INTEGRATION OF GNSS RECEIVERS WITH EXTERNAL ENVIRONMENTAL SENSORS FOR MOBILE AIR MONITORING APPLICATIONS (JAKARTA STUDY)

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Jakarta is the world’s most polluted city
(CNN, Augt 11 2023)

Air pollution has cost an estimated 11,000 deaths* in Jakarta in 2023, also cost approximately $2,800,000,000 USD (IQAir, Oct 13 2023)
• 22 million vehicle units per day (Greater Jakarta Metropolitan Regional Police, 2023)

• Jakarta’s traffic index at 29th out of 389 cities in the world in 2022 with average travel time for a 10-kilometre trip in Jakarta is 22 minutes 40 seconds (TomTom International BV, Feb 23 2023)
Rapid development of Jakarta causes massive traffic congestion problems. Jakarta was ranked 4th most world wide congested city in 2017, then ranked 4th in 2018, in 2019 Jakarta saw the worst congestion on Wednesday, March 6, with a congestion rate reaching 91 percent (TomTom Traffic Index, 2021). The problems occurred due to the domination of private vehicles increase, which is not followed by the development of sufficient infrastructures.

In 2019, Jakarta also spotlighted as the worst polluted city in the world (The Jakarta Post, 2019). Pandemic has reduced the air pollution intensity in Jakarta due restriction of urban mobility. However, recently, in June 2022, Indonesia ranked 17th among the most polluted in the world (worst in South East Asia) (Tempo, 2022). The carbon emissions of Jakarta is mainly contributed by the transportation sector.

<table>
<thead>
<tr>
<th>Types</th>
<th>Quantity (Units)</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars</td>
<td></td>
<td>2.827.399</td>
<td>3.082.616</td>
<td>3.310.426</td>
<td>3.365.467</td>
<td>4.111.231</td>
</tr>
<tr>
<td>Buses</td>
<td></td>
<td>31.593</td>
<td>33.419</td>
<td>34.905</td>
<td>35.266</td>
<td>34.467</td>
</tr>
<tr>
<td>Trucks</td>
<td></td>
<td>587.860</td>
<td>631.156</td>
<td>669.724</td>
<td>679.708</td>
<td>785.600</td>
</tr>
<tr>
<td>Motorcycles</td>
<td></td>
<td>14.137.126</td>
<td>15.037.359</td>
<td>15.868.191</td>
<td>16.141.380</td>
<td>16.519.197</td>
</tr>
</tbody>
</table>

Source: BPS, 2022

The Increase of Motorized Vehicles in Jakarta from 2017-2021

Estimation of CO2 Emissions from Road Transportation in Jakarta (Cottrell & Streitferdt, 1999)

Integrated and responsive study needed
What is the current air quality in Jakarta?

<table>
<thead>
<tr>
<th>Air pollution level</th>
<th>Air quality index</th>
<th>Main pollutant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unhealthy</td>
<td>171</td>
<td>PM2.5</td>
</tr>
</tbody>
</table>

Pollutants:
- **PM2.5**: 94.6 μg/m³
- **NO2**: 39.4 μg/m³
- **SO2**: 12.9 μg/m³

**PM2.5 concentration** in Jakarta is currently 18.9 times the WHO annual air quality guideline value.
What is the current air quality in Jakarta?

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<tr>
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<td>177</td>
<td>PM2.5</td>
</tr>
</tbody>
</table>

**PM2.5 concentration** in Jakarta is currently 21.3 times the WHO annual air quality guideline value.
Road to ASEAN SUMMIT 2023:
KOTA CERDAS ASEAN,
TINGKATKAN KUALITAS HIDUP

SELASA 08 AUG 2023
LIVE ON: FMB9ID_IKP

Tifanny Raytana
Host

Tifanny Raytama, Heru Budi Harsono, Lin Yola

KOTA CERDAS ASEAN, TINGKATKAN KUALITAS HIDUP
Pemprov DKI Gunakan Smart City untuk Perizinan dan Pengendalian Banjir
Jakarta's effort to increase participation in vehicle emissions test pt. 1

Jakarta orders civil servants to work from home to fight soaring pollution

By Heather Chen, CNN
3 minute read · Updated 3:08 AM EDT, Mon August 21, 2023

Jakarta Government Plans To Create Manmade Rain To Solve Air Pollution Problem

Jakarta is notorious for its unclean air, but becoming the city with the world's worst air pollution took it to the next level. Can man-made rain fix this?

By Utturn Rosasto

Indonesia shuts down factories, to spray mist to reduce air pollution

In the past few weeks, the government has been rushing to take action to address air pollution amid public outcry over worsening air quality in the region.

The Jakarta Post
In November 2020, TransJakarta won the 2021 Sustainable Transport Award.

the number of motorized vehicles in the capital city reached 23 million (Aug 2023). According to the DKI Jakarta Province Transportation Agency, the growth of motorized vehicles over the last five years is approximately 10% annually in average, with the growth in passenger car type vehicles per day around 240 vehicles, while for the type of motorcycle as much as 890 vehicles.
Non-Integrated System

Integrated System
This study covers the selected main routes of Jakarta as follow:

- Blok M - Jakarta Kota (Urban Center - Remote Area)
- Jakarta Kota - Blok M (Remote Area - Urban Center)
- Juanda - Kalideres (Urban Center - Remote Area)
- Kalideres - Juanda (Remote Area - Urban Center)

Scopes (Case Study Conducted to closely see the synchronization between GNSS receiver and CO2 sensor)

Scope of the research investigations as follow:

**Day**
Monday, Friday, Saturday

**Time**
Morning Trip and Noon Trip

**Social Mobility Restriction**
PPKM (Pemberlakuan Pembatasan Kegiatan Masyarakat) or Community Activities Restriction Enforcement

**Timeline**
- Timeline 1 (Mar & Apr 2021): PPKM Mikro
- Timeline 2 (Sep & Nov 2021): PPKM Level 1 and PPKM Level 3
- Timeline 3 (Mar 2022): PPKM Level 2 and PPKM Level 3
- Timeline 4 (Mar 2023): Post Pandemic

**Mode of Transportation (Vehicle Navigator)**
Private Car & BRT
Integrated SPP System

MH-Z19C Sensor → Electric Supply or Portable Battery (Min 2.1 A) → Raspberry Pi → Node-Red Software → CSV
  - Serial port
  - CO2
  - date, time, latitude, longitude, quality (SPP), speed, CO2

U-Blox GNSS Antenna → U-Blox F9P/M8T GNSS Receiver

Integrated RTK System

MH-Z19C Sensor → Electric Supply or Portable Battery (Min 2.1 A) → Raspberry Pi → Node-Red Software → CSV
  - Serial port
  - CO2
  - date, time, latitude, longitude, quality (RTK), speed, CO2

WiFi

U-Blox GNSS Antenna → U-Blox F9P GNSS Rover Receiver

Internet

Trimble GNSS Antenna → Trimble NetR8 GNSS Base Station Receiver
Node Red System Design,
collaboration with TUMSAT University
### Statistical Summary of Speed and CO\textsubscript{2} in NIS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>No. data of Plotting</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (km/h)</td>
<td>86051</td>
<td>15.63</td>
<td>0</td>
<td>68.83</td>
</tr>
<tr>
<td>CO\textsubscript{2} (ppm)</td>
<td>85495</td>
<td>494.16</td>
<td>365</td>
<td>1381</td>
</tr>
</tbody>
</table>

### Statistical Summary of Speed CO\textsubscript{2} Synchronization

<table>
<thead>
<tr>
<th>Parameter</th>
<th>No. data of Plotting</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (km/h)</td>
<td>74024</td>
<td>15.80</td>
<td>0</td>
<td>68.83</td>
</tr>
<tr>
<td>CO\textsubscript{2} (ppm)</td>
<td>74024</td>
<td>494.75</td>
<td>400</td>
<td>862</td>
</tr>
</tbody>
</table>

### Statistical Summary of Speed and CO\textsubscript{2} in IS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>No. data of Plotting</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
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</thead>
<tbody>
<tr>
<td>Speed (km/h)</td>
<td>87138</td>
<td>15.44</td>
<td>0</td>
<td>68.74</td>
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<tr>
<td>CO\textsubscript{2} (ppm)</td>
<td>87138</td>
<td>535.20</td>
<td>400</td>
<td>1188</td>
</tr>
</tbody>
</table>

### Speed NIS to Speed IS & CO\textsubscript{2} NIS to CO2 IS Synchronization

<table>
<thead>
<tr>
<th>Parameter</th>
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<th>Mean</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (km/h)</td>
<td>74464</td>
<td>15.85</td>
<td>0</td>
<td>68.83</td>
</tr>
<tr>
<td>CO\textsubscript{2} (ppm)</td>
<td>85782</td>
<td>493.70</td>
<td>400</td>
<td>862</td>
</tr>
</tbody>
</table>

### Integrated System (IS)

<table>
<thead>
<tr>
<th>Parameter</th>
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<th>Mean</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (km/h)</td>
<td>74464</td>
<td>15.87</td>
<td>0</td>
<td>68.74</td>
</tr>
<tr>
<td>CO\textsubscript{2} (ppm)</td>
<td>85782</td>
<td>534.78</td>
<td>400</td>
<td>1188</td>
</tr>
</tbody>
</table>
NIS vs IS - Vehicle Speed

NIS vs IS - CO2
NIS and IS Distribution of Pattern of Vehicle Speed Data
NIS and IS Distribution of Pattern of CO$_2$ Data
This study investigates the comparison between the NIS and IS by comparing the process of data extraction, data analysis and output.

The results show that the IS reliable to generate the valid csv data. Overall, the output csv data of NIS and IS are all acceptable.

However, the data processing (extraction and analysis) makes the big gap between the two systems. The manual time data synchronization takes long steps and process in NIS, while IS set for automatic input and output csv data. As NIS consist of two separate main technologies of GNSS receivers and CO2 sensor, it involves more feature and installation.

Therefore, IS is more effective, simple, less data processing time, and less data error or faulty. The main concerns in the processing are time synchronization and error removal technique.

However, the improvement of prototype development including study on the receiver accuracy etc is required for future stage.
Thank You

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attachment
Results.

Highlights of the Congested Area

Blok M - Jakarta Kota Route

Vehicle Speed (km/h)
- 0 - 4.99 (Heavy)
- 5 - 14.99 (Medium Heavy)
- 15 - 29.99 (Medium)
- 30 - 49.99 (Medium Light)
- 50 - 75 (Light)
Results. Highlights of the Congested Area

Juanda - Kalideres Route

Vehicle Speed (km/h)
- 0 - 4.99 (Heavy)
- 5 - 14.99 (Medium Heavy)
- 15 - 29.99 (Medium)
- 30 - 49.99 (Medium Light)
- 50 - 75 (Light)
Urban Traffic (Speed) vs Air Pollution (CO2)

Blok M - Jakarta Kota Round Trip Route

Vehicle Speed (km/h)
- 0 - 4.99 (Heavy)
- 5 - 14.99 (Medium Heavy)
- 15 - 29.99 (Medium)
- 30 - 49.99 (Medium Light)
- 50 - 75 (Light)
- >999 (Critical)

CO2 (ppm)
- 410 - 499 (Typical)
- 500 - 599 (Moderate)
- 600 - 799 (Unhealthy)
- 800 - 999 (High Risk)
- >999 (Critical)
Urban Traffic (Speed) vs Air Pollution (CO2)

Blok M - Jakarta Kota Route
Morning Trip

Vehicle Speed (km/h)
- 0 - 4,99 (Heavy)
- 5 - 14,99 (Medium Heavy)
- 15 - 29,99 (Medium)
- 30 - 49,99 (Medium Light)
- 50 - 75 (Light)

CO2 (ppm)
- 410 - 499 (Typical)
- 500 - 599 (Moderate)
- 600 - 799 (Unhealthy)
- 800 - 999 (High Risk)
- >999 (Critical)
Urban Traffic (Speed) vs Air Pollution (CO2)

Blok M - Jakarta Kota Route

Timeline 2
Timeline 3

Speed
CO2

Mon Fri Sat
Mon Fri Sat

Vehicle Speed (km/h)
- 0 - 4,99 (Heavy)
- 5 - 14,99 (Medium Heavy)
- 15 - 29,99 (Medium)
- 30 - 49,99 (Medium Light)
- 50 - 75 (Light)

CO2 (ppm)
- 410 - 499 (Typical)
- 500 - 599 (Moderate)
- 600 - 799 (Unhealthy)
- 800 - 999 (High Risk)
- >999 (Critical)
Urban Traffic (Speed) vs Air Pollution (CO2)

Juanda - Kalideres Round Trip Route

Vehicle Speed (km/h)
- 0 - 4,99 (Heavy)
- 5 - 14,99 (Medium Heavy)
- 15 - 29,99 (Medium)
- 30 - 49,99 (Medium Light)
- 50 - 75 (Light)

CO2 (ppm)
- 410 - 499 (Typical)
- 500 - 599 (Moderate)
- 600 - 799 (Unhealthy)
- 800 - 999 (High Risk)
- >999 (Critical)
Urban Traffic (Speed) vs Air Pollution (CO2)

Juanda - Kalideres Route

Noon Trip

<table>
<thead>
<tr>
<th>Vehicle Speed (km/h)</th>
<th>CO2 (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 4.99 (Heavy)</td>
<td>410 - 499 (Typical)</td>
</tr>
<tr>
<td>5 - 14.99 (Medium Heavy)</td>
<td>500 - 599 (Moderate)</td>
</tr>
<tr>
<td>15 - 29.99 (Medium)</td>
<td>600 - 799 (Unhealthy)</td>
</tr>
<tr>
<td>30 - 49.99 (Medium Light)</td>
<td>800 - 999 (High Risk)</td>
</tr>
<tr>
<td>50 - 75 (Light)</td>
<td>&gt;999 (Critical)</td>
</tr>
</tbody>
</table>

Timeline 2

Timeline 3

Speed

CO2

Speed

CO2
Graphic Pattern of Urban Traffic (Speed) vs Air Pollution (CO2)

Blok M - Jakarta Kota Round Trip Route

Morning Trip

- Mon
- Fri
- Sat

Noon Trip

- Mon
- Fri
- Sat

Timeline 2

Timeline 3
Graphic Pattern of Urban Traffic (Speed) vs Air Pollution (CO2)

Juanda - Kalideres Round Trip Route

**Morning Trip**

- **Monday**
- **Friday**
- **Saturday**

**Noon Trip**

- **Monday**
- **Friday**
- **Saturday**

**Timeline 2**

**Timeline 3**
Graphic Pattern of Urban Traffic (Speed) vs Air Pollution (CO2) (Sample Zoomed In)

Blok M - Jakarta Kota

Juanda - Kalideres

Noon Trip

Morning Trip
Statistical Regression Analysis of Urban Traffic and Air Pollution

In Conclusion:
1. The lower the vehicle speed, the higher the concentration of CO2.
2. The higher the vehicle speed, the lower the concentration of CO2.

In this context of data setting, every increase of 1 km/h vehicle speed reduces 0.179 ppm CO2.