WEIGH-IN-MOTION FOR PLANNING APPLICATIONS IN LOUISIANA

FINAL REPORT

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ABSTRACT

Weigh-In-Motion (WIM) is a method of weighing vehicles at highway speeds with the use of scales on or flush with the road surface. It has been used experimentally in Louisiana since 1976, but until recently little was done to prove its accuracy and usefulness as a highway design or planning tool. In this study, two WIM locations were selected near permanent Louisiana Department of Transportation and Development (LDOTD) scales to provide weight comparisons between dynamic (WIM) weighing and static (stationary) weighing. At present, the LDOTD Traffic and Planning Section collects weights every other year at 12 sites for approximately four hours at each site, using portable scales. This procedure is very labor intensive, requiring 10 to 15 persons, and provides only a small data base. Using the WIM system, a large data base was collected over an 18-month period utilizing only 2 to 3 persons.

After processing the WIM data, between 80 to 85% of WIM vehicles collected were usable for analysis. Manual traffic counts were used to supplement WIM vehicle counting. Statistical analysis showed that there is very good correlation between WIM, static and portable scales. An analysis of the WIM data was used to calculate EAL (18-kip equivalent axle load) design factors at both sites. Based on the accuracy of the WIM system established in this study, it was recommended that WIM equipment be used at various locations to show variations of truck loading for design purposes.

IMPLEMENTATION

This study confirmed that WIM equipment represents a substantial improvement over methods currently used to collect truck load data in terms of reduced manpower and increased sample size. The semi- permanent WIM equipment used in this study experienced problems that make it undesirable for long term use. A portable WIM system is thought to be a more manageable system for obtaining truck weight samples at multiple locations.

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INTRODUCTION

WIM equipment was used by LTRC from 1976 to 1983 on an
experimental base project (74-1G) on U.S. 71 near Alexandria(1).
The WIM computer used during this study was acquired in 1981.
Traffic loading data in the state of Louisiana in recent years has been estimated from a small number of truck weights gathered at 12 different sites every other year. This data is used to determine the damaging effects of trucks on the pavement structure and is essential for pavement design. Weigh-In-Motion (WIM) equipment now available can collect large volumes of data which, if accurate, can provide a more complete picture of regional truck loading patterns. WIM equipment requires less manpower and can be left unattended for extended periods, depending upon the traffic volume and data storage capacity. In view of these potential advantages, this study was undertaken to evaluate the accuracy of WIM and determine its effectiveness as a planning tool.

PURPOSE AND SCOPE

The purpose of this study was to evaluate the accuracy of WIM with permanent weigh scales by weighing trucks with each method. Also, the existing method of collecting truck loading data was compared with WIM.

This was accomplished by acquiring commercial truck WIM weights and comparative (permanent and portable) static weights at two interstate highway locations near LDOTD weigh stations. WIM locations were on jointed concrete pavement in the outside travel lane. About 50,000 truck weights were collected during an 18-month period.

METHODOLOGY

WIM INSTALLATION

Two sites were chosen on the interstate system for evaluation with different flow directions (i.e., eastbound and northbound). Some factors considered in choosing locations were: (1) clear line-of-sight (no curves), (2) level roadway for transducer placement, (3) accessibility to utilities (electricity, telephone), (4) ease of construction during transducer installation, (5) ease of placement of WIM trailer, (6) absence of metal reinforcement in the pavement, which would affect speed loop performance, and (7) close proximity to existing LDOTD static scales. The I-10 eastbound (Breaux Bridge) location rated well on these factors.

In April 1985, the Breaux Bridge installation was placed on I-10 East (ADT=21,732, % Trucks = 20.4) near Lafayette in the outside lane at the LA 31 overpass (1/2 mile east of Breaux Bridge LDOTD scales). Part of the WIM weighing system consists of presence and speed wire loops embedded just below the road surface. The speed loops were placed over two adjacent 20-ft. slabs to avoid interference from metal at the pavement joints (see Figure 1) (2). A transducer pit was excavated for placement of transducer frames which were set in epoxy. Two transducers, one for each wheelpath, were placed within the WIM steel frames. Wires from the transducers were run in conduit to a junction box about 100 feet from the roadside.

District 03 (Lafayette) provided maintenance crews to remove concrete with jackhammers and some manual chiseling. A trough was constructed in the middle of the pit to facilitate drainage to the roadside. Pieces of polystyrene foam were placed in the trough to keep epoxy out during frame anchoring (Figure 2). With a concrete saw, a 1/4-inch saw kerf was cut at the pre-marked rectangles on the concrete surface for placement of wire loops.

A double-insulated, No. 12 stranded wire was carefully placed into the cuts, making three loops in each rectangle. These loops detect the presence of metal in moving vehicles. Cuts were made in the pavement to allow wire passage to the trough at the transducer pit area.

After the pit area was cleaned, the weighing frames were lowered and supported by jigs (Figure 3) in readiness for epoxy pouring. For added structural integrity, protruding bolts were added to the frames, such that the bolt heads would be within the epoxy. An epoxy grout with hardener was mixed and poured around the perimeter and under each frame. After several hours, the frames were set in place. Concrete was placed between the frames and adjacent to the roadside. Two transducers, one for each wheelpath, were placed within the frames. Three square steel plates were laid on top of each transducer (Figure 4). Wires from the transducers were run in conduit to a junction box about 100 feet from the roadside. To provide drainage into a gravel bed, holes were drilled into the conduit about midway between the roadside and the trailer. The transducer wires were run through 1/4-inch rubber hose before being placed in the conduit. The hose mated with the transducer's center junction box to keep dirt and moisture out.

In November 1985, the Kentwood installation was placed in the outside lane on I-55 North (ADT=7240, % Trucks = 25.8), one-half mile south of the northbound Kentwood LDOTD static scales which is about 80 miles northwest of New Orleans. The roadway consists of 58.5-foot jointed concrete pavement with wire mesh reinforcement. Because the wire mesh posed a problem for the speed loops, a 36-foot section of highway in the right travel lane was removed. A wooden box was constructed prior to the concrete pouring to provide the space needed for the WIM frames and drainage trough. Concrete was replaced with high early strength concrete and no reinforcing steel. A new joint with load transfer devices was created approximately at the center of the patch. District 62 (Hammond) maintenance crews assisted with this procedure. High early strength concrete was used to reduce lane closure time. However, the concrete set accelerator caused the mix to harden before all of the concrete could be properly finished, resulting in an uneven approach surface. While the concrete was setting, an attempt was made to press pieces of thin wood into the surface in preparation for embedding loop wire just below the surface. Because the concrete hardened before this could be done, a concrete saw had to be used to embed the loop wire. The roadway approach was later ground in an attempt to remove the surface irregularities.

The remainder of the Kentwood (I-55 North) equipment installation was very similar to the Breaux Bridge site (i.e., frame placement, epoxy pouring, wire loop placement, conduit to junction box, etc.). For both locations, transducer cables and loop wires were soldered to a multi-pin connector. The connector mated to the cable of the WIM trailer.

WIM OPERATION

Transducers in each wheelpath weigh every axle of each truck by converting force into an electrical signal. The electrical signal is transformed into a digital form by the WIM computer (housed in a movable trailer on the roadside). With WIM software, axle and gross weights are indicated on a CRT screen and stored on floppy disk (which has a capacity of about 1800 trucks). The WIM computer, which runs automatically, offers some manual input (i.e., vehicle classification, vehicle identification) prior to the weighing of a vehicle. To determine speed, axle spacings and vehicle lengths, three wire loops were critically placed at predetermined distances just below the road surface and interfaced to the WIM computer.

The Radian WIM system receives 10 different pulses for a 3S2 5-axle vehicle, five pulses per vehicle side. A plot of one vehicle axle side (Figure 5) demonstrates the unevenness of the weighing during wheel WIM weighing. This graph was generated from stored data points in a digital oscilloscope which was connected at the jobsite to the WIM transducer signal conditioner board. The WIM software generates weights for each wheel by taking the average of the center one-third of voltage pulses above the preset weight threshold. Figure 5 indicates peaks which may or may not be averaged into the weight, depending upon where they are measured. These peaks are related to vehicle impact upon the WIM scales.

A WIM operator adjusts controls to calibrate the weighing transducers, which is accomplished by comparing WIM weights against static scales. Calibration of the WIM scales starts with zeroing the two wheelpath scales to negate the tare weight of the six steel plates. Each scale has strain gages interconnected to form a Wheatstone bridge. Each gage is actually a precision resistor that changes its resistance when stressed or strained. When an initial state is chosen, this can be considered the zero state (i.e., unloaded scale). A calibration resistor across one or more gages acts like a stress change, which is used to provide a calibrated state. The unbalanced state caused by the resistor correlates to a certain weight (lbs. or kg). Assuming no scale or weather (temperature, humidity, etc.) changes, this calibrated state should not change through the scale's usage. Slight changes in calibration occurred during the study at each site. When the weight indicated by the WIM transducer signal conditioner amplifier output matches the static weight, the calibration number generated from the calibration resistor and transducer amplifier was logged for future usage.

WIM COMPARED TO STATIC SCALES

For WIM weight accuracy checks, the WIM weights were compared with static weights at the LDOTD static scales, which at both sites were approximately one-half mile away. The static scales are calibrated several times a year and must meet a tolerance of 0.2% of applied load. The WIM scales were checked against the static scales. On-site checks usually consisted of comparisons of gross weights only.

PORTABLE SCALES OPERATION

Two 4-hour evaluations were conducted at each WIM site by weighing truck axles and measuring axle spacings. LDOTD Traffic and Planning personnel collected weights by weighing only one side of each axle on a truck and doubling the weights to estimate the total vehicle weight. The portable scales were calibrated prior to this study. However, no calibration checks were used on the scales during the study.

WIM PROBLEMS

Road surface and the smoothness of the WIM scales' profile to the road are characteristics that affect WIM accuracy. Another factor that affects accuracy is the vehicle's motion, which is influenced by vehicle suspension, flexibility, length, and weight. After constructing the Breaux Bridge WIM site, there was little disturbance to the road surface integrity. However, the Kentwood location had a very noticeable surface irregularity. Because it was suspected that vibration could damage or loosen the WIM frames, a profilograph device was brought to the site to isolate areas which needed grinding to make a smoother traveling surface. A grinding machine made several passes over the patch surface leading to the WIM frames, resulting in a more level surface. There was virtually no change in the average gross weight difference between WIM and static scales before and after grinding. No comparison was done with axle weight differences.

During the study, four different weighing transducers were used. Some repairs were necessary on two of the transducers. Some load cells had faulty solder connections while one transducer was damaged by remaining underwater for more than 24 hours during a hurricane. Amplification of transducer signals required to achieve proper weight indication according to static weight comparisons varied depending on the site and transducer. The new transducers were slightly less sensitive, which required more amplification. At one point, the limit of the amplifier was reached. A modification to the signal conditioner board suggested by a Radian engineer increased its gain, which solved weighing problems. There is no explanation why Breaux Bridge's WIM site had more variability in its calibration number than did Kentwood's location.

The capacity of the WIM floppy disks limited unattended operation. If the computer was left unattended overnight, the operator would have to return early the next morning because of the capacity problem. One method used to prevent overfilling the disk was to set a timer at preselected running times on the transducer signal conditioner board to shunt the transducer signals from the roadway.

This allowed the operator more time away from the computer. This method was used several times during the study, so that the computer could run overnight and over the weekend. The trailer, which has housed several WIM computers since 1976, contained no suspension and therefore subjected the computer to shock while in transit. One of the major results of this was that the printed circuit board edge connectors wore down, causing poor contact. Occasionally it became difficult to program the computer for the weighing mode because of this poor contact.

About mid-1986, some WIM data disk errors caused recovery problems. File markers were not readable, which caused Radian's software not to transmit. After several conversations with a Radian software specialist, an alternative data recovery method was found. The WIM printer port sends ASCII (American Standard Code for Information Interchange) characters to the printer. This feature is used when weighing trucks, but it can also be used to observe records already stored on disk. An IBM PC-AT computer which, when loaded with certain communication software, can receive and store ASCII characters through a 9-pin connector on the IBM's back panel. Direct wiring between the WIM printer port and the IBM PC-AT modem port worked after researchers found correct baud rate, number of stop and start bits, parity, etc. The IBM computer stored the WIM data on 5-1/4 inch disks, which were directly readable at LDOTD main computer by another IBM PC computer. A translation program was needed on the mainframe to place data in the pre-existing storage format.

Some WIM data consists of misweighs, which through programming is eliminated during analysis. These problems, along with corrective action, are described in Table 1.

TABLE 1

WIM WEIGHING PROBLEMS AND SOLUTIONS

WIM Data Problem	Corrective Action
SKIPS (Weight threshold was reached before axle(s) left the WIM scale. In this case, WIM usually generates 2 or more axles instead of 1 axle. These occurred on unloaded flatbeds.)	Delete vehicle data unless through programming the extra axle(s) can be eliminated and acceptable low weights can be substituted for computing EAL data.
Incorrect Axle Spacings (Loop detectors were inactive or malfunctioned during weighing.)	Delete vehicle data
Low Axle Weight (Under 900 lbs.)	Delete vehicle data
Recorded More Axles than Actual Amount (Loop Problem) -	Delete vehicle data

determined on the computer

by unusual axle spacings

DATA ANALYSIS AND RESULTS

WIM vs. STATIC SCALES WEIGHT COMPARISON

Data on nine vehicle types was collected in this study. Since 3S2 (a tractor-trailer combination with three axles on the tractor and two axles on the semi-trailer) was the most common truck type found in this data, it was used to indicate weighing difference and standard deviation in Table 2 (gross vehicle weights) and Table 3 (3S2 second tandem weights). The different truck types encountered during this study are indicated in Figure 6 (3).

For the I-10 site at Breaux Bridge, the percent mean 3S2 gross weight difference for gross weights between WIM and static scales (Table 2) ranged from -1.2% to -5.3%. The percent standard

TABLE 2

PERCENT DIFFERENCE BETWEEN WIM AND STATIC SCALES FOR GROSS WEIGHT OF 3S2 TRUCKS*

Gross Weight Midpoint (lbs.)	Number Of Vehicles	Percent Mean Wt. Difference	Standard Dev. (in percent)
		BREAUX BRIDGE	
30,000	21	- 5.3%	8.6%
40,000	21	- 3.6%	9.8%
50,000	34	- 4.6%	7.2%
60,000	51	- 1.9%	7.8%
70,000	154	- 1.2%	7.2%
80,000	136	- 1.6%	7.0%
Total	417	Mean - 2.0%	Mean 7.5%
		KENTWOOD	
30,000	44	1.1%	6.2%
40,000	16	- 0.4%	5.2%
50,000	7	3.0%	3.1%
60,000	9	1.8%	4.4%
70,000	49	1.4%	7.3%
80,000	32	3.6%	12.0%

Total 157 Mean 1.6% Mean 7.8%

* (+) POSITIVE NUMBERS, WIM STATIC WEIGHTS
(-) NEGATIVE NUMBERS, WIM STATIC WEIGHTS
Gross Weight Midpoint indicates midpoint of 10,000 lb. range
(Example: 80,000 Midpoint is 75,000 Gross Wt. 85,000)

deviation for paired observations at the same location was between 7.0% and 9.8%, which when all data point sets are averaged equates to 7.5%. For the I-55 site at Kentwood, the percent mean difference for 3S2 gross weights between scales ranged from -0.4% to +3.6%. Using standard deviation for paired observations, the Kentwood location ranged from 3.1% to 12.0% (average = 7.8%).

The percent mean weight difference in Table 2 and tables that follow were directly affected by the WIM calibration value chosen at each particular WIM data gathering. If the calibration value did not result in a zero percent mean difference, then the calibration value should have been adjusted. At each WIM run, an acceptable value was chosen after weighing several trucks, but continuous fine tuning was impractical.

In Figure 7, the best fit line (middle line) and the 95% upper and lower confidence levels are drawn within the field of WIM vs. static (3S2 Gross weights - both sites combined) plotted points. A cluster of data points occurred at the 80,000 lb. range (3S2 legal limit for gross weight on interstate highways).

In Table 3, the percent mean weight difference and standard deviation between WIM and static scales for 3S2 second tandem axle groups is analyzed. At the Breaux Bridge location, there were low percent mean differences (+2.5% or less) on all weight ranges with a total mean difference of -0.1%. Percent standard deviation for 3S2 second tandems at the same site was 9.5% or higher which resulted in a total mean standard deviation of 11.3%. The Kentwood site had all positive percent mean weight differences except at the 20,000 lb. range (-3.0%) which averaged to 3.9% mean weight difference. The lowest standard deviation in Table 3 at the Kentwood site was 6.4% at the 5,000 lb. range (2 vehicles available), while the highest was 15.2% at the 20,000 lb. range. The total mean standard deviation for Kentwood equated to 10.1%. The best fit line and 95% confidence levels are shown in Figure 8 for 3S2 second tandem axle groups. Many points were grouped at the 30,000-34,000 lb. range according to the static scales which is at or near the legal limit for tandems on interstate highway. The WIM scales did indicate above this limit several times.

TABLE 3

PERCENT DIFFERENCE BETWEEN WIM AND STATIC SCALES

FOR THE SECOND TANDEM OF 3S2 TRUCKS*

Tandem Weight Midpoint (lbs.)	Number Of Vehicles	Percent Mean Wt. Difference	Standard Dev. (in percent)
			BREAUX BRIDGE
10,000	31	2.5%	17.0%
15,000	23	- 1.6%	13.2%
20,000	39	0.4%	9.5%
25,000	41	1.3%	11.4%
30,000	130	- 0.6%	10.9%
35,000	151	- 0.7%	10.3%
Total	415	Mean - 0.1%	Mean 11.3%
			KENTWOOD
5,000	2	1.4%	6.4%
10,000	51	5.3%	10.7%
15,000	11	3.6%	13.0%
20,000	7	- 3.0%	15.2%
25,000	11	5.3%	7.8%
30,000	43	3.9%	8.6%
35,000	32	3.3%	10.0%
Total	157	Mean 3.9%	Mean 10.1%

* (+) POSITIVE NUMBERS, WIM   STATIC WEIGHTS

(-) NEGATIVE NUMBERS, WIM   STATIC WEIGHTS

Tandem Weight Midpoint indicates midpoint of 5,000 lb. range

(Example: 30,000 Midpoint is 27,500   Tandem Wt.   32,500)

Using simple regression on the two data sets (WIM and static scales - all truck types) in Table 4, the slope constant is nearly one and the y-intercept is near zero (-0.708 KIPS, KIPS = 1,000 lbs.). The coefficient of correlation is 0.938. T-tests on the slope and intercept indicate a linear relationship at the confidence levels shown in Table 4. From this information, there seems to be nearly a one-to-one relationship between the WIM and static scales.

TABLE 4
WIM vs. STATIC
SIMPLE REGRESSION AT BOTH SITES ON ALL TRUCK TYPES
(GROSS WEIGHT)

Equation of the line	WIM = -0.708 + (1.002*Static) (WIM and Static in KIPS)
R^2 - Coefficient of Correlation	0.938
T-test on slope at a 99.9%	Rejects null hypothesis that there is not a linear relationship confidence level
95% confidence interval for the slope	0.982 = slope = 1.021
T-test on intercept	Rejects null hypothesis that the intercept = 0 at a 87.0% confidence level
95% confidence interval for the intercept	-1.921 = intercept = 0.506

WIM vs. PORTABLE SCALES WEIGHT COMPARISON

The Traffic and Planning Section collected weights with portable scales along with the WIM and static scale weights on four different dates. After eliminating improper weights and mismatches, there was weight data on 146 trucks with all three weighing methods available.

With both locations combined, all percent mean weight differences for 3S2 gross weights were negative (Table 5), which indicates that the portable scales weighed higher than the WIM scales on the average. Percent mean weight difference for 3S2 gross weights between the two weighing methods at both sites ranged from -2.5% (for 80,000 lb. weight range) to -24.9% (for 2 trucks at 40,000

TABLE 5

PERCENT DIFFERENCE BETWEEN WIM AND PORTABLE SCALES FOR GROSS WEIGHTS OF 3S2 TRUCKS*

Gross Weight Midpoint (lbs.)	Number Of Vehicles	Percent Mean Wt. Difference	Standard Dev. (in percent)
			BREAUX BRIDGE
30,000	4	-10.8%	9.8%
40,000	2	-24.9%	1.4%
50,000	3	-12.7%	5.6%
60,000	4	- 5.4%	11.9%
70,000	16	- 3.9%	7.7%
80,000	16	- 2.5%	8.6%
Total	45	Mean - 5.7%	Mean 9.5%
			KENTWOOD
30,000	18	- 9.8%	6.3%
40,000	5	-12.2%	6.9%
50,000	3	- 3.7%	7.6%
60,000	4	- 8.3%	6.7%
70,000	13	- 3.8%	8.3%
80,000	14	- 0.6%	7.7%

Total 57 Mean - 6.0% Mean 8.1%

* (+) POSITIVE NUMBERS, WIM PORTABLE WEIGHTS
(-) NEGATIVE NUMBERS, WIM PORTABLE WEIGHTS
Gross Weight Midpoint indicates midpoint of 10,000 lb. range
(Example: 80,000 Midpoint is 75,000 Gross Wt. 85,000)

lb. range). Overall, standard deviation at both study sites indicated that WIM vs. portable had the highest deviation of all three paired comparisons: between 8.1% and 9.5% for 3S2 gross weights (Table 6). In Figure 9, a plot of WIM vs. the portable scales is shown, which indicated the scatter involved between the two weighing methods. With statistical analysis, fitting a straight line through the gathered data points is also shown along with the 95% confidence levels.

TABLE 6

COMPARATIVE STATISTICS BETWEEN WEIGHING SYSTEMS BASED ON GROSS WEIGHTS

	Number of 3S2	S(3S2) (%)	R^2 (3S2)	Number of ALL Trucks	S(ALL) (%)	R^2 (ALL)
BREAUX BRIDGE						
WIM vs. STATIC	417	7.49	0.881	481	7.75	0.921
WIM vs. PORTABLE	45	9.48	0.838	67	9.36	0.934
PORTABLE vs. STATIC	45	7.84	0.889	67	7.83	0.956
KENTWOOD						
WIM vs. STATIC	158	7.79	0.934	212	8.00	0.956
WIM vs. PORTABLE	57	8.10	0.949	79	8.60	0.948
PORTABLE vs. STATIC	57	5.58	0.984	79	6.01	0.985

ALL = All Truck Types

R^2 = Coefficient of Correlation

S = Percent Standard Deviation when comparing paired observations

3S2 second tandem axle groups between WIM and portable are compared in Table 7, there were two weight groups at Kentwood and one weight group at Breaux Bridge with greater than -1.0% mean weight difference. The total percent mean difference was -1.2% at the Breaux Bridge location and -4.7% at the Kentwood site. Over half of the standard deviations shown in Table 7 were above 10.0%. The total standard deviation was 13.4% at Breaux Bridge and 12.5% at Kentwood. Figure 10 shows plotted data points (WIM vs. portable) plus the statistical lines (best fit line and 95% confidence levels) for the second tandem axle group of 3S2 trucks.

TABLE 7

PERCENT DIFFERENCE BETWEEN WIM AND PORTABLE SCALES FOR THE SECOND TANDEM OF 3S2 TRUCKS*

Tandem Weight Midpoint (lbs.)	Number Of Vehicles	Percent Mean Wt. Difference	Standard Dev. (in percent)
BREAUX BRIDGE			
10,000	4	- 9.5%	18.4%
15,000	2	-23.0%	7.6%
20,000	2	-13.2%	7.4%
25,000	5	- 0.5%	18.5%
30,000	15	2.4%	8.3%
35,000	16	1.7%	13.2%
Total	44	Mean - 1.2%	Mean 13.4%
KENTWOOD			
10,000	21	-10.9%	12.1%
15,000	4	- 0.2%	15.2%
20,000	2	- 7.9%	8.3%
25,000	3	- 3.9%	13.9%
30,000	13	1.4%	10.9%
35,000	13	- 0.9%	11.0%
Total	56	Mean - 4.7%	Mean 12.5%

* (+) POSITIVE NUMBERS, WIM   PORTABLE WEIGHTS

(-) NEGATIVE NUMBERS, WIM   PORTABLE WEIGHTS

Tandem Weight Midpoint indicates midpoint of 5,000 lb. range
(Example: 30,000 Midpoint is 27,500 Tandem Wt. 32,500)

WIM and portable scales are compared in Table 8 with simple regression analysis. The slope constant is nearly one and the y-intercept is -2.115 KIPS. The coefficient of correlation is 0.943. T-tests on the slope and intercept indicate a linear relationship at the confidence levels shown in Table 8. It can be assumed that there is a near one-to-one relationship between the WIM and portable scales from these statistics.

TABLE 8

WIM vs. PORTABLE
SIMPLE REGRESSION AT BOTH SITES ON ALL TRUCK TYPES
(GROSS WEIGHT)

Equation of the line	WIM = -2.115 + (0.977*Portable) (WIM and Portable in KIPS)
R^2 - Coefficient of Correlation	0.943
T-test on slope	Rejects null hypothesis that there is not a linear relationship at a 95.0% confidence level
95% confidence interval for the slope	0.938 = slope = 1.017
T-test on intercept	Rejects null hypothesis that the intercept = 0 at a 95.5% confidence level
95% confidence	-4.568 = intercept = 0.338

interval for the
intercept

PORTABLE vs. STATIC SCALES WEIGHT COMPARISON

In Table 9, static scales and Traffic and Planning's (T&P) portable scales are compared for differences in 3S2 vehicular gross weights to show accuracy of portable scales weighing which is used for loadometer studies. The portable scales are calibrated to within 1% weight tolerance prior to each truck study (once every two years). All percent mean weight differences for 3S2 gross weights calculated for the weight ranges were positive (+), which translates into portable (T&P) scales weighing higher than the static scales. Weight differences from 1.6% to 18.8% occurred at Breaux Bridge with less differences having occurred at higher weights. The total percent mean weight difference for 3S2 gross weights between portable and static scales was 5.1% for Breaux Bridge and 9.4% for Kentwood. The lowest percent standard

TABLE 9

PERCENT DIFFERENCE BETWEEN PORTABLE AND STATIC SCALES FOR GROSS WEIGHT OF 3S2 TRUCKS*

Gross Weight Midpoint (lbs.)	Number Of Vehicles	Percent Mean Wt. Difference	Standard Dev. (in percent)
BREAUX BRIDGE			
30,000	4	9.9%	3.3%
40,000	2	18.8%	5.6%
50,000	3	15.0%	3.0%
60,000	4	7.4%	6.4%
70,000	16	3.3%	7.5%
80,000	16	1.6%	6.5%
Total	45	Mean 5.1%	Mean 7.8%
KENTWOOD			
30,000	18	13.7%	4.5%
40,000	5	11.1%	5.7%
50,000	3	7.1%	7.1%
60,000	4	8.0%	6.4%
70,000	13	5.6%	5.4%
80,000	14	7.6%	2.5%

Total 57 Mean 9.4% Mean 5.6%

* (+) POSITIVE NUMBERS, PORTABLE STATIC WEIGHTS
(-) NEGATIVE NUMBERS, PORTABLE STATIC WEIGHTS
Gross Weight Midpoint indicates midpoint of 10,000 lb. range
(Example: 80,000 Midpoint is 75,000 Gross Wt. 85,000)

deviation at both sites was 2.5% which was at the Kentwood location at the 80,000 lb. range. The total standard deviation between the two scales was 7.8% for Breaux Bridge and 5.6% for Kentwood. Referring to Table 6 (page), the lowest standard deviation for 3S2 gross weights or the gross weights for all vehicle types when comparing scales at Kentwood is shown: 5.6% for 3S2's and 6.0% for all trucks (portable vs. static). In addition, the highest R^2's between scales are indicated at Kentwood with 0.984 and 0.985 for the portable and static comparison. The 3S2 portable and static gross weight data points and statistical lines are indicated in Figure 11. The 95% confidence lines and the best fit line are shown. Fewer data points were available for this comparison.

Comparing Tables 9 and 10, the overall percent mean weight difference and standard deviation is higher for the 3S2 second tandem weights than the gross weights except for the second tandems' percent mean weight difference at Breaux Bridge (3.77%). Within individual weight ranges in Table 10, there were two mean weight differences for 3S2 second tandems near zero: 30,000 lb. midpoint with -0.58% (15 vehicles) and 35,000 lb. midpoint with -0.34% (16 vehicles) at the Breaux Bridge location. The total percent mean weight difference was 3.8% for Breaux Bridge and 11.5% for Kentwood. The lowest standard deviation was at the Breaux Bridge site with 3.1% at the 15,000 lb. range (2 vehicles). The standard deviation for all 3S2 second tandems compared at Breaux Bridge and also at Kentwood was 12.1%. Figure 12 presents 3S2 second tandem data points with statistical lines.

TABLE 10

PERCENT DIFFERENCE BETWEEN PORTABLE AND STATIC SCALES FOR THE SECOND TANDEM OF 3S2 TRUCKS*

Tandem Weight Midpoint (lbs.)	Number Of Vehicles	Percent Mean Wt. Difference	Standard Dev. (in percent)
BREAUX BRIDGE			
10,000	4	21.8%	11.0%
15,000	2	23.1%	3.1%
20,000	2	9.8%	4.3%
25,000	5	3.6%	11.0%
30,000	15	- 0.6%	10.2%
35,000	16	- 0.3%	9.5%
Total	44	Mean 3.8%	Mean 12.1%
KENTWOOD			
10,000	21	20.9%	11.9%
15,000	4	4.9%	16.6%
20,000	2	16.0%	5.9%
25,000	3	10.9%	6.3%
30,000	13	3.0%	7.2%
35,000	13	5.5%	4.9%
Total	56	Mean 11.5%	Mean 12.1%

* (+) POSITIVE NUMBERS, PORTABLE   STATIC WEIGHTS
(-) NEGATIVE NUMBERS, PORTABLE   STATIC WEIGHTS
Tandem Weight Midpoint indicates midpoint of 5,000 lb. range
(Example: 30,000 Midpoint is 27,500   Tandem Wt.   32,500)

Portable and static scales are compared at both sites on all truck types in Table 11 with simple regression analysis. The slope constant is 1.107 and the y-intercept is 2.861 KIPS. The coefficient of correlation (0.971) for this data set comparison is better than the other two scale comparisons (Tables 4 and 8).

From Table 11, a linear relationship is evident from the T-tests on the slope and intercept at the confidence levels presented. One can assume that there is a near one-to-one relationship between the portable and static scales from the statistics available in Table 11.

TABLE 11

PORTABLE vs. STATIC
SIMPLE REGRESSION AT BOTH SITES ON ALL TRUCK TYPES
(GROSS WEIGHT)

Equation of the line	Portable = 2.861 + (1.017*Static) (Portable and Static in KIPS)
R^2 - Coefficient of Correlation	0.971
T-test on slope	Rejects null hypothesis that there is not a linear relationship at a 95.0% confidence level
95% confidence interval for the slope	0.988 = slope = 1.045
T-test on intercept	Rejects null hypothesis that the intercept = 0 at a 99.9% confidence level
99% confidence interval for the intercept	0.632 = intercept = 5.090

ANALYSIS OF WIM DATA

The WIM data collected during this study encompassed approximately 50,000 vehicles. Through manual traffic counts, vehicle distribution between lanes was determined. Out of the total truck traffic at the Breaux Bridge WIM site, 10.0% of the trucks were in the inside lane and 90.0% in the outside or travel lane. The distribution at the Kentwood site was 5.7% for the inside lane and 95.2% for the outside lane. The usual stream of traffic was interrupted near both of the WIM sites because of the weigh station operations. Trucks were required to leave the highway to be inspected for weight, licenses, size, etc.

A frequency distribution of 3S2 tandem loads at each WIM site is shown in Figures 13 and 14. The I-10 location (Figure 13) had more loaded tandem axles than unloaded. A loaded peak occurred at 33,000 lbs. with a frequency of 1450 tandem axles. The frequency of tandem weights in the 0- to 20,000-lb. range may be slightly higher than shown. The magnitude of the lower weighted trucks have some tandem weights which are less than the weighing threshold value of the WIM system. The weighing threshold was set at 1,800 to 2,000 lbs. per wheel. Therefore, these vehicles were eliminated if both sides of any axle were below the threshold limit.

The Kentwood site had more even distribution between loaded and unloaded trucks. The two plateaus in Figure 14 (12,000 to 15,000 lbs. and 30,000 to 34,000 lbs.) are in the 300 vehicle count range.

The total number of vehicles weighed in the study by truck type is shown in Figures 15 and 16. In both figures, the vehicle type that occurs most often is the 3S2 (Breaux Bridge = 22,000; Kentwood = 5,500). All other vehicle counts are smaller but do contribute slightly to the equivalent axle loading.

There were many weights collected that were eliminated during analysis. Some of these vehicles were not categorized by the data conversion program because of axle spacings that did not fit a standard type. These nonstandard types occurred when there were: (1) speed loop detection errors, (2) lightly weighted axles which were under the WIM weighing threshold value, (3) nonstandard vehicle types, or (4) extra axles created by the transducer signal bouncing across the threshold value during the weighing of one axle.

WIM overweight vehicles accounted for 23.3 % for both sites combined. In Table 12, WIM, static, and portable scales are compared to show when a vehicle was overweight according to the three methods during the study period. 3S2 vehicles represent

TABLE 12

CUMULATIVE NUMBER OF OVERWEIGHT VEHICLES FOR BOTH SITES

Vehicle Type	WIM	Static Scales	Portable Scales	Total Population
DBL5	2	0	2	6
DBL6	0	0	4	5
2-AXLE	0	0	0	9
2S1	0	0	0	3
2S2	1	0	0	15

3-AXLE	0	0	0	4
3S2	30	16	36	102
3S3	1	1	1	2

almost all overweights in the table. WIM and the portable scales indicated more overweight vehicles than the static scales (used as the standard). A vehicle is considered overweight based on the parameters in Table 13. For 3S2, 102 trucks were compared: WIM overweight = 30, static overweight = 16, and portable overweight = 36.

TABLE 13

VEHICLE OVERWEIGHT PARAMETERS (INTERSTATE HIGHWAY)

Vehicle Type	Number of Overweight Single Axles	Number of Overweight Tandem Axles	Maximum Allowable Gross Wt.
2 axle, 6 tire	2 (if 20 KIPS)	X	40 KIPS
3 axle	1 (if 20 KIPS)	1 (if 34 KIPS)	54 KIPS
2-S-1	3 (if 20 KIPS)	X	60 KIPS
3-S-1	2 (if 20 KIPS)	1 (if 34 KIPS)	74 KIPS
2-S-2	2 (if 20 KIPS)	1 (if 34 KIPS)	74 KIPS
3-S-2	1 (if 20 KIPS)	2 (if 34 KIPS)	80 KIPS
3-S-3	1 (if 20 KIPS)	1 (if 34 KIPS)*	83.4 KIPS
DBL 5	5 (if 20 KIPS)	X	80 KIPS
DBL 6	4 (if 20 KIPS)	1 (if 34 KIPS)	80 KIPS

X=Not Applicable

KIPS = 1,000 lbs.

* also has tridum set of axles which are overweight if 42,000 lbs.

From the WIM data available, an average hourly WIM vehicle count for weekdays and weekends was developed, as shown in Figures 17 and 18. Weekend traffic at both sites was about 60% of weekday traffic; however, not all hours were available for the weekend at Kentwood.

As shown in Table 14, the Breaux Bridge data contained 21.1%
vehicles which were deleted, whereas the Kentwood data contained a 15.1% deletion. It is thought that with appropriate software

TABLE 14

VALID VERSUS INVALID WIM MEASUREMENTS

NUMBER OF VEHICLES WEIGHED

BREAUX BRIDGE

VEHICLE	INVALID	VALID
DBL5	3	750
DBL6	0	163
0DD	8146	0
2AX	26	4940
2S1	4	539
2S2	8	1137
3AX	38	788
3S1	8	907
3S2	75	21787
3S3	44	237
TOTAL	8352 (21.1%)	31248 = 39600

KENTWOOD

VEHICLE	INVALID	VALID
DBL5	3	449
DBL6	2	89
0DD	1351	0
2AX	6	1415
2S1	2	238
2S2	14	549
3AX	30	179
3S1	4	64
3S2	58	5443
3S3	34	39
TOTAL	1504 (15.1%)	8465 = 9969

modification to the WIM computer, fewer low weight misweighs would occur. One possible solution would be to discriminate which vehicles to keep by a pre-determined vehicle length. Automobiles

would be eliminated, but lightly weighted trucks would be kept. In addition, a lower weighing threshold could be used to give a better average value for each axle weight.

EAL DATA

An important type of information available from WIM data is equivalent 18-kip axle loading (EAL), a factor used in pavement design. For a single axle with a load of 18,000 lbs. (18-KIP), the EAL = 1.00. EAL factors vary in magnitude for different pavement types. Rigid pavement factors were used in the following analysis.

Numbers have been developed by American Association of State Highway and Transportation Officials (AASHTO) to cover the weight ranges needed to evaluate axle weight data for EAL information(4). There are rigid design numbers available for single, tandem and tridum axles (see Equivalency Tables in Appendix). As can be seen, the relationship between load and pavement EAL is not linear. The following single axle weights and corresponding EAL's display an apparent exponential change: 18K = 1.00, 22K = 2.38, 36K = 18.3 (rigid pavement p_t= 2.5 where p_t is the terminal serviceability index, slab thickness = 10 inches).

By using these tables and linear interpolation between 2,000 lb. ranges, an EAL was given to each axle or axle group. For one truck type, adding all EAL's for each axle or axle group gives the total 18-kip EAL for the truck. In this report the total 18-kip truck EAL will be referred to as the F FACTOR. For each truck type, a mean F FACTOR was developed. When enough data is averaged, the mean F FACTOR multiplied by truck volume for each truck type per 24 hours at a particular site will equate to the average daily loading (ADL). Design factors representing each truck type were developed by combining WIM axle weight data (by truck type) and AASHTO axle load equivalency factors.

Figure 19 shows 3S2 Breaux Bridge F FACTOR distribution for rigid pavement for intervals of 0.25 EAL. There is a large peak at the 0.25 level, which is related to approximately 5,200 unloaded trucks (low EAL's). At the 0.50 level, there are an additional

1,000 trucks recorded, which are still unloaded trucks. The next peak is broad, between 2.75 and 3.50 EAL's, and is more significant than the first two peaks because of higher EAL and total frequency of vehicles. For this reason, the magnitude of the initial large peak can be misleading in significance. From Table 15, the mean F FACTOR (rigid) is 2.35 at the Breaux Bridge location, which is lower than the broad peak between 2.75 and 3.50 due to the influence of unloaded trucks. The mean F FACTOR (rigid) is 1.87 for 3S2's at the Kentwood site, which indicates relatively higher truck loadings at the Breaux Bridge location (Table 15).

The mean equivalency loading per truck type developed from loadometer studies is also shown in Table 15, and is generally applied as a statewide average in pavement design. The 3S2 F FACTOR from WIM data at Kentwood and the 3S2 factor from loadometer data are approximately equal, 1.87 and 1.749, respectively. The mean factors for 3S2's computed from WIM data collected at Breaux Bridge was found to be 32.6% higher than the loadometer factor representing a statewide average. This is attributable to the large amount of loaded trucks vs. unloaded trucks occurring in the traffic stream of this east-west interstate route. WIM data for 3S2 trucks at Kentwood indicated a 5.5% higher loading factor than the state loading factor.

TABLE 15

CALCULATED LOAD EQUIVALENCY FACTOR BY VEHICLE TYPE
(MEAN F FACTOR - RIGID PAVEMENT)
(pt=2.5,Depth=10")

VEHICLE TYPE	NUMBER OF VEHICLES	MEAN VALUE
	BREAUX BRIDGE	
DBL5	750	2.46
DBL6	163	1.48
2AX-6 tire	4723	0.12
2S1	539	0.35
2S2	1137	0.72
3AX	788	0.39
3S1	907	0.14
3S2	21787	2.35
3S3	237	2.61
	KENTWOOD	
DBL5	449	1.49
DBL6	90	1.09
2AX-6 tire	1386	0.06
2S1	238	0.25
2S2	549	0.41
3AX	179	0.23
3S1	64	0.11
3S2	5443	1.87
3S3	39	3.03
	TRAFFIC & PLANNING'S STATE AVERAGE Loadometer - Portable Static Scales	
DBL5		1.840a
DBL6		N/A
2AX-6 tire		0.168
2S1		0.502
2S2		0.989
3AX		0.578
3S1		0.989
3S2		1.772
3S3		2.873b

N/A - Not Available   a - Calculated by LTRC, based on

77,000 lb. Gross Weight, b - From previous WIM data vehicle loaded 50% of the time

CONCLUSIONS AND RECOMMENDATIONS

1. Measurement comparisons between portable and static scales indicated the least overall amount of standard deviation. The other two weighing pairs (WIM vs. static, WIM vs. portable) were only slightly higher degrees of deviation.

2. From linear regression analysis, there is high degree of correlation between WIM, static, and portable scales. Therefore, the WIM equipment can be useful for gathering highway planning data.

It is recommended that the department expand the number of WIM sites across the state to provide an improved vehicle loading data base. This can provide information to adjust pavement thickness design or adjust overlay thickness for individual highway systems. The WIM equipment can be used to supplement or replace the existing loadometer study methods. Due to installation and maintenance problems involved with the WIM system used in this study, it is recommended that a portable WIM system to be evaluated.

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APPENDIX A

AASHTO Loading Equivalency Factors

Weigh-In-Motion (WIM) is a method of weighing vehicles at highway speeds with the use of scales on or flush road surface. It has been used experimentally in Louisiana since 1976, but until recently little was done to accuracy and usefulness as a highway design or planning tool. In this study, two WIM locations were selec permanent Louisiana Department of Transportation and Development (LDOTD) scales to provide weight com between dynamic (WIM) weighing and static (stationary) weighing. At present, the LDOTD Traffic and Plannin collects weights every other year at 12 sites for approximately four hours at each site, using portable scal procedure is very labor intensive, requiring 10 to 15 persons, and provides only a small data base. Using the WIM a large data base was collected over an 18-month period utilizing only 2 to 3 persons.

After processing the WIM data, between 80 to 85% of WIM vehiclescollected were usable for analysis. Manu counts wereused to supplement WIM vehicle counting. Statistical analysisshowed that there is very good co between WIM, static and portable scales. An analysis of the WIM data was used tocalculate EAL (18-kip equiva load) design factors at both sites. Based on the accuracy of the WIM system established in this study, it was recom that WIM equipment be used at various locations to show variations of truck loading for design purposes.