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Indoor air quality evaluation in intercity buses in real time traffic

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Abstract. Road transport allows all forms of land conditions to be met at less cost. Because of this function, despite numerous disadvantages, it becomes the most frequently used method of transport, especially in underdeveloped or developing countries. One of the most significant factors used in evaluating the atmosphere's air quality is the amount of CO_2, increasing people's density in indoor spaces. The amount of CO_2 indoors is, therefore, vital to determine. In this study, CO_2 and temperature measurements made on nine different bus journey was made in Turkey. The minimum and maximum values were recorded as 555 ppm and 3000 ppm CO_2, respectively, in the measurements. On all journeys, the average concentration is 1088.72 ppm. The minimum and maximum values were measured as 17.4^{o}C and 32.7^{o}C in the temperature measurements, and the average of all trips was calculated to be 25.76^{o}C. In this study conducted before the Covid-19 pandemic, it was determined that the amount of CO_2 increased with the density and insufficient ventilation in the buses. The risk of infection increases in places with high human density and low clean air. For situations such as pandemics, CO_2 measurement is a rapid indicator of determining human density.

Keywords: bus; CO_2; indoor air quality; intercity transport; temperature

1. Introduction

In the continuity of daily life and economic processes, transportation is an essential kind of system. By definition, it can be expressed to benefit moving freight and passengers from one location to another. The numerous modes of transport (land, air, sea, and rail) and transport (private cars, public transport, etc.) with diverse technology of vehicles, energy, and infrastructure have been built from past to present. In other words, transportation systems have been built in parallel to living conditions. Therefore it is a guiding factor that is agreed to trigger economic growth (Artar 1991, Korkmaz and Alacahan 2013, URL-1 2020). Unlike other alternatives, road transport can conform to any form of terrain conditions, and where natural conditions do not allow alternate systems, road transport is preferred. On the other hand, it can be done in a less complicated and quicker period than traffic options and needs a comparatively, less fixed transport

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vehicle investment. This feature, despite its various disadvantages, is widely preferred in underdeveloped and developing countries. Road transport is the only transport that can provide short distances and periods and transport passengers flexibly. It also can transport from output to consumption point rapidly and directly. Road transport is very significant both in its own right and in its subsectors where it has an influence, which is of considerable significance for economic growth and social welfare (Alaybeyoğlu 1994, Korkmaz and Alacahan 2013).

Road transport firms can be set up faster than their air and sea counterparts and need less money than the expense of alternative investment. Investors who would invest in the sector are favored for those reasons. The air, sea, and rail transportations are not as widespread, and their current terminals are situated in only the most crucial transport hub of the world. Besides, air, sea, and rail transportation systems are not as broad as they would like (Karagülle 2007, Korkmaz and Alacahan 2013). In Turkey, there were a total of 9468 passenger buses in 2003. In 2011, it increased to 52707 and grew annually according to population and travel requests (URL-2 2020).

There are some limitations in comparison to the benefits of transporting passengers by bus. Besides, intercity transportation is lengthy, and the number of passengers is high among these negative aspects. Some effects on passengers can occur as a result of the long journeys in an enclosed atmosphere. After a time, due to the polluting sources it contains, it contaminates the indoor air (Alptekin 2007). The definition of indoor air also includes interior environments for transport vehicles such as buses, trains, and aircraft (Karakaş 2015). Pollution from 2 primary causes can occur in indoor air. These are the emissions generated by the indoor atmosphere's substances and practices and the emissions from the natural environment that chemicals have generated to reach the indoor environment. Pollution from indoor air in recent years has become more significant. Since people are subjected to contaminants through breathing, skin touch, and food intake, contaminants are very significant regarding their health risk in environments where they spend a substantial amount of time and concentration in the setting. When researching literature, people spend more of their time indoors (87.2% indoor, 7.2% indoor, and 5.6% outdoor) (Arslanbaş 2008, Wallace 1996). Determination of indoor air quality, temperature, relative humidity, lighting, sound (Schibuola and Tambani 2020), air velocity, carbon dioxide (CO_2), particulate matter (PM), volatile organic compounds (VOC), nitrogen oxides (NO_x), carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), radon, formaldehyde (HCHO) and bacteria count (Özkaynak 2001, Avcı 2014). These contaminants differ in their composition and diversity based upon their attributes, the objects' properties in the atmosphere, and individuals' actions. Poor air quality indoors is a result of inadequate ventilation (Fernandez-Ramos *et al.* 2020). This results in a low impact on human productivity (Akal 2013, Alyüz 2006). The main parameter for indoor air quality assessment is CO_2. It is natural gas with a smaller proportion of atmospheric air (around 0.038% or 380 ppm by Volume). Though air typically contains 400 ppm of CO_2, breathing air can increase to 40,000 ppm. Therefore, the CO_2 level rises dramatically in closed and crowded areas (Parhizkar *et al.* 2020). CO_2 levels can be measured as indoor ventilation and indicator for air quality indoors since this gas is the primary waste product from human metabolism (Gall *et al.* 2016), and its results can be attributed to CO_2 levels (Schibuola *et al.* 2016). Exposure to high levels of CO_2 has been thought to cause respiratory problems, and sadness called Sick Building Syndrome. Conditions such as headache, exhaustion, difficulties focusing, respiratory discomfort, headache, moodiness, sleepiness, sneezing, and cough are often known to induce exposure to more than 1000 ppm of CO_2. Furthermore, high CO_2 exposure has psychological consequences such as reduced decision-making and performance, anxiety (Hong *et al.* 2018, Shriram *et al.* 2019, Gładyszewska-Fiedoruk 2011, Demirarslan and Başak 2018, Başak *et al.* 2017). In studies examining (CO_2) concentrations in different vehicle cabins, it has been shown that elevated CO_2 concentrations in the steering wheel trigger sleepiness, exhaustion, and unsafe actions, and it has been determined that concentration potential is minimal (Chiu *et al.* 2015).

Ceiling vents or air conditioning systems are used to ventilate buses often used by persons in different geographies. As in all other interiors, buses must meet the European standard (PN-EN

13779 2018), WHO (WHO 2000), or ASHRAE standard (ASHRAE 1989), which are indoor air quality (IAQ) standards. However, indoor air quality measurements in buses have been conducted in only a few nations (Gajewski 2013, Chiu *et al.* 2015). The frequent use of individual vehicles and air travel in countries such as America and Canada, and further rail travel in Europe, is one of the main reasons for this.

One of the most important needs of people is to be mobile. However, due to the geographical conditions of the countries and/or the high initial investment costs, bus and similar land vehicles are a more practical and cheaper solution than the rail system, sea transportation, and air transportation. If there is an opportunity, land vehicles can also be used between countries, except for transportation between villages, towns, and cities. Buses are produced with less technology than trains and planes, making them cheaper and more accessible. Road investment costs are also much more convenient than other alternatives, and it is possible to reach many villages by road. This makes buses frequently used vehicles. While the windows of most buses are not opened, the doors are not opened while driving.

On the other hand, air conditioners are seen by the driver from time to time as a factor in the vehicle's burning of excess fuel and are turned off. This situation limits the access of bus workers and passengers to fresh air. Especially on long roads that take hours, the indoor air of the buses can reach the dimensions that will disturb people. The CO_2 level, the biggest factor affecting indoor air quality, can be reduced by taking fresh air from outside into the bus. Most vehicle drivers and passengers are not aware of this situation, and due to exposure to high CO_2 levels during the journey, side effects such as headache and fatigue can be seen. Fully automatic ventilation systems, which are activated by sensing the indoor air quality as in some passenger cars, cannot be used widely, as there is less physical space for equipment in buses, and they are produced by paying attention to low costs. In this study, indoor air quality, which is a common problem in buses and midibuses used by most of the society, was measured based on CO_2 level, taking into account ASHRAE standards. In this way, it is aimed that the study will be a reference for the companies to warn and raise awareness of their drivers, even though they do not have the opportunity to prefer vehicles with fully automatic ventilation systems.

CO_2 and temperature measurements in this study intercity buses in 9 different routes in Turkey are made. Depending on the routes, the forms and passenger size of the buses vary. For example, although midibus with passenger capacity 27, measurements were carried out on one route, measurements were made on another route on a city bus. Other measurements on passenger buses, which are commonly used between cities, were carried out. This article is one of the few studies on indoor air quality conducted particularly in public transportation vehicles.

2. Materials and methods

2.1 Measurement device

For buses with six different intercity routes and nine different trips in total, CO_2 and temperature measurements were made in the study. The routes were randomly chosen, and the travels took place at varying times, each with different vehicle types. Outdoor temperatures are relatively low compared to the spring and summer months, as the analysis was done in March and April. On the journey, in-vehicle heating systems are enabled for this reason. Measurements were made on the seats in the middle and front of the buses. The measuring points are set to be 1 m

Table 1 Travel information from which measurements were taken

Route	Distance (km)	Duration (minute)	Capacity	Current Passengers	Vehicle Type	Approx. Inner Volume (m^3)
A	210	285	27+2	27+2	Midibus	53.2
B	228	235	46+2	15+2	Passenger Bus	56.7
C	133	120	54+2	25+2	Passenger Bus	56.7
D	133	110	54+2	54+2	Passenger Bus	56.7
E	457	460	54+2	30+2	Passenger Bus	56.7
F	228	280	46+2	46+2	Passenger Bus	56.7
G	67	80	84+1	84+1	City Bus	87.01
H	227	235	54+2	54+2	Passenger Bus	56.7
I	170	120	46+1	46+1	Passenger Bus	56.7

above the ground and 1 m away from the doors, at least. PCE-AC 3000 (Germany) brand CO_2 measuring device was used in the study. This device is used in indoor spaces where persons are concentrated to control the CO_2 level. The device has a maximum and minimum value feature and a 24 hour capable of operating a data logger. The measuring range is 0 to 3000 ppm CO_2, accurate to ± 5% or ± 50 ppm (URL-3 2020).

2.2 Measurements

Information on measurements is given in Table 1. The midibus has been used for one measurement and the city bus the other. On passenger buses, which are commonly used in intercity transport, other measurements have been made. As control measurement a total of 60 minutes of measurement was conducted on an empty midibus during 30 minutes with the doors open and 30 minutes with the doors closed as control sample. Since the interior volumes of the vehicles are about the same, a control measurement was carried out inside only in one midibus. which were not used for 24 hours. For other measurements, approximate occupancy rates during the journey are the current passenger numbers given in Table 1 and include the driver and hosts. Approximate interior volumes and passenger capacities are taken from the technical data of the vehicles.

2.3 General O_2 consumption and CO_2 production calculations

In closed environments the CO_2 production rate is approximately 0.31 L/min per person (Erdman 2002). In addition, the per capita consumption of Oxygen in Eq. (1) must be known in L/sec (Persily and Jonge 2017) to calculate the rate of CO_2 production in closed areas.

$$V_{O_2} = \frac{0.00276 \times A_D \times M}{0.23 \times RQ + 0.77} \tag{1}$$

Where

A_D : Body surface area (1.8 m^2 for an adult person) (Persily and Jonge 2017)

M : Movement level coefficient

RQ : Respiratory coefficient

Body surface area AD is a ratio of human height (H) and mass (W), calculated as in Eq. (2) (Persily and Jonge 2017).

$$A_D = 0.202 \times H^{0.725} \times W^{0.425} \tag{2}$$

M is the physical activity level which is sometimes called metabolism. For various tasks this coefficient differs and takes the magnitude of 1.0 for the sitting posture (Engineering ToolBox 2004). Respiratory factor RQ is normally diet-dependent. This amount is equal to 0.85 due to nutrition of sugar, calcium, and carbohydrates. Equation (3) calculates the CO_2 rate in lt/s per capita (Persily and Jonge 2017, Ji *et al*. 2018).

$$V_{CO_2} = V_{O_2} \times RQ = \frac{0.00276 \times A_D \times M \times RQ}{(0.23 \times RQ + 0.77)} \tag{3}$$

3. Results

Results of in-vehicle CO_2 and temperature measurements performed in intercity buses are given in Figure 1-3. Measurements can be seen on the midibus traveling across cities in Fig. 1(a). During the first 30 minutes of the route, the CO_2 concentration increased. Due to the doors opening during the passenger get on-off process, the level decreased in the 40th minute and increased again. This increase continued until the bus took a break, and because of the opening of the doors and the majority of passengers moving out, there was a drop in the break time. There were no passengers on the way after the break; on the contrary, people were getting off, so a decrease in concentration was observed. The temperature inside the vehicles, on the other hand, increased to the moment of the break and decreased dramatically after the break. As a result of the reduction in the heating level due to passenger complaints, the temperature value decreased along the way after the break and began to decrease after the 185th minute. According to the measurements given in Fig. 1(b), the CO_2 concentration reached 1240 ppm during the 20th minute of the journey. In this process, with the ventilation's opening, the concentration level decreased, and a dramatic decrease occurred in the 40th minute when a break was taken. An increase was again observed during the journey, which occurred in the late of the break. Another break also triggered a decrease in concentration in the 90th minute. Although there were reductions in the time between the 110th and the end of the journey due to passenger get-on and off processes, there were increases as the journey approached.

While the temperature increased in the first 20 minutes, owing to the modified heating system, the temperature decreased due to the degradation of heat comfort in the interior, but in the times at the end of the journey, there were excessive increases of up to 30 °C. On the route in Fig. 1(c), no breaks were made during the journey. When the graph is examined, the CO_2 concentration during the journey showed an increasing trend from the first minutes and reached 1185 ppm in the 70th minute. Afterward, although the concentration level decreased, there was a fluctuation from the 100th minute. The temperature increased until the 90th minute and fluctuated after this time. The route given in the graph of Fig. 2(d) is the return of the route in Fig. 1(c). The bus's brand and model are the same, but the only difference is that the number of passengers on this journey is the same as shown in the bus's technical details. The concentration of CO_2, which in the first minutes of the journey was 1240 ppm, decreased to 890 ppm in the 10th minute. The cause for this can be

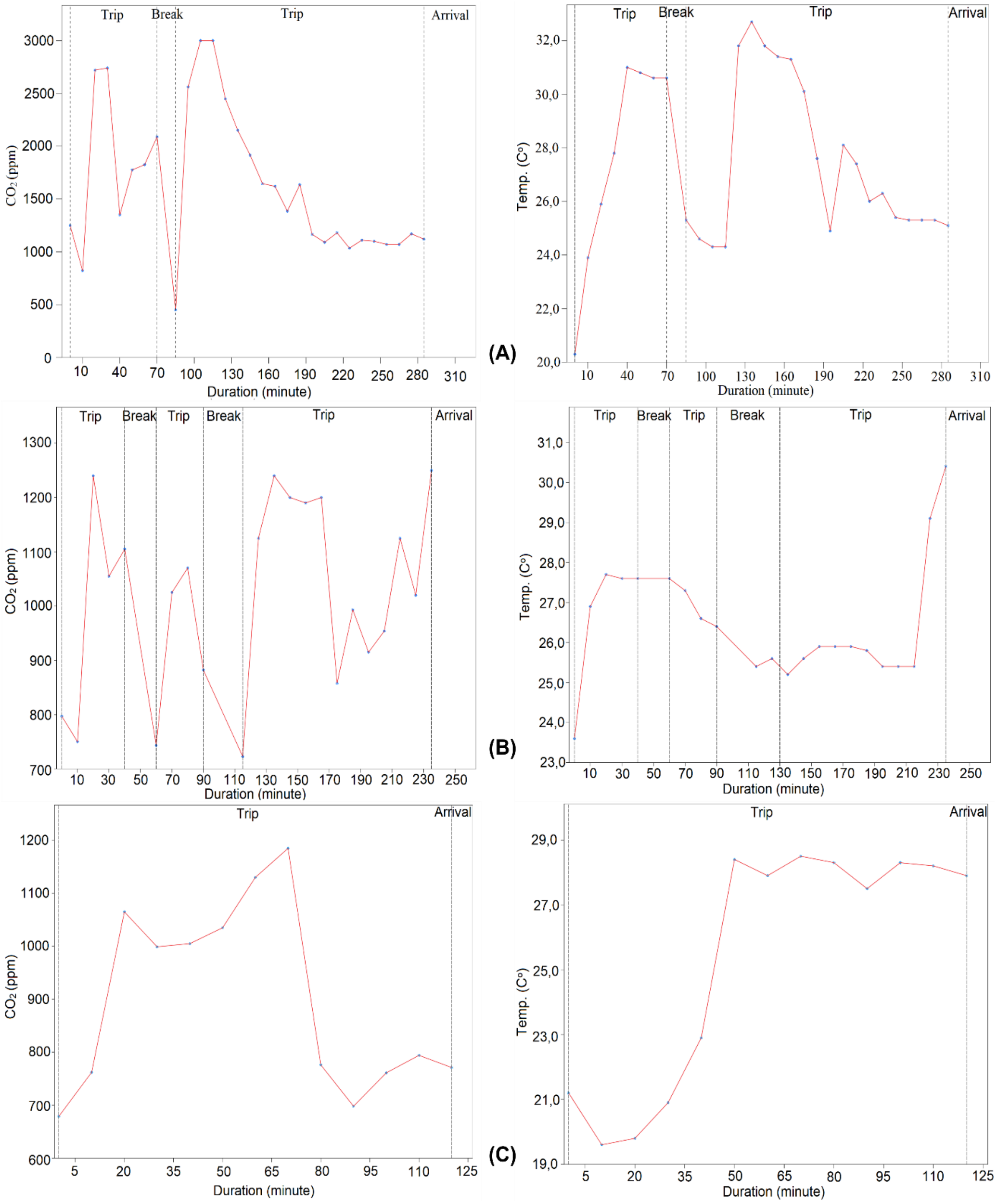


Fig. 1 Measurement graphs of indoor air quality on route A-B-C

described as the lack of fresh air inside the bus waiting at the bus station for the departure time.

Although the level decreased with the ventilation operation, it increased again and continued to fluctuate in the 20th minute. When the temperature graph is analysed, it is known that it shows an increasing trend during the journey. The route in Fig. 2(e) is the longest route measured in the study. The CO_2 concentration, which fluctuated during the journey, decreased during the break and then increased until the 300th minute. After the 400th minute, it increased to the destination, and

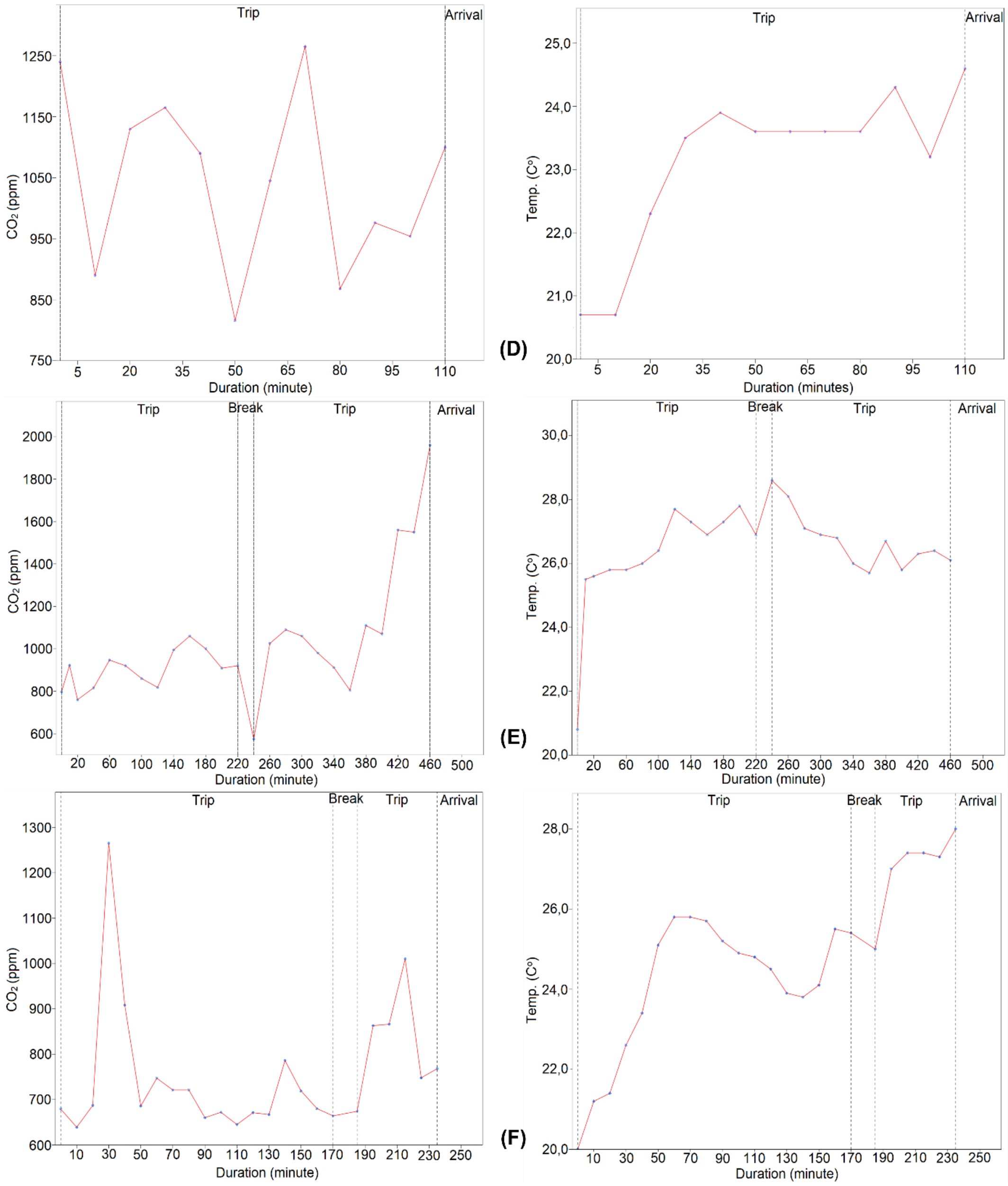


Fig. 2 Measurement graphs of indoor air quality on route D-E-F

finally, the concentration of 1960 ppm was measured. Considering the temperature graph, it increased until the 220th minute and started to decrease at the break. The temperature value, which increased at the end of the break, decreased when the journey began. It can be seen in Fig. 2(f) that the CO_2 level peaked (1265 ppm) in the 30th minute on the route. The average concentration up to the break time is around 714 ppm. At the beginning of the break, the concentration was 664 ppm, measured as 674 ppm at the end of the break. The concentration shows a fluctuating feature until it

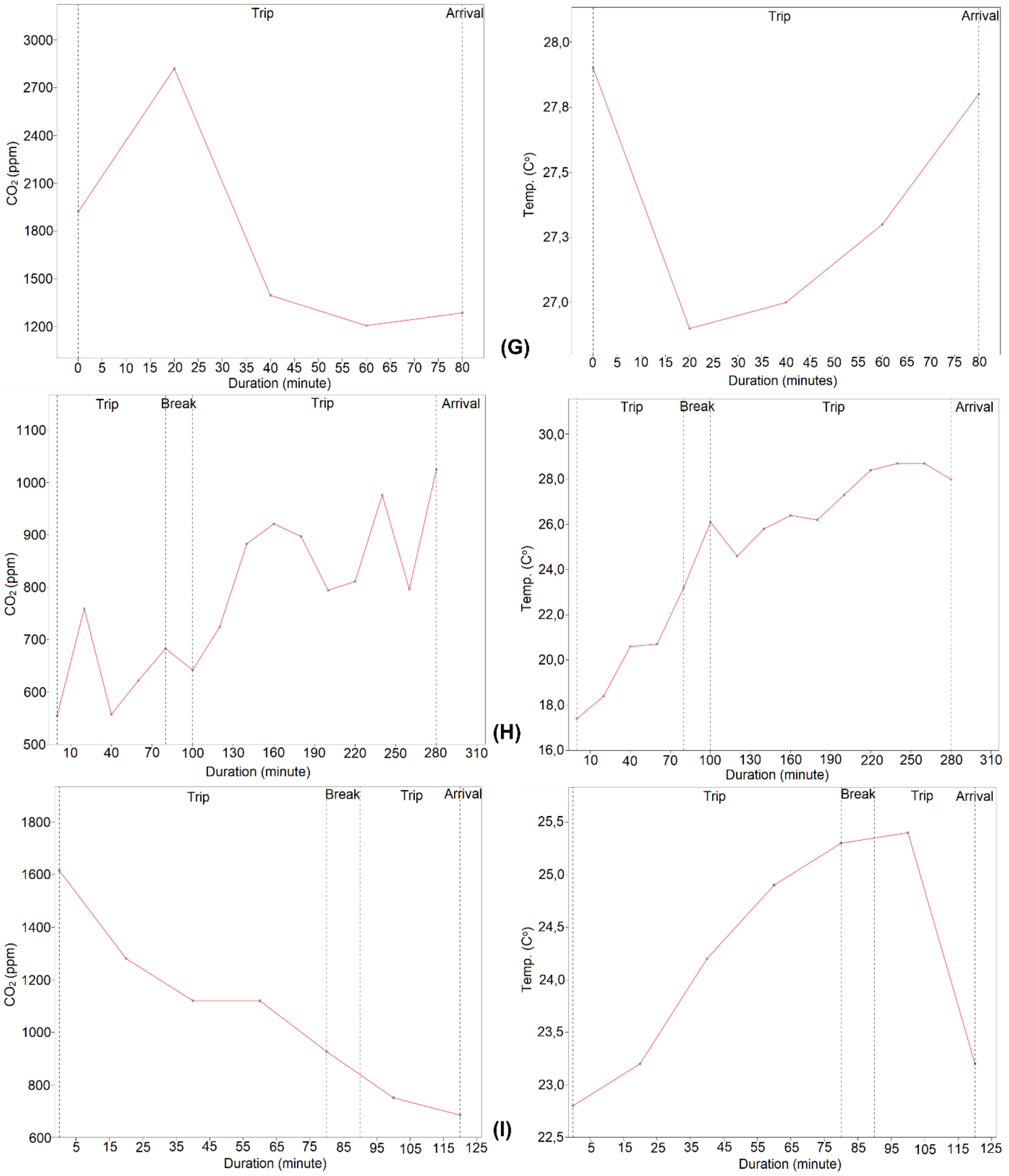


Fig. 2 Measurement graphs of indoor air quality on route D-E-F

reaches its destination. The temperature increasing from the beginning of the journey until the 130th minute has been measured as different values until the break. After the break, an increase in temperature was observed until the destination.

The route given in Fig. 3(g) is an intercity road of approximately 65 km, and the measurements were measured on the city bus running between these routes. During the measurement, the city bus has the number of passengers in the technical specifications given in Table 1. The municipal buses

Table 2 Descriptive statistics for the measurements

Route	CO_2 (ppm)				Temp. (°C)			
	Min.	Mean	Max.	σ	Min.	Mean	Max.	σ
A	451	1637.66	3000	691.12	20.3	27.42	32.7	3.15
B	723	1020.91	1250	172.56	23.6	26.46	30.4	1.47
C	649	896.92	1185	175.95	19.6	25.33	28.5	3.75
D	816	1044.92	1265	145.83	20.7	23.12	24.6	1.26
E	547	1016.8	1960	289.15	20.8	26.41	28.6	1.43
F	639	756.08	1265	142.83	20.0	24.8	28.0	2.03
G	1205	1725	2820	672.67	26.9	27.38	27.9	0.45
H	555	776.33	1025	146.67	17.4	24.7	28.7	3.77
I	685	1071.14	1615	320.56	22.8	24.14	25.4	1.08

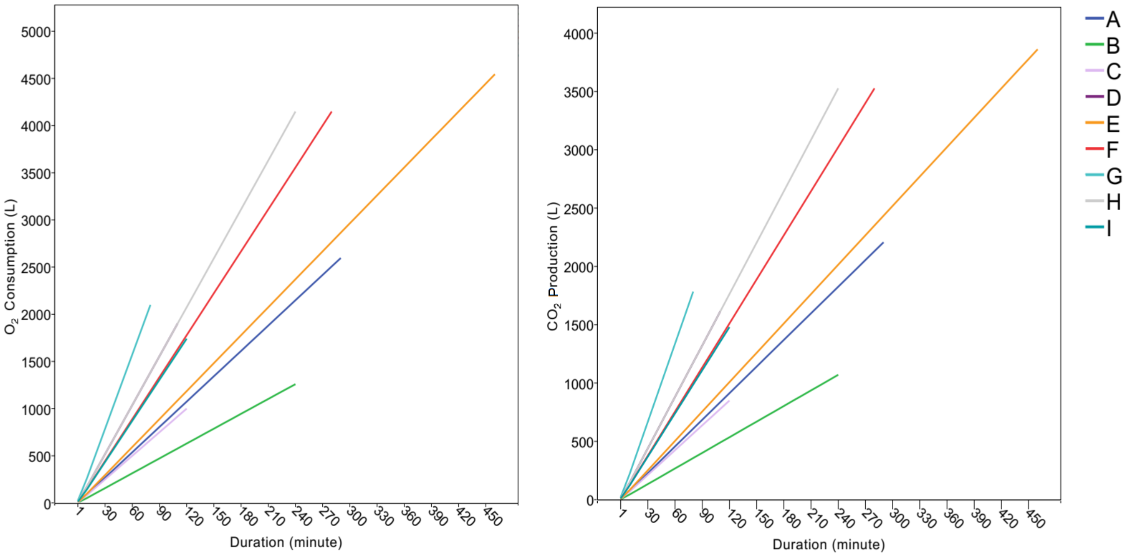
running on this route come full to the departure point, and new passengers get on after the passengers get off. Adequate ventilation, therefore, cannot be provided. As a consequence, the CO_2 level was measured as 1920 ppm in the first minutes. This level increased to 2820 ppm in the 20th minute, and the opening windows were opened by the passengers due to the decrease of the indoor air quality, allowing for fresh air intake. These windows, however, were not enough, and the amount of CO_2 persisted about 1205-1285 ppm. Temperature values were measured at high levels parallel to the concentration. Fluctuations in the concentration from the beginning to the end of the journey and the increase in the temperature graph from the beginning to the end of the journey are seen by looking at the graph's measurements shown in Fig. 3(h). On the route given in Fig. 3(i), passengers got off at various stops during the journey, and no new passengers were taken. The CO_2 concentration, thus, has reduced. For measurements of temperature, however, this cannot be said. At the end of the journey, only a decreasing trend was found in the increased temperature level since the beginning of the journey. Descriptive statistics are presented in Table 2 of the measurements in the analysis. The CO_2 concentration exceeded the device's upper limit of 3000 ppm in just one measurement. However, other measurements are within the measuring range of the device.

According to Table 2, the route with the highest average CO_2 concentration is G. On this route, city buses are used on the intercity road. The other route is A, and here we travel with vehicles called midibuses. It was determined that the lowest route is F. In temperatures, the maximum averages were obtained for the vehicle used on route A and the lowest for the vehicle on route D.

For the accuracy of the measurements, CO_2 measurements were made in an empty bus. These measurements were carried out for 60 minutes, with the vehicle doors open for the first 30 minutes and closed for the last 30 minutes. According to the measurement results, the average CO_2 in the first 30 minutes was 432 ppm, the average temperature was 18.8°C, the average of the last 30 minutes was 526 ppm, and the average temperature was 19.4°C.

O_2 consumption and CO_2 production calculations were made for the buses traveling on the entire route in the study. The equations in Eqs. (1) and (3) were used in the calculations. In addition, the number of passengers in Table 1 was used in the calculations, and it was assumed that the majority of the passengers were adults. The results are given in Fig. 4.

According to Figs. 4(a) and 4(b), the level of O_2 consumed increases from 0 to 136 L as the average of all buses in the first 10 minutes. It was determined that the O_2 consumption and CO_2



(A) O_2 Consumption (B) CO_2 Production

Fig. 4 O_2 consumption and CO_2 production during the journeys

production level in buses increased with the number of passengers. As a result, the city bus on the G route has the highest O_2 consumption and CO_2 production level in the buses calculated in the first 10 minutes. This situation confirms that the high number of passengers will increase the amount of consumption and production.

4. Discussion

Different studies related to indoor air quality in terrestrial transport vehicles in the world and Turkey and CO_2 measurement (Chiu *et al.* 2015, Chen 2005, Haung and Hsu 2009, WHO 2020, Cakir and Temir 2018). Unlike similar studies, this study was carried out on different bus and passenger numbers on many different routes.

The indoor air quality will deteriorate dramatically during the journey as the buses are closed. As a result, drivers and passengers can face concerns such as fatigue, restlessness, sleepiness, and inattention. Numerous accidents have been reported due to drowsiness while driving due to CO_2 accumulation in vehicles (Lohan *et al*. 2021). Studies show an increase in drivers' sickness and mortality rates and their hosts exposed to the low air quality inside the vehicle (Dhital *et al.* 2014). Most of the studies in the literature examining in-vehicle air quality show that the cabins' CO_2 concentrations generally exceed 1000 ppm, which causes the drivers to feel sleepy and tired (Chiu *et al.* 2015). For example, in the study conducted by Chan (2005) in Hong Kong, it was stated that CO_2 concentrations in buses reached 1900 ppm while traveling on the highway and 2500 ppm in the city. Huang and Hsu (2009) measured the hourly averages of CO_2 concentrations in long-distance buses in Taiwan as 959 ppm and reported that it ranged from 339 to 3722 ppm along the way. In the study conducted by Kim (2020) in Hong Kong, the interior air qualities of 10 city buses, ten express buses, ten shuttle buses, and ten city buses were examined. In the measurements, conditions such as daytime hours, passengers, seasons, ventilation conditions, and distance travelled were compared. As a result of the study, it was observed that the CO_2 levels were higher in the rush hours and the summer months compared to the winter. In the same study, it was stated in previous studies conducted by the Ministry of Environment of Hong Kong that the average CO_2 concentrations were measured as 1753 ppm, the amount of CO_2 was observed to increase with human respiration, and the concentration increased with the increase of passengers in public transportation. In the study conducted by Hsu and Huang (2009), measurements were made on long-distance passenger buses in Taiwan. The study's average CO_2 concentration was found to be 1493 ppm, and it was stated that these results did not comply with local regulations. Kwon *et al.* (2008), CO_2, and temperature measurements were made in Seoul Metropolitan subway. The average CO_2 concentration is 2426 ppm, and the temperature is 25.05°C in the study. Zhu et al. (2010), measurements were made on buses used in urban public transportation. The average CO_2 concentration in the measurements was found to be 835 ppm. In the study conducted by Çakır and Temir (2018), CO_2 and temperature measurements were made in buses used in urban transportation in Istanbul/Turkey, and the average CO_2 concentration was found to be 1200 ppm. The highest concentration and temperature were measured as 3191 ppm and 46.5°C, respectively. This study is based on measurements made in Turkey in the Metrobus. However, these measurements were made on the same passenger line and at the vehicle ventilation outlet, where CO_2 concentrates. It may not fully reflect the feelings of the individuals traveling inside.

In this study conducted on nine different routes, when the average CO_2 concentrations are examined, it can be seen that they are between 756.08-1725 ppm. Especially in A, B, D, E, G, and I routes, it is seen that the CO_2 concentration exceeds the limit value of 1000 ppm given in ASHRAE, which is the limit value for indoor air quality. It can be said that this situation poses a danger, especially in intercity buses, and may cause adverse physiological effects on drivers and assistants. Likewise, when the indoor temperatures were examined, it was determined that the highest averages were A, G, B, and E, respectively. It can be stated that the increase in temperatures may cause adverse effects for passengers and drivers over long journeys.

The results also showed a severe lack of ventilation in buses, which is obvious that bus drivers can be affected by poor air quality, increasing distraction, and even the risk of traffic accidents. Another factor that increases CO_2 concentrations in vehicle cabins is mainly more passengers, lower driving speed, and setting the air conditioning (AC) system to recirculation mode (Chiu *et al.* 2015). Using the air conditioning system in vehicles can reduce the vehicle's performance per kilometre by 5-25%. For this reason, not operating the air conditioning system in order to reduce fuel consumption and not affect its performance increases the CO_2 ratio inside the vehicle (Chiu *et al.* 2015).

5. Conclusions

These studies intercity buses in Turkey for nine different routes CO_2, and temperature measurements were made for the cabin indoors. The types and capacities of the buses differed according to the routes. The average of all CO_2 measurements made in the spring months before the pandemic was calculated as 1088.72 ppm and the average temperature as 25.76°C.

When the measurement results are evaluated, the minimum highest CO_2 concentration was measured in the city bus, an 80 minute journey. The highest concentration was also found on the same bus when computing the average concentrations. The highest concentration measured was found in the midibus, which is a 210 km journey. Given the temperature calculation results, the highest minimum values were found for the municipal bus, the average mean temperature, and the maximum temperature for the 210 km midibus trip.

Average CO_2 concentrations of 1000 ppm and above were determined in 6 trips. High CO_2 concentrations and temperatures can cause adverse effects, especially on drivers. In such an environment, people experience fatigue, sleepiness, attention deficit, and unwillingness. As a result, accidents occur. As can be seen from the results obtained, the cabin's CO_2 value decreases with the low number of passengers and the opening of the doors, especially during breaks. However, it is forbidden for passenger buses to travel with the doors open according to traffic rules. Bus drivers usually open the windows on their sides instead of renewing the entire air of the vehicle and trying to reach fresh air in this way. However, when weather conditions are not suitable, such as rainy weather, this possibility can be distracting. Since the ventilation made by opening the driver's window has a local effect, other employees and passengers on the bus cannot benefit from this. To prevent such undesirable situations, the bus ventilation systems' maintenance should be complete, and the equipment should be operated properly. It is recommended to ventilate the vehicles by opening the doors before the start of the cruise and during the breaks and ventilating the buses by opening the setting that allows fresh air from outside, paying attention to thermal comfort conditions cruise. CO_2 measurement is a rapid indicator of determining human density.

In addition, no regulations determine the indoor air quality for public transportation in Turkey. Due to the lack of regulation, there are no inspections and sanctions regarding indoor air quality, especially in buses. In order to prevent this situation, limit values for CO_2, temperature, particulate matter parameters in public transportation should be determined, and air quality measurements in public transportation should be made and supervised instantly. Systems that will automatically operate external ventilation by measuring indoor air quality through sensors without the initiative of people on public transportation vehicles can make journeys more less risky for employees and more comfortable for passengers.

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