# Potential of FUDIKA (Train Dynamic Testing Facility) for Rolling Stock Testing in Indonesia

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**Abstract.** According to Ministerial Regulation No. 24 of 2015, Law No. 23 of 2007, and Government Regulation No. 56 of 2009, the government as the regulator is obligated to ensure that the operation of rolling stock is in accordance with the regulatory standards and can be operated safely as demonstrated by testing and certification of the rolling stock. The standards for rolling stock testing consist of design, static and dynamic tests referring to Ministerial of Transportation Regulation No. 13 of 2011, No. 14 of 2011, No. 15 of 2011, No. 16 No. 2011, and No. 17 of 2011. There are 11,752 units of rolling stock operating in Indonesia and there is a high risk of safety measures in the dynamic testing, so the FUDIKA (Train Dynamic Test Facility) as a rolling stock testing technology is required. However, FUDIKA was not used in the test yet. The results of the study show that the use of 1 unit FUDIKA only serves 3,840 units of rolling stock, so there is a backlog for rolling stock testing in Indonesia. In addition, not all railway networks are connected in Sumatra. It becomes the obstacle to the mobilization aspect of FUDIKA. Therefore, 5 units FUDIKA are proposed to be placed in Pulubrayan (Divre I), Padang (Divre II), Payakabung (Divre III and Divre IV), Depok (Daop 1, Daop 2, Daop 3, Daop 5), and Ngrombo (Daop 4, Daop 6, Daop 7, Daop 8, and Daop 9) to accommodate the rolling stock testing in Java and Sumatra.

**Keywords:** FUDIKA · rolling stock · testing

## 1 Introduction

The railway is a system that consists of infrastructure, rolling stock, and human resources, as well as norms, criteria, requirements, and procedures for the operation of rail transportation. The operation of the railway is divided into the operation of railway infrastructure and the operation of the rolling stock. The operator of the railway infrastructure is assigned to the Badan Usaha Penyelenggara Prasarana to carry out the operation of the railway infrastructure, whereas the rolling stock operator is a business entity that carries out activities for the procurement, operation, maintenance, and management of rolling stocks. Rolling stock is a wheeled vehicles that can move on railroads.


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Ministerial Regulation No. 24 of 2015 concerning Railway Safety Standards mandates that every rolling stock must be operated safely and according to its technical lifespan. The government, as the regulator, is obliged to ensure that the rolling stock operated meets the regulatory standards and is safe. To ensure the operated rolling stock is only the rolling stock that meets regulatory standards, the government has to conduct testing and certification of each rolling stock. By testing and certifying rolling stock, railway safety can be improved. It is in accordance with Law No. 23 of 2007 concerning Railways and Government Regulation No. 56 of 2009 concerning the Operation of Railways and also strengthens the regulating aspect of government in railway operation.

Every operated rolling stock worldwide must comply with the regulatory standards proven by rolling stock testing. For example, in Europe, any new or modified rolling stock must pass a verification process before being allowed to enter regular service in the EU railway network (Genovese, et al., 2019) and the mission of the Siemens Wegberg-Wildenrath test center in Germany is to deliver railway vehicles which are well tested and certified (Sörensson and Öberg, 2012). Rolling stock tests are performed to examine its conditions and functions to comply with technical requirements and specifications, after that the rolling stock certification can be conducted. These activities are regulated according to each type of rolling stock. In Indonesia, there are some regulations regarding certification of rolling stock. Ministerial Regulation No. 13 of 2011 concerning the standards, test procedures, and certification of rolling stock with an engine or electric motor. Ministerial Regulation No. 14 of 2011 concerning the standards, test procedures, and certification of the locomotive. Ministerial Regulation 15 of 2011 concerning the standards, test procedures, and certification of passenger cars. Ministerial Regulation No. 16 of 2011 concerning the standards, test procedures, and certification of railway equipment. Ministerial Regulation No. 17 of 2011 concerning the standards, testing procedures, and certification of freight cars.

According to the 2021 Railway in Numbers, Indonesia has 11,752 units of rolling stock. Rolling stock testing consists of design and engineering testing, static testing, and dynamic testing. Dynamic tests of rolling stock are high-risk tests, especially for cars or freight cars. Personnel who conducted dynamic testing of rolling stock have to move from each freight car to another while the train is running. In this situation, personnel are at high risk of falling over the freight car, falling on the railroad, or being run over by a train. Implementing railway technology and reducing the risk of testing railway facilities, Directorate General of Railways via Directorate of Railway Facilities has a modern equipment for rolling stock dynamic test called FUDIKA. Therefore, this study aimed to optimize the potential of FUDIKA for the rolling stock test in Indonesia by taking into account the productivity and the number of facilities that need to be tested.

## 2 Literature Study

### 2.1 Rolling Stock Testing

Rolling stock testing in Indonesia is regulated in the Ministerial Regulation of the Ministerial of Transportation No. 13 of 2011, Ministerial Regulation No. 14 of 2011, Ministerial Regulation No. 15 of 2011, Ministerial Regulation No. 16 of 2011, and Ministerial Regulation No. 17 of 2011. The items of rolling stock testing are shown in Table 1.

**Table 1.** Rolling stock design, static, and dynamic testing (Kementerian Perhubungan, 2011)

| **Ministerial Regulation No. 13, 14, and 17 of 2011** Rolling stock with engine/electric motor, locomotive, and railway equipment | **Ministerial Regulation No. 17 of 2011** Freight car | **Ministerial Regulation No. 15 of 2011** Passenger car |
|---|---|---|
| **A. Rolling Stock Design Testing** | | |
| • strength test<br>• endurance test<br>• crash/destructive test | • strength test<br>• endurance test<br>• crash/destructive test | • strength test<br>• endurance test<br>• crash/destructive test |
| **B. Rolling Stock Static Testing** | | |
| • dimension test<br>• clearance space test<br>• weight test<br>• brake test<br>• crack test<br>• loading test<br>• air circulation test<br>• temperature test<br>• electrical test<br>• noise test<br>• light intensity test<br>• exhaust emission test<br>• horn test<br>• communication equipment test<br>• leaking test | • dimension test<br>• clearance space test<br>• weight test<br>• brake test<br>• crack test<br>• loading test<br>• air circulation test<br>• temperature test | • dimension test<br>• clearance space test<br>• weight test<br>• brake test<br>• crack test<br>• loading test<br>• air circulation test<br>• temperature test<br>• noise test<br>• light intensity test<br>• leaking test |
| **C. Rolling Stock Dynamic Testing** | | |
| • braking test<br>• temperature test<br>• vibration test<br>• loading and pulling test<br>• accelerating test<br>• air circulation test<br>• electrical test<br>• noise test | • braking test<br>• temperature test<br>• vibration test<br>• loading and pulling test<br>• accelerating test<br>• air circulation test | • braking test<br>• temperature test<br>• vibration test<br>• loading and pulling test<br>• accelerating test<br>• air circulation test<br>• electrical test<br>• noise test |

The rolling stock testing in Indonesia is always held in regular track, with the exception of the crash/destructive test, which uses computer simulation. There was a plan to use a test center for rolling stock testing, but the problems were the difference in the railroad gauge (1,067 mm and 1,435 mm) and mobilization of the rolling stock to the test center. Meanwhile, in Japan, Mitsubishi Heavy Industries (2016) explain that they have completed the 3.2 km long railway test loop track and it provides dual gauge turnout

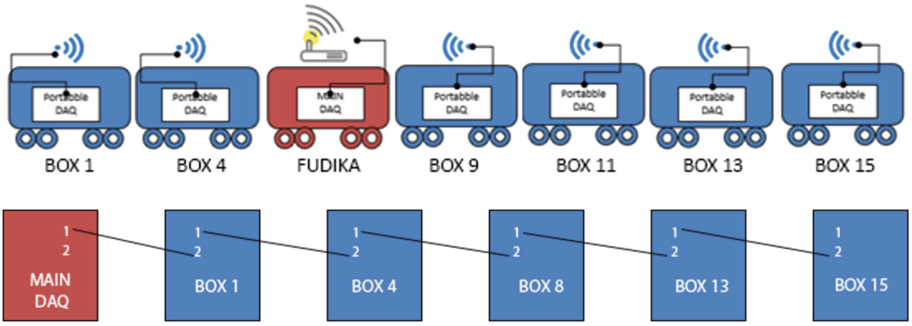


**Fig. 1.** FUDIKA's sending and receiving data system.

so that rolling stock in standard-gauge and narrow-gauge can be tested there, so that applications for use by external organizations have increased and the operating ratio has been enhanced. In addition, considering the compatibility test of the rail transit system such as large railways and urban rail transit, Yiping (2018) also mention that developing an internal loop test line, outer loop test line, and high-speed test line can complete any different test projects and test objectives.

Myamlin, et al. (2017) explain that track tests play an important role in the approval of new rolling stock, but they cost a lot of money and time, which also difficult to organize. Moreover, the track tests would never be suitable for initial experiments with all-new concepts of new rolling stocks because in that case, it is not easy to fulfill all the safety requirements. Nowadays, the role of the testing is often being replaced by computer simulations, one of them is a laboratory simulation using roller rigs. Roller rigs can be used for various purposes, such as tracking railway vehicle dynamics, wheel-rail contact investigation, verification and validation of simulation models, and other utilization.

### 2.2 Technology Application in Dynamic Testing of Rolling Stock in Indonesia

According to PT Tugu Sena Sinergi, FUDIKA is a rolling stock used for dynamic testing of rolling stock on rail facilities, including locomotive, rolling stock with engine/electric motor, freight car, and passenger car. The function of FUDIKA is as a monitoring and data acquisition center in the rolling stock dynamic testing system to determine rolling stock condition from the aspect of safety and comfort. Items that can be tested by FUDIKA are ride index, bearing temperature, acceleration, speed, deceleration, braking distance, air pressure, and strain gauge (Fig. 1).

The advantage of using FUDIKA for rolling stok testing in Indonesia are FUDIKA provides lower risk for dynamic testing especially for freight car testing, the results of the test will be recapped, and it is a national pride, even some of the parts are needed to be imported from foreign country. However, it's price is not cheap, so it must be well-operated and well-used.

The first step to test rolling stock with FUDIKA is to place the sensors on each rolling stock on train stamformation. FUDIKA placed in the middle of train stamformation. The coverage of FUDIKA can reach 15 sensors so that 15 rolling stocks can be tested every rolling stock dynamic testing. Then the sensors send wireless data to the main system

located inside the FUDIKA, then the data is processed and displayed in the monitoring system. Data transmission from the sensor box can also be done using an Ethernet cable in case of connectivity problem due to dense signal location.

FUDIKA has a lot of sensors for rolling stock dynamic testing. Each sensor has different function and purpose. For checking the vibration that occurs in the rolling stock FUDIKA uses the accelerometer that capturing the horizontal and vertical movement or ride index of the rolling stock. For checking the boogie and train suspension, FUDIKA using the strain gauge that installed in the boogie. FUDIKA also has temperature sensor so every train ambient temperature can be tested. For brake testing, FUDIKA uses the pipe and cylinder located under its cars and has barometer connected to the control unit.

## 3 Methodology

### 3.1 Research Data

The collection of research data was carried out using the following methods (Table 2).

1. Interview with the Railway Testing Center/Balai Pengujian Perkeretaapian.
2. Interview with the Railway Maintenance Center/Balai Perawatan Perkeretaapian.
3. Data collection of rolling stock in Indonesia.
4. Regulatory review.

### 3.2 Analysis

The analysis is carried out by taking into account the productivity of FUDIKA compared to the number of rolling stock in Indonesia. FUDIKA's annual productivity is calculated by considering the following aspects.

1. Operating days per year
   The number of days per year without FUDIKA's periodic maintenance.
2. Days off per year
   The number of days off from work (include Saturday and Sunday) as well as FUDIKA's mobilization and demobilization to the test location.
3. Operating working days per year
   The operating days per year minus days off per year.
4. Number of rolling stocks testing per day.
   After obtaining FUDIKA's annual productivity, a comparison is made with the number of rolling stock that must be tested. If FUDIKA's annual productivity is less than the number of the rolling stock that must be tested, then a recommendation for optimizing the number and placement of FUDIKA should be carried out to overcome the backlog of the testing.

**Table 2.** Rolling stock data in Indonesia (Ministry of Transportation, 2021)

| No | Description | Unit | Java | Sumatera | Sulawesi |
|---|---|---|---|---|---|
| **A** | **Locomotive** | | | | |
| 1 | Diesel Locomotive | units | 233 | 262 | |
| **B** | **Pasenger car** | | | | |
| 1 | Passenger car with an engine or electric motor | units | 1.452 | 38 | |
| 2 | Passenger car pulled by locomotive | units | 1.591 | 173 | |
| **C** | **Wagon/Freight car** | units | 2.067 | 5.712 | |
| **D** | **Railway Equipment** | | | | |
| 1 | Railway equipment with an engine or electric motor | units | 113 | 49 | 8 |
| 2 | Railway equipment pulled by locomotive | units | 37 | 27 | |
| **Total Rolling Stock in Each Region** | | units | **5.493** | **6.261** | **8** |
| **Total Rolling Stock in Indonesia** | | units | **11.762** | | |
| **Total Rolling Stock in Java & Sumatera (Exclude Aceh)** | | units | **11.752** | | |

## 4 Results and Discussion

### 4.1 Potential Productivity of the FUDIKA

The use of modern technologies and equipment in rolling stock testing, especially in dynamic testing, makes it easier to implement rolling stock testing. Dynamic test equipment using FUDIKA, in addition to improving the safety of train operations through more accurate test result data, will also maintain the safety of the test officers in dynamic testing, especially in freight car testing. However, FUDIKA also has gaps and limits, in addition to high procurement costs, FUDIKA also requires maintenance and mobilization. Times needed for rolling stock dynamic testing is showed in the Table 3.

With 210 min or 3.5 h to testing for one stamformation or one locomotive and eleven cars or trains, there are 24 cars or trains tested in one day or eight hours. Taking into account working days, maintenance, and mobilization, the rolling stock testing using FUDIKA has limitations, which are only 3,840 units of rolling stock that can be tested as shown in Table 4. Due to FUDIKA implementation and mobilization, testing with the current unit can only be carried out on Java, yet it still has backlog of testing.

**Table 3.** The times needed for a rolling stock stamformation testing with FUDIKA

| No | Activity | Time | Unit |
|---|---|---|---|
| **A** | **Preparation** | | |
| 1 | Shunting & coupling rolling stock with FUDIKA | 20 | minutes |
| 2 | Installing the equipment/sensors | 15 | minutes |
| 3 | Turning on the equipment | 10 | minutes |
| 4 | Checking all the sensors connection | 15 | minutes |
| **B** | **Testing** | | |
| 1 | Brake test | 20 | minutes |
| 2 | Temperature test | 10 | minutes |
| 3 | Vibration test | 10 | minutes |
| 4 | Loading test | 20 | minutes |
| 5 | Acceleration test | 20 | minutes |
| 6 | Air flow test | 10 | minutes |
| 7 | Electrical test | 10 | minutes |
| 8 | Noise test | 10 | minutes |
| **C** | **Finalization** | | |
| 1 | Shutting down equipment | 5 | minutes |
| 2 | Taking off the equipment/sensors | 15 | minutes |
| 3 | Shunting & decoupling rolling stock with FUDIKA | 20 | minutes |
| **D** | **Total Time** | 210 | minutes |

**Table 4.** The number of testable rolling stocks

| No | Description | Unit | Volume |
|---|---|---|---|
| **A** | **Data and Assumption** | | |
| 1 | Operating days per year | days/year | 304 |
| 2 | Days off | days/year | 144 |
| 3 | Operating working days per year | days/year | 160 |
| 4 | Assumed number of rolling stocks testing per day | units/day | 24 |
| **B** | **Number of Rolling Stocks in 2nd Semester of 2021** | | |
| 1 | Rolling stock in Java | units | 5,493 |
| 2 | Rolling stock in Sumatera | units | 6,261 |
| **C** | **Number of Testable Rolling Stocks per Year** | | |
| 1 | 1 unit of FUDIKA | units/year | 3,840 |
| **D** | **Backlog of Testing** | | |
| 1 | 1 unit of FUDIKA (all area) | units/year | 7,914 |
| 2 | 1 unit of FUDIKA (only in Java) | units/year | 1,653 |

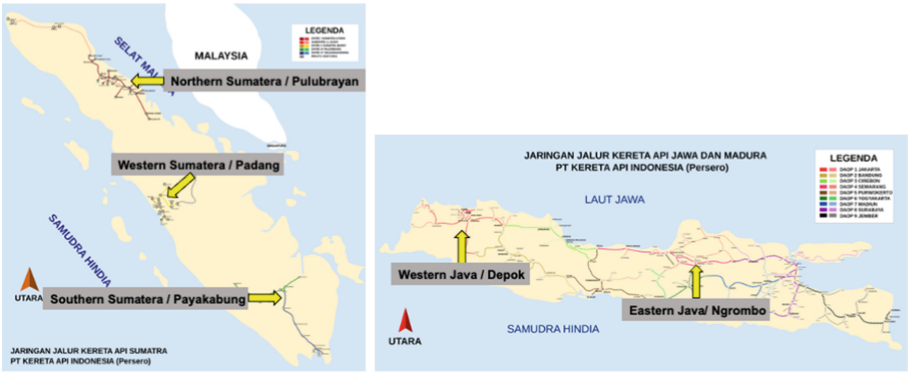


**Fig. 2.** Railroad maps in Java and Sumatera and placements of 5 units of FUDIKA

### 4.2 Optimization of the FUDIKA

In ideal conditions, rolling stock testing needs 5 units of FUDIKA which are placed on an unconnected railroad, as well as areas that have a lot of rolling stock as shown in Fig. 2.

By using 5 units of FUDIKA, there is no need for intermodal mobilization of FUDIKA that requires time, effort, and cost. In addition, if there is any damaged unit, there are still other units available that can be used. Meanwhile, the drawbacks of providing these 5 units of FUDIKA are the need for a higher cost for procurement, maintenance, operation, and calibration.

The placement of the 5 units of FUDIKA is in the locations which are assets of the Directorate General of Railways, Ministry of Transportation, as follows:

1. Pulubrayan Train Depot
   FUDIKA is placed at the Pulubrayan Train Depot to serve the testing of all rolling stocks that are operated and have a railroad that is connected to the Pulubrayan Train Deport in the northern part of Sumatera (Divre I Sumatera Utara).
2. Padang
   FUDIKA is placed in the Padang area to serve the testing of all rolling stocks that are operated and have a rail roadthat is connected to the Padang area in the western part of Sumatera (Divre II Sumatera Barat).
3. Payakabung Infrastructure Warehouse
   FUDIKA is placed at the Payakabung Infrastructure Warehouse to serve the testing of all rolling stocks that are operated and have a railroad that is connected in the southern part of Sumatera (Divre III Palembang and Divre IV Tanjungkarang).
4. Depok Commuter Line Depot
   FUDIKA is placed at the Depok Commuter Line Depot to serve the testing of all rolling stocks that are operated and have a railroad that is connected in the western part of Java (Daop 1 Jakarta, Daop 2 Bandung, Daop 3 Cirebon, and Daop 5 Purwokerto).
5. Ngrombo Workshop
   FUDIKA is placed at the Ngrombo Workshop to serve the testing of all rolling stocks that are operated and have a railroad that is connected in the eastern part of

**Table 5.** The number of testable rolling stocks with 5 units of FUDIKA (2 of them are in Java)

| No | Description | Unit | Volume |
|---|---|---|---|
| **A** | **Data and Assumption** | | |
| 1 | Operating days per year | days/year | 304 |
| 2 | Days off | days/year | 144 |
| 3 | Operating working days per year | days/year | 160 |
| 4 | Assumed number of rolling stocks testing per day | units/day | 24 |
| **B** | **Number of Rolling Stocks in 2nd Semester of 2021** | | |
| 1 | Rolling stocks in Java | units | 5,493 |
| 2 | Rolling stocks in Sumatera | units | 6,261 |
| **C** | **Number of Testable Rolling Stocks per Year** | | |
| 1 | 2 units of FUDIKA in Java | units/year | 7,680 |
| 2 | 5 units of FUDIKA in all area | units/year | 19,200 |
| **D** | **Backlog of Testing** | | |
| 1 | 2 units of FUDIKA in Java | units/year | - |
| 2 | 5 units of FUDIKA in all area | units/year | - |

Java (Daop 4 Semarang, Daop 6 Yogyakarta, Daop 7 Madiun, Daop 8 Surabaya, and Daop 9 Jember).

Taking into account working days, maintenance, and mobilization, rolling stock testing using optimization scenario with 5 units of FUDIKA can serves almost all of rolling stock in Indonesia and there is no backlog in Java and Sumatera as shown in Table 5.

In the meantime, there are still several areas that cannot be served by 5 units of the current FUDIKA model (1,067 mm gauge) due to the unconnected rail road and different railway systems, as follows:

1. Aceh, because it uses different infrastructure (1,435 mm gauge), only a few rolling stocks there, and still under construction,
2. Palembang Light Rail Transit, because there are only a few rolling stocks there,
3. Jakarta Light Rail Transit, because it uses different infrastructure (1,435 mm gauge), only a few rolling stocks there, and is still under construction,
4. Jabodebek Light Rail Transit, because it uses different infrastructure (1,435 mm gauge) and is still under construction,
5. Jakarta Mass Rapid Transit, because there are only a few rolling stocks there and is still under construction,
6. Soekarno-Hatta International Airport Skytrain, because it uses different infrastructure and only a few rolling stocks there,
7. Jakarta – Bandung High-Speed Rail, because it uses different infrastructure (1,435 mm gauge) and is still under construction,
8. South Sulawesi, because it uses a different infrastructure (1,435 mm gauge), only has a few rolling stocks there, and is still under construction.

Another thing that needs to be considered in improving testing facilities and infrastructure in order to optimize the implementation of the test is the provision of a storage building for testing facilities and infrastructures that contain all of the equipment in order to support the independence of rolling stock testing.

## 5 Conclusion and Recommendation

### 5.1 Conclusion

Based on the study, there are the following conclusions:

1. The potential productivity of 1 unit of FUDIKA can only carry out testing of 3,840 rolling stocks annually, so there is a backlog of 1,653 rolling stocks only for Java,
2. The procurement of 5 units of FUDIKA can carry out testing of 19,200 rolling stocks annually so that there will be no backlog of rolling stocks testing. In addition, testing with FUDIKA will be carried out not only in Java,
3. With the procurement of 5 units of FUDIKA, it is expected to be able to test the entire rolling stocks entire of the rail network in Indonesia. As a result, it is necessary to place FUDIKA for each rail network, including Pulubrayan for testing in the northern part of Sumatera (Divre I), Padang for testing in the western part of Sumatera (Divre II), Payakabung for testing in the southern part of Sumatera (Divre III and IV), Depok for testing in the western part of Java (Daop 1, Daop 2, Daop 3, and Daop 5), and Ngrombo for testing in the eastern part of Java (Daop 4, Daop 6, Daop 7, Daop 8, and Daop 9).

### 5.2 Recommendation

There are several recommendations for further research as follows:

1. It is necessary to conduct further studies related to the tariff aspect of rolling stock testing using conventional method and modern method (FUDIKA),
2. It is necessary to calculate the time used in the reality of using FUDIKA for rolling stock dynamic testing,
3. It is necessary to conduct further studies related to income from rolling stock testing in order to calculate the financial feasibility of the FUDIKA.

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