

# Evaluation and Application of A Novel Low-cost Wearable Sensing Device in Assessing Real-time PM<sub>2.5</sub> Exposure in Major Asian Transportation Modes

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**Parts and cost of LASS**

Website: [http://www.icshop.com.tw/product\\_info.php/products\\_id/20524](http://www.icshop.com.tw/product_info.php/products_id/20524)

Parts:

- Linkit One mainboard
- G3 Sensor (Plantower PMS3003)
- GPS Sensor
- Wi-Fi module
- DHT22 Temperature and RH Sensor

Total cost: 3199 NT dollars, ~ 107 \$USD

Considering the extra cost for designing and printing the outer cases with a 3D printer by a machine shop, the total cost were ~ 150USD per LASS.

**Temperature and humidity conditions of six transportation modes**

The temperature and RH conditions of the three air-conditioned transportation modes were 27.5-34.6 °C and 47.5-80.3%, 26.3-37.2 °C and 34.7-77.7%, and 23.4-39.0 °C and 25.2-71.4% in MRT, bus, and car modes, respectively. For the other three modes, the temperature ranges were 28.9-42.5 °C, 29.1-42.0 °C, and 28.7-39.4 °C and RH ranges were 40.5-84.4%, 41.3-82.0%, and 46.0-81.7% in scooter, bike, and walk modes, respectively. The air-conditioned transportation modes covered lower temperature ranges, with bus and car having obviously lower RH ranges compared to the other modes.

**Table S1.** The correlation coefficients of five air quality stations in Taipei in 2016.

	A	B	C	D	E
A	1.000				
B	0.930	1.000			
C	0.931	0.994	1.000		
D	0.957	0.950	0.967	1.000	
E	0.930	0.992	0.993	0.971	1.000

<sup>a</sup> Station A: Guting; station B: Zhongshan; station C: Wanhua; station D: Shilin; station E: Songshan.

<sup>b</sup> Data source: Taiwan Environmental Protection Agency website,  
[https://data.epa.gov.tw/en/dataset/aqx\\_p\\_13](https://data.epa.gov.tw/en/dataset/aqx_p_13).

There are five Taiwan EPA air quality stations (Guting, Zhongshan, Wanhua, Shilin, and Songshan stations, which were named as stations A-E, respectively, in the Table S1) in the Taipei basin. Based on PM<sub>2.5</sub> data in 2016, the paired correlation coefficients of PM<sub>2.5</sub> variations for these five stations showed high correlation between these station. Therefore, these data showed evidence for our statement in the main text, “Taipei metropolitan is in a basin with pollutant levels in ambient air quite uniformly distributed spatially”.

**Table S2.** Sample size of monitoring with (a) LASS in 2016, (b) GRIMM in 2016, (c) PEM in 2004, and (d) PEM in 2005; one sample in 2016 representing one hour of monitoring while one sample in 2004-2005 representing monitoring for one complete monitoring duration (2 or 4 hours); data presented exclude rainy events.

<b>(a)</b>				
<b>Transportation Mode</b>	<b>Morning</b>	<b>Noontime</b>	<b>Afternoon</b>	<b>Total</b>
MRT	25	10	18	53
Bus	23	12	18	53
Car	26	11	23	60
Scooter	25	12	20	57
Bike	24	12	20	56
Walk	26	13	19	58
<b>(b)</b>				
<b>Transportation Mode</b>	<b>Morning</b>	<b>Noontime</b>	<b>Afternoon</b>	<b>Total</b>
MRT	6	1	4	11
Bus	6	3	4	13
Car	27	12	23	62
Scooter	26	12	20	58
Bike	6	3	5	14
Walk	6	3	3	12
<b>(c)</b>				
<b>Transportation Mode</b>	<b>Morning</b>	<b>Noontime</b>	<b>Afternoon</b>	<b>Total</b>
MRT	5	5	5	15
Bus	--	--	--	--
Car	5	5	5	15
Scooter	5	5	5	15
Bike	--	--	--	--
Walk	--	--	--	--
<b>(d)</b>				
<b>Transportation Mode</b>	<b>Morning</b>	<b>Noontime</b>	<b>Afternoon</b>	<b>Total</b>
MRT	5	5	5	15
Bus	--	--	--	--
Car	5	5	5	15
Scooter	5	5	4	14
Bike	--	--	--	--
Walk	--	--	--	--

**Table S3.** Ambient PM levels from nearby monitoring stations of Taiwan Environmental Protection Administration.

Monitoring period	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	PM <sub>10</sub> (µg/m <sup>3</sup> )
	mean (SD)	mean (SD)
2004	26.8 (13.0)	41.2 (18.5)
2005	49.2 (19.0)	56.4 (21.5)
2016	18.5 (8.2)	28.8 (9.4)

**Table S4.** Mean values of absolute error and accuracy of LASS measurements in the six transportation modes.

mode	Overall		Rush hours		Non-rush hours	
	AE <sup>1</sup>	Accuracy <sup>2</sup>	AE	Accuracy	AE	Accuracy
	mean (SD <sup>3</sup> )	mean (SD)	mean (SD)	mean (SD)	mean (SD)	mean (SD)
MRT	5.6 (5.4)	18 (12)	5 (5.5)	15 (12)	3.1 (1.1)	13 (5)
Bus	2.4 (3.8)	12 (28)	1.9 (2)	10 (9)	1.4 (1.3)	8 (7)
Car	1.4 (1.6)	25 (21)	1.5 (1.8)	23 (18)	1.3 (1.9)	27 (29)
Scooter	4.8 (4)	22 (16)	5 (4)	23 (16)	6 (4.8)	24 (16)
Bike	5.3 (5.6)	18 (11)	4.9 (4.2)	21 (11)	8.8 (8.1)	21 (9)
Walk	2.5 (2)	11 (8)	2.3 (1.7)	11 (8)	2 (1.4)	10 (7)
Total	3.3 (3.9)	21 (18)	3.2 (3.6)	20 (16)	3.7 (4.7)	21 (21)

<sup>1</sup> AE (absolute error): |GRIMM-LASS| (µg/m<sup>3</sup>)

<sup>2</sup> Accuracy: |GRIMM-LASS|/GRIMM(%)

<sup>3</sup> SD: standard deviation

**Table S5.** The results of multiple regression analysis with the converted LASS, GRIMM, temperature, and relative humidity (RH) in the six transportation modes.

<b>mode</b>	<b>adjusted R<sup>2</sup></b>	<b>intercept</b>	<b>GRIMM PM<sub>2.5</sub></b>	<b>Temperature</b>	<b>RH</b>
MRT	0.343	90.1	0.39*	-1.63	-0.40
Bus	0.789	4.4	0.88*	-0.06	-0.01
Car	0.883	-2.9	0.92*	0.02	0.04*
Scooter	0.736	8.8	0.78*	-0.24	-0.01
Bike	0.898	-40.9	0.61*	0.89	0.25
Walk	0.863	-2.2	0.79*	0.02	0.06

\* p-value < 0.05

**Table S6.** Coefficients of regression analysis with dummy variables for different transportation modes.

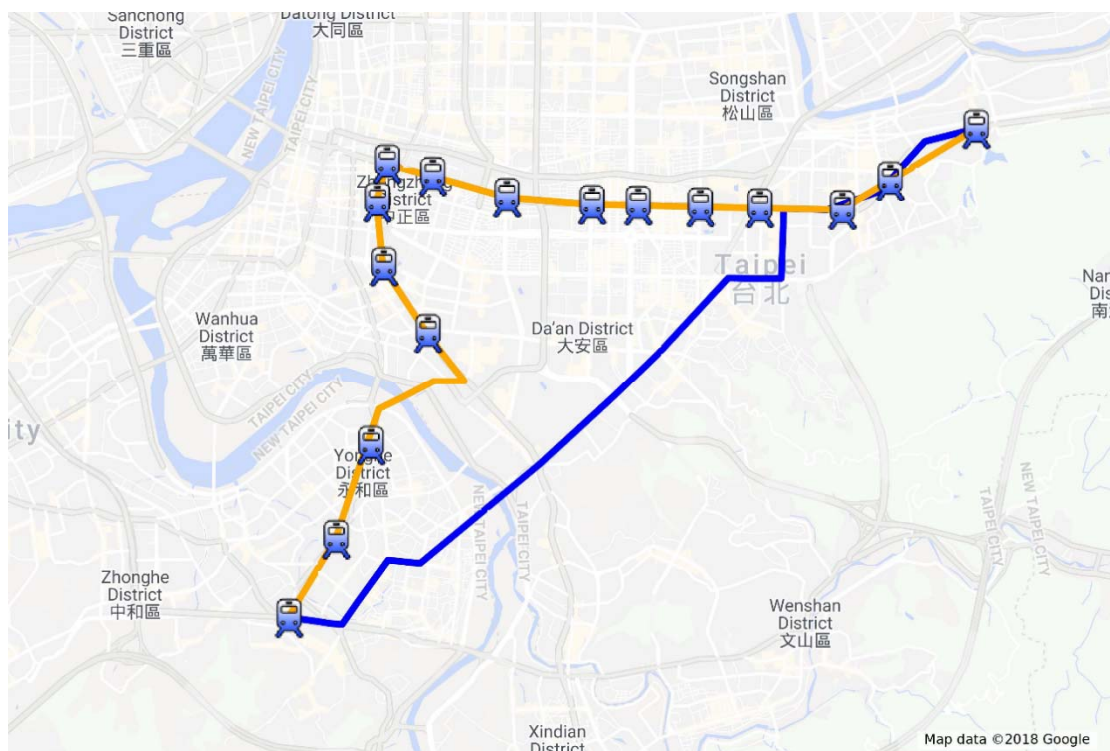
mode	GRIMM		LASS	
	Non-standardized coefficients	Standardized coefficients	Non-standardized coefficients	Standardized coefficients
Intercept (car)	-26.7		-19.2	
MRT	15.9	0.333	15.6	0.640
Bus	4.6	0.118	6.7	0.264
Scooter	9.9	0.450	8.1	0.356
Bike	9.3	0.252	6.1	0.262
Walk	4.9	0.120	7.1	0.287
Air temperature	-0.1	-0.026	-0.3	-0.114
Relative Humidity	0.4	0.425	0.3	0.386



(a)



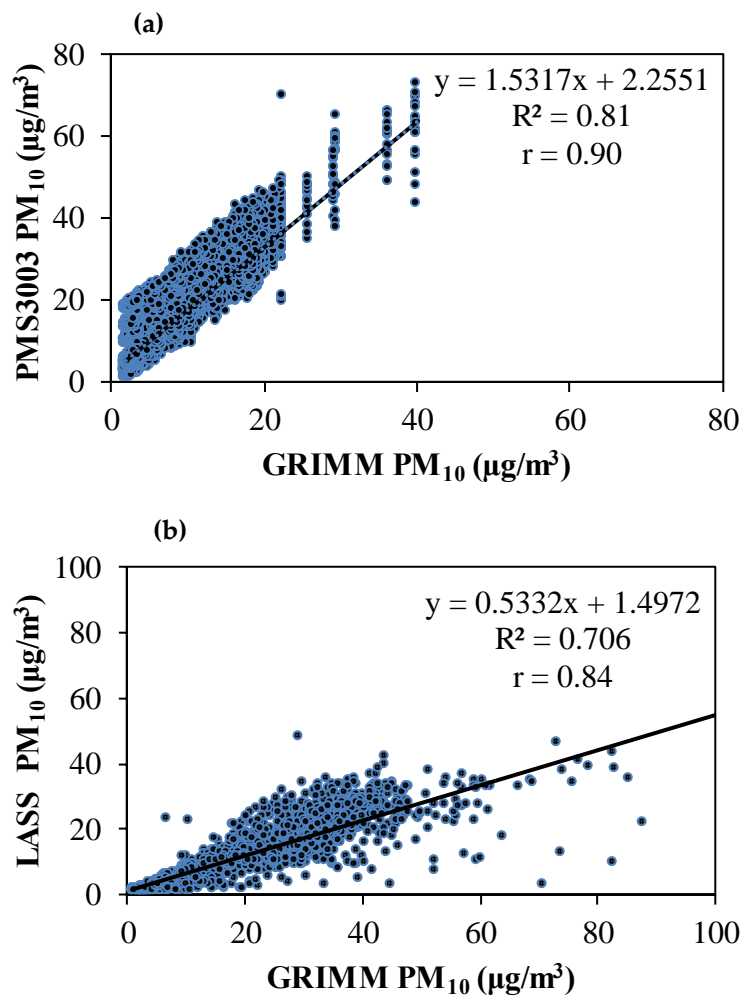
(b)



**Figure S1.** Monitoring Routes in (a) 2016 (the green line) and (b) 2004 and 2005 (car and scooter on the blue line; MRT on the yellow line) in Taipei.



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