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A Dashboard System for Monitoring Air Pollution in Surabaya based on PM2.5

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Abstract

In developing countries where population grows rapidly, air pollution has been a serious issue for the public health. Among various pollutants, fine particulate matters (PM2.5) is associated with distinct serious health problems, e.g., asthma, cancer, cardiovascular and respiratory diseases. To raise the awareness of the community and decision makers in order to solve the air-pollution problem, the level of the PM2.5 index should be monitored. In this paper, we propose a dashboard system for monitoring air pollution based on PM2.5. A portable device (i.e., Edimax Airbox) was installed inside the building of Stikom Surabaya college to measure the PM2.5 level. The sensors in this device read the PM2.5 level, air temperature, and humidity level, and then it transmits the data to the cloud service. The cloud platform makes the collected data accessible through an open data API that allows our system to interact with the data in the JSON format. The data then was parsed in a web server and visualized in a dashboard system. The dashboard system provides two indicators, the live PM2.5 sensor measurement and the measurement history. The dashboard successfully visualized the indicator of air pollution index, based on PM2.5 standards by WHO and *Dinas Kesehatan Indonesia* (the Indonesian Department of Health). Within seven days of the study, PM2.5 level reaches the maximum value of 65 $\mu\text{g}/\text{m}^3$ with the average value of 39.36 $\mu\text{g}/\text{m}^3$ on July 8, 2018. This is an alarming rate given that the indoor average level threshold of PM2.5 by WHO is 25 $\mu\text{g}/\text{m}^3$.

I. INTRODUCTION

PM2.5 (particle matters with less than 2.5 micrometers in diameter) is one of the most hazardous air pollutants that is related with various diseases such as asthma, pneumonia, chronic bronchitis, heart disease, and cancer. These particles cannot be filtered down by the hairs of the nose and throat. As a result, it can reach the end of the respiratory tract with airflow and accumulate there through diffusion, harming the other body parts in consequence of air exchange in the lungs [1]. These particles penetrate to the lungs and settle in the bloodstream-along with the pollutants such as benzene [2]. PM2.5 particles are mainly produced by motor vehicle fumes and combustion.

A study in Canada and the US discovered that long-term disclosure to PM2.5 inevitably increased not only the possibility of cardiopulmonary issues but also lung cancers. Another study conducted in the US from 2000 to 2007 proved that the average lifespan was increased by 0.35 years for every 10 $\mu\text{g}/\text{m}^3$ reduction of PM2.5 [3]. Therefore, reducing the level of PM2.5 pollutants is beneficial for our healthy lives.

The level of air pollution in Indonesian big cities has reached an alarming stage. In the first half of 2016, Jakarta's air pollution PM2.5 levels are already at 45 $\mu\text{g}/\text{m}^3$, higher than the threshold set by the World Health Organization.

* Corresponding author

A research in 2010 mentioned that 57.8% of Jakarta's disease is related to air pollution, based on data analysis from hospitals in Jakarta [4].

The danger of PM_{2.5} pollutant not only be exposed while people are being outside since it can be found in the indoor also. Researchers in Poland did an experiment in a secondary school, it showed that the concentrations of PM_{2.5} and PM₁₀ were greater inside than outside the school building during the winter, whereas PM₁₀ concentrations were greater inside during the summer only [5]. The data from this study is summarized in Table 1. Meanwhile, a study in Bekasi showed the risk of Acute Respiratory Infection (ARI) as a result of a high indoor average level of PM_{2.5}. The results showed that the average level of PM_{2.5} in toddlers' house had reached twice the quality standard (70 µg/m³). A high PM_{2.5} level was found in homes with fewer air ventilation, with a kitchen that merged with another room, and the condition of a busy road with motor vehicles [6].

TABLE I
SUMMARY OF INDOOR/OUTDOOR 24-H AND 8-H MEAN MASS CONCENTRATIONS OF PARTICULATE MATTER (IN µG/M³) [5]

PM fraction	Indoor				Outdoor			
	24-h mean	SD	8-h mean	SD	24-h mean	SD	8-h mean	SD
Winter								
PM ₁	21.2	5.3	24.3	5.2	25.5	7.8	30.4	10.0
PM _{2.5}	59.8	21.6	96.9	38.5	49.1	15.6	51.2	16.9
PM ₁₀	68.5	21.8	127	30.8	56.8	17.3	62.1	17.3
Summer								
PM ₁	8.5	3.6	8.9	2.2	8.9	3.4	7.3	2.6
PM _{2.5}	13.5	4.1	24.7	12.8	16.0	9.1	10.4	4.1
PM ₁₀	43.1	17.9	113	31.8	24.7	10.5	24.0	8.0

SD : Standard Deviation.

The World Health Organization (WHO) defines Air Quality Guidelines (AQGs) with the basis target level of PM_{2.5}. The short-term (24-h average) AQGs by WHO are 25 µg/m³ for PM_{2.5} and 50 µg/m³ for PM₁₀. Although PM₁₀ is the more widely reported measure, the WHO AQGs (Air Quality Guidelines) for PM are based on research that apply PM_{2.5} as an index. Based on recognized health impacts, both long-term (annual mean) and short-term (24-h mean) standards are used for PM pollution index. Hence, WHO established interim targets (IT) for PM_{2.5} (see Table 2). Countries should refer to these interim targets in the process of firmly decreasing population exposures to PM. If the guideline values for the 24-hour mean can be met, then peaks of pollution can be minimized. Countries with regions not fulfilling the 24-hour guideline values are suggested to take response as soon as possible to achieve these levels [7].

TABLE II
WHO AIR QUALITY GUIDELINES: 24-HOUR MEAN

	PM _{2.5}	PM ₁₀	Description of the selected level
Interim target - 1 (IT-1)	75	150	Resulting in around 5% addition of short-term mortality over the AQG value
Interim target - 2 (IT-2)	50	100	Resulting in around 2.5% addition of short-term mortality over the AQG value
Interim target - 3 (IT-3)	37.5	75	Resulting in around 1.2% addition of short-term mortality over the AQG value
Air quality guideline (AQG)	25	50	Based on connection between annual and 24-hour PM levels

Indonesia has defined guidelines regarding this matter. Based on the government rules (*Indonesian Government Regulation No. 41 of 1999 regarding Air Pollution Control*), the threshold of PM_{2.5} is 65 µg/m³ for 24-hours average, while the indoor average level threshold of PM_{2.5} is 35 µg/m³ (based on *Minister of Health regulations No. 1077 of 2011*). [8] However, there are not many Air Quality Monitoring (AQM) stations in Indonesia yet. Jakarta, the capital city of Indonesia, only has 5 Air Quality Monitoring Station run by the Provincial Government of Jakarta. [4] They are still using the technology standard of PM₁₀. This technology has been left behind because it should have used a reference PM_{2.5}. The AQM stations are also rare in the other areas. Based on the mapping from the Air Quality Index (AQI) website [9], there are only limited numbers of AQIs can be seen in Jakarta, Sumatra Island, and Kalimantan Island. Surabaya as the second largest city in Indonesia, however, does not have any Air Quality Index measurement as shown in Fig. 1.



Fig. 1 Mapping of Air Quality Monitoring stations in Indonesia [9]

This problem becomes crucial in big cities in developing countries, inhabited by lower-middle class people with motorized vehicles and the manufactory where these people work. As such, monitoring or measurement of the air-pollution level is important to raise the awareness of the community and decision makers in order to solve the air-pollution problem [10].

A study showed that reports regarding air pollution issues through various media such as newspaper, magazine, radio, or websites have progressively influenced people's alertness of urban air pollution and its negative health impact. The diversified communication form and the prevalence of the reported message can be the decisive factors affecting the public's awareness, approach and procedure of urban air pollution. [11]

Internet, social media and blogs are the media to promote such issues and will strengthen the understanding of the air pollution health-related risk (i.e., the media amplifier effect) [12]. Alternatively, informal communication or dialogue among the community also acts as a springboard to adjust people's perception about the air pollution issues. A study in China shows that there are respondents mentioning that they received health-related information about urban air pollution through conversation with their relatives, friends, or professionals. Findings from this study emphasize the urge for more continual education campaigns on air-pollution related health risks and protections in order to raise people's awareness along with to monitor and improve air quality [13].

Nowadays, low-cost sensors, mobile apps, and open data platforms can be utilized to support the campaign of air quality issues around the world. Low-cost IoT devices connected to the internet are common nowadays at a reasonable price, enabling the number of monitoring points to be expanded considerably [14]. As such, dashboard systems or visualizations have been implemented to raise people's awareness regarding air-pollution issues. A project was launched in Madrid that connected 24 government monitors and a website was built for visualization [15]. 'In the Air' is a visualization project with objective to raise awareness and decision making. The interpretation of the data can be utilized as a sophisticated selection of locations based on the air quality and also a base for political action [16].

In this study, a portable device (i.e., Edimax Airbox) is presented to measure the PM2.5 level. The device is installed inside the college building to measure indoor air pollution index (PM2.5 level). This device can be connected online to an online service that collects and stores sensor data in the cloud and provides open data. This paper presents the device and web service used to build the dashboard system for PM2.5 monitoring, explains the relation between the dashboard system and the cloud service for data visualization, analyzes the results, and lastly, conclusions are presented.

II. METHODS

This research was done in four steps, with the system architecture as shown in Fig.2. The Edimax Airbox device installed in Stikom Surabaya was connected through Wi-Fi network. The sensors in this device read the PM2.5 level, air temperature, and humidity level, and then it transmits the data to the cloud service. The cloud platform aggregates real-time data from the Edimax Airbox devices around the world, then the aggregate data are accessible through an open data API (Application Programming Interface) that allows our web server to interact with the data in the JSON format. The data then was parsed in a web server and visualized in a dashboard system.

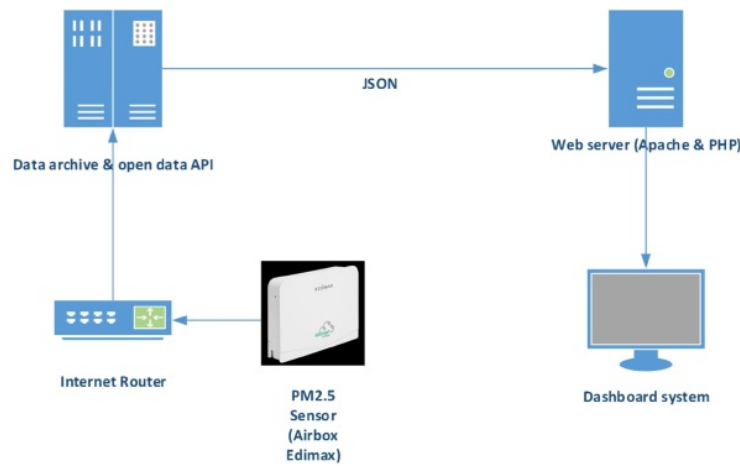


Fig. 2 System Architecture

A. Device installation

The device used for the sensor in this study is Edimax AirBox. It is equipped with an HTS221 sensor of temperature/humidity and the PMS5003 sensor of PM2.5 [17]. AirBox deployment will have some expected advantages such as 1) ensure the placement of PM2.5 monitoring devices around the city is distributed evenly to expand the coverage area; 2) maintain the quality of the measurement results as all the tools are built with identical components from the same source; and 3) provide dependable PM2.5 measurements to support constant air quality monitoring and further data analysis. For this research, the device was installed inside the building of Stikom Surabaya college and kept available for 24 hours and 7 days per week (see Fig.3). The device is connected to the internet using a Wi-Fi router.



Fig. 3 AirBox Edimax device installation

B. Data archive and open data API

A data archive service is provided that collect all records contributed by all AirBox devices. A web service that provides open data portal can be accessed at the LASS Community / Academia Sinica website [18]. In this site, various application programming interfaces (APIs) are implemented, and the real-time PM2.5 measurement outputs are distributed in JSON data format. This data archive helps to support a one-stop data service for all ongoing PM2.5 monitoring projects, thus facilitate innovation and application development.

C. Data Retrieval and Analysis

The data is filtered by the device ID that was identified by the GPS longitude and latitude. The device ID is '74DA38B05372' with GPS latitude -7.311 and GPS longitude 112.782. The JSON data is then collected from this API URL with the format \$URL\$/last.php&device id=X [18]. Each data collected from the JSON file was in an interval of between 30 to 60 minutes. During 7 days of observation, records would be collected that contain the

attribute like following: device_id, date, time, GPS coordinate ("gps_lat" and "gps_lon"), PM2.5 ("s_d0"), temperature ("s_t0"), and humidity ("s_h0") as shown in Fig. 4.

```
{
  "AirBox": [
    {
      "2018-07-04T03:38:43Z": {
        "gps_num": 9.0,
        "app": "AirBox",
        "s_d1": 55.0,
        "fmt_opt": "1",
        "s_d2": 32.0,
        "s_d0": 45.0,
        "gps_alt": 2.0,
        "s_h0": 62.0,
        "gps_fix": 1.0,
        "ver_app": "0.35.2",
        "gps_lat": -7.311,
        "s_t0": 29.25,
        "timestamp": "2018-07-04T03:38:43Z",
        "gps_lon": 112.782,
        "date": "2018-07-04",
        "tick": 1530675523.0,
        "device_id": "74DA38B05372",
        "s_1": 100.0,
        "s_0": 1.0,
        "s_3": 0.0,
        "s_2": 1.0,
        "ver_format": "3",
        "time": "03:38:43"
      }
    }
  ]
}
```

Fig. 4 The JSON data file

This study collected data in a week. After that, data were grouped by the day to calculate the average, minimum, and maximum value per day. This is to extract information using descriptive statistics.

D. Dashboard System

The real-time dashboard shows two indicators, the live PM2.5 sensor measurement and the 24 hours measurement history. The live sensor measurement displays the latest PM2.5 index collected by the sensor. In addition, a dial gauge is implemented to visualize the PM2.5 measurement outputs. The PM2.5 concentration level is determined by the colour that correlates to the cautionary messages issued by the Department of Health in Indonesia. Google Charts was implemented to visualize the data in a dashboard system. It utilizes JavaScript and HTML/SVG technology to provide cross-browser and cross-platform compatibility [19]. Google Charts provides a number of chart types to address the needs of data visualization. A line chart is one of the charts that used to plot the PM2.5 index in 24-hours.

III. RESULTS

After the device is installed and connected to the internet, it submits the data to the cloud service. A mapping visualization of all online Airbox Edimax devices can be seen at the Airbox Edimax Cloud website [20]. Fig. 5 below shows some devices in Indonesia were active. However, the number of the city that can be monitored was still very limited (only Jakarta and Surabaya). Airbox is based in Taiwan, thus the visualization here was based on Chinese Google Maps and the location name was also displayed in the Chinese language.



Fig. 5 Airbox Edimax data visualization

Each device point can be clicked to show the detailed information. Fig. 6 below show the device at Stikom Surabaya is active, thus showing the collected data (note that it is also in Chinese). Here we can see the data from our installed device in Stikom Surabaya on July 14, 2018 (11:19 a.m.). The PM2.5 level was recorded at $45 \mu\text{g}/\text{m}^3$ which is not considered good. In addition, the PM2.5 graph also showed that the PM2.5 level also reached above $50 \mu\text{g}/\text{m}^3$ between 3:00 a.m. and 7:00 a.m. We can also see the temperature level (28.25 C) and humidity level (60%) from the graph.

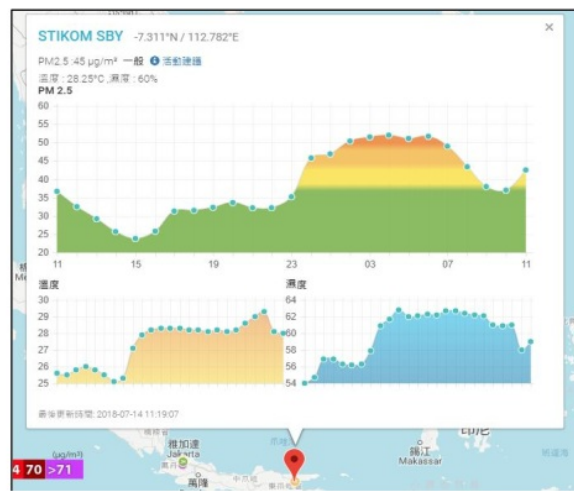


Fig. 6 Monitoring the data from Airbox Edimax device at Stikom Surabaya

The study collected data from seven days of observation. The data were grouped by the date and then summarized using descriptive statistics (minimum, maximum, and average value).

TABLE III
DESCRIPTIVE STATISTIC OF THE COLLECTED DATA

Date	Minimum of PM2.5	Maximum of PM2.5	Average of PM2.5
July 5, 2018	23	41	35.04
July 6, 2018	17	45	30.14
July 7, 2018	17	53	34.53
July 8, 2018	18	65	39.36
July 9, 2018	24	47	34.53
July 10, 2018	19	53	36.13
July 11, 2018	19	53	33.78
AVERAGE	19.57	51	34.74

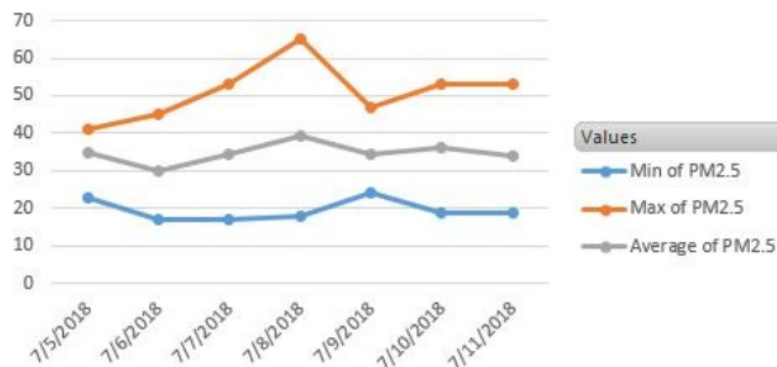


Fig. 7 The dashboard system for monitoring air pollution

During the seven days of the study, the minimum level of PM2.5 was 17 $\mu\text{g}/\text{m}^3$ (recorded on July 6 and July 7), while the highest level was 65 $\mu\text{g}/\text{m}^3$ (recorded on July 8). This shows the fluctuation of the PM2.5 level throughout

the day. This information is useful so that people aware whether the current air condition is good or not. However, the average of PM2.5 was considerably steady throughout the week. It was recorded around 30 to 39 with the mean of 34.74. According to the Indonesian government rules, the number has met the indoor standard (less than 35 $\mu\text{g}/\text{m}^3$). However, the WHO's standard for PM2.5 is 25 $\mu\text{g}/\text{m}^3$ so the air quality level in Surabaya is not considered good. The aggregation of the data during seven days of the study was plotted in Fig. 7 below.

One of the most substantial indicators in the air-pollution monitoring systems is PM2.5 concentration level. Generally, the PM2.5 concentration would be the main concern when there are no sources of large particles such as the dirt roads or sandstorms. The latest data of PM2.5 measurement was visualized in a gauge chart on the top left display, indicates the real-time PM2.5 level. This gauge chart was supported with the indicator information on the top right display, as shown in Fig. 8. The level of PM2.5 concentration is pointed out by the color that can be interpreted by the users based on the indicator information. For instance, the current level of PM2.5 as shown in Fig. 8 is 17 $\mu\text{g}/\text{m}^3$ thus it is considered good. If the PM2.5 goes higher, it will indicate a warning status that can be read in the top right panel of the dashboard.

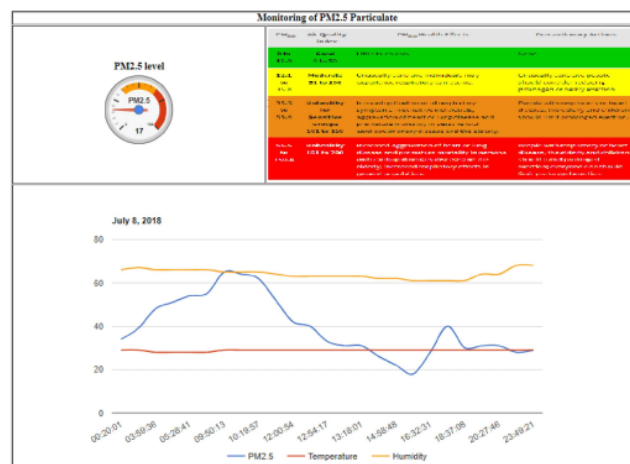


Fig. 8 The dashboard system for monitoring air pollution

In addition to the measurement of PM2.5, the temperature and humidity data are also collected. These data then plotted with line charts to shows the fluctuation throughout a day. Fig. 9 shows the measurement of PM2.5, temperature, and humidity in the last 24 hours. The chart helps the users to understand at what time the index increases or decreases.

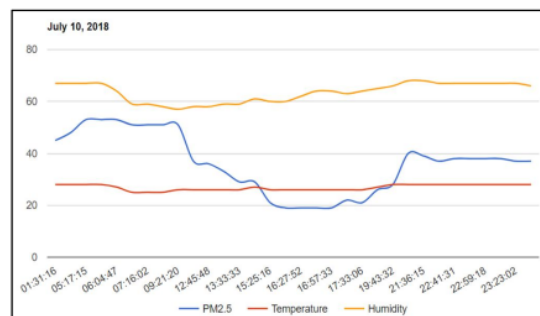


Fig. 9 24-hours chart of PM2.5, temperature, and humidity level

IV. DISCUSSION

The development of a dashboard system to monitor air-pollution level successfully visualized the indicator of air pollution index, based on PM2.5 standards by WHO and Indonesian Department of Health. Within seven days of the study, PM2.5 level reaches the maximum value of 65 $\mu\text{g}/\text{m}^3$ with the average value of 39.36 $\mu\text{g}/\text{m}^3$ on July 8, 2018. This is an alarming rate given that the indoor average level threshold of PM2.5 by WHO is 25 $\mu\text{g}/\text{m}^3$. Compared to the study in Poland (see table 1), this PM2.5 indoor average value is considerably higher (the 24-h mean value in Poland are 13.5 during summer and 59.8 during winter [5]. Meanwhile, the results agree with other study in Indonesia (Jakarta and Bekasi) showing that the PM2.5 level is already above the threshold set by the World Health Organization. [4][6]

This study aims to provide insight that can be obtained by analyzing the PM2.5 measurement data. Table 3 displays the maximum values of the measurements for seven days (July 5, 2018 – July 11, 2018). PM2.5 reaches the maximum value of 65 on July 8, 2018, with the average value of 39.36. It was a Sunday and it is a holiday, so there is no student's activity. For this reason, the maximum PM2.5 level could be higher due to inactivity of the air conditioner. An air conditioner is helpful to circulate the air and cool down room temperature. During the weekdays, the maximum value of PM2.5 was 53 and the average was around 34. This is still considered good as the 24-hour average value standard is below 35. However, an improvement is still necessary to achieve the AQG levels from WHO [7].

In the future, this project essentially needs to have a larger network and collect big data, hence, a statistical analysis of the data can report a lot of valuable information. Currently, the project has only used the PM2.5 index as an air-pollution measurement indicator. In the future, additional analysis relating the other measures can be done, and advance systems can be developed in order to support decision making. However, the focus of the study at this point is the design and implementation of the dashboard system for monitoring air-pollution based on PM2.5. The dashboard system can be displayed around the college area so that the academic community is able to monitor the air quality around them and raise the awareness about the dangers of air pollution.

V. CONCLUSIONS

A dashboard system for PM2.5 monitoring was designed and implemented. PM2.5 sensor using Airbox Edimax device was installed inside Stikom Surabaya college building. The device was connected to a Wi-Fi network to enable control operations, data acquisition, and data transfer to the cloud. An open data platform was used to collect and store the air quality measurement data in the cloud. After that, the data with JSON format were collected successfully within seven days of the study. Based on this data, a dashboard system was developed to monitor the air-pollution level. This dashboard aims to be presented to the users in Stikom Surabaya so that they can monitor the air quality in the college building. From the visualization in the dashboard system, the PM2.5 level fluctuates throughout a day and at some time is considered not healthy. This information is important to raise the awareness about the air pollution and public health issues. Based on the information from this dashboard, people can take appropriate actions related to air pollution (e.g., using an air filter mask when going outside) so that diseases caused by air pollution can be avoided. Right now, we are working in the development of a new air-pollution monitoring system and evaluating the impact on the users. The future work of this study is to provide a questionnaire survey asking whether this tool actually enhances awareness.

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Front Cover Information

Shinkansen (新幹線) is a high-speed railway lines in Japan, running all the way from Shin-Hakodate (Hokkaido island) to Kagoshima (Kyushu island). Shinkansen is well-known for its safety and punctuality. Japan Rail Central reported the average delay from schedule per train in 24 seconds (2016).

In picture: Yamabiko, Hayabusa, and Komachi trains park in Sendai station, Miyagi prefecture, Japan, February 2018.

Photo credit: Ira Puspitasari

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