Journal Homepage: - www.journalijar.com
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)
Article DOI: 10.21474/IJAR01/1750
DOI URL: http://dx.doi.org/10.21474/IJAR01/1750
ISSN NO. 2320-5407

RESEARCH ARTICLE

A Comparison between SAW and WIM Systems on Highways.

Abdulkhalek M. Kadir.
Erbil Technical Engineering College, Erbil Polytechnic University-Iraq.

Manuscript Info

Manuscript History

Received: 12 July 2016
Final Accepted: 15 August 2016
Published: September 2016

Key words:-
SAW, WIM, Quality standards, trucks.

Abstract

Weigh-in-Motion "WIM" is a new system for weighing process of trucks loading material loads which is strongly required to be operated on highways anywhere, it is required to replace Stationary Axle Weigh "SAW" system which is now used for weighing process of trucks with their loaded materials in many countries and the systems are managed by local transporting authorities. WIM holds many advantages; it can give effective results and assist to preserve roads from damages and defects more than SAW. The size of transporting materials has maximized in recent years and average of trucks numbers with extra loads has much increased. SAW is operated now but it cannot balance progressed state, millions of trucks with their loads are move now on highways worldwide, in order to make balance with new state, it is too required to use new system of WIM on highways, therefore the installation is vital issue and comparison between WIM and SAW is necessary to know their operating data. Many studies have affirmed that WIM can give greater advantages than SAW and higher quality level can be obtained because WIM consists of two stages of weighing process and contains new equipment and devices, and it can better monitor the process, and preserve roads component. SAW will lead to more time and losses, and there are many differences between them.
As a new topic, the comparison between SAW and WIM is regarded as new approach to indicate their system's operating, required specific equipments, differences, and advantages of both systems. As a new tactic, the comparison between them comes via detailed data about components, installation, quality standards, and discusses their comparison elements.

Introduction

Transport of materials by trucks on highways has considerably increased in recent years, therefore the movement of materials and transporting have maximized, and hence the goods, products, and wares have increased and transported to projects and firms to continue their works, when comparison this matter with state of twenty years ago, we see that the average of roads damages and defects increased highly, because now more trucks with their loads are move per a day on many highways in most cities of different countries, they bring goods or supply projects with different materials, in an international report [1] there are more than 250 million trucks with their loads moving on the highways in the world. The highways are the main public road, especially one linking towns and cities [2], and there are limits of resistance from the highways which resist extra loads of the trucks, but it depends on the type

Corresponding Author: Abdulkhalek M. Kadir.
Address:- Erbil Technical Engineering College, Erbil Polytechnic University-Iraq.

of trucks and axel numbers to bear increased loads and any excess over these limits will bring a lot of unsafe conditions and make damages and defects in basic roads components, for this reason, it brings greater losses and it should spend extra efforts to achieve repair and maintenance. Figures 1& 2 show photos examples of damages and defects of highways, and in order to eliminate these losses and efforts, it should be front continuous increased numbers of trucks, and use other weighing process such as WIM which become an urgent requirement, therefore, at first WIM compared with SAW to indicate qualitative and quantitative features, in order to select best way of weighing without losses and time interval, and to resist raised loads and moved trucks. The internal standards have been published 83 types of trucks, they indicate their dimensions, permitted loads by tons, and number of axels, but there are instructions of how to decrease exceeded loads. With SAW the control becomes difficult more than before, because many losses and road congestion were made, more damages occurred.

WIM is assumed as new system of weighing process of trucks loading material loads, it is much essential to be installed and operated on highways anywhere because it provides more advantages when compared with SAW, it has new technology of control and working, it achieves procedures of monitoring, controlling, calibration, and accurate results. There are differences between WIM and SAW in many ways of weighing process. WIM is working and be operated according to international standards of ASTM E1318 Standard and the COST 323 European Specification [3].

Many studies have confirmed that the trucks illegally overloaded cause damages on the road in direct proportion to the axle weight by 4th power, hence, it would greatly increase the cost of the road maintenance and repair, shorten the service life of pavement, and even affect the traffic safety and capability [4], also, other study proved that an extensive tests conducted have suggested that the pavement damage increases exponentially with axle weight to a power of four, and it is called "fourth power" rule [5], and the overloaded vehicles damage roads and dramatically increases maintenance costs [6]. Figure 3 shows photos examples of repair and maintenance of damages and defects that happened to roads.

Figure 1: Photos examples of damages and defects of highways

Figure 2: Photos examples of damages and defects of highways

Figure 3: Photos examples of repair and maintenance of damages and defects

There were many studies about process of weighing and both systems of WIM and SAW, some of them were as follows:

- A study was prepared about transporting process [7], it was the European WIM specification and provided as reference of the technical specifications for WIM manufacturers and users as well, it mentioned specifications associated to WIM in order to be at higher quality such as: (1) site selection of system's installation, (2) operation rules, and (3) calibration and assessment. The study presented 5 requirements such as: (1) six accuracy classes, (2) statistical data, (3) design, (4) maintenance, and (5) legal purposes, and it gave 17 criteria of WIM sites such as: (1) road geometry, (2) pavement characteristics, and (3) bridge sort. In addition it published 23 requirements of connected tasks such as: (1) environmental features, (2) sensors, (3) climate conditions, (4) traffic conditions, (5) mechanical resistance, (6) electronics, and (7) facilities. It presented other specifications such as: 45 types of on-site checks and calibration, 19 classes of accuracy tolerances, 20 modes of approval works, 8 sorts of verifications for both initial and in-service, 7 categories of vehicle classification, and 17 types of data storage and processing.
- A study of master's thesis [8] achieved the review of other several studies on some topics but related to WIM such as weighing accuracy, types of bridges used in WIM, axel detection, dynamic algorithms, and installation procedures. It clarified three sort of fixed equipments and devices which are permanently mounted to the pavement, semi-portable equipments and devices, and portable equipments and devices used either wheel or axle scales placed on the pavement surface. In its efforts, the study resulted that many attempts were made in order to move away method of static weighing because of some reasons:

(a) The staff and time are required to select and intercept trucks in order to perform measurements
(b) Increased numbers of heavy trucks traffic on highways and motorways have led the static weighing to become ineffective and be a limited deterrent.
(c) This type induces delays of between 10 to 30 minutes.

- A study made by De Wet [3], it researched in order to develop an accurate and robust WIM calibration method, and quality of practical data checks in order to apply as a wide range of the system, it affirmed ASTM- E1318 and COST 323 as recognized international standards of WIM, therefore the author developed method of post-calibration to receive WIM data called Truck Tracker (TT) method, for this objective, the presented study used technology in WIM, problems of data collection, pavement requirements, physical requirements of WIM, calibration of data, and quality of data would be checked to eliminate wrong weigh records.

Data collection and methodology

2.1. SAW System

SAW means "Stationary Axle Weighing" sometimes called "axle weighbridge system", this type of weighing process is designed in a manner that can provide fast gross weight information of any type of trucks from lightest vans to heaviest multi-axle vehicles, it assumed as stable system on roads as permanent or portable devices. In SAW system, the truck stops on the platform to let each axle to be weighed individually and indicates weight linked to each axel, then weighing results can be viewed on a screen and total weight can be seen from display unit located in control room beside weighing equipment. Figure 4 shows photos examples of SAW that represents weighing of static position. This system takes low location and requires minimum cost for installation, it holds easy assembly to any required place, and requires minimum space to operate, in addition it has good accuracy in weighing process and results can be printed [9].

Figure 4: Photos examples of SAW system

2.2. WIM System

WIM means "Weigh-in-Motion", this type of weighing process is designed in a manner that can quickly compute each of axle weights of trucks, number of axles, axle groups, and axle distances, it can also compares these results with limits of related standards and specifications. WIM uses the type of technology that can achieve several procedures, it combines truck's sensors with devices of weight and measuring dimensions, it indicates classification of trucks based on number of axles, axle spacing, and dynamic load of each axle in order to estimate the corresponding truck's static mass [10]. After process of weighing, the trucks loaded with extra loads are directed to low speed LS-WIM station through a special system called VMS (variable message sign), while other trucks continue their route. WIM system contains sensors for weights measuring, loop detectors, VMS, and control unit located into a cabinet placed beside the road, and it enables to achieve the process of weighing trucks loading different loads, while they are continue without hindering traffic stream, because WIM consists two stages of weighing, on the road and in the static station, as HS-WIM and LS-WIM [11], the plate number recording, security image camera system, and measuring truck's dimensions can be integrated to WIM system as well.

WIM gives many advantages or benefits in traffic monitoring by containing reduction of accident frequency rates, reduction of pavement damages, reduction of noxious emission and fuel consumption [5], but WIM can be described as measuring dynamic for tires of moving vehicle in the standard specifications [12]. Figure 5 shows overall sketch of WIM system includes both stages, and figures 6, 7 show sketches of ANPR, VMS, DIM, camera, and fleeing systems [9].

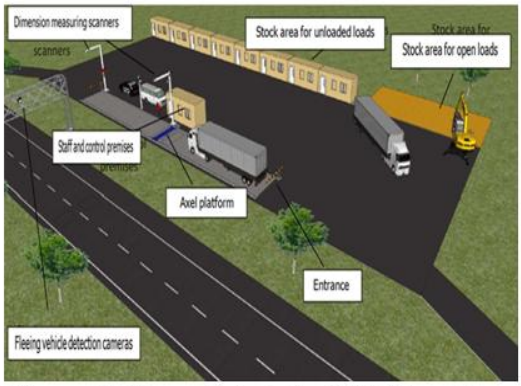


Figure 5: Overall sketch of WIM system and station

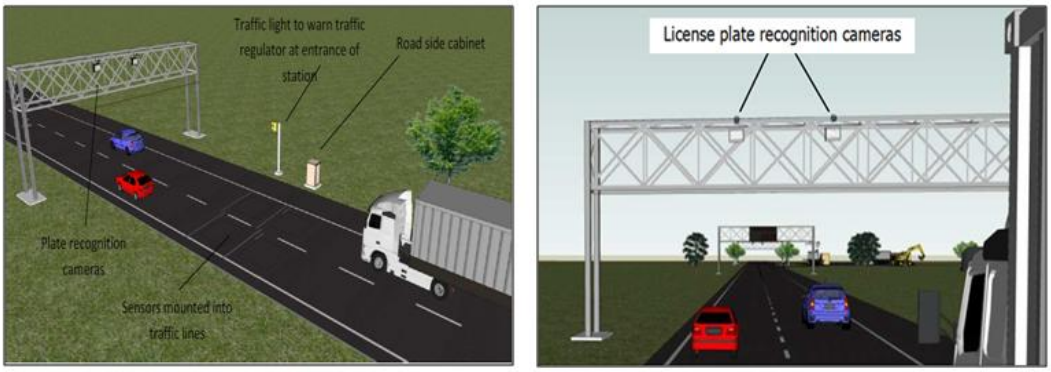


Figure 6: Sketch of WIM view and recognition cameras

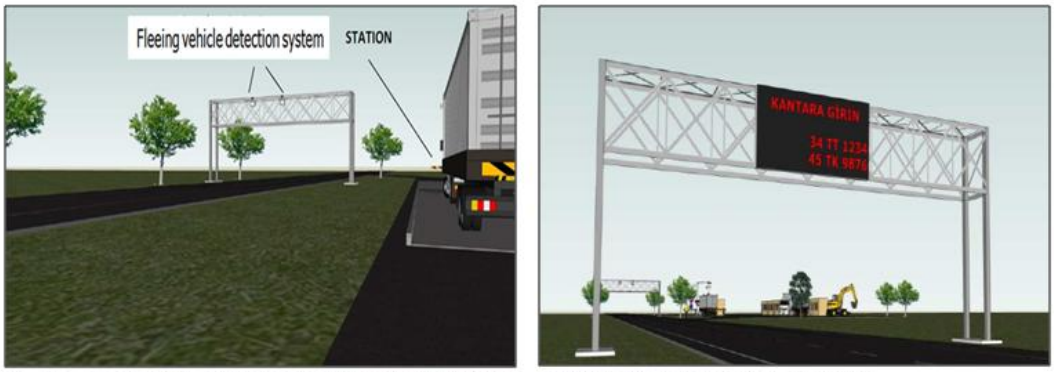


Figure 7: Sketch of entering the weighbridge and fleeing detection system

2.3. Quality standards

For higher quality level, there are two standards and one specification. They should be implemented in WIM, all processes of operation, installation, and arrangement of WIM system would be according to ASTM-E1318 (American Society for Testing and Materials ASTM-E1318-02), the last revision was in 2002, this standard provides performance & accuracy to WIM, it deals with three concepts of functional performance requirements of wheel load, axel load, calibration method, and methods of test of WIM [3]. Second standard is COST 323 (The European WIM specification), it was developed under forum leadership of European National Highway Research Laboratories FFHRL, but it should mention that COST 323 is not a standard as such as it has become a "de-facto standard for European countries", it was developed and published in 1999, now it represents 18 European countries. COST 323

focuses on accuracy & calibration, it defines accuracy of six classes based on interval of error tolerated for measurements of truck mass and axle groups but in ambient temperature range from -20 ºC to +60 ºC. Other specification is list of trucks' types with detailed information, it is connected to industry and design to give specific features of quality level, the firms of trucks manufacturing worldwide will gives five main features such as:

- Size of trucks
- Number of axels
- Assessment of weights
- Number of single tires
- Number of coupled tires

The list gives types of trucks loading material loads moved on highways, it contains a table of trucks type which licensed to pass without excess loads from 2 to 72 tons and from 2 to 15 unit axels and from 4 to 30 tires. Table 1 indicates a part of list of truck's types and some technical description as acceptable specifications [13].

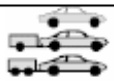
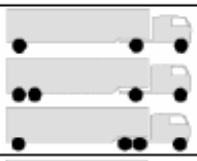
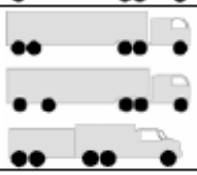
Class	Type	Vehicle	Number of Axles
1	Motorcycles		2
2	Passenger Cars		2 3 4
3	Other Two-Axle, Four-Tire Single Unit Vehicles		2,3,4
4	Buses		2,3
5	Two-Axle, Six-Tire, Single Unit Trucks		2
6	Three-Axle Single Unit Trucks		3
7	Four or More Axle Single Unit Trucks		4
8	Four or Less Axle Single Trailer Trucks		3 4 4
9	Five-Axle Single Trailer Trucks		5
10	Six or More Axle Single Trailer Trucks		6,7
11	Five or Less Axle Multi-Trailer Trucks		5
12	Six-Axle Multi-Trailer Trucks		6
13	Seven or More Axle Multi-Trailer Trucks		7 or more

Table 1: List of trucks' types

2.4. Motives to use WIM

- WIM uses new technology in its operation, therefore it gives better performance, accuracy, and calibration with reliable monitoring when it is compared with SAW and many experiments prove that WIM has important benefits in traffic monitoring [14].
- WIM can assist to reduce frequency rates of accidents and reduces damages of pavement, other motive is that it will help to reduce noxious emission and fuel consumption; also it gives more perfect data results [15].
- WIM can collect continuous data in such a way that can be used for statistical purpose and helps responsible traffic administration, it can describe dynamic measurement of tire forces of moving trucks, also it can estimate corresponding tire loads as document in standards and specification [12].

There are other advantages leads to use WIM and compare with SAW [12,9,15] such as:

- WIM gives accurate weighing at low and high vehicle speeds.
- WIM can determine vehicle dimensions, axle weights, gross weight of trucks; axel numbers, axel group, speed, and vehicle class, theses are useful data for perfect results, roads protection, and full accurate data in the system, and data communication with central information system in the city.
- WIM contains automatic truck identification by ANPR camera system, this leads to more control and directing trucks by message panel and traffic signalization system.
- WIM contains scale software program and warning of exceed loads that leads to easily manageable weighing process.

2.5. Problems presentation

The problems presented in this research will be the same problems which relate to WIM absence state which results several problems such as:

- If there is no WIM used or operated in highways in the city, many problems will continue to occur in case of still operating SAW.
- Both number of trucks and weights of loaded materials were increased and they continue to raise their rates from time to time worldwide, this generates more damages and defects every day.
- Saw system which is now in work in highways in most countries cannot accept new development; it cannot balance with raised rate of damages and defects to roads and pavements, there will be many losses.
- Comparison between SAW and WIM is essential as initial step to know advantages of new system WIM against SAW, without comparison, the problems cannot be presented and known, and to point out real importance of WIM, SAW has lower quality level in compare with WIM that has higher quality level.

2.6. Objectives of the research

The objectives of this research are to:

- Show damages, cracks, and defects as a result of using SAW
- Indicate the advantages of WIM
- Present quality standards specific to WIM and present list of trucks' types
- Compare between SAW and WIM

2.7. Methodology

In order to achieve objectives of this research, the methodology is as follows:

- Collection of data on SAW and WIM from references, and manufacturing companies.
- Doing comparison between SAW and WIM.
- Doing sketch of site plan, showing equipments and devices, indicate figures and photos for both systems.
- Analyzing data of systems, results and discussion, and present conclusions with author recommendations.

Data Analysis:-

1. Most WIM vendors want to use this system because depends on two of most recognized standards of ASTM-E1318 and COST 323, because they prefer to be used more than other international standards [3].
2. Cost 323 has good reliable value to WIM because it contains 212 parts of full perfect needs for the system application such as: (1) stages, (2) requirements, (3) calibration, (4) verifications, (5) vehicle classification [7].
3. WIM holds many advantages and specific technical features because it is fully automated weighing system, it can weigh all types of vehicles regardless of speed or axle configuration, it not requires additional infrastructure, and it can be installed after good pavements and side road [8].

4. Data analyzing indicates that SAW holds many names related to scientific and manufacturing firms, it can be named as: (1) Static axle scale (SAS), (2) Weigh axles (WA), (3) Axle weighing or weighing axle, (4) Fixed axle weighing (FAW), and (5) Axle weighbridges [6,11,9].
5. The data referred that WIM is called "Weigh-In-Motion" in most literatures, but after its continual improvement, it becomes to take two stages of working as high speed HS-WIM and low speed LS-WIM [9,12].
6. For accuracy of WIM's data, the system regulate three elements of sensor's temperature in order to give high value on recorded readings since it offers more resistance, site profile according to ASTM- E 1318- specific guidance in order to give flat and strong pavement surface, and calibration includes two types of initial calibration and calibration maintenance over time to compare dynamic and static weights to minimize the errors by adjusting scale factor [13].
7. Data analyzing indicated that HS-WIM has technical design features as it can weigh trucks at high speeds of up to 130 km/hr on highways or other busy roads and the trucks with extra loads can be warned and stopped, in addition it can weigh trucks despite different parameters like gross truck mass, axle unit mass, axle spacing and truck speed, and it has advanced technology and assist pavement design [16].

Comparison between SAW and WIM:-

Several researches and experimental studies [5,6,7,11,9] were pointed out differences between SAW and WIM. Table 2 indicates points of comparison between them.

Table 2: Comparison between SAW and WIM

No.	SAW	WIM
1	Weighing process takes several minutes	Weighing process takes only several seconds
2	It has one stage of static weighing	It takes two stages of motion and static weighing
3	It has one speed in weighing process	It has two speeds: high speed and low speed in weighing process
4	The truck should be stopped in order to begin weighing process	The truck moved without interrupted, if has no error, it will go ahead, if has excess load, it should be stopped and directed to begin weighing process
5	It makes road congestion	It makes no road congestion
6	It leads to large time loss	It not leads to time loss
7	It leads to cost loss	It leads to smaller cost loss
8	It takes small area location and requires minimum cost for installation	It takes more area location and requires larger cost for installation
9	It holds easy assembly to any required place, and requires minimum space to operate	It holds more complex to fixed required place, and requires maximum space to operate
10	It has one calibration	For accuracy of WIM data, it uses two steps of calibration: initial calibration and calibration maintenance over time
11	It has no further procedures	It has further procedures of measuring dimensions, license plate recognition, and additional inspections
12	The system has little choice of functions in order to operate	The system has various choice of functions in order to operate
13	It has only one feature, it will do one control process	It has further features, it will do three control processes: on the road, VMS, and inside station
14	It has no further equipments	It has further equipments, devices, and sensors to achieve weighing process, it has five main components in both speeds: HS-WIM-ANPR- Plate Recognition System LS-WIM-DIM- measuring truck's dimensions LS-WIM-Traffic Light and Mechanic Barriers HS-WIM- Fleeing Truck Detection System HS-WIM- Security Camera System

Results and discussion:-

Results

We got some results, the cities become larger and more trucks are moving between cities worldwide, many industrial firms were built, number of moving trucks per a day were increased, more industrial and commercial firms comes out, the occupation highways by loaded trucks were very increased, hence more road congestion occurred till now, and larger damages, defects, and losses were happened to roads and pavements in last years as a result of extra loads more than permitted limits of the loading.

We found that there are many static weighing process of SAW is now installed on highways and operating in most countries, and is assumed as old system when compared with working methods of WIM system. WIM can achieve effective process of trucks weighing loaded by extra load and gives 5 kinds of data by two operating stages, it holds new technology of 9 equipments, devices, and sensors divided by two groups, 3 for high speed and 6 for low speed of weighing. As a practical calculation result, WIM needs 10 hours (600 minutes) to achieve weighing 200 trucks daily, if there is 3 minutes for weighing each truck. We found that WIM can generate effective work and has less road's occupations. In this research we found also that there are 14 major differences between SAW and WIM when compare each to other one, WIM lead to no congestion as SAW do, for higher quality level WIM is operated, installed, and arranged according to two standards of ASTM-E1318-2 and COST 323 and one specification of list of truck's types, the standards focus on performance, accuracy, and calibration, the list of truck's types focus on 2 to 72 tons, 2 to 15 unit axels, and 4 to 30 tires.

Discussion

We realized that many big damages happened for the highways everywhere because a huge numbers of trucks loaded by extra loads move on the highways more than permitted loads, and their number increases every year, but this state was comes out as a result of increased different projects and various firms around cities in all countries, because the projects and firms needed materials permanently and still they need. Transporting products and raw materials in the loaded trucks more than requirements by international standards and issued specifications were caused damages and defects and brought many losses, therefore we need to apply limits in such a way to preserve highways, but this will be done by apply required standards and specifications. SAW used by traffic authorities in order to weigh loads transported by trucks, but SAW has initial technology and inefficient equipments to achieve process of weighing in a good manner, it makes congestion on roads and lead to stoppage of trucks and causes damages, defects, and further obvious losses.

WIM is more developed system to weigh loaded trucks on highways, because it contains developed technology represented by advanced equipments, devices, and sensors as well, it can be taken instead SAW, and ready to do best quality procedures and gives better control, because it gives accurate weighing at low and high truck speeds and able to eliminate damages and accidents. WIM contains both motion and static weighing process therefore it has full integration with systems of low speed and high speed, it is required to be installed on highways because holds many advantages and works with 9 advanced technology systems such as equipments, devices, sensors, ANPR is the plate recognition system which recognizes reflective coated license plates, DMS which is measuring truck's dimensions which is installed in low speed weighing, because it enable to measure length, width, and height of trucks, fleeing truck detection is crucial function system because it allows detecting trucks with extra load hat pass without entering into weighing station, and security camera system used in high speed weighing because it takes further detection, WIM contains also AR, it is steel platform that trucks passes over it for more fixed weighing process, the surface roughness of the concrete road has an important role in the accuracy of weight measuring.

WIM is more effective because results will be more accurate and has little cot loss, SAW has more, WIM has two stage of process of weighing, and SAW has one, therefore WIM makes no road congestion, it not leads to time loss, but leads to smaller cost loss, it takes more area location and requires larger cost for installation, and it holds more complex to fixed required place, but requires maximum space to operate because it has further technical procedures and features.

6. Conclusions and recommendations:-

Conclusions

There are many highways in any country, they are used by trucks to transport materials and raw materials to projects and firms or to needed places, with extra loads, the trucks make damages and defects on highways, because large number trucks now working worldwide, SAW system of weighing is not reply new developed situation and cannot respond increase trucks and their loads, in addition it has less technology than WIM which assumed more

acceptable, practicable and new system, and it depends on two of international standard and specification related to list of truck's types with other features as well. The trucks with extra loads can damage roads and many studies were affirmed that the trucks illegally overloaded can cause damages on the road in direct proportion to the axle weight by 4th power. When **comparison** SAW with WIM, many differences are exist and WIM holds many advantages which encourage us to think to install and operate this advanced system instead of old system of SAW. WIM minimizes traffic congestion and costs, it has more safety procedures. The installation procedures intends to install WIM on highways worldwide in the cities, it contains equipments and devices for two stages of HS-WIM and LS-WIM. HS-WIM contains 3 sub-systems and LS-WIM contains 6 sub-systems, WIM is suitable and higher quality and can challenge many problems.

Recommendations

We recommend installing and operating WIM system in highways to fill lacks in weighing process, we recommend operating this method with full required technology in order to fill gaps during weighing trucks with extra loads and in order to respond new developed situation. We recommend employing professional employees to mange this new WIM system, and installing many station on highways in each country.

References:-

1. http://www.greencarreports.com
2. http://www.thefreedictionary.com/Highways
3. D.P.G. De Wet, March 2010, Post-calibration and quality management of Weigh-in-Motion traffic data, master thesis of science in engineering at Stellenbosch University, Page 1-7.
4. Lu Cheng, Hongjian Zhang, Qing Li, Design of a Capacitive Flexible Weighing Sensor for Vehicle WIM System, ISSN 1424-8220, 2007 by MDPI, Sensors 2007, 7, 1530-1544, Page 1531.
5. P. Barsanescu1, P. Carlescu, D. Mihai Stefanescu, A new weigh-in-motion and traffic monitoring system, IMEKO 20th TC3, 3rd TC16 and 1st TC22 International Conference, Cultivating metrological knowledge, 27th to 30th November, 2007. Merida, Mexico, Page 1.
6. Avery Weigh-Tronix, Avery Weigh-Tronix is an ITW company, 2014 Illinois Tool Works, V1 AWT35-501307, www.averyweigh-tronix.com/axle-weighing, Page 1-3.
7. Cost 323, transport research, 2002, Weight-In-Motion of road vehicles, Appendix 1- European WIM specification, final report 1993-1998, editors: B. Jacob, E. Brien, S. Jehaes, Paris, Page 3-51.
8. Alan James Brown, 2011, Bridge Weigh-In-motion Deployment opportunity in Alabama, Master thesis, Department of Civil, Environmental and Construction Engineering, University of Alabama Tuscaloosa, Alabama, Page 2-10.
9. http://www.esit-scale.com/ShowProduct.aspx?ID=99&langID=en
10. David Mitchell, 2010, Trends in non-urban road freight using weigh-in-motion (WIM) data, Australasian Transport Research Forum 2010 Proceedings, 29 September - 1 October 2010, Canberra, Australia, Page 2.
11. Tunayler manufacturing company, 2012, WIM- Weigh in motion system, Tunaylar, www.tunaylar.com., Technical information brochure.
12. ASTM Standard E1318-02, Highway Weigh-in-Motion (WIM) systems with user requirements and test method, Annual book of ASTM Standards.
13. AMRUTHA DONAIAH, May 2008, Truck identification using new jersey weigh in motion data, Master thesis, School of New Brunswick, State University of New Jersey, Page 32-39.
14. Bushman R., Pratt A., Weigh-in-Motion technology – economics and performance, North American Travel Monitoring Exhibition and Conf., Charlotte, NC, 1998.
15. P. Martin, Y. Feng, X. Wang, Detector technology evaluation, University of Utah Traffic Lab., Nov. 2003.
16. Tshekisho Victor Leeuw, 2012, Weighing of Trucks in Road Traffic, University of Pardubice, Jan Perner Transport Faculty, Bachelor Thesis, Page 17-19.