# Research Report on Electronic Highway Scales for Weighing Trucks in Motion

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ABRIDGMENT

•THE NEED for a dependable method of weighing the axle loads of moving vehicles has long been recognized by those agencies and individuals concerned with the planning and operation of the highway system. In the past 15 yr, many researchers in the United States (1, 2, 5, 12, 13, 17, 18) and in Europe (3, 4, 14, 15, 16) have attempted to develop such a method. Several state highway departments have made experimental installations of dynamic weighing devices with varying degrees of success (7, 8, 9, 10, 11).

The paper describes the construction, installation, testing and performance analysis of three types of dynamic electronic highway scales: (a) the Taller-Cooper, a commercially developed four-load cell scale; (b) the broken bridge, an adaptation of a German prototype employing two load cells (16, 21); and (c) the beam-type scale (12, 19), an experimental scale with a pair of instrumented aluminum beams as the weight sensors. The research was done by the Department of Civil Engineering of the University of Kentucky in cooperation with the Kentucky Department of Highways and the U. S. Bureau of Public Roads (23). The project was started in 1960 for the purpose of determining the best mechanical configuration for a scale which would perform the dynamic axle weighing function in an overall data-gathering system.

The testing program was carried out by installing the Taller-Cooper and broken bridge scales in the approach ramp to a truck weighing station on I-64. The program was divided into two phases. The first consisted of a series of runs across the scales with a truck of known axle weights, varying the speed and the amount and method of vertical stabilization (preload). The second series utilized trucks diverted from the I-64 traffic stream; speed was not controlled, but the preloading variables were again introduced. Static weights of the axles of each diverted vehicle were obtained at the weight station. A similar program was conducted for the beam-type scale.

In analyzing the test data, the basis of comparison was the deviation of the dynamic axle weight as measured by each scale from the known static weight. The characteristic output waveforms obtained from the weight measurements by each of the scales were also compared. Because of differing mechanical configurations and methods of mounting the transducers, each scale produced a distinct output waveform for the same applied load.

Some specific conclusions were reached from the study:

1. The deviations of dynamic axle weights from static weights over a range of crossing speeds follow a pattern for a given set of approach and site conditions.
2. The addition of preload to the scale platform does not, in general, reduce the differences between the recorded dynamic and static axle weights, but it does stabilize the weighing system and tends to increase the consistency of the linear relationship between the dynamic weights and the corresponding static weights.
3. Heavy coil springs are more satisfactory than stiff rods and turnbuckles for applying preload to the scale platforms because they do not reduce the sensitivity of the

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recording system (20) and their greater resilience reduces the effect of temperature changes on the preloading mechanism.

4. Under zero preload, the broken bridge scale is more sensitive to high crossing speeds than the Taller-Cooper scale. The addition of a heavy preload is more effective in stabilizing the output of the Taller-Cooper scale than it is for the broken bridge scale.

5. Limited tests of the beam-type scale show it to be a feasible weighing system comparable in performance to the other two scales.

6. Any of the three scale types will do a creditable job of detecting overloaded vehicles.

7. Simultaneous measurement of the dynamic axle weights of a test vehicle by axle housing strain, accelerometer and the electronic scales showed that, within the limits of the probable chart reading error, the output of the scale indicates the actual applied load and that any of the three methods will, if properly calibrated, yield a true measure of the dynamic axle weight. This finding confirmed the results of previous research (6).

8. For an individual axle the dynamic weight measurement is equal to the static only in isolated and unpredictable instances. However, if its characteristic behavior is known, any one of the scales can be used to obtain a reasonably accurate estimate of the gross static tonnage passing over a section of highway during a given period of time.

9. The choice of a particular type of scale for an electronic in-motion weighing system will be determined by the ultimate form of the recorded weight measurements, and by the use to be made of the measurements (22).

10. The actual loads applied to the highway pavement by the wheels of a moving truck vary from the static weights over a wide range; therefore, dynamic axle weights rather than static should be considered in establishing pavement design criteria.

Future research in the field of dynamic weighing should include:

1. The development of a portable scale designed to be installed in the pavement at previously prepared locations in the state and Federal highway systems where the axle load characteristics of the traffic are desired;

2. A feasiblity study of the use of the dynamic scale to measure speed, volume and axle spacing in addition to axle weight;

3. The installation of an electronic scale in the approach to an enforcement weighing installation to test the practicality and desirability of culling out lightly loaded trucks from those required to stop for static weighing;

4. A study of a very large sample of dynamic weight recordings to determine the feasibility of deriving approximate static weights by a statistical consideration of the effects of specific approach conditions, crossing speeds, axle location, scale type and preload; and

5. Studies of the ranges of variation in the amplitude and oscillating frequency of the in-motion axle weights of trucks commonly used including consideration of vehicular variables such as body type, suspension systems, loading, and environmental factors such as temperature, wind velocity vectors, and driver habits.

## REFERENCES


1. Normann, O. K. Weighing Vehicles Static and In Motion by Electronic Scales. SAE Trans., Vol. 63, p. 373, 1955.
2. Heatley, J. J. Weighing Vehicles in Motion. AASHO Conv., Papers and Discussions, pp. 70-71, 1956.
3. Dearinger, J. A. Dynamic Weighing of Vehicles. Public Roads, pp. 200-210, Oct. 1961.
4. Puckett, R. E., and Knight, S. P. A Survey of Components and Systems for Measuring Dynamic Loads. Univ. of Kentucky, Eng. Exp. Sta. Bull., Vol. 16, No. 2, Dec. 1961.
5. Normann, O. K., and Hopkins, R. C. Weighing Vehicles in Motion. Highway Research Board Bull. 50, 1952. 27 pp.
6. Hopkins, R. C., and Boswell, H. H. A Comparison of Methods Used for Measuring Variations in Loads Transferred Through Vehicle Tires to the Road Surface. Public Roads, Vol. 28, No. 10. p. 221, Oct. 1957.

7. Weighing Trucks in Motion. Iowa State Highway Comm., Oct. 1954.
8. Electronic Weighing Equipment. Minnesota Dept. of Highways, Nov. 1956.
9. Stiffler, W. W., and Blensly, R. C. Weighing Trucks in Motion and the Use of Electronic Scales for Research. Oregon State Highway Dept., Nov. 1955.
10. History of Repairs and Calibrations of the Electronic Scales, Baldock Freeway Test Section. Oregon State Highway Dept., Nov. 1956 to Dec. 1957.
11. Blythe, D. K. Memorandum to Research Team, Inspection of Electronic Scale at Michigan State Highway Department Research Lab. July 12, 1960.
12. Maggard, S. P. Weighing Vehicles in Motion. Unpubl. M.S. thesis, Univ. of Kentucky, 1957.
13. Lee, Edward C. A Portable Electronic Scale for Weighing Vehicles in Motion. Unpubl. M.S. thesis, Mississippi State College, May 1956.
14. Edholm, S. Methods of Traffic Measurement—Determination of Number and Weight of Vehicles. Highway Research Board Bull. 338, pp. 81-99, 1962.
15. Trott, J. J., and Williamson, P. J. An Apparatus for Measuring, Classifying and Counting the Wheel Loads of Moving Vehicles. Dept. of Sci. and Ind. Res., Road Res. Lab. (Great Britain), Res. Note No. RN 34871JJT.PJW, May 1959.
16. Schwaderer, W., and Reimund, W. Die Automatische Achslastwaage bei Grunbach (Remstal). Strasse und Autobahn, pp. 41-47, 1959.
17. Epsco, Inc. Feasibility Study, Automatic Weighing of Vehicles in Motion and Collection of Traffic Data by Electronic Methods. Michigan Proj. 52F-26, March 1961.
18. Epsco, Inc., Michigan State Highway Dept. and U. S. Bureau of Public Roads. Final Report, Part A and Part A (abridged), Automatic Weighing of Vehicles in Motion and Collection of Traffic Data. Oct. 1963.
19. Investigation of Stresses in the San Leandro Creek Bridge. Univ. of California, Inst. of Transp. and Traffic Eng., Res. Rept. No. 13 and Appendices to Res. Rept. No. 13 A, May 1953.
20. Puckett, Russell E., and Gover, J. E. Comparison of Two Methods for Preloading Electronic Scales. Public Roads, pp. 181-185, June 1963.
21. Schimpeler, C. C. A Description and Analysis of the Broken Bridge Type Electronic Scale. Unpubl. M.S. thesis, Univ. of Kentucky, 1962.
22. Puckett, R. E. Selecting the Best Scale for In-Motion Weighing. Public Roads, pp. 45-47, Aug. 1964.
23. Weighing Vehicles in Motion—A Summary Report. Kentucky Dept. of Highways, Div. of Res., Proj. KYHPR-61-27; HPS-HPR-1(25), April 1964.