Impact of car free day on foyer building environment

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Abstract. Universiti Teknologi Malaysia has been organizing the car-free day (CFD) on the campus since 2016 among others to reduce air pollution and improve environmental awareness among campus community. This study aims to determine the effect of the car-free day on two foyer's building environment with three objectives; to determine the variation of traffic volume, to assess the CO₂ concentration and noise level variation, and to evaluate the impact of traffic volume variation on CO₂ concentration and noise level in building. Two different locations of building are selected; inside and outside CFD. Traffic volumes on the nearby roads are counted and CO₂ concentration and noise level at the foyer of the selected building are recorded i.e 8:00-3:00 pm, both during CFD and NCFD at each location. The significant impact of traffic compositions on CO₂ and noise level variation are evaluated by using the statistical method including T-test, simple and multiple regression analysis with R² and ANOVA test, with significant level of 5%. The results show that the implementation of CFD has good and adverse impacts on building environment. The good is CFD reduces traffic volumes up to 80%, and significantly reduce both CO₂ and noise level at building located in car free zone. At the selected site, the reduction of CO₂ is 13.57±4.87 ppm per hour and the reduction of noise level is 4.7±1.74dBA. During CFD, the concentration of CO₂ is significantly governed by the volume of the bus while noise level is significantly correlated with the total volume of traffic. Reduction of noise level is significantly related with decrease of volume of lorries on road. On the other hand, CFD causes adverse impact on building environment as there is significant increase in traffic volume, noise level and CO₂ concentration at a selected site outside of CFD zone. The traffic volume increase up to 82% which dominantly characterized by car and motorbikes. These results in increment of noise level by 1.77 ±1.37 dBA and sharp increase of CO₂ more than 9999 ppm after the first 3 hours of CFD and remain the same values until end of CFD which may be not acceptable for human comfort. Result from this study shows that CFD improve the environment in building located at CFD zone but worsen the building environment in NCFD.

1 Introduction

CO₂ emission and noise pollution are the two elements significantly related with the increasing number of vehicles on the road. CO₂ is one of greenhouse gases (GHGs) in which a distinct increase in the atmosphere will give a distinct threat to the climate change [1]. It was observed that concentration of CO₂ in the atmosphere has been increased significantly during last 150 years. In 2016, the average concentration of CO₂ was 40% higher than in the mid-1800s [2,3]. According to [4], transportation sector is the main source of CO₂ emissions [5] as almost ninety-five percent of the world's transportation energy comes from petroleum-based fuels [5,6] like gasoline and diesel. Meanwhile, noise pollution is the threat for community health that can lead to several non-auditory effect[7].

Several steps have been taken to decrease the CO₂ emissions and noise pollution in the transportation sector. These include the transport management like automatic traffic control system that made the traffic flow smooth and energy-source shifted green fuels such as hybrid and solar driven [8,9]. However, these may not sufficient and in this regard, the concept of CFD (CFD) has been introduced to minimize the energy consumption, CO₂ emission and noise pollution [10].

CFD is a term which means, restrict the certain area for any kind of transport where it considered to be necessary for a definite time. CFD is organized in various cities of the world every year in the month of September with the goal of spreading the awareness about environmental concerns and global warming. It discourages use of cars and encourages the use of public transport [11] and so far has shown a good impact on the betterment of the environment and spreading awareness. Universiti Teknologi Malaysia has also taken an initiative by organizing the car-free day on the campus to make atmosphere clean. It is an environment-friendly initiative which is assisting to promote the awareness about the importance of CFD and its contribution towards sustainable developments.

This study aims to determine the impact of the car-free day on building environment. The objectives of the study are to; determine the variation of traffic volume, assess the CO₂ concentration and noise level variation, and evaluate the impact of traffic volume variation on CO₂ concentration and noise level in building. Two different locations in UTM are selected; One inside the car-free zone while other is outside of it. The data assessment for both cases is critically analyzed and elucidated the future perspective of the car-free approach in UTM and also nationwide in Malaysia.

2 Methodology

In this study, two different sites have been selected; the first site is the building of Faculty of Built Environment (BE) and the second is the Faculty of Electrical Engineering (E) shown in Fig. 1. Site BE is situated in car-free zone while E is situated just outside of car-free zone. The point measurement for this study were in the foyer of each building. Building BE is attached to a one-way road which links the vehicle coming from the main entrance of UTM to the rest of the locations in the UTM. On the other hand, Site E is situated just outside of the car-free zone at two adjacent roads which are Jalan Lingkar Ilmu and Jalan Kempas.

Fig. 1. Site selection.

2.1 Data Collection

Data of traffic volume, CO₂ concentration and noise level were recorded from the start of CFD i.e 8:00 am -3:00 pm at each location. The concentration of CO₂ (ppm) were recorded by using a digital Thermo-hygrometer (Model: M0198132S). Measuring range of this instrument is 0 to 9,999 ppm with a CO₂ accuracy of $\pm 5\%$ of the reading. This instrument was installed at foyer area of buildings BE and E and attached to a data logger. The data logger records reading after an interval of five seconds within the range of 7 hours CFD. The digital Noise Meter (Model: WS1361) was utilized for noise measurement with unit dBA. Measuring range of this device is between 30 to 130 dB, whereas accuracy is ± 1.5 dB. This instrument was also attached with data logger which records readings of every second for 7 hours.

Traffic volume were recorded by using manual method which was manual traffic counting. This method is most commonly practiced in order to obtain the number of individual types of vehicles such as car, bus, lorry etc accurately. In this method, multiple observers recorded the number of vehicles types passing through a certain point. For location BE a point was selected for counting the vehicle at Jalan Lingkar Ilmu in front of BE. Similarly, for location E, three points were used for counting the traffic from Jalan Lingkar Ilmu (N24), Jalan Kempas (KP) and Jalan Kempas-Ilmu, respectively.

2.2 Data Analysis

Descriptive analysis for three variables such as traffic volume, CO₂ concentration and noise level, and their variation between CFD and NCFD and were all analysed. The significant

of these variables change due to CFD were tested by using T-test if the data were normal and Wilcoxon Signed Rank was used if vice versa. For noise level variation, the significance changes are also characterised by the rule of thumb; a 3 dBA change is considered discernible; a 5 dBA change is clearly discernible; and a 10 dBA change louder is perceived as a doubling or halving of volume, respectively [12]. For CO₂, comparison with the Threshold Limit Value for 8-hour time-weighted-average exposures to CO₂ is 5,000 ppm were made. Currently, the American Society of Heating, Refrigeration, and Air conditioning Engineers (ASHRAE) suggested the maximum is 1000ppm for human comfort[13]. Tsai, Lin, and Chan [14] shows that workers exposed to indoor CO₂ levels greater than 800 ppm were likely to report more eye irritation or upper respiratory symptoms [15]. Finally, the traffic composition were investigated which may significantly affect the CO₂ and noise level variation by using the simple and multiple regression analysis with R² and ANOVA test with significant level of 5%. According to previous research, a rough rule of thumb for R² of 0.25, 0.50 and 0.75 are weak, moderate and substantial respectively[16].

3 Results and discussions

CFD executed in Universiti Teknologi Malaysia has changed the traffic flow in the campus areas. The traffic from main university entrance are prohibited to get to campus through Jalan Universiti except the granted vehicles such as electric and hybrid vehicles, and public transport such as buses, express postal van etc. Other vehicles are diverted to the Lengkok Universiti road which is linked with outside of CFD zone where Building of Faculty Electric Engineering (E) is situated. Fig. 2 shows the flow of vehicles during CFD. It can be seen that to avoid restricted road, many vehicles used Jalan KP and small road in front of Faculty of Electrical Building to proceed to unrestricted Jalan Lingkar Ilmu (N24) to reach other buildings.

Fig. 2. Traffic flow during CFD.

3.1 Traffic volume variation

The total traffic volume during CFD and NCFD at Jalan Lingkar Ilmu is shown in Fig. 3. When compared with normal day, traffic volume at CFD are reduced more than 80% with

average reduction of 729.85 ± 207.95 vehicle/hour. The highest reduction is 94% during 12 to 1 pm while the lowest is at 2-3 pm with 81.68%. On the other hand, the total of traffic volume at Jalan N24 and Jalan KP is shown in Fig. 4. It can be expected that the reduction in Jalan Lingkar Ilmu has increased the Jalan KP as this is the easiest way to proceed to the other buildings at unrestricted Jalan Lingkar Ilmu. The average increase is 249.14 ± 212.63 vehicle/hour with highest total volumes increase is 82% at 11am to 12pm. Statistically, the distribution of traffic volume and it's reduction or increase for all roads follow the normal distribution when the test of Shapiro-Wilk show $p > 0.05$. Parametric test by using T-test showed that the variation of traffic volume between CFD and NCFD for both places are significant, $P < 0.05$ (Table 1). Thus, statically CFD reduced the traffic volume at Jalan Lingkar Ilmu with $p = 0.000$ while increased the traffic volume at Jalan N24 and KP with $p = 0.02$.

Fig. 3. Variation of traffic volume/hour during CFD and non-CFD at Jalan Lingkar Ilmu.

Fig. 4. Variation of traffic volume/hour during CFD and non-CFD at Jalan N24 and Jalan KP.

Table 1. Average traffic volume, normality test and T-test.

	Jalan Lingkar Ilmu- CFD (A)	Jalan Lingkar Ilmu-NCFD (B)	Jalan KP + N24- CFD (C)	Jalan KP + N24-NCFD (D)	(A)- (B)	(C)-(D)
Mean of traffic volume	89.85	819.71	916.85	667.71	- 729.85	249.14
Std. Deviation of traffic volume	36.53	197.37	186.62	98.40	207.95	212.63
Normality test by Shapiro-Wilk						
Statistic	.934	.904	.891	.975		
df	7	7	7	7		
Sig.	.584	.357	.277	.933		
T-test						
t					-9.28	3.10
df					6	6
Sig. (2-tailed)					.00	.02

Fig. 5 shows the composition of traffic consist of cars, busses, lorries, motorcycles and others such as van during CFD and NCFD at Jalan Lingkar Ilmu. The distribution of cars, busses, lorries, motorcycles and others follow normal distribution as shown by the test of Shapiro-Wilk show $p>0.05$ except for the other category. During NCFD cars has highest composition with mean of 637 ± 167.84 followed by bus, lorry and others with 21.35 ± 8.31 , 8.00 ± 2.75 , 148.00 ± 48.45 and 4.57 ± 4.03 , respectively. According to T-test only volume of car, lorry and motorcycles in each hour of CFD significantly reduced the volume (Table 2). Nevertheless, CFD o not reduce significantly the volume of buses each hour ($p=0.075$). There are also significant differences in variation of volume for other category between CFD and NCFD when tested by using non-parametric test of Wilcoxon Signed Ranked.

Fig. 5. Composition of traffic changes between CFD and NCFD at Jalan Lingkar Ilmu in front of BE.

Table 2. Significant test for traffic composition changes due to CFD.

Changes of	Mean	Std.	Std. Error	t	df	Sig. (2-
volume		Deviation	Mean			tailed)
Cars	597.14	170.10	64.29	9.28	6	.000
Buses	3.57	4.39	1.65	2.15	6	.075
Lorries	4.85	2.85	1.07	4.50	6	.004
Motorcycles	124.14	51.05	19.29	6.43	6	.001

Fig. 6 shows the composition of traffic during NCFD and CFD at Jalan N24. Shapiro-Wilk also shows that the distribution of traffic composition follow normal distribution as $p>0.05$ except for the other category (Table 3). During CFD it can be seen that the number of cars cruising on N24 fluctuated with high increase at 11 am-12 pm and 1-2 pm. Overall, the average volume of cars per hour is 372.42 ± 127.02 during CFD compared with NCFD with 363.14 ± 84.07 , however the increased is not significant according to T-test($p=0.89$)(Table 3). The scenario also happen to the number of lorries and busses with the variation are not statistically significant ($p>0.05$). The trend of motorcycles are vice-

versa with in each hour the average is 125.85 ± 41.79 during CFD and 92.42 ± 42.61 during NCFD with the changes happen significantly($p=0.004$). Again, there are significant differences in variation of volume for other category between CFD and NCFD when tested by using non-parametric test of Wilcoxon Signed Ranked.

Fig. 6. Composition of traffic changes during CFD and NCFD at Jalan N24.

Table 3. Significant test for traffic composition changes due to CFD at Jalan N24.

Changes of volume	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2- tailed)
Cars	-9.28	175.99	66.51	-.14	6	.894
Buses	13.57	21.39	8.08	1.67	6	.144
Lorries	-.85	3.28	1.24	-.69	6	.516
Motorcycles	-33.42	19.13	7.23	-4.62	6	.004

Fig. 7 shows the composition of traffic changes between NCFD and CFD at Jalan KP. As the other roads, the distribution of traffic volume of car, bus, lorry and motorcycles are following normal distribution. During CFD, only volume of cars (280.26±118.32) and motorcycles (107.71±16.73) each hour exceeded the non CFD. Consequently, the different of each are tested by using t test (Table 4) and showed that only changes of traffic volume of motor cycles (57.00±13.82)and cars(165.14±110.05)are statistically significant as p <0.05.

3.2 Carbon Dioxide concentration variation

Concentration of CO2 and variation is the first indicator to analyze the environmental impact on CFD at site BE and E (Table 5). At BE, the average of CO2 during NCFD is 419.09±10.66 and reduced to 405±13.47 ppm. Both with and without CFD the CO2 is within the range of typical indoor environment of 350 to 2,500 ppm under the Threshold Limit Value for 8-hour time-weighted-average exposures of 5,000 ppm. The reading follow the normal distribution and according to T-test, it can be concluded that there are a statistically significant reduction in CO2 concentration at BE following the CFD program t(7)=7.36 (p=0.00).

At E, it can be seen that during the first 2 hour it remains normal but during the rest of the hour it started increasing rapidly and jumped to >9999 (ppm) till 3 PM. This value exceeded the ASHRAE thet suggested CO2 maximum is 1000 ppm for human comfort. This uneven increase in reading may occur due to the CO2 accumulation as a result of the high traffic volume and poor ventilation. In the first 3 hours the reading CO2 shows six times more than at the first hour while the increment are more than 30 times. The test of Shapiro-Wilk test showed these are not normally distributed (Table 6).

Fig. 7. Composition of traffic changes during CFD and NCFD at Jalan KP.

Table 4. Significant test for traffic composition changes due to CFD at Jalan KP.

Changes of volume	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2- tailed)
Cars	-165.14	110.05	41.59	-3.97	6	.007
Buses	.85	2.03	.76	1.11	6	.308
Lorries	-1.14	1.67	.63	-1.80	6	.121
Motorcycles	-57.00	13.82	5.22	-10.91	6	.000

Table 5. Hourly average concentration of CO₂ at Location BE and E.

Time	CO2 at BE during NCFD (ppm)	CO2 at BE during CFD (ppm)	Reduction	CO2 at E during NCFD (ppm)	CO2 at E during CFD (ppm)	Increase
08 - 09 AM	433.44	430.59	2.85	446.13	540	93.87
09 - 10 AM	433.02	415.67	17.35	449.14	756.23	307.09
10 - 11 AM	416.31	402.42	13.89	422.81	3349.89	2927.08
11 - 12 PM	417.89	402.73	15.16	428.14	>9999	-
12 - 01 PM	417.07	400.82	16.25	426.01	>9999	-
01 - 02 PM	411.34	396.01	15.33	413.08	>9999	-
02 - 03 PM	404.61	390.44	14.17	401.24	>9999	-
Mean	419.09	405.52	13.57	426.65		
Std. Deviation	10.66	13.47	4.87	16.99		

Table 6. Normality test of CO₂ at Location BE and E.

	Statistic	df	Statistic	df	Sig.
CO2 at BE during CFD	.296	7	.897	7	.311
CO2 at BE during NCFD	.259	7	.897	7	.316
CO2 at E during CFD	.356	7	.729	7	.008
CO2 at E during NCFD	.179	7	.952	7	.749

3.3 Noise level variation

The results of variation of sound pressure level at BE and E for each hour is shown in Fig. 8. At BE reduction are highest at two hours from 11 am to 1 pm of more than 6 dBA while least at 8 to 10 am with reduction of 2.3 dBA (not perceptible). Thus overall, CFD reduces the SPL with average of 4.77 dBA and its clearly discernible. Statistically, the data at BE and E for both CFD and NCFD and NCFD are normally distributed when tested with Shapiro-Wilk test (Table 7). In contrast, variation of noise level at E due to CFD increases more than 3 dBA at 11 -12 am and 2-3 pm while the other times the increase are not

perceptible. The t-test on compared mean showed that the reduction of noise level at BE and increase of noise level at E are statistically significant (Table 7).

Fig. 8. Hourly sound Pressure Level at Location BE and E.

Table 7. Significant test on sound Pressure Level at Location BE and E.

	Noise level at BE during CFD	Noise level at BE during NCFD	Reduction	Noise level at E during CFD	Noise level at E during NCFD	Increase
Mean	60.17	64.84	4.67	65.45	63.68	1.77
Std. Deviation	1.59	1.06	1.74	1.28	0.88	1.37
Normality test						
Statistic	.887	.943		.978	.857	
df	7	7		7	7	
Sig.	.262	.668		.948	.143	
T-test						
t			7.06			3.41
df			6			6
Sig. (2-tailed)			0.00			0.014

3.4 Impact of traffic volume variation on noise level

Table 8 and 9 show the analysis of impact of traffic volume on noise level by investigating the strength of relationship between traffic volume as predictor of noise level. Noise level at BE during CFD has significant relationship with traffic volume with ANOVA analysis $p<0.05$ which is not for NCFD. Simple linear regression shows that $R^2=0.644$ (moderate to substantial) in which 64 percent of traffic volume at Jalan Lingkaran Ilmu describe the noise level during CFD. ANOVA analysis also shows the significant $p=0.03$ implies that volume of traffic give an impact on noise level. Investigation by using correlation and multiple regression with volume of car, bus, lorry, motorcycles as independent variables showed that reduction of noise level during CFD significantly depend on reduction of volume of lorry($p=0.007$) (Table 8). At E, during CFD, noise level is significantly influenced by; first is traffic total volume of motorcycles and total volume of cars($p=0.035$) and second by volume of bus coming from Jalan KP ($p=0.010$) (Table 9). Thus, according to R^2 value , the first has the greatest impact as the R^2 is higher. Whilst, during normal day, noise level only statistically influenced by either total volume of motorcycles ($p=0.006$) or volume of motorcycles coming from Jalan N24.

Table 8. Regression analysis on relationship between noise Level and traffic volume at Location BE.

Dependent	Predictor	R	R ²	Adjusted R Square	F Change	Sig. F Change
Noise level during NCFD	Volume of traffic during NCFD	.439 ^a	.193	.031	1.194	.324
	Volume of traffic during CFD (VBE@CFD)	.803 ^a	.644	0.573	9.057	.030
Decrease noise level due to CFD	Reduction of volume of lorries(DL)	0.891 ^a	0.793	.752	19.187	0.007 ^b

Table 9. Regression analysis on relationship between noise Level and traffic volume at Location E.

Dependent	Predictor	R	R Square	Adjusted R Square	F Change	Sig. F Change
Noise level during CFD	Total volume of motorcycles (TOTVBIK) and total volume of cars (TOTVC)- at Jln KP and N24	.902 ^a	.814	.721	8.755	.035 ^b
	Volume of Bus coming from Jalan KP(BUS@ECFDKP)	.875 ^a	.765	.718	16.268	.010 ^b
Noise level during NCFD	Total volume of motorcycles during NCFD (TOTVNCFDBIK)	.899 ^a	.808	.770	21.067	.006 ^b
	Volume of motorcycles coming from Jalan N24 (BIKE@ENFCDN24)	.845 ^a	.714	.656	12.458	.017 ^b

3.5 Impact of traffic volume variation on CO2 concentration

The analysis of impact of traffic volume on CO₂ is also identified by investigating the strength of relationship between traffic volume as predictor of CO₂ concentration. It is clear that relationship between amount of CO₂ during CFD with traffic volume is very weak (R²=0.12). Further investigation by using correlation between traffic composition and CO₂ concentration as shown in Table 10. There is good correlation between CO₂ concentration and volume of bus (BUS@BECFD) and moderate correlation with motorcylcles and others, ad weak correlation with volume of car. Thus multiple regression analysis is performed and obtained that moderate and substantial relationship occurs between CO₂ and volume of bus cruising on Jalan Lingkaran Ilmu in front of building BE with R²=0.69 and p=0.020.

Table 10. Correlation between CO2 with traffic composition at BE.

	CO2 during CFD	Volume of car	Volume of bus	Volume of lorry	Volume of motorcycles	Volume of others
CO2 during CFD	1	-.017	.832*	-.264	-.400	.444
Volume of car	-.017	1	.225	.586	.761*	.068
Volume of bus	.832*	.225	1	-.183	-.231	.641
Volume of lorry	-.264	.586	-.183	1	.636	.165
Volume of motorcycles	-.400	.761*	-.231	.636	1	-.205
Volume of others	.444	.068	.641	.165	-.205	1

4 Conclusions

The implementation of CFD at UTM has two impacts on building environment. First is good impact in which CFD reduces traffic volumes, CO₂ and noise level at Building BE that located in car free zone. The reduction of CO₂ is 13.57±4.87 ppm per hour and the reduction of noise level is 4.7±1.74dBA, both as statically significant reduction. As expected, noise level is significantly correlated with the total volume of traffic on Jalan Lingkaran Ilmu and when the reduction of noise level is concerned, it is significantly related with decrease of volume of lorries on Jalan Lingkaran Ilmu. The concentration of CO2 is significantly governed by the volume of the bus. Second is the adverse impact which is the significant increase in traffic volume from the Jalan KP and Jalan N24 which dominantly characterized by car and motorbikes. These results in increase in noise level as much as 1.77 ±1.37 dBA. Moreover, at foyer of building E, CO2 increase more than 9999 ppm after the first 3 hours of CFD till the end of CFD. This make the foyer of building is considered as sick during CFD and need more proper ventilation. In general, result from this study shows that CFD improve the environment in building located at CFD zone but worsen the building environment in NCFD.

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