Modeling and Estimation of Air Pollutants from Vehicles in Yangon, Myanmar with Google Traffic Map

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ABSTRACT: Air pollution is one of the most serious issues around the world. According to World Health Organization, air pollution causes 4.2 million deaths per year. Particularly in recent years, PM 2.5, which is a micro substance whose diameter is less than 2.5 micro meter, has been drawing attention because it has serious health impact. PM 2.5 often includes harmful substances. When you draw PM2.5 into lungs, it is absorbed deep into the lungs and blood and causes respiratory diseases and lung cancer, myocardial infarction, stroke. According to the Health Effect Institute, it was estimated that 6 million people were dead because of longtime absorption of polluted air. In Yangon, which is the largest city in Myanmar, the amount of PM2.5 sharply increased in recent years. The traffic volume has also increased in Yangon, so it is considered that the growth in traffic volume is one of the cause of increment in air pollution. To solve the problem, it is important to evaluate the detailed distribution of PM2.5 from traffic and the relationship between PM2.5 and health hazard. We estimated the amount of PM2.5 discharged from road traffic. So far, various studies related to traffic flow and air pollution have been conducted. For example, "High Resolution Air Pollution Assessment System for Road Transport Policy Evaluation" conducted by Kuwahara. However, there is no method which observes the large scale real time PM2.5 distribution exhausted from traffic at short interval. We attempted to estimate the traffic flow by using traffic data of Google traffic map, which shows the traffic speed on each road section. Processing the information, we tried to estimate the volume of traffic. Moreover, combining it with the amount of PM2.5 of each car, the average amount of PM2.5 in every hour was estimated. In the end, in order to confirm the validity of the result, compared it with the result from field survey which we carried out in Yangon. The estimated value is lower than the surveyed value. The reason is considered that the estimated value did not include the background value.

1. INTRODUCTION

1.1 Back ground

Air pollution is one of the most serious issues around the world (Aaron, 2005). According to the Health Effect Institute, it was estimated that 6 million people were dead because of longtime absorption of polluted air (Takeuchi, 2018). In recent years, environmental problems have become more serious in Yangon's largest city, Yangon, where the economy is growing and the population is increasing (Shi, 2018). As a result, diseases such as asthma, which are thought to be caused by PM2.5, are increasing. It is considered that vehicle exhaust product mainly contributes to the increment in PM10 and PM2.5 levels in urban site (Rodoriguez, 2004). It can be considered that the main cause of high PM2.5 level in Yangon is PM2.5 from traffic because the rate of vehicle sales increase in Myanmar is the highest in that in ASEAN countries (Myanmar Survey Research Co., 2019). In fact, the Myanmar government has enacted the "Environmental Conservation Law" and established exhaust gas regulation to reduce air pollution hazard. In order to implement appropriate policy, such as traffic regulation, 10 m resolution PM2.5 map is necessary to detect in which street PM2.5 concentration is high and how large hazard it causes.

1.2 Existing Method

There is no method to observe large scale detailed PM2.5 value. It is said that it stays in the atmosphere in large area for several days to several weeks except when it rains since PM2.5 is difficult to diffuse and is not affected by sedimentation due to gravity (Nakano, 2013). Therefore, the concentration of PM2.5 is different even if the distance of measuring spots are a little away. Moreover, PM2.5 is transferred in a long distance, so large scale detailed PM2.5 data is also necessary. However, there is no method which meets those criteria with limited resources, such as budget, personnel, and supplies, whereas there are various studies related to traffic flow and air pollution have been conducted.

There is direct measurements and indirect measurements of PM2.5. Currently, PM2.5 is mainly measured by physically measuring PM2.5. Direct measurement methods are the filter method and the automatic measurement method. A typical filter method is the Federal Reference Method of the US EPA.

As for automatic measuring machines, there are measuring machines using Tapered Element Oscillating Microbalance, β-ray absorption method, light scattering method and the like (Ministry of the environment government of Japan, 2011). In Japan, there fixed point observation station whose name is "Soramame-kun" and many field survey conducted which use physical measuring, such as the one which conducted by Yamagami in Nagoya in 2008. The disadvantage of direct measurement methods is they cannot be used to measure broad area in detail simultaneously.

Indirect measurements are remote sensing and simulation. PM2.5 concentrations is predicted by using aerosol optical thickness retrieved by satellite such as MODIS. However, it cannot distinguish attenuation because of cloud and because of suspended matter (Zhang, 2015). Moreover, the resolution is coarse, being more than 10km (Kishi, 2011).

The other method is simulation. One of simulation method is "High Resolution Air Pollution Assessment System for Road Transport Policy Evaluation" conducted by Kuwahara. Kuwahara combined atmospheric circulation model with traffic flow simulation. The disadvantage of the research is that it cannot estimate current situation because cars in the simulation supposed to run at average speed.

1.3 Objective

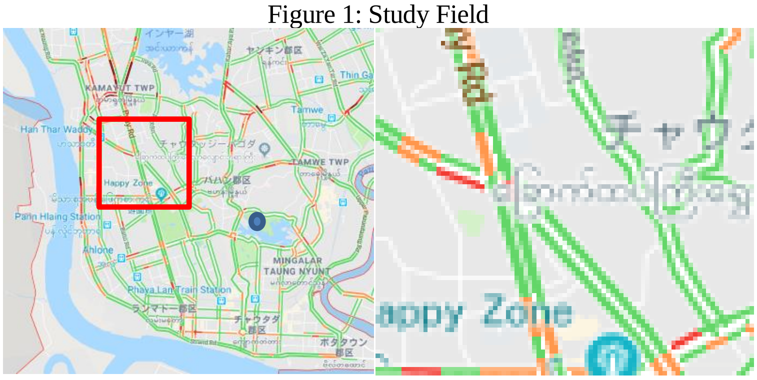
In order to accurately grasp the current status of PM2.5, we tried to estimate current PM2.5 emission from road traffic which one of the main resources of PM2.5. In the purpose of measuring accurate PM2.5 concentration, we estimated it from traffic volume estimated from Google Traffic.

2. METHOD

2.1 Study Site

Study field is a spot in a road going north on the Pyay Road around Hantha Waddi, which is one of congested roads in Yangon. It represented by blue dot in Figure 1. On 3th October, 2018, we measured PM2.5 concentration there.

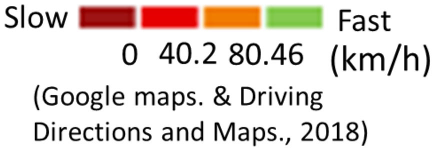
Figure 1: Study Field



2.2 Verification of Traffic Flow Pattern

Traffic flow was estimated by colors of Google traffic congestion map. Those colors show the speed of cars per minutes. Red-black, red, yellow, green and other colors means respectively almost 0 km per hour, less than 40.2 km per hour, from 40.2 to 80.46 km per hour, more than 80.46 km per hour and no traffic information (Google maps, 2018) (Figure 2). However, In order to make it calculate, every color line are supposed to have one fixed speed respectively. Red-black supposed to be 1 km per hour because red-black indicate extremely slow or stopped traffic. Red was supposed to 20 km per hour because the middle speed in red line is 20 km per hour. Green line is 56 km per hour even though Google map indicate the speed is over 80 km per hour because when I visited Yangon, there is no car run over 80 km per hour even in line which Google traffic showed green. Schrank and Lomax (2005) used 56km per hour for arterial roads as free flow speed for comparison with congested speeds, so speed in green line was supposed to be 60 km per hour. The orange was supposed to be 40 km per hour because it is the approximately middle speed between speeds in red line and green line.

Figure 2: Google Traffic speed



We took screenshot every 5 minute, checked which color the point was and counted. Screenshot was taken from 14th July to 10th August in 2018. Counted data was classified by day of week, then we searched average traffic pattern of day of week and if those pattern is different from each day of week. In the same way, we checked hourly trend. For example, we checked if traffic has the same trend from 8 o'clock to 9 o'clock even if the day is different.

2.3 Estimation of The Number of Cars

The number of vehicles are estimated by combining Google traffic congestion map with the width of the road and distance between cars (equation 1). Pyay road has 3 lane in one side. Distance between cars of red-black, red lane, yellow lane and green lane are supposed to 1m, 9 m, 22 m and 45 m respectively. Those distances are safe inter-vehicle distance defined in Japan.

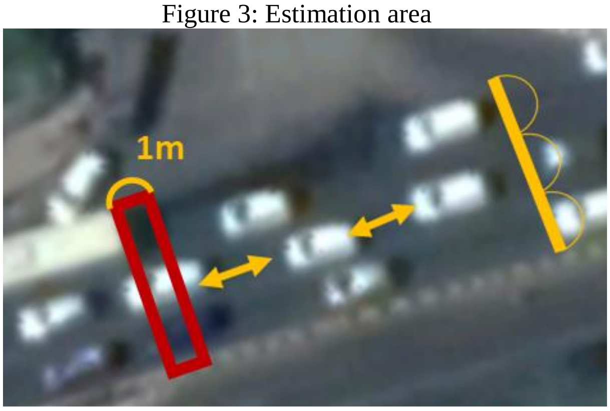
$$Traffic\ volume = \frac{velocity}{distance} * lane \quad (1)$$

2.4 The Estimation of Amount of Air Pollution

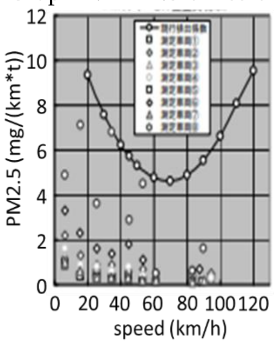
Amount of PM2.5 was estimated by using the number of vehicles and average amount of exhausted gas of car. In this thesis, PM2.5 concentration was supposed to emission a part of road like area in figure 3. Over 90 % cars which run in Yangon are imported cars from Japan. Therefore, we use PM2.5 emission data which were measured by Japanese Ministry of Land, Infrastructure and Transport (Graph 1). The weight of vehicle and the distance the vehicle run were supposed to be 1.5 t, 1 m respectively. The estimated amount of PM2.5 of a car in red-black lane, red lane, yellow lane and blue lane are supposed to be 0.0120, 0.0095, 0.0048 and 0.0050 (g/ km/ ton) respectively (Sone, 2011). To make model simple, 1 m/s wind supposed to blow in traffic flow direction.

$$\mathrm{PM2.5_{total}} = \frac{Traffic\ volume * PM2.5_{each}}{3600} \quad (2)$$

Figure 3: Estimation area



Graph 1: PM2.5 emission



(Sone et.al, 2005)

3. Result and Discussion

3.1 Color Pattern of Google Traffic in Survey Point

Table 1 shows probabilities of each color in every hour from 14th July to 10th August. The highest probability in the hour is bolded. The second one is underlined. From 0 o'clock to 5 o'clock, green and no color occupied. From 6 o'clock, red and orange gradually increased and from 12 o'clock to 16 o'clock the probability of red is the highest. After 17 o'clock orange and green increased and gradually shifted to green.

Table 1: Probability of each color (Average)

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
Black	0	0	0	0	0	0.033	0.092	0.116	0.058	0.026	0.05	0.121	0.133	0.02	0.059	0.089	0.033	0	0	0	0	0	0	0	
Red	0	0	0	0	0	0.174	0.359	0.255	0.182	0.092	0.254	**0.308**	**0.377**	**0.366**	**0.467**	**0.472**	0.208	0.051	0	0	0	0	0	0	
Orange	0	0	0	0	0	0.144	0.157	0.139	0.136	0.224	0.234	0.295	0.273	0.33	0.33	0.243	0.363	0.212	0.084	0.014	0	0	0	0	
Green	0.36	0.23	0.33	**0.892**	**0.99**	**0.646**	**0.382**	**0.447**	**0.578**	**0.64**	**0.462**	0.272	0.214	0.284	0.144	0.197	**0.396**	**0.737**	**0.905**	**0.979**	**0.993**	**0.997**	**0.971**	**0.76**	
No color	**0.64**	**0.77**	**0.66**	0.105	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.029	0.24	
PM2.5_ave.	2.8	1.8	2.7	7.1	8.0	11.8	15.6	13.6	11.8	10.4	13.7	15.3	16.6	15.8	18.0	18.0	13.1	9.6	8.2	8.0	7.9	8.0	7.8	6.1	10.5
PM2.5_var.	217	222	218	174	161	85	−19	41	86	117	37	−10	−52	−26	−98	−100	53	134	158	161	162	161	165	188	115

From table 2 to table 8 show the probability of colors in each day of week in the left side and shows estimated amount of PM2.5 and variance of that. Table 9 shows estimated average amount of PM2.5 in a day of every day of week and average variance of that. Compared to variances of weekdays, those of weekends are large, so it can be considered that estimated PM2.5 in weekdays likely to follow pattern. Therefore, it is supposed that it is appropriate to compare field survey data to estimated weekdays data when the field survey data is weekday data.

Table 2: Probability of each color (Saturday)

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
Black	0	0	0	0	0	0	0	0.265	0.176	0	0	0	0.057	0	0	0	0	0	0	0	0	0	0	0	
Red	0	0	0	0	0	0	0.118	0.029	**0.324**	0.212	**0.394**	0.324	**0.429**	0.265	**0.371**	0.188	0.242	0.057	0	0	0	0	0	0	
Orange	0	0	0	0	0	0	0.059	0.118	0.147	0.182	0.364	**0.471**	0.257	0.176	0.343	**0.438**	0.091	0.257	0.176	0.029	0	0	0	0	
Green	**0.6**	0.38	**0.66**	**0.794**	**0.97**	**1**	**0.794**	**0.588**	0.294	**0.606**	0.242	0.206	0.257	**0.559**	0.286	0.375	**0.667**	**0.686**	**0.794**	**0.971**	**1**	**1**	**1**	**0.848**	
No color	0.4	**0.62**	0.34	0.206	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.152	
PM2.5_ave.	4.8	3.1	5.3	6.4	7.8	8.0	10.1	10.7	15.1	12.4	16.3	15.3	17.0	13.4	15.8	12.7	12.7	9.8	8.3	8.1	8.0	8.0	8.0	6.8	10.2
PM2.5_var.	202	216	197	185	165	161	123	110	−4	71	−41	−10	−65	46	−25	63	63	129	157	160	161	161	161	179	122

Table 3: Probability of each color (Sunday)

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
Black	0	0	0	0	0	0	0	0	0	0.182	0.067	0.065	0	0	0.068	0	0	0	0	0	0	0	0	0	
Red	0	0	0	0	0	0	0	0.043	0.348	**0.318**	**0.444**	0.239	0.261	0.304	**0.364**	0.022	0	0	0	0	0	0	0	0	
Orange	0	0	0	0	0	0	0.087	0.109	0.239	0.205	0.222	**0.391**	**0.391**	**0.413**	0.227	0.333	0.196	0.044	0.022	0	0	0	0	0	
Green	**0.69**	**0.76**	0.49	**0.826**	**1**	**1**	**0.913**	**0.848**	**0.413**	0.295	0.267	0.304	0.348	0.283	0.341	**0.644**	**0.804**	**0.956**	**0.978**	**1**	**1**	**0.978**	**1**	**0.609**	
No color	0.31	0.24	**0.51**	0.174	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.391	
PM2.5_ave.	5.5	6.0	3.9	6.6	8.0	8.0	8.3	9.1	15.1	15.7	17.3	14.0	13.9	14.8	15.8	9.4	8.6	8.1	8.1	8.0	8.0	7.8	8.0	4.9	9.7
PM2.5_var.	195	188	210	181	161	161	157	142	−3	−22	−74	30	31	6	−26	137	152	159	160	161	161	164	161	201	131

Table 4: Probability of each color (Monday)

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
Black	0	0	0	0	0	0.152	0.222	0.156	0.048	0	0.182	**0.378**	0.106	0.045	0.022	0.065	0.067	0	0	0	0	0	0	0	
Red	0	0	0	0	0	**0.391**	**0.6**	**0.422**	0.262	0	**0.318**	0.289	**0.447**	0.273	**0.457**	**0.739**	**0.333**	0.085	0	0	0	0	0	0	
Orange	0	0	0	0	0	0.217	0.089	0.133	0.095	0.261	0.182	0.2	0.17	0.295	0.37	0.196	**0.333**	0.213	0.133	0.022	0	0	0	0	
Green	0.24	0.07	0.11	**0.889**	**1**	0.239	0.067	0.289	**0.595**	**0.717**	**0.318**	0.133	0.277	**0.386**	0.152	0	0.267	**0.702**	**0.867**	**0.978**	**1**	**1**	**0.936**	**0.907**	
No color	**0.76**	**0.93**	**0.89**	0.111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.064	0.093	
PM2.5_ave.	1.9	0.5	0.9	7.1	8.0	16.9	20.7	17.2	13.4	8.6	15.7	16.5	17.5	14.2	17.6	22.6	15.6	10.2	8.4	8.1	8.0	8.0	7.5	7.3	11.3
PM2.5_var.	221	225	224	174	161	−60	−202	−72	45	151	−20	−49	−80	24	−86	−286	−17	121	155	160	161	161	169	172	96

Table 5: Probability of each color (Tuesday)

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
Black	0	0	0	0	0	0.043	0.091	0.093	0.064	0	0.064	0.2	**0.444**	0.045	0.068	0.043	0	0	0	0	0	0	0	0	
Red	0	0	0	0	0	0.391	**0.477**	0.256	0.106	0.068	0.234	**0.333**	0.2	**0.523**	0.364	**0.681**	0.022	0	0	0	0	0	0	0	
Orange	0	0	0	0	0.02	0.217	0.227	0.163	0.064	0.273	0.298	0.156	0.133	0.341	**0.545**	0.213	**0.667**	0.239	0.022	0	0	0	0	0	
Green	0.33	0.05	0.33	**1**	**0.98**	**0.348**	0.205	**0.465**	**0.766**	**0.659**	**0.404**	0.311	0.222	0.091	0.023	0.064	0.311	**0.761**	**0.978**	**1**	**1**	**1**	**0.913**	**0.733**	
No color	**0.67**	**0.96**	**0.67**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.087	0.267	
PM2.5_ave.	2.6	0.4	2.7	8.0	8.1	16.1	18.1	13.6	10.6	10.0	13.6	16.0	15.2	18.9	16.8	21.5	10.3	8.7	8.1	8.0	8.0	8.0	7.3	5.9	10.7
PM2.5_var.	218	225	218	161	160	−35	−101	39	113	124	40	−30	−5	−133	−56	−235	118	149	160	161	161	161	172	191	111

Table 6: Probability of each color (Wednesday)

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
Black	0	0	0	0	0	0	0.152	0.136	0.128	0	0	0.087	0.114	0.022	0.133	0.37	0.152	0	0	0	0	0	0	0	
Red	0	0	0	0	0	0.222	**0.543**	**0.523**	0.128	0.067	0.087	**0.348**	**0.364**	0.348	**0.778**	**0.565**	**0.326**	0.067	0	0	0	0	0	0	
Orange	0	0	0	0	0	0.178	0.304	0.295	0.213	0.2	0.13	0.283	0.273	0.196	0.089	0.022	0.261	0.311	0.087	0	0	0	0	0	
Green	0.22	0.16	0.13	**0.822**	**1**	**0.6**	0	0.045	**0.532**	**0.733**	**0.783**	0.261	0.227	**0.435**	0	0.043	0.261	**0.622**	**0.891**	**1**	**1**	**1**	**1**	**0.733**	
No color	**0.78**	**0.84**	**0.87**	0.156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.267	
PM2.5_ave.	1.8	1.2	1.1	6.6	8.0	12.6	19.9	19.4	11.9	9.8	10.0	15.7	16.1	15.1	23.5	21.0	15.8	10.1	8.1	8.0	8.0	8.0	8.0	5.9	11.1
PM2.5_var.	222	223	224	182	161	66	−172	−152	84	129	125	−20	−35	−4	−327	−218	−25	122	160	161	161	161	161	191	103

Table 7: Probability of each color (Thursday)

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Average
Black	0	0	0	0	0	0.023	0.109	0.067	0	0	0.023	0.091	0.111	0	0.065	0.044	0	0	0	0	0	0	0	0	
Red	0	0	0	0	0	0.07	0.304	0.378	0.022	0.022	0.318	0.227	**0.467**	**0.478**	0.239	**0.467**	0.261	0.068	0	0	0	0	0	0	
Orange	0	0	0	0	0	0.14	0.13	0.133	0.065	0.196	0.205	0.205	0.356	0.391	**0.5**	0.222	**0.37**	0.295	0.152	0.044	0	0	0	0	
Green	0.41	0.22	**0.5**	**1**	**1**	**0.744**	**0.457**	**0.422**	**0.913**	**0.761**	**0.455**	**0.477**	0.067	0.13	0.196	0.267	**0.37**	**0.636**	**0.826**	**0.933**	**0.978**	**1**	**0.956**	**0.556**	
No color	**0.59**	**0.76**	0.48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.044	0.444	
PM2.5_ave.	3.3	1.7	4.0	8.0	8.0	9.7	14.7	15.8	8.6	8.8	14.6	13.4	18.4	17.9	14.3	17.5	13.9	10.1	8.3	7.9	7.8	8.0	7.6	4.4	10.3
PM2.5_var.	214	222	209	161	161	131	8	−25	151	147	11	45	−114	−96	20	−83	32	123	157	162	164	161	167	205	119

Table 8: Probability of each color (Friday)

Time	1	2	3	4	5	6	7	8	9	10	11	12
Black	0	0	0	0	0	0	0.044	0.133	0.022	0	0	0
Red	0	0	0	0	0	0.089	0.422	0.089	0.13	0	0.023	**0.4**
Orange	0	0	0	0	0	0.222	0.178	0.022	0.13	0.244	0.273	**0.4**
Green	0.07	0	0.17	**0.889**	**1**	**0.689**	**0.333**	**0.489**	**0.457**	**0.689**	**0.705**	0.2
No color	**0.93**	**1**	**0.83**	0.111	0	0	0	0	0	0	0	0
PM2.5_ave.	0.5	0.0	1.4	7.1	8.0	10.3	16.4	8.5	8.8	8.2	9.2	16.5
PM2.5_var.	225	225	223	174	161	119	−44	153	147	158	140	−48

Time	13	14	15	16	17	18	19	20	21	22	23	24	Average
Black	0.087	0.022	0.043	0.068	0	0	0	0	0	0	0	0	
Red	**0.478**	0.348	**0.674**	**0.545**	0.286	0.086	0	0	0	0	0	0	
Orange	0.326	**0.457**	0.239	0.341	**0.571**	0.114	0	0	0	0	0	0	
Green	0.109	0.174	0.043	0.045	0.143	**0.8**	**1**	**0.971**	**0.971**	**1**	**1**	**1**	
No color	0	0	0	0	0	0	0	0	0	0	0	0	
PM2.5_ave.	18.3	15.9	21.4	19.5	14.9	9.9	8.0	7.8	7.8	8.0	8.0	8.0	10.1
PM2.5_var.	−112	−28	−232	−155	2	127	161	165	165	161	161	161	123

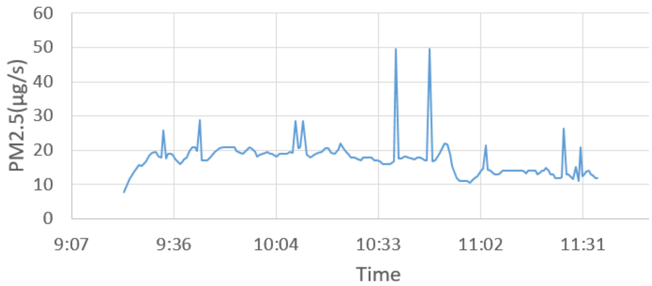
Table 9: Average and variance of PM2.5

Day of wee	PM2.5_ave.	PM2.5_var.
Sat.	8.75	307.84
Sun.	8.21	316.81
Mon.	10.41	251.07
Tue.	9.54	277.44
Wed.	10.08	255.75
Thu.	8.95	297.40
Fri.	8.82	291.80
all	9.27	291.22

3.2 Accuracy Verification

Graph 2 shows field survey data of from 9:07 to 11:31 on 3th October 2018. That day is Wednesday, we compared that data to average amount of PM2.5 of Wednesday for verification. Average of field survey data is 17.03(µg/ m^3). Average estimated value from 9:00 to 11:00 is 9.05(µg/ m^3). It is revealed that Google traffic has pattern and the traffic in weekdays have stronger regularity than that in weekends have. In this time, the estimated amount of PM2.5 is lower than the field survey data. It is considered that the background PM2.5 value and cause the gap.

Graph 2: Field survey data (PM2.5)



4. Conclusion

We tried to make the average PM2.5 emission from traffic processing Google traffic data. It is revealed that Google traffic has pattern and the traffic in weekdays have stronger regularity than that in weekends have. In this time, the estimated amount of PM2.5 is lower than the field survey data. It is considered that the background PM2.5 value and cause the gap.

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