0.4 m s^{-1} at 24 °C; air exchange per person (clean air): 25–50 m^3 h^{-1} of fresh air; maximum concentration of pollutants: 0.17% CO_2, 0.01% CO and 1 mg m^{-3} of dust. Scientific studies, Anderson (1998) in the past have shown the effects of inappropriate working conditions on fatigue, which significantly applies to prolonged driver's working hours. A suitable microclimate is very necessary for to improve the safety features of vehicles, and the systems must ensure it.

However, the increasing awareness of the strong influence of car microclimate on drivers and travellers leads to automobile users also being interested in the provision of actual and comprehensive characteristics of air quality inside the vehicle cabin, for their own knowledge. In this case, it is assumed that air quality evaluation should be performed quickly on-site, and should result in concise, easy to absorb information. Unfortunately, the outputs of a measuring system cannot be directly used for comprehensive description of air quality (Szczurek & Maciejewska, 2015).

The driver's cabin features a large flat windscreen. A small volume of air inside and relatively low heat insulation, resulting in a greater degree of influence on the operating conditions. If the temperature in a driver's cabin is below 17 °C, it provides comfortable zone inside the cabin; resulting in a reduction of efficiency and a risk of muscle fatigue. In addition, inaccuracy and constraints of movements are observed. If the temperature is above 25 °C, reactions slow down and the rate of physical tiredness accelerates. At a temperature above 30 °C, mental activity will worsen. Generally, drivers are sensitive to humid air because the human body uses evaporative cooling as the primary mechanism to regulate temperature. Under humid conditions, the rate at which perspiration evaporates on the skin is lower than it would be under arid conditions. Because human beings perceive the rate of heat transfer from the body rather than temperature itself, we feel warmer when the relative humidity is high than when it is low (Zewdie & Kic, 2016b).

Some drivers experience difficulty breathing in humid environments. Some cases may possibly be related to respiratory conditions, while others may be the product of performance anxiety disorder. In times of extreme stress, a driver may shake uncontrollably, hyperventilate (breathe faster and deeper than normal) or even vomit in response, causing sensations of numbness, faintness, and loss of concentration, among others (Gladyszewska, 2011). Air conditioning reduces discomfort in the summer not only by reducing temperature but also by reducing humidity. In winter, heating cold outdoor air can decrease relative humidity levels indoor to below 30% leading to discomforts such as dry skin, cracked lips and excessive thirst (Zewdie & Kic, 2015).

The interior of a vehicle is considered as a specific microenvironment. It is mainly experienced via quality of air and thermal conditions, noise levels, vibration inside the cabin. Air quality is a term that describes the physical, chemical and biological state of indoor air at some specific place at specific time. Mainly, it is characterized by physical and chemical parameters such as temperature (T), relative humidity (RH%) and airflows (Musat & Helerea, 2009).

Generally, transport technology improvement is correlated to safety. Microclimate composition rate is an important index factor affecting the contentment of drivers in the cabin. Numerous researchers used different measurements to assess the driver workload under diverse driving conditions. The conclusions reached by monitoring measures support an objective and continuous analysis in a dynamically changing microclimate situation (Zewdie & Kic, 2016a).

In the course of breathing, we exhale CO_2, which can displace O_2 in an indoor environment such as a vehicle cabin, leaving the environment O_2 deficient. Such high CO_2 and low O_2 concentrations can cause adverse human health effects. Various independent studies, Galatsis et al. (2001) have also shown that through this process, the concentrations of O_2 and CO_2 may come to exceed safety limits. Interestingly, a study on fatal single-vehicle crashes highlights that the vehicle is more likely to have closed windows and a heater on than to have fresh air and air conditioning fitted, Maroni et al. (1995).

An O_2 deficient environment has been termed 'hazardous' when the O_2 concentration is less than 19.5%, Galatsis et al. (2000). Low O_2 levels can impair judgment, increase heart rate and impair muscular coordination. In the conclusion in their respective findings that thermal state of internal microclimate inside the drivers' cabins has a strong correlation with drivers' comfort which has an influence on the safety of drivers.

In vehicles that are parked, no ventilation and no air conditioning takes place. If a vehicle is exposed to direct solar radiation, an immediate temperature rise occurs. The high cabin air temperature can threaten children and animals that are left unattended in vehicles. In the USA, lethal heat strokes cause a mean death rate 37 children per year (Horak et al., 2017).

MATERIALS AND METHODS

The authors carried out the research on three different passenger cars equipped with air-conditioning (AC). For research implementation, the authors applied two Skoda cars (Skoda Octavia II and Skoda Octavia III Combi) and KIA Sportage. Main technical data and parameters of all three vehicles are summarized in Table 1.

Table 1. Researched cars

Type of Car	Production year	Kilometer reading	Engine
Skoda Octavia II	2007	217,745	1.9 TDI
Skoda Octavia III Combi	2016	10,000	1.6 TDI
KIA Sportage	2016	3,424	1.7 L I4(TD)

Both cars of the Skoda Octavia were equipped with an automatic Climatronic air-conditioning system. This system is a combination of automatically operating heating, ventilation and cooling equipment that ensures optimal passenger comfort. Climatronic automatically keeps the set temperature.

The first car Skoda Octavia II was regularly serviced, but the air conditioning system since 2010 has not been serviced. In 2013, they changed only cabin filter. The second car Skoda Octavia III Combi was a new car with perfect condition AC system.

The third tested car was KIA Sportage. It was also new car as written in above table kilometer reading was 3,424 km. The AC system of the car was perfect and it had well-functioning sensor system to keep comfortable zone inside the cabin.

Data on the microclimate conditions in all drivers cabin were collected from measurement devices which were installed on the passenger seat next to the driver in the cab of the respective vehicles.

Following instruments used for measurements: the thermal comfort in the cabin was continuously measured by globe temperature (measured by globe thermometer FPA 805 GTS with an operative range from –50 to +200 °C with the accuracy ± 0.01 K and diameter of 0.15 m) together with temperature and humidity of surrounding air measured by sensor FH A646-21. The temperature sensor NTC type N with the operative range from –30 to +100 °C with accuracy ± 0.01 K and air humidity by capacitive sensors with the operative range from 5 to 98% with accuracy ± 2% was installed. All installed equipment's had very good accuracy range.

The concentration of CO_2 was measured by the sensor FY A600 with operative range 0–0.5% and accuracy ± 0.01%. The informative noise level measurements were conducted by UNITEST Sound Level Meter 93411capacitor microphone and measuring ranges: 30–100 dB(A) or 65–135 dB(A), resolution 0.1 dB(A), during the measurement used frequency evaluation filter A, time evaluation slow (1.5 s), frequency range 30 Hz – 12 kHz. The sound level meter is a produce of Ch. BEHA GmbH, Germany. All data were measured continuously and stored at intervals of one minute to the measurement instrument ALMEMO 2690–8 throughout the measurement process.

The research was focused on the verification of the function of air-conditioning equipment of passenger cars in various modes of operation outside the Prague city. Measurements were carried out on identical routes. The route was starting from Prague Suchdol via Unětice and Tursko to Kralupy nad Vltavou and back. The total length of the route was 42.6 km. All cars were air-conditioned, but the tests were provided at different levels of air conditioning (without 0, minimum, medium 50% and maximum 100%). The measurements have been carried out during three principal periods of the year (winter, spring, and summer). During each measurement, outdoor climatic conditions were observed. The AC function was set at 22 °C during the winter and spring measurements, and on 24 °C during the summer.

Assuming steady conditions, with a uniform distribution of pollutants in space the required volume airflow for ventilation V_c is calculated according to (Szekyova et al., 2006) by the Eq. (1).

$$V_c = \frac{M_p}{c_i - c_e} \qquad (1)$$

where: V_c – required volume airflow for ventilation, m^3 h^{-1}; M_p – mass flow of produced pollutant, uniformly leaking into the space, kg h^{-1}; c_e – concentration of pollutant in inlet air, kg m^{-3}, (usually is $c_e = 0$); c_i – concentration of pollutant in outlet air, kg m^{-3}, (usually considered OEL – Occupational Exposure Limits or MEL – Maximum Exposure Limits).

The thermal conditions composed of internal globe temperature t_g, and internal temperature t_i as well as internal relative humidity RH_i are carefully collected for further analysis. The obtained results of airflow for ventilation V_c were processed by Excel software and verified by statistical software Statistica 12 (*ANOVA and TUKEY HSD Test*). Different superscript letters (a, b) mean values in common are significantly different from each other in the column (*ANOVA; Tukey HSD Test; P ≤ 0.05*), e.g. if there are the same superscript letters in all the rows it means the differences between the values are not statistically significant at the significance level of 0.05.

RESULTS AND DISCUSSION

The mean values including standard deviation were calculated from the results of measurements of external temperature t_e (°C) and each internal microclimatic parameter internal temperature t_i (°C), internal relative humidity RH_i (%), internal globe temperature t_g (°C) and noise level L_A (dB(A)) are summarized in the Tables 2, 4, 6 and 8.

The mean values including standard deviation were calculated from the results of measurements of total dust concentration, PM_{10}, PM_1, concentration of CO_2(%) and calculated volume of ventilation air flow V_c ($m^3 h^{-1}$) in the driving cabin are presented in the Tables 3, 5, 7 and 9.

Mainly external conditionings outside the cars influenced the first measurements in the cars with passengers (Table 2 and 3) during the parking (not working engine, without AC). The inside temperatures t_i and relative humidity RH_i are in relation to the external conditions according to psychometrics principle. The inside air temperature t_i = 21.1 °C in Octavia III was near to the optimal temperature 22 °C. The noise caused only by the external conditions were slightly higher in KIA during the summer measurement, probably because of the higher traffic in the surrounding, but the differences between the car's measurements are not statistically significant.

Table 2. Thermal state of the environment (external temperature t_e, internal globe temperature t_g, internal temperature t_i, relative humidity RH_i and noise level L_A) in tested vehicles without function of AC. Different letters (a, b) in the superscript are the sign of high significant difference (*ANOVA; Tukey HSD Test*; *$P \leq 0.05$*)

Car	t_e	t_i	t_g	RH_i	L_A
	°C ± SD	°C ± SD	°C ± SD	% ± SD	dB(A) ± SD
Octavia II	3.2 ± 0.1	14.8 ± 0.2	15.9 ± 0.6	51.6 ± 1.2	49.7 ± 4.9^a
Octavia III	12.7 ± 0.1	21.1 ± 0.9	21.7 ± 0.3	47.2 ± 1.5	49.1 ± 6.6^a
KIA	28.9 ± 0.2	33.8 ± 0.3	33.1 ± 1.4	38.8 ± 1.8	54.7 ± 6.1^a

SD – Standard deviation.

The dust and CO_2 concentrations (Table 3) were highest in comparison with the other measurements. As the AC was switched off, the CO_2 concentrations are extremely high and therefore the calculated ventilation rate V_c is very low (only natural air exchange by cars leakages). High concentrations of CO_2 and dust can cause adverse human health effects.

Table 3. Total dust concentration and concentration of dust fractions PM_{10} and PM_1, concentration of carbon dioxide CO_2 and values of the intake fresh air V_c in tested vehicles without function of AC. Different letters (a, b) in the superscript are the sign of high significant difference (*ANOVA; Tukey HSD Test*; *$P \leq 0.05$*)

Car	Total dust	PM_{10}	PM_1	CO_2	V_c *
	μg m^{-3} ± SD	μg m^{-3} ± SD	μg m^{-3} ± SD	ppm ± SD	$m^3 h^{-1}$
Octavia II	53 ± 25	21 ± 6	5 ± 0	4,340 ± 1,190	8.5 ± 3.4^a
Octavia III	36 ± 13	13 ± 0	12 ± 1	3,420 ± 1,105	12.0 ± 5.9^a
KIA	48 ± 9	27 ± 2	23 ± 2	2,530 ± 844	24.4 ± 9.6^b

* – calculated value; SD – Standard deviation.

The AC switched on the minimum level (Tables 4 and 5) increased internal temperature (t_i = 16.4 °C) in winter (Octavia II), temperature t_i = 23.2 °C in Octavia III was slightly over the set AC temperature 22 °C. Very high internal globe temperature t_g = 37.9 °C in KIA was caused mainly by solar radiation through the windows. The inside air temperature t_i = 32.6 °C was also higher than the set AC temperature 24 °C, which means that the AC in minimum level is not able to cool enough supply air in the hot summer season. The noise level (L_A = 63.7 dB(A)) in old Octavia II was significantly higher than in other cars.

Table 4. Thermal state of the environment (external temperature t_e, internal globe temperature t_g, internal temperature t_i, relative humidity RH_i and noise level L_A) in tested vehicles with minimum ventilation rate (minimum level of AC). Different letters (a, b) in the superscript are the sign of high significant difference (*ANOVA; Tukey HSD Test*; *P ≤ 0.05*)

Car	t_e	t_i	t_g	RH_i	L_A
	°C ± SD	°C ± SD	°C ± SD	% ± SD	dB(A) ± SD
Octavia II	3 ± 0.1	16.4 ± 1.1	15.7 ± 0.5	42.5 ± 6.7	63.7 ± 3.4^a
Octavia III	12.1 ± 0.2	23.2 ± 0.4	22.9 ± 0.3	36.4 ± 2.0	59.8 ± 2.6^b
KIA	29.5 ± 0.6	32.6 ± 1.3	37.9 ± 2.3	30.7 ± 0.9	59.3 ± 2.1^b

SD – Standard deviation.

Total dust concentration 47 µg m^{-3} in Octavia II was approximately twice higher than in other cars (Table 5). The concentration of PM_{10} was in all cars lower than 50 µg m^{-3}. Increased airflow rate V_c caused the lower concentration of CO_2, which stalled rather high in all cars. The worst situation was in old Octavia II. Minimum ventilation rate $V_c = 26.2$ m^3 h^{-1} was not sufficient, therefore the inside concentration CO_2 = 2,370 ppm was so high. On the basis of the previous studies in this area, these measurements proved that this measured condition of microclimate inside the cabin can be the cause of performance anxiety and stress for drivers and travelers in the situation of traffic jam during their journey in the summertime.

Table 5. Total dust concentration and concentration of dust fractions PM_{10} and PM_1, a concentration of carbon dioxide CO_2 and values of the intake fresh air V_c in tested vehicles with minimum ventilation rate (minimum level of AC). Different letters (a, b) in the superscript are the sign of high significant difference (*ANOVA; Tukey HSD Test*; *P ≤ 0.05*)

Car	Total dust	PM_{10}	PM_1	CO_2	V_c *
	µg m^{-3} ± SD	µg m^{-3} ± SD	µg m^{-3} ± SD	ppm ± SD	m^3 h^{-1}
Octavia II	47 ± 21	15 ± 3	8 ± 1	2,370 ± 1,530	26.2 ± 13.8^a
Octavia III	18 ± 6	14 ± 1	14 ± 2	1,200 ± 848	99.0 ± 63.6^b
KIA	22 ± 6	20 ± 3	18 ± 1	1,000 ± 155	67.4 ± 14.8^b

* – calculated value; SD – Standard deviation.

The AC switched on the medium level (Tables 6 and 7) increased internal temperature (t_i = 22.8 °C) in winter (Octavia II), temperature t_i = 23.4 °C in Octavia III was slightly over the set AC temperature 22 °C. In case of KIA there was a little decrement in temperature t_i = 27.9 °C (summer) but it was still much higher than the set AC temperature 24 °C, but nevertheless, it was the positive result because at the medium operational condition of AC showed little cooling effect. The noise level (L_A = 65.5 dB(A)) in the old Octavia was still higher than other cars.

Total dust concentration 37 µg m^{-3} in Octavia III was higher than other cars (Table 7). The concentration of PM_{10} was less than 40 µg m^{-3} in all cars. V_c caused a lower concentration of CO_2. At medium operational condition of AC, it showed positive results as a decrement in CO_2 level inside the cabin. The minimum ventilation rate was again in Octavia II (V_c = 114.6 m^3 h^{-1}) and maximum V_c = 212.8 m^3 h^{-1} was in Octavia III. The difference between Octavia III and KIA was not statistically significant.

Table 6. Thermal state of the environment (external temperature t_e, internal globe temperature t_g, internal temperature t_i, relative humidity RH_i and noise level L_A) in tested vehicles with medium ventilation rate (medium 50% level of AC). Different letters (a, b) in the superscript are the sign of high significant difference (*ANOVA; Tukey HSD Test*; *P ≤ 0.05*)

Car	t_e	t_i	t_g	RH_i	L_A
	°C ± SD	°C ± SD	°C ± SD	% ± SD	dB(A) ± SD
Octavia II	3 ± 0.1	22.8 ± 1.3	18.6 ± 0.9	25.8 ± 2.1	65.5 ± 2.6^{a}
Octavia III	12.1 ± 0.2	23.4 ± 1.8	23.9 ± 0.1	35.3 ± 0.4	61.3 ± 4.1^{b}
KIA	29.5 ± 0.6	27.9 ± 0.5	32.0 ± 0.7	36.1 ± 0.6	62.5 ± 2.9^{a,b}

SD – Standard deviation.

Table 7. Total dust concentration and concentration of dust fractions PM_{10} and PM_1, the concentration of carbon dioxide CO_2 and values of the intake fresh air V_c in tested vehicles with medium ventilation rate (medium 50% level of AC). Different letters (a, b) in the superscript are the sign of high significant difference (*ANOVA; Tukey HSD Test*; *P ≤ 0.05*)

Car	Total dust	PM_{10}	PM_1	CO_2	V_c *
	µg m^{-3} ± SD	µg m^{-3} ± SD	µg m^{-3} ± SD	ppm ± SD	m^3 h^{-1}
Octavia II	23 ± 6	17 ± 2	14 ± 4	590 ± 50	114.6 ± 19.0^{a}
Octavia III	37 ± 13	16 ± 2	16 ± 3	470 ± 32	212.8 ± 50.3^{b}
KIA	28 ± 5	28 ± 4	27 ± 2	550 ± 52	211.0 ± 42.5^{b}

* – calculated value; SD – Standard deviation.

The AC switched on the maximum level (Tables 8 and 9) increased internal temperature (t_i = 23.5 °C) in winter (Octavia II), temperature t_i = 23.8 °C in Octavia III was slightly over the set AC temperature 22 °C. According to the result of measurements of both Octavia cars (winter and spring), the maximum operating condition of AC system was very effective for increment in temperature for achieving desired comfortable temperature inside the cabin. In third car (KIA Sportage) result was also satisfactory. In KIA Sportage cabin temperature reached 26.6 °C (summer), there was little difference between cabin temperature and set temperature (24 °C). The noise level (L_A = 68.7 dB(A)) in Octavia II was again higher than other cars and lowest was in Kia Sportage (L_A = 66.5 dB(A)). Total dust concentration was higher in KIA Sportage (24µg m^{-3}).

Table 8. Thermal state of the environment (external temperature t_e, internal globe temperature t_g, internal temperature t_i, relative humidity RH_i and noise level L_A) in tested vehicles with maximum ventilation rate (maximum 100% level of AC). Different letters (a, b) in the superscript are the sign of high significant difference (*ANOVA; Tukey HSD Test*; *P ≤ 0.05*)

Car	t_e	t_i	t_g	RH_i	L_A
	°C ± SD	°C ± SD	°C ± SD	% ± SD	dB(A) ± SD
Octavia II	3 ± 0.1	23.5 ± 0.3	21.3 ± 0.6	24.6 ± 0.5	68.7 ± 1.1^{a}
Octavia III	12.1 ± 0.2	23.8 ± 0.2	24.3 ± 0.2	34.3 ± 0.6	67.8 ± 1.5^{a,b}
KIA	29.5 ± 0.6	26.6 ± 0.3	32.6 ± 0.4	36.9 ± 0.5	66.5 ± 1.3^{b}

SD – Standard deviation.

At maximum operational condition of AC, the concentration of CO_2 was overall low but it was higher in KIA Sportage (440 ppm) as compared to other cars. The main reason for high concentration of CO_2 in KIA Sportage was low ventilation rate as compare to other cars. The value of PM_{10} was less than 25 µg m^{-3} in all cars. On the behalf of measurements of maximum operating condition of AC system there is no doubt AC system is very effective to keep all recommended parameters of microclimate inside the cabin. The recommended values of parameters are mentioned above in introduction.

The result of the measurements in all cars shows that without AC operation the level of CO_2 was very high inside the cabins but after in operational condition with switched on AC system it decreased several times. The ventilation V_c rate increased according to operational conditions of AC system. It was highest in Octavia III V_c = 1,216.8 m^3 h^{-1} (Table 9). Relative humidity more effectively decreased in Octavia II by operation of AC system. It reached approximately on its half. The value of total dust decreased according to operational conditions of AC system in each car. It was measured lowest in Octavia II 15µg m^{-3} (Table 9). The value of PM_{10} was lower than the value of external limit 50 µg m^{-3}. Due to AC, the value of PM_1 was also very low in all measured situations.

Table 9. Total dust concentration and concentration of dust fractions PM_{10} and PM_1, the concentration of carbon dioxide CO_2 and values of the intake fresh air V_c in tested vehicles with maximum ventilation rate (maximum 100% level of AC). Different letters (a, b) in the superscript are the sign of high significant difference (*ANOVA; Tukey HSD Test*; $P \leq 0.05$)

Car	Total dust	PM_{10}	PM_1	CO_2	V_c *
	µg m^{-3} ± SD	µg m^{-3} ± SD	µg m^{-3} ± SD	ppm ± SD	m^3 h^{-1}
Octavia II	15 ± 4	10 ± 2	10 ± 4	380 ± 40	1,159.2 ± 397^a
Octavia III	22 ± 2	22 ± 10	18 ± 4	360 ± 19	1,216.8 ± 291^a
KIA	24 ± 2	18 ± 3	18 ± 1	440 ± 33	543.2 ± 284^b

* – calculated value; SD – Standard deviation.

According to the results of the measurement can be summarized, that the more modern model of Octavia III has better parameters of AC than the older model Octavia II. Nevertheless, those results can be influenced by many years of previous use of Octavia II.

CONCLUSION

Solar radiation plays a big role to rise up temperature t_i inside the cabin. It resulted in the higher values of globe temperature t_g than the temperature of the air t_i. The concentration of CO_2 and RH_i is depend on ventilation rate V_c, in other words, they are inversely proportional to ventilation rate V_c. Ventilation rate depends on the construction of AC system, its regulation, and control system and design of the cabin. Overall ventilation rate V_c was good in Octavia III Combi as well as in KIA.

AC system shows the best result on its maximum operational condition. AC system always increases little noise level L_A inside the cabin. Noise level L_A depends on the technical condition of the car. The lowest level of noise was in KIA Sportage car during the maximum operational condition of AC system.

CO_2 concentration and RH_i is the main challenge during winter and spring season inside the cabin. Total dust reduction depends on the operational condition of AC system. Level of total dust depends on material and condition of mats and carpet and seat covers of the car. Textile material more increases dust level inside the cabin than rubber material. The AC has a positive impact on the dust reduction inside the cars.

Time taken for achieving desired comfortable condition inside the cabin is also dependent on the positioning of blowers inside the cabin. Sensor system inside the cabin plays a big role to maintain desired comfortable condition inside the cabin.

It can be a generalized conclusion, that the AC has a very positive impact on inside comfort in cars cabins from all points of view during all periods of the year.

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