Pre-study of the application of weigh-in-motion technology to enforcement of regulations on heavy-duty vehicles in Indonesia

B N Priambudi¹, M I Hadi¹ and N M Ariani¹
¹Diponegoro University, Vocational School, Department of Civil and Planning, Semarang, Indonesia

Abstract. Overloading and over dimension are common problems in transportation of distribution. In Indonesia, the distribution of goods is carried out mostly by road; until today, goods transports often exceed load limits. The government established the regulations for the Motorized Vehicle Weighing Unit (UPPKB) to fix this problem. Towards the era of the 4.0 industry, the Indonesian government attempted to apply weigh-in-motion technology in UPPKB. This paper aims to provide an initial overview of the application of weigh-in-motion technology to support load limit regulation in Indonesia. The sample for research location in UPPKB Balai Raja in Riau, which is currently undergoing a revitalization and trial implementation of weigh-in-motion technology. The research will discuss the suitability of physical-nonphysical characteristics and goods transport characteristics, as well as challenges and problems in applying weigh-in-motion technology, so that it is in accordance with the characteristics of the regions in Indonesia.

1. Introduction

1.1. Background

The movement of product transport plays a vital role in supporting the economic process of the world [1]. Road conditions will affect the rate of the economic process of the world [2]. Safe road is obligatory as harm can impede the traffic [3]. Damaged roads hinder the distribution flow of products and services, as well as private transportation. Besides, it can even cause the rise of operational cost due to the damage sustained caused by the load of the vehicles and the bumpy roads [4]. In recent years, the movement of product transport within the national road network in provinces of southern Sumatra is increasing, resulting in a lot of interest. A persistent problem is the overloaded vehicles. In line with Government Regulation [5] and [6] issued by Ministry of Transportation, UPPKB is the solution to this problem. UPPKB plays an essential role in overloaded goods transport. To support the operational system of UPPKB, the government issued the most recent regulation [7]. It explains that if a vehicle was overloaded over the limit by 5%, it should be considered as weight because of the limited duty. UPPKB may present the most straightforward and acceptable service of the standards of such service [8].

The majority of UPPKBs in Indonesia use the concept of static measurement: the entire vehicle loads once the vehicle is directly on top of the detector. As a result, measuring takes time and it
typically causes a queue of vehicles. This kind of UPPKB is thought to be less economical nowadays [9]. The problem is then answered by the Ministry of Transportation in 2019 with the implementation of a brand new system called weigh-in-motion method. This method works with devices, lifting the load of the vehicle once moving. On a paved surface, sensors detect vehicles moving and send data to a computer. The computer then shows the calculable results of the calculation of the entire weight of the passing vehicle [10].

This method is considered simpler, efficient, and safer, which in turn makes it well-liked. Besides, the method makes it easier to understand better for future transportation designing [11]. The research was conducted in 2018, focused on testing the implementation of WIM in Jakarta—Merak Toll Road in collaboration of the Directorate General of Highways and Jasa Marga [12]. In 2017, the Road and Bridge Study Center, the Directorate General of Highways, has tried to implement the WIM Bridge on the north coast network (Pantura) in Central Java. It is precisely located in Pawiro Baru B Bridge, Weleri, which is on the border of Kab. Batang—Weleri (009), KM SMG + 48.03. With the reason in mind, authors attempt to study of the application of Weigh-In-Motion, particularly in UPPKB in Indonesia. The aim of this study is to review at the quality Weigh-In-Motion system applied in UPPKB Indonesia. This analysis was conducted at one location, UPPKB in Riau. As a result, in 2020, this UPPKB can begin implementing the Weigh-In-Motion system.

2. Method

2.1. Motor Vehicle Weighing Unit (UPPKB)

Motor Vehicle Weighing Unit (UPPKB) is a unit under the Ministry of Transportation of the Republic Indonesia, the task of which is supervising and enforcing regulations on goods transports that exceeds the load limit [6]. UPPKB is a policy minimize road damage due to goods transport exceeding limits [13]. There are two types of UPPKB classified based on the number of vehicles weighted as follows:

- Type I, an UPPKB located on roads with the number of goods transport being ≤ 2000 vehicles per day, requiring one weigh device.
- Type I, an UPPKB located on road with the number of goods transport being ≥ 2000 vehicles per day, requiring more than one weigh device.

The specifications of the weighs device are as follows:

- Capable of weighting at least 80 tons;
- Platform along with weighting at least 18 meters long;
- Using an international system unit;
- Using a digital electronic system.

![Figure 1. Simulation Weighing Process at UPPKB (Source: Minister of Transportation, 2015)](image-url)
2.2. Weigh In Motion (WIM)

WIM is the method of measuring the dynamic tire forces of a moving vehicle and estimating the corresponding tire forces of various static vehicle [14]. Efforts to develop and use WIM systems to collect a truck’s weight information dated back to the 1950s. One of the earliest examples was a WIM system developed in 1951 by Norman and Hopkins at the U.S. Bureau of Public Roads [15, 16]. The WIM system used a floating concrete platform that was embedded within the route and supported at its corners by gauge load cells. The measurements were non inheritable by taking images of the traces from Associate in Nursing electronic equipment. Following developments with the embedded weight sensors enclosed completely different iterations on platform styles, exploiting steel plates and gauge load cells, steel bending plates instrumented with strain gauges, and strip sensors. The utility of the earliest WIM systems was severely restricted by the sensing, signal learning, and information acquisition technologies on the market at the time. The technical limitations of the past, for the most part, unencumber trendy WIM systems and usually include route sensors that classify vehicles by kind and live the vehicle weight and therefore the supporting electronic hardware and computer code required to the method, sort, analyze, and transmit the recorded information [17].

These WIM systems effectively capture and record the shaft or axle cluster weights and, therefore, the GVW, whereas the vehicle is moving at average main road speeds. The operational principle of WIM sensors relies on measure shaft hundreds through the signals recorded by sensors, comparable to voltage, strain, and resistance [17]. Typically, WIM sensors are embedded within the pavement surface. The accuracy of WIM systems is stricken by the interaction between pavement and vehicle, which relies on pavement roughness, vehicle suspension, and speed. Different factors that influence the accuracy of WIM systems are the installation, standardization, and maintenance procedures of the device system. WIM systems are accustomed to verify vehicle characteristics, together with GVW, speed, shaft weight, and shaft spacing. Current WIM device technologies accustomed to living weight embody compound, ceramic, and quartz electricity systems, bending plates, and cargo cells. B-WIM was first accustomed to living vehicle weight within the 1970s; the information acquisition hardware and computer code of B-WIM are unceasingly developed since then [16, 18]. A B-WIM system uses the measured responses of a bridge (usually strain) to see the load and different characteristics of crossing trucks. B-WIM systems usually need additional elaborate information analysis and interpretation procedures to see the truck characteristics than are necessary for ancient WIM systems put in in a single lane of pavement. This can be thanks to factors comparable to the chance of multiple presences of trucks and different vehicles on the structure, changes in structural behavior thanks to environmental effects, geometric and structural complexness of the bridge, and dynamic interactions between trucks and therefore the bridge [17].
2.3. Research Method
The analysis approach is a methodology in conducting research that aims to realize the objectives of the research [19]. The tactic employed in this analysis is quantitative deductive analysis. This method was chosen because it aims to develop an initial hypothesis related to the characteristics of the research area [20]. This hypothesis is the basis for further research. The purpose of using this method is to examine the suitability of the characteristics of the Weigh-in-motion system to the characteristics of the UPPKB in Riau, so that this technique will effectively scale back the problem of overloading and over-dimension in Sumatera. This analysis comprises the stages of: (1) Literature Study, (2) Knowledge Validation, (3) Analysis, and Conclusions. Within the initial stage, the author reviewed the literature on the characteristics of the application of the WIM system and adjusted it to the laws and regulations concerning the UPPKB. The output at the primary stage is the indicator that’s the idea for validation within the land. The second stage was conducting validation to assess the suitability and possibility of implementing WIM in the UPPKB Balai Raja. The third stage was conducting quantitative descriptive analysis and drawing conclusions. The ultimate results of this study can verify that there are indicators to follow to adjust the characteristics of the region so that this technology will run effectively.

3. Analysis

3.1. Result
UPPKB Balai Raja is an UPPKB located in Bengkalis Regency, Riau. This UPPKB started operating again in 2016. UPPKB Balai Raja lies on an area of 3,800 m², with a capacity of 1 weighing platform of 80 tons. This UPPKB is on Duri-Kandis road No. 008, serving 2-way weighing, namely the directions of Pekanbaru-Duri and Duri-Pekanbaru. The width of the road in front of the UPPKB is 11 meters with a 2/2 UD type road. In 2020, UPPKB Balai Raja will be renovated and begin using a Weigh-in-motion (WIM) system. Figure 3 below depicts the location of UPPKB Balai Raja.
In the process of implementing a weigh-in-motion system, several indicators need to be considered. These indicators include the characteristics of the location of the installation of WIM, the characteristics of goods transport vehicles, and environmental characteristics [21]. Table 1 below explains the indicators used for field validation.

**Table 1.** An indicator in this research (Source: Austroads 2000, Indonesian Road Capacity Guide (PKJI) 2014, Jihanny, et al., 2017, and Researcher Analysis, 2020)

| No | Variable                  | Indicator                  | Information                                                                                                                                 |
|----|---------------------------|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
|    |                           | Installation Site          |                                                                                                                                              |
| 1  | Weigh-in-Motion Location  | Characteristics           | • Low-speed WIM systems, the installation site requirements are well defined by suppliers and vendors and require strict adherence. In most cases, the actual installation site is specially built or modified from the original |
|    | Approach to The Installation Site |                   | • High-speed WIM systems, the installation site approach is critical. Usually, the 100 meters or so to the WIM system must be smooth, straight lane, and free-flowing (not accelerating or decelerating) traffic |
|    | Vehicle Speed             |                           | The average speed of vehicles passing through the location UPPKB                                                                          |
| 2  | Vehicle Characteristics   | Acceleration              | The average top speed of vehicles passing the UPPKB location                                                                               |
|    |                           | Deceleration              | The average low speed of vehicles passing the UPPKB location                                                                               |
| No | Variable               | Indicator                                                                 | Information                                                                 |
|----|------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|
|    | Body and Suspension Type | Characteristics of shape, model, and suspension trucks often passing the UPPKB |                                                                             |
|    | Truck Type             |                                                                           | The most frequent types of trucks passing the UPPKB                         |
|    | Road Type              |                                                                           | - Two undivided two-way lines (2/2 UD)                                    |
|    |                        |                                                                           | - Four-lane two-way split (4/2 D)                                         |
|    |                        |                                                                           | - Four-lane two way undivided (4/2 UD)                                    |
|    |                        |                                                                           | - Six-lane two-way split (6/2 D)                                          |
|    |                        |                                                                           | - One-way road (1-3 / 1)                                                  |
|    | Width of The Road      |                                                                           | The width of the road from the pivot point                                |
|    | Road Surface Conditions |                                                                           | - The road is smooth and flat                                              |
|    |                        |                                                                           | - The road is uneven and bumpy                                              |
|    |                        |                                                                           | - Roads are damaged and potholed                                            |
|    | Environmental Characteristics |                                                                           |                                                                             |
|    | Road Pavement         |                                                                           | - Asphalt                                                                   |
|    |                        |                                                                           | - Concrete                                                                  |
|    | Air Temperature        |                                                                           | Average temperatures are in the area                                        |
|    | Weather                |                                                                           | The weather of the past week at the study site                             |
|    | Land Use               |                                                                           | - Settlements / Residential area                                           |
|    |                        |                                                                           | - Trade and Services area                                                   |
|    |                        |                                                                           | - Offices area                                                              |
|    |                        |                                                                           | - Industry area                                                             |
|    |                        |                                                                           | - Education area                                                            |
|    |                        |                                                                           | - Plantation area                                                           |

Table 1 shows the 14 indicators used in this study. The indicator was obtained based on the study of the application of Weigh in Motion in several study locations. The indicator is then validated with the field data at UPPKB Balai Raja to find out the appropriateness of the application of the weight in the motion system. Table 2 shows the results of data validation in the field for the application of weigh in motion systems.
Table 2. Results Indicator Based on Field Validation (Source: Researcher Interpretation, 2020)

| No | Variable | Indicator | Field Validation | Information |
|----|----------|-----------|------------------|-------------|
| 1  | Weigh-in-Motion Location Characteristics | Installation Site | Easy | The topography and land area are sufficient |
|    |          | Approach to The Installation Site | Easy | - |
|    |          | Vehicle Speed | 50-80 km / h | - |
|    |          | Vehicle Acceleration | 80 km / h | - |
| 2  | Vehicle Characteristics | Vehicle Deceleration | 50 km / h | - |
|    |          | Body and Suspension Type | Factory Stock | Dump trucks sometimes look overload |
|    |          | Truck Type | Dump truck, oil truck, container | Transporting processed palm oil products |
|    |          | Road Type | 2/2 UD | Two lanes of 2 directions with a road divider |
|    |          | Width of The Road | 11 meters | - |
| 3  | Environmental Characteristics | Road Surface Conditions | Bumpy road | - |
|    |          | Road Pavement | Asphalt | - |
|    |          | Air Temperature | 26°C and wind speed 5-10 km / h | - |
|    |          | Weather | Cloudy, sunny | - |
|    |          | Land Use | Oil palm plantations and residential areas | - |
3.2. Weigh-in-Motion Location Characteristics

A basic consideration for the performance of a WIM system is the characteristics of the situation where the system is installed [21]. Evidenced by Table 2 of the present analysis, no difficulties were found in installing the WIM system. However, within the installation, some requirements should be followed. For low-speed WIM systems, the requirements of the installation are well outlined by suppliers and vendors; these will require strict adherence. In most cases, the particular installation web site is specially designed, or altered. For high-speed WIM systems, the installation web site approach is crucial. Usually, the one hundred meter lane to the WIM system have to be smooth, straight lane with free-flowing traffic (not accelerating or decelerating) [21]. With the installation’s requirements of the WIM system matching the characteristics of the situation, a high-speed WIM could be installed, given that the speed of truck passing around 40-80 km/hour. However, in Indonesia, the usage of a WIM system integrated with the scale has not nonetheless been enforced. As a result, bulk of trials on the application of WIM system are conducted on bridges and freeways [9, 22, 10]. The trials were sufficient to look for the VHF (Vehicle Harm Factor) that is caused by the limit-exceeding transport. The conclusion is that the WIM system is sort of helpful if it is integrated with
UPPKB to cut back the overload and over-dimension in goods transport. However, for the installation, WIM still requires an in-depth study to work out a most suitable style.

3.3. Characteristics of Vehicles

The majority of trucks passing the location are dump trucks, oil trucks; instrumentality transporting processed oil merchandise as a result of the land use around the analysis location is associate feather palm plantation. Average speed of transport vehicles passing by is 40-80 km/h with Body and Suspension kind industrial plant Stock. Generally, if transporting oil Product Use, dumper Look Overload. The analysis location is a component of the southern section of Jalintim Road. Within the Sumatra’s Jalintim Network, the trucks that pass the most are freight trucks with two-axle, then followed by a three-axle freight truck. Once viewed from the VDF (Vehicle Injury Factor), the characteristics of the vehicle on top of are the foremost vital contributor to road injury if it exceeds the limit [22]. The transportation arrangement of product transportation aspects in Sumatra continues to be inferior. Compared to alternative countries, the number of products transportation that passes is incredibly high, particularly for trucks with two axes and three axes [22]. Another study in the European nations states, the share of vehicles full within the very of 6% to 16.5% and Sumatra over that [23]. The WIM system will solely scan vehicle classifications with closed truck models corresponding to containers. Nevertheless, for dump trucks model, WIM finds difficulties observing the full weight. As a result of there is no actual total space on the truck [21]; this statement is the same as the results of a study conducted by Jongga Jihany in 2017 [22] that five kinds of trucks may be detected from the WIM System. Figure 6 explains the classification of freight transport that may be detected by the WIM system:

| CLASS | CONFIGURATION | VDF   |
|-------|---------------|-------|
| 6B    | 6 ton 10 ton  | 3.898 |
| 1.2H  |               |       |
| 7A    | 6 ton 18 ton  | 3.679 |
| 1.2   |               |       |
| 2.2   |               |       |
| 7C1   | 6 ton 18 ton  | 5.934 |
| 1.2+2.2 |           |       |
| 7C2   | 6 ton 18 ton  | 6.222 |
| 1.2+2.2 |           |       |
| 2.2   |               |       |
| 7C3   | 6 ton 18 ton  | 6.003 |
| 1.2+2.2 |           |       |
| 2.2   |               |       |

*Figure 6. Information on types of truck (Source: Jihany, 2017)*

Vehicle characteristics are interconnected with location characteristics in this installation site, and their approaches are typically chosen to reduce or manage conveyance characteristics. Factors corresponding to acceleration and lane positioning are often influenced if not controlled. However, suspension sorts and tire conditions are a lot of complicated [21]. The conclusion is that the WIM system has limitations in the detection of the transport of products with associated open models. However, the bulk of goods transportation is usually overladen at the analysis location with an open model. Therefore, the implementation in Indonesia is going to be quite severe if there has not been any improvement within the system of suppliers’ service.
3.4. Environmental Characteristics

Temperature (pavement and road), wind, and ice will significantly affect the performance of the WIM system. The bulk of this data and its result on the performance of the WIM system belong to the seller. Effectively it is their proprietary data, and most vendors are reluctant to disclose it [21]. A pair of road pavement and air temperature are common, further as different indicators. Nonetheless, the survey results in indicators of paved surface conditions within the study web site are jarring. This indicator becomes a retardant that has to be resolved, or else it will affect the sensitivity level of the WIM sensing element. Mississippi State School had experimented with overcoming this downside. The Mississippi State School was in 1955 experimenting with a metal-plate/rubber-sheet sandwich-type condenser scale for consideration significant vehicles [24]. With this technique, difficulties were encountered with temperature, friction forces, impact, and edge effects. The most effective answer in order that the WIM system to run effectively at the location is to try and do a standardization. The standardization of the placement, that is, conveyance and environmental characteristics are accomplished at the placement by the installer. The vendor and provider sometimes advocate the primary standardization methodology and any subsequent re-calibrations. This standardization data is not proprietary and is usually non-existent. Many literatures exist on WIM system’s location standardization [25, 26, 27, 28]: check vehicle(s) and simulation models, comparison between the pavement’s roughness and WIM system activity error, comparison between static and dynamic weights of check vehicle(s), and distribution of gross vehicle mass.

3.5. The Challenge in the Implementation WIM Technology in UPPKB

The implementation of WIM aims to be able to accelerate Indonesia to be free from Over Dimension and Over Loading (ODOL) vehicles. The solution is to use the system Weigh in Motion in all UPPKB. However, it still faces several challenges and problems in the implementation process. For example, the condition of poor infrastructure, lack of quantity, and human resource’s lack of capabilities in the operation of UPPKB, lack of technology in the operation of UPPKB, and lack of utilization of existing assets [29]. Solution by the Ministry of Transportation to address these problems is by conducting focus group discussions and technical guidance for the managers of WIM in each UPPKB. Additionally, some researchers have also begun to develop a WIM system that can be applied in Indonesia. The trial of the application of WIM in road construction in Banda Aceh resulted in the International Roughness Index (IRI) value being in a proper category (from 4 to 8), precisely with a value of 5.03. At the same time, the Surface Distress Index (SDI) value is less than 50 m/km [11]. Laboratory of the Electrical Engineering of Universitas Borneo Tarakan in 2019 started manufacturing of WIM systems tailored to the characteristics of Indonesia’s land. The results was a prototype WIM able to measure the speed and weight of the vehicle running successfully, run the vehicle’s load measurement with an average error of 14.9% [9]. The implementation of WIM in UPPKB to reduce Over Dimension and Over Loading (ODOL) vehicles has encountered many challenges, as the system is still quite new in Indonesia and still requires much in-depth technical study. Several alternatives and solutions have been proposed so that the WIM system may be applicable and suitable to the characteristics of Indonesia’s requirements. Hopefully, in the next five years, this system can be implemented in all of UPPKBS.

4. Conclusion & Discussion

The implementation of WIM system in UPPKB Balai Raja is possible to actualize, but it still requires more adjustment in terms of design, so that the WIM system can work optimally to solve the problem of overloading and over-dimension of goods transport. Since the WIM system is still new, it still requires a lot of in-depth technical studies. This fact is a challenge in itself: to be able to produce a WIM system that is more applicable to Indonesian characteristics, because the suitability of the application of the WIM system with the characteristics existing in Indonesia to support the performance of the UPPKB is essential. Several studies conducted on the WIM system trial found several obstacles and proved the need of in-depth study for their application [9, 22]. For now, the
WIM system is still not suitable for implementation with the existing characteristics in Indonesia. It is hoped that in the next five years, this system can be implemented in all of UPPKB in Indonesia. This research still has many limitations in terms of a detailed study. Recommended themes for future researchers are in-depth studies of design and technical aspects to produce a conceptual model of the WIM system. The government can conduct comparative studies with the creator of WIM, in order to transfer the knowledge. Also, to accelerate the trial run of the WIM system, the government is expected to purchase one such system, so that experts and scientists can conduct detailed exploration directly on the system.

5. References
[1] Zulkarnaen T R 2011 Implementation of policy for supervision and control of more content (case study of implementing motorized vehicle weighing unit transportation agency North Sumatra province) Journal Garuda 2
[2] Sholichin I and Rumintang A 2018 Relation analysis of road damage with excessive vehicle loads on Kalianak road Surabaya Phys: Conf. Ser. 953
[3] Hadiwardoyo S 2012 Tolerance limit for trucks with excess load in transport regulation in Indonesia Makara of Tech. Ser. 16 85–92
[4] Otegbulu A 2011 Economic valuation of poor road infrastructure Lagos: a focus on urban households Glob. J. of Hum. Soc. Sci.
[5] -- 2014 Peraturan Pemerintah Nomor 79 Tahun 2013 Tentang Jaringan Lalu Lintas dan Angkutan Jalan (Jakarta: Pemerintah Republik Indonesia)
[6] -- 2015 Peraturan Menteri Perhubungan Nomor 134 Tahun 2015 Tentang Penyelenggaraan Penimbangan Kendaraan Bermotor di Jalanan (Jakarta: Kementerian Perhubungan Republik Indonesia)
[7] -- 2013 Peraturan Pemerintah Nomor 74 Tahun 2014 Tentang Angkutan Jalan (Jakarta: Pemerintah Republik Indonesia)
[8] Hartati 2018 Parking spatial planning and maneuvering of goods transport vehicles at the UPPKB based on Government Regulation Number 74 of 2014 (case study: UPPKB Wanareja) Proceeding National Conference IENACO 8
[9] Syarif I A and Prasetya A M 2019 Aplikasi Weigh in Motion menggunakan metode estimasi untuk mengukur beban dan kecepatan kendaraan bergerak Borneo Engineering Journal Teknik Sipil 3
[10] Bahtera D, Firdaus, Yendri D and Arief L 2015 Implementasi metode analisa pulsa WIM (Weigh in Motion) pada pengukuran beban kendaraan bergerak berbasis mikrokontroler Seminar Nasional Teknologi Informasi dan Komunikasi Terapan 2015 ISBN 979-26-0280-1
[11] Martina R, Saleh S M and Isya M 2018 Kajian Beban Aktual Kendaraan Pada Konstruksi Jalan Menggunakan Weigh In Motion (WIM) Jurnal Teknik Sipil Universitas Syiah Kuala 2 701–14
[12] Hasan M 2018 Gelaran FGD Balitbang Peluang dan Tantangan Penerapan WIM (Weigh In Motion) Untuk Mendukung Kebijakan Over Dimension Over Loading (ODOL)
[13] Bima S and Chandrasari 2003 Identification of Road Damage Due to Overload on the Kali Krasak Road - Magelang City (Semarang: Diponegoro University)
[14] ASTM 2009 Standard Specification for Highway Weigh-In-Motion (WIM) Systems with User Requirements and Test Methods E1318-09.2009 (West Conshohocken, PA: ASTM International)
[15] Norman O K and Hopkins R C 1959 Weighing vehicles in motion Highway Research Board Bulletin 50
[16] Lee C E and Garner J E 1966 Collection and Analysis of Augmented Weigh-in-Motion (WIM) Data (Austin: Center for Transportation Research, The University of Texas) 987-8
[17] U.S. Department of Transportation, Federal Highway Administration 2016 LTBP Program's Literature Review on Weigh-in-Motion Systems (Georgetown: Research, Development, and
Technology Turner-Fairbank Highway Research Center

[18] Moses F 1979 Weigh-in-motion system using instrumented bridges J. of Trans. Eng. 105 233–49

[19] Prasetyo B and Jannah L M 2012 Metode Penelitian Kuantitatif (Yogyakarta: Rajawali Pers)

[20] Ahyar H 2020 Metode Penelitian Kualitatif & Kuantitatif (Yogyakarta: CV Pustaka Ilmu)

[21] Koniditsiossis C 2000 Weigh-In-Motion Technology AP–R168/00 (Sydney: Austroads Incorporated)

[22] Jhanny J, Subagio B S and Hariyadi E S 2017 The analysis of overloaded trucks in Indonesia based on weigh-in-motion data (east of Sumatera national road case study. MATEC Web of Conferences 02006(2018) 147

[23] Rys D, Judycki J and Jaskula P 2016 Analysis of the effect of overloaded vehicles on fatigue life of flexible pavements based on weigh-in-motion (WIM) data Inter. J. of Pavement Eng. 17 716726

[24] Snyder R and Moses F 1985 Application of in-motion weighing using instrumented bridges Trans. Res. Rec. 1048 83–8

[25] Koniditsiotis C 1990 The Golden River capacitive pad weigh-in-motion system - its life and times Proc. 15th Australian Road Research Board Conference

[26] Dahlin C 1990 Proposed method for calibrating WIM systems and for monitoring that calibration over time Trans. Res. Rec. 1364

[27] Davies P and Sommerville F 1988 Calibration and accuracy testing of WIM systems Trans. Res. Rec. 1123

[28] Papagiannakis T and Senn K 1995 On-Site WIM System Calibration: An Overview Of NHRCP Study 3-399(2)

[29] Maris S 2020 Eight in Motion, Sistem yang Bantu Wujudkan Indoneisa Bebas ODOL

Acknowledgment
This article represented one of research foci in a group study on Urban and Regional Spatial Planning. The authors would like to express much gratitude to the Department of Civil and Planning, Vocational School of Universitas Diponegoro, for facilitating this study and providing insight and expertise that greatly assisted the research. However, they may not always agree with the interpretations/conclusions of this paper.