Supplementary material:

Assessing the impact of traffic emissions on fine particulate matter and carbon monoxide levels in Hanoi through COVID-19 social distancing periods

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Section S1. Meteorological conditions in study periods

Fig. S3. presents the meteorological conditions in the study period. In the period, the dominant wind came from the northeast, east and southeast, with wind speed ranged from 0-2 to 6.6-8.9 m/s (Fig. 6(a)). A small portion of wind came from northwest and north, with wind speed mainly < 4 m/s. The effects of wind on $PM_{2.5}$ concentrations are further discussed in Section 3.2.1.

Air mass trajectories were distributed into four clusters: C1 – Northeast originated, moved toward Hanoi via South-China sea (21.6%); C2 – Northeastern originated, entered from continent China (26.6%); C3 – Southeastern originated, passing over South-China sea (25.5%); C4 – Southwestern cluster originated from Laos-Cambodia region (26.4%) (Fig. 6(b)).

The temperature varied and gradually increased from March to April, rarely surpassed 25°C (Fig. 6(c)). Since May, the temperature became different, grew to higher than 25°C. Effects of temperature on $PM_{2.5}$ concentrations were also demonstrated and discussed in previous studies (Hien et al., 2002, Ly et al., 2018, Ly et al., 2020). Relative humidity ranged between 60 to 95% (Fig. 6(d)). The relative humidity in May was almost always smaller than 80%. Radiation also gradually increased from March to May (Fig. 6(e)). The radiation in March and April was in the range of approximately 50 to 250 Wm^{-2}, except for the increase to over than 300 Wm^{-2} in late April. In May, higher radiation was observed ranging from 150 to approximately 300 Wm^{-2}.

Regarding precipitation, the heaviest rain (1.5 mm) in the study period happened at the beginning of March (Fig. 6(f)). Afterward, almost no rainfall occurred for the rest of month. April observed two events of slight rain with less than 0.5 mm. In May, rainfall was higher than in April in both frequency and intensity, though precipitation rate barely reached 0.5 mm (except for one occasion that got 0.5 < depth < 1.5 mm. It is worth noted that the precipitation in this study periods was very small and the effects on air pollutants' concentrations were negligible.

Section S2. Calculation of the reduction of emission from transportation in lockdown period

In order to estimate the effects of transportation on the air quality during the social distance period in Hanoi, the emission of CO and $PM_{2.5}$ are calculated as follows:

$$E_{e,i} = N \times EF_i \times VKT \times 10^{-3} \text{ (kg/day)} \qquad [1]$$

Where: $E_{e,i}$ is the total emission of pollutant i (kg/day); N is the number of vehicles of the estimated vehicle type (e.g. motorcycle, bus); EF_i is the emission factor of pollutant i for the estimated vehicle type (g/km); VKT is the daily average vehicle kilometers travelling of the estimated vehicle (km/day). In this study only the emissions of motorcycle and truck were focused as motorcycle has a highest share in the fleet and bus has a highest daily driving distance (average distance of 212 km/day

(Nguyen Thi Kim Oanh & Huynh, 2015)). The data used in estimating emission are presented in Table S4.

As can be calculated from the emission amount from Table S4, comparing with pre-social distancing period, the amount of air pollutants released from road vehicles in Hanoi in hard social distancing period were impressively reduced, by 49% and 60% for CO and $PM_{2.5}$, respectively. It implies that the pollutants concentration in ambient air also could be reduced remarkably.

Table S1: Air quality monitoring stations in Hanoi

Station ID	Station name / Location	Characteristics
U-1	Trung Yen	Urban
U-2	Hoan Kiem	Urban
U-3	Tan Mai	Urban
U-4	Kim Lien	Urban
U-5	My Dinh	Urban
T-1	Minh Khai	Traffic
T-2	Thanh Cong	Traffic
T-3	Pham Van Dong	Traffic
T-4	Hang Dau	Traffic

Table S2. Statistical parameters of observed $PM_{2.5}$ and CO data

	00 before_lockdown (N = 458)	01 prepared lockdown (N = 264)	02_lockdown (N = 528)	03_after_lockdown (N = 933)
2020 PM2.5 traffic observations				
Min	13	22	12	0
Max	158	94	121	122
Median	59.1	53.0	52.6	41.5
mean (95% confidence intervals)	62.2 (95% CI: 59.33, 65.01)	53.0 (95% CI: 51.07, 54.90)	53.6 (95% CI: 51.62, 55.65)	43.9 (95% CI: 42.83, 44.87)
2020 PM2.5 urban observations				
Min	7	11	7	0
Max	128	83	109	96
Median	46.1	38.6	41.7	31.5
mean (95% confidence interval)	48.1 (95% CI: 45.78, 50.45)	39.7 (95% CI: 38.09, 41.32)	42.0 (95% CI: 40.38, 43.63)	34.3 (95% CI: 33.40, 35.09)
	00 before_lockdown (N = 480)	**01 prepared lockdown (N = 264)**	**02_lockdown (N = 528)**	**03_after_lockdown (N = 936)**
:————————	:—————————-	:———————	:—————————-	:—————————-
2019 PM2.5 traffic observations				
Min	19	22	17	17
Max	169	122	117	118
Median	50.1	58.7	45.5	44.2
mean (95% confidence interval)	60.9 (95% CI: 57.9, 63.90)	64.0 (95% CI: 60.9, 67.1)	47.1 (95% CI: 45.85, 48.42)	45.8 (95% CI: 44.90, 46.65)
2019 PM2.5 urban observations				
Min	13	19	16	16
Max	125	120	102	84
Median	41.3	52.6	39.0	35.8
mean (95% confidence interval)	50.2 (95% CI: 47.8, 52.62)	54.5 (95% CI: 51.9, 57.2)	39.8 (95% CI: 38.76, 40.86)	36.6 (95% CI: 35.87, 37.25)
	00 before_lockdown (N = 451)	**01 prepared lockdown (N = 264)**	**02_lockdown (N = 528)**	**03_after_lockdown (N = 940)**
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2020 CO traffic observations				
Min	305	276	233	0
Max	4950	4899	4783	6388
Median	1224.0	960.0	976.8	1407.8
mean (95% confidence interval)	1,416.8 (95% CI: 1,341.48, 1,492.11)	1,155.4 (95% CI: 1,070.2, 1,240.6)	1,142.0 (95% CI: 1,081.62, 1,202.37)	1,525.8 (95% CI: 1,471.08, 1,580.54)
2020 CO urban observations				
Min	45	52	79	0
Max	3284	1984	3652	3695
Median	674.0	432.3	532.8	573.7
mean (95% confidence interval)	803.5 (95% CI: 755.05, 852.02)	517.8 (95% CI: 479.4, 556.3)	622.3 (95% CI: 587.59, 656.93)	640.3 (95% CI: 613.70, 666.90)
	00 before_lockdown (N = 480)	**01 prepared lockdown (N = 264)**	**02_lockdown (N = 528)**	**03_after_lockdown (N = 936)**
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2019 CO traffic observations				
Min	473	424.0	364	399
Max	5699	3906	8161	5056
Median	1786.9	1567.2	1714.3	1561.3
mean (95% confidence interval)	1,870.0 (95% CI: 1,794.57, 1,945.35)	1,598.6 (95% CI: 1,518.3, 1,678.9)	1,827.2 (95% CI: 1,751.3, 1,903.2)	1,638.2 (95% CI: 1,590.9, 1,685.5)
2019 CO urban observations				
Min	198	170	124	143
Max	3381	1767	2560	2583
Median	757.6	772.4	621.0	688.4
mean (95% confidence interval)	815.5 (95% CI: 778.22, 852.86)	843.5 (95% CI: 800.6, 886.4)	739.2 (95% CI: 703.2, 775.2)	751.1 (95% CI: 728.9, 773.3)

Table S3: Model performance parameters of weather normalized $PM_{2.5}$ at traffic and urban sites

	Traffic	Urban
Random Forest		
FAC2	0.99	1
MB	-0.72	-0.27
MGE	6.09	5.32
NMB	-0.01	-0.01
NMGE	0.11	0.12
RMSE	8.73	7.48
r	0.97	0.96
COE	0.73	0.70
IOA	0.86	0.85
Normalize Weather		
Type	Regression	Regression
Number of trees	100	100
Sample size	1690	1701
Number of independent variables	16	16
Mtry	7	10
Target node size	5	5
Variable importance mode	permutation	permutation
Split Rule	variance	variance
OOB prediction error (MSE)	79.67	57.30
R squared (OOB)	0.92	0.91

Note: FAC2: fraction of predictions within a factor or two; MB: Mean bias; MGE: Mean Gross Error; NMB: Normalise mean bias; NMGE: Normalise Mean Gross Error; RMSE: Root mean squared error; R: correlation coefficient; COE: coefficient of Efficiency; IOA: Index of Agreement.

Table S4: Model performance of weather normalized CO in traffic and urban sites

	Traffic	Urban
Random Forest		
FAC2	0.95	0.92
MB	-51.54	-8.36
MGE	348.62	179.11
NMB	-0.037	-0.01
NMGE	0.25	0.27
RMSE	610.58	316.81
r	0.76	0.76
COE	0.47	0.45
IOA	0.73	0.73
Normalize weather		
Type	Regression	Regression
Number of trees	100	100
Sample size	1,690	1,706
Number of independent variables	15	17
Mtry	4	5
Target node size	5	5
Variable importance mode	Permutation	Permutation
Split rule	Variance	Variance
OOB prediction error (MSE)	313476.8	108202.4
R squared (OOB)	0.60	0.6

Note: FAC2: fraction of predictions within a factor or two; MB: Mean bias; MGE: Mean Gross Error; NMB: Normalise mean bias; NMGE: Normalise Mean Gross Error; RMSE: Root mean squared error; R: correlation coefficient; COE: coefficient of Efficiency; IOA: Index of Agreement.

Table S5. Estimating the CO, $PM_{2.5}$ emission reduction relating to transportation during the social distance period

Input parameters	Motorcycle	Bus*	Source
The number of vehicles	3008280	1634	(Bus-WebGPS, 2018; Nguyen et al., 2019)
VKT (km/day)	20	212	(Kim Oanh et al., 2012; Kim Oanh & Huynh, 2015)
EF_{CO} (g/km)	12.09	2.9	(Nghiem et al., 2019; Tung et al., 2011)
$EF_{PM2.5}$ (**)	0.088	3.0	(Kim Oanh et al., 2012; Lien & Dung, 2017)

Estimating emission reduction	Motorcycle	Bus	**Total**
Baseline period (13/1/2020)			
Mobility reduction percentage	0	0	
The amount of CO emission (kg)	727402	1005	728407
The amount of PM10 emission (kg)	5295	1039	6334
Pre-social distancing period			
Mobility reduction percentage	30	0	
The amount of CO emission (kg)	509181	1005	510186
The amount of PM10 emission (kg)	3706	1039	4745
Soft-social distancing period			
Mobility reduction percentage	53	52	
The amount of CO emission (kg)	341879	482	342361
The amount of PM10 emission (kg)	2488	499	2987
Hard-social distancing period			
Mobility reduction percentage	64	100	
The amount of CO emission (kg)	261865	0	261865

The amount of PM10 emission (kg)	1906	0	1906
Post-social distancing period			
Mobility reduction percentage	19	20	
The amount of CO emission (kg)	589196	804	589999
The amount of PM10 emission (kg)	4289	831	5120

Note: (*) Bus number for each period is collected at Hanoi. (**) We applied the EF_{PM10} from previous studies due to lacking the study results of $EF_{PM2.5}$ for the road vehicle in Vietnam. However, in these studies, EF_{PM10} were determined according to the particle matter emission from the vehicle exhaust. In fact, nearly all particle matters released from the vehicle exhaust are found in the form of fine fraction ($PM_{2.5}$)(Brizio & Genon, 2008; Ketzel et al., 2007). Therefore, an approximation may estimate $EF_{PM2.5}$ equal to EF_{PM10}.

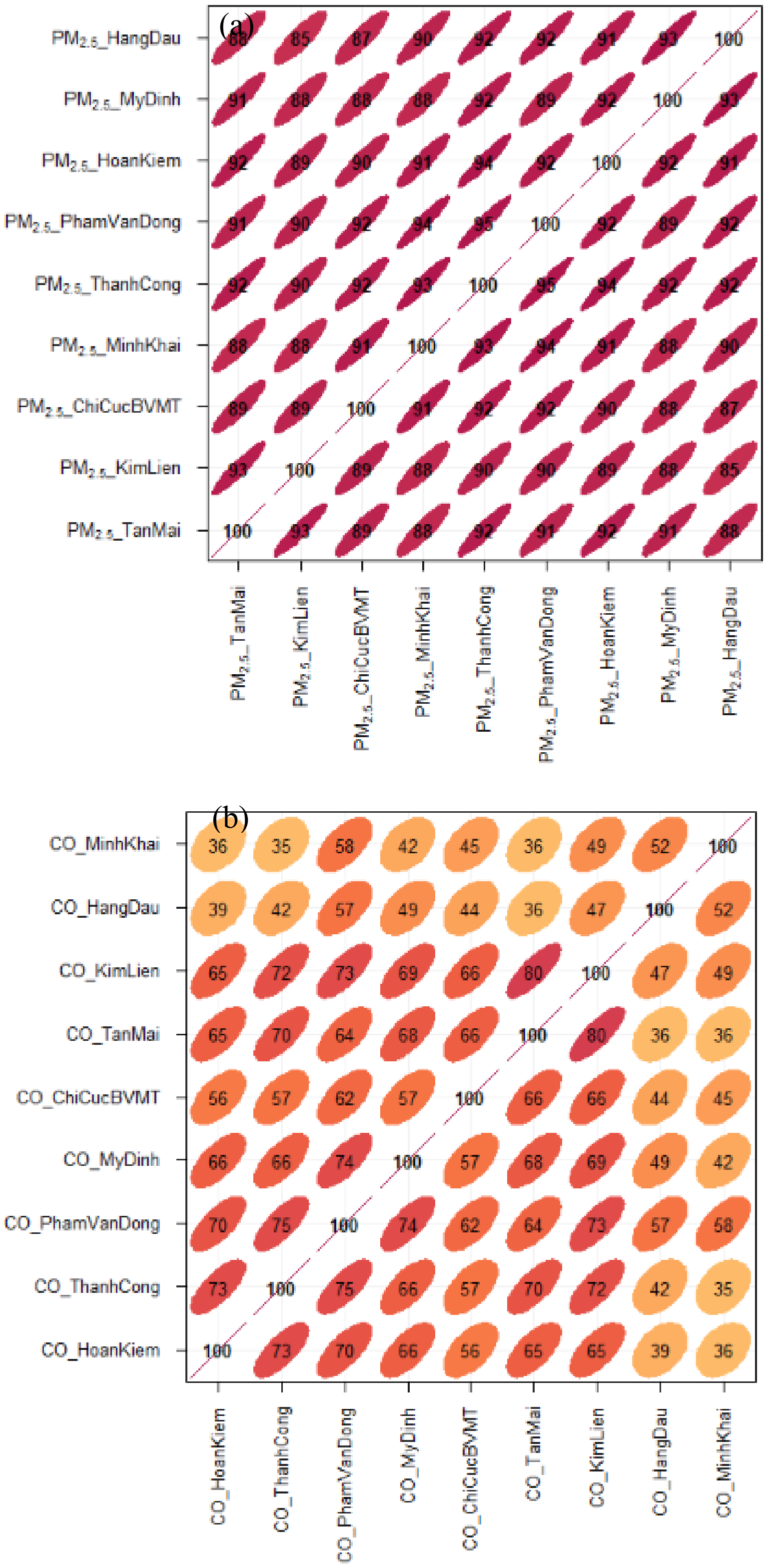

Fig. S1. The Pearson correlation coefficients (*r*) 5 in nine stations in Hanoi: a) $PM_{2.5}$, b) CO

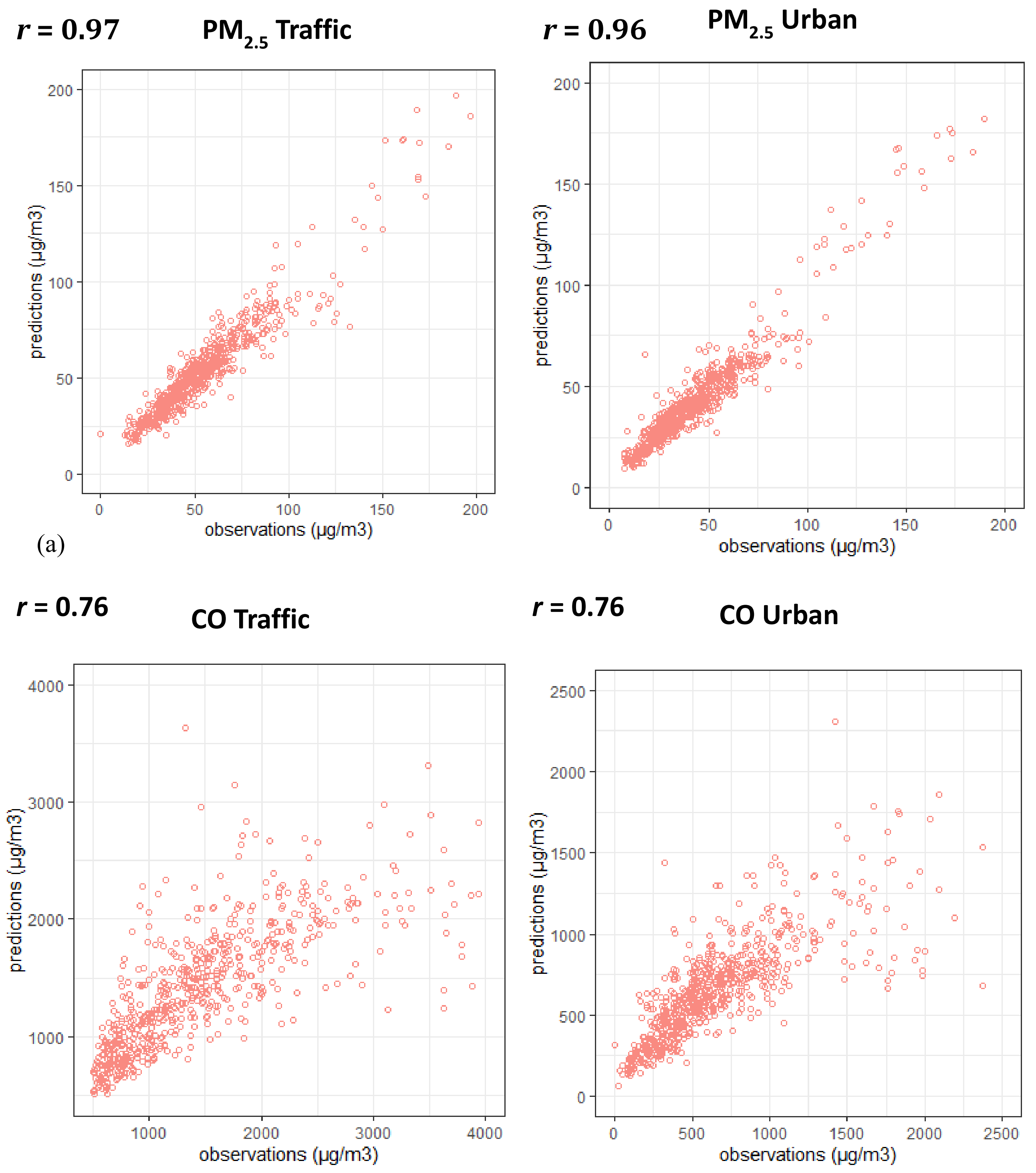

Fig. S2. The correlations between the predicted and observed concentrations in traffic and urban sites: a) $PM_{2.5}$, b) CO

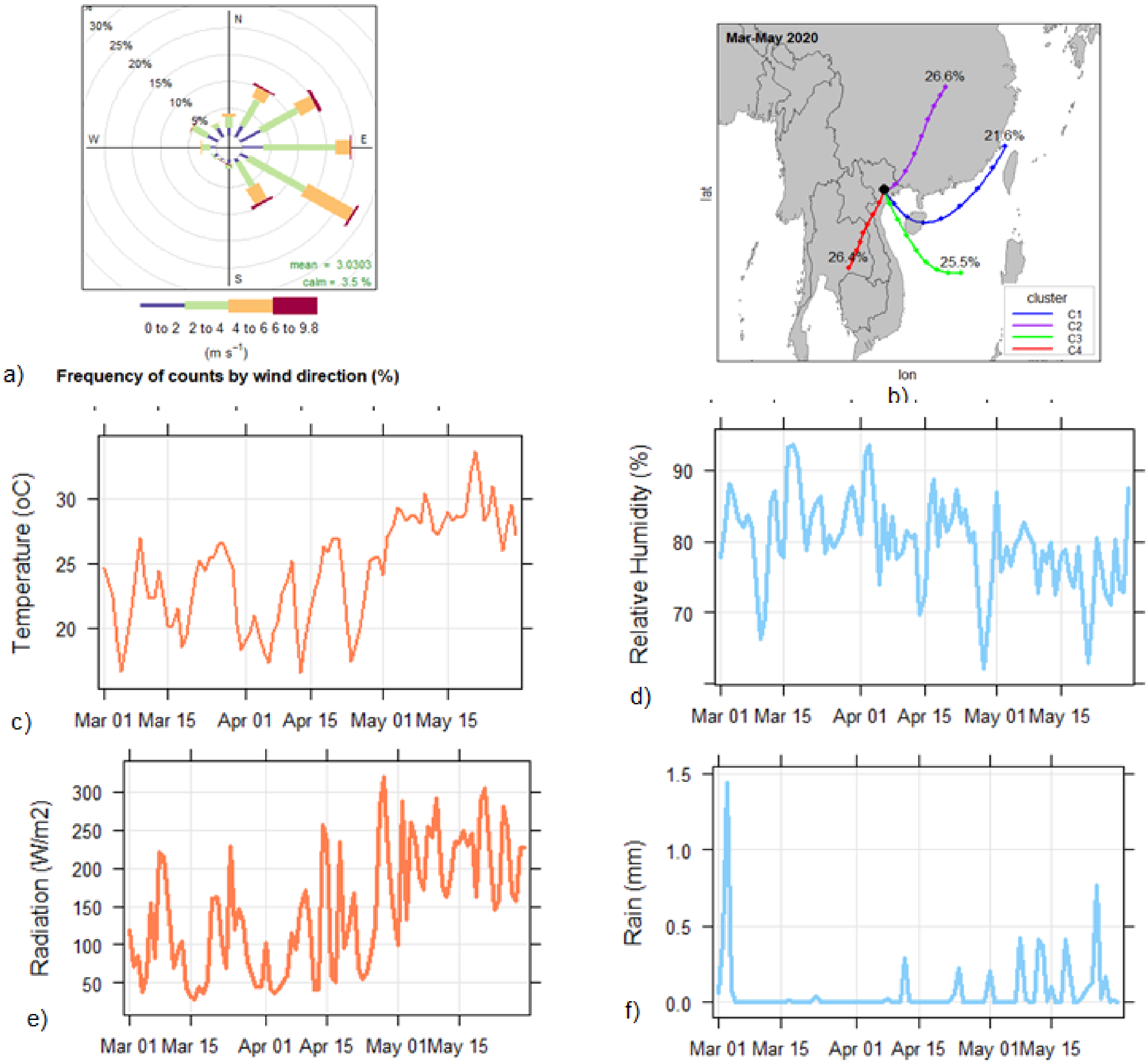

Fig. S3. Meteorological conditions in the study period: a) Wind direction; b) Air mass trajectory cluster to Hanoi; c) Temperature; d) Relative humidity; e) Radiation; f) Rain

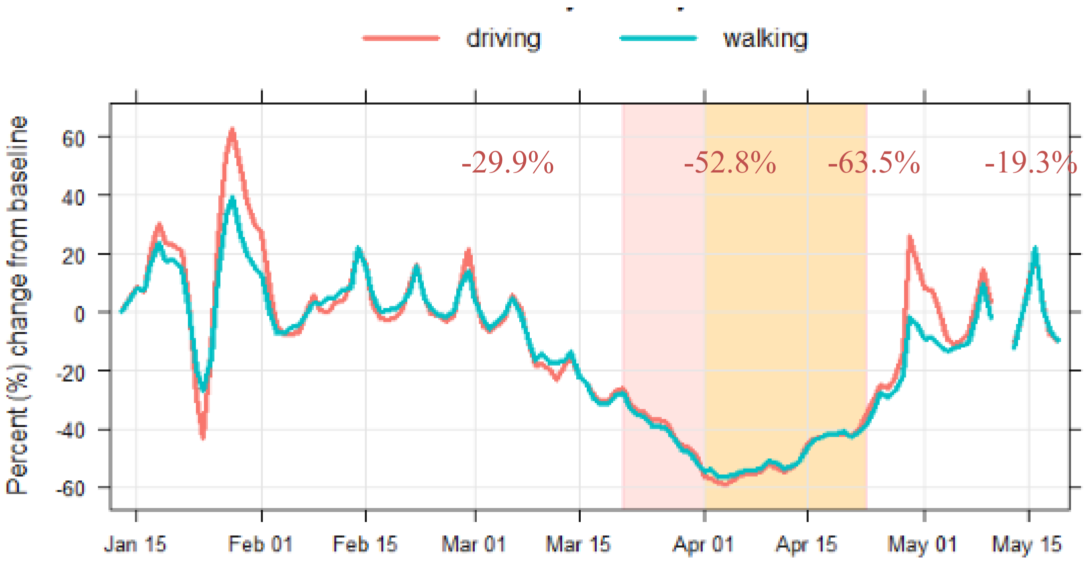

Fig. S4. The mobility trend profile of Vietnam from Jan 2020 to May 2020 obtaining from Apple

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