The Evolution of Weighing-in-Motion in the United States

By

Perry M. Kent

As I stand here today, I have been asked to give to you a brief overview of the history of weighing-in-motion in this country. There are others who may be able to do a better service to various parts of the story, but I have been deeply involved for more than thirty years. And I have probably experienced a little bit of the story for the last thirty years or more. The most intriguing part of all of this is the fact that all of this history of weigh-in-motion has taken place over the time span of just over fifty years.

But let me not step over the reason we got into this situation in the first place. Thaddeus Fairbanks patented the first common weighing device for large quantities in 1831. With the development of major roads between cities and towns, it became desirable to develop large platform scales that could weigh an over-the-road vehicle. Initially, weighing was carried out using large platform scales when available. These scales were balanced on low-friction surfaces and counter-balanced with a series of lever arms connected to the weighing beam. The weighing beam had several weights of different size and a small sliding weight which were used together to balance the weight on the platform. A true and rigid foundation was required and while they were accurate, they were also expensive.

Later, it became apparent that weight must be enforced to protect the roads. However, such scales were rarely available for use directly for enforcement or weight surveys for highway use unless they were located on a main truck route. Because truck weight enforcement and truck weight surveys were concerned with the weight of each axle, it was necessary to obtain a separate loading as each axle came onto the platform. This was time-consuming because most scales required manual adjustment of a major and a minor counterweight. By the 1930s, it was increasingly evident that proper administration of the highway program would require a formalized data collection effort, and that as a part of that effort, truck issues could only be addressed by the development and use of a simple system for collecting axle weight information.

It was about that time that we were introduced to what we have come to know as the portable static scale, or as it was to many of you, the loadometer. The company name actually is Loadometer, and it is still used as a reference to this day. It allowed us to weigh a vehicle axle by axle, though it was very time-consuming. It allowed us to operate along main truck routes and to collect important survey data. But as we all know, this was not going to be the final answer.

Returning to the subject of weighing-in-motion, we only have to go back to 1950 to learn about the pioneering efforts of O. K. Normann and Dick Hopkins of the Bureau of Public Roads (BPR) using military surplus strain gage load cells under a concrete slab. In their attempt to weigh trucks, they also began developing a low-mass wheel-force transducer using the strain-gage technology of the time. Following this work, several of the States proceeded with similar tests, though their failures usually centered on the massive concrete slab.

Later in the 1950s, the University of Kentucky experimented with spring damping of the BPR and broken-bridge designs, though without much success. They also attached strain gages to the aluminum girders of a special bridge section without overcoming the mass-oscillation problem. Also during the 1950s, Dr. Charles Scheffey glued strain gages on bridge girders in California to study stress patterns in bridges. Twenty years later, he had determined that this was also a method for weighing trucks.

So as others have observed, we can look back now and see that more than thirty years ago, virtually all of the basic principles that are in use today for weigh-in-motion transducers had already been tried and implemented. The real problem was that adequate electronic instrumentation was not yet available at that time.

In the 1970s began the time of attempting to do more with less. That is, people were going to try to weigh vehicles with smaller and smaller sensors. But the people involved in this work also had to maintain some semblance of communication with each other. The State of Florida hosted a meeting right here in Orlando in 1974 that generally addressed all phases of data collection. Those who attended this early conference were introduced to one of the first implemented weigh-in-motion systems in this country.

After that, the State of New Mexico hosted a meeting in Santa Fe that focused more directly on the topic of weighing-in-motion, and concentrated on more of the upper-level management personnel. There was no doubt that continued communication was of primary importance. At that period in our lives, who could have imagined something called "e-mail?"

It was in the early 1970s at Case Western Reserve University that a portable weigh-in-motion system was being developed in research sponsored by the Ohio Department of Transportation. This system used strain-gage load cells clamped to the lower flange of support beams on the under side of a highway bridge. Various devices attached to the roadway surface were used as axle sensors. The equipment was marketed in the United States by Bridge Weigh Systems. This was the offshoot of the effort to monitor the stresses and strains on a bridge structure by instrumenting the girders with strain gages.

Within that same time frame, the capacitance mat was being developed in South Africa. The unit consisted of layers of rubber and steel, and was designed to convert load into a change in capacitance. It was then introduced in the United States as part of Federal Highway Administration Rural Transportation Assistance Program. I can still remember taking this rubber mat out of the wooden crate in Phoenix, Arizona and wondering how we were going to weigh vehicles with it.

Coincidentally, at about that same time, a research company that was involved in deep-sea research work had developed a capacitance mat based upon the technology of fiber optics. The Federal Highway Administration was in search of a low-cost weigh-in-motion system at the time. And although this company had a working prototype that they had demonstrated for me, the projected market cost for it was far too high.

In 1983, the first Weigh-in-Motion Conference sponsored by the Federal Highway Administration was held in Denver, Colorado. In reality, this was an experiment to see if there was enough interest in the subject to draw people from around the country. Those of us who were there now know just how successful it was and how much this meeting was needed. These conferences have been our way to exchange experiences and ideas along the way, helping us all in the end. Can any of you remember your first look at the installation and operation of a capacitance mat?

It was also in this approximate time frame that a small group of individuals got together at a meeting of the American Society for Testing and Materials in San Antonio, Texas to initiate an effort to develop a standard specification for all weighing-in-motion devices. Led by Dr. Clyde E. Lee, this group worked for several years in the writing of a document that would serve as a tool to enable all such weighing devices to be measured and compared against one standard. I mention the efforts of ASTM because the work done there has been very important in establishing an understanding between purchasers and vendors of highway data collection equipment.

One of the first of the new breed of sensors was the piezo-electric cable patented by Philips in 1971. After many years of testing and analyses in the United Kingdom and elsewhere in Europe, this system was introduced in the United States in 1986 in a Federal Highway Administration Demonstration Project. The sensors were installed in the State of Iowa in concrete pavement and in the State of Minnesota in asphalt pavement. The results seemed promising, but it became obvious that the condition of the pavement itself held many of the secrets to success.

This piezo-electric cable project was the leadoff for the rest of Demonstration Project 76, which was being developed at that same time. The purpose of this phase of the project was to take the technology of weighing-in-motion around the country. This included taking the actual equipment, to discuss it, to install it in a temporary mode, and then to operate it. This project also included speed, volume, and classification equipment, along with the weigh-in-motion equipment. All of the manufacturers were invited to participate, and their equipment was included in the demonstration. Spending three full days in each State, forty-three States, the District of Columbia and Puerto Rico were visited over a two and a one half year period.

A low-cost bridge weigh-in-motion system was developed under the National Cooperative Highway Research Program Project 3-36. The objective of the study was to conduct a field evaluation of the system with the cooperation of several State Departments of Transportation. This was an enhanced version of the system developed some twenty years previously. This program was conducted in 1990 and 1991.

At the 1996 NATMEC conference held in Albuquerque, New Mexico, many of you were introduced to the quartz piezo and the piezo film. In addition, a new term was added to the menu of entrees … the brass linguini! These technologies have undergone several phases of field-testing, and are currently being marketed and installed.

Let me return to something that I had mentioned earlier. And this had occurred nearly twenty years ago. That was my introduction to the fiber optic capacitance mat. This technology has now returned to the forefront. Presently, we have companies working on fiber optic weighing systems that would install in the pavement much the same as the piezo sensor. Researchers are looking at the advantages and disadvantages of the fiber optic sensors as compared to the piezo sensors.

And so the industry and the research have progressed, and the age of the computer has made its way into our lives. And we have moved from the massive platform scales and the concrete slabs of the past to the tiniest of sensors of today, all in search of the elusive goal of an accurate axle weight.