Comparison of Weight Data Collected at Weigh-in-Motion Systems on the Same Route

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An analysis has been made of weigh-in-motion (WIM) data that were collected by continuously operating systems at three different sites on the same route. The analysis examined the gross weight distribution of 5-axle tractor-semitrailers. Each direction had its own unique pattern. The eastbound 5-axle tractor-semitrailers were predominantly loaded and showed a similar pattern at all three WIM stations. The westbound 5-axle tractor-semitrailers were predominantly empty and showed the same pattern at the three WIM stations. One result of these consistent patterns at the three WIM stations is that, as a minimum, on selected routes where long-haul loading characteristics (origin-destination, commodities hauled, etc.) are known, data users, such as forecasters, can confidently use weight data collected at one location and apply it to another location on that route. A second result is that these repeating patterns make it possible to monitor the calibration of WIM systems. When a shift in the weight distribution takes place at one site while remaining constant at the other two, it indicates a possible change in calibration. These changes in calibration are readily observable. The techniques demonstrated here can also be used to analyze data collected at WIM sites that may be distant from other WIM sites.

In recent years, there has been a dramatic increase in the number of weigh-in-motion (WIM) sites in many states. The Minnesota Department of Transportation (Mn/DOT) also has increased its sites, primarily to meet the needs of the Strategic Highway Research Program (SHRP). The installation of continuously operating WIM systems at an increasing number of sites provides the analyst with the opportunity to look for patterns that repeat at a number of sites. This report looks at data that are repeated on a given route.

The weight data studied were those collected for 5-axle tractor-semitrailers. They are the principal trucks carrying cargo long distances in Minnesota. They typically contribute 70 to 90 percent of the equivalent single-axe loads (ESALs) to Minnesota's pavements.

Weight data from three sites located on one route, Trunk Highway 2 (TH-2), were selected for study. TH-2 is an east-west route in the northern part of the state. The sites, listed from west to east, are located as follows:

1. East of TH-32,
2. On the Bemidji Bypass, and
3. East of Deer River.

They are numbered Sites 1 through 3, respectively. It is about 110 km (70 mi) between Sites 1 and 2 and 90 km (55 mi) between Sites 2 and 3. All three sites are on a four-lane highway. Sites 1 and 3 have bending plate scales, whereas Site 2 has hydraulic load cell. The data used in this report are from the right lane only. That is where most of the 5-axle tractor-semitrailers travel, and it is also the design lane.

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The weight pattern on TH-2 is characterized by the presence of primarily loaded 5-axle tractor-semitrailers eastbound and empty 5-axle tractor-semitrailers westbound. The principal commodity moved here is grain from North Dakota to the Great Lake ports at Duluth-Superior. Grain also moves eastbound (hence the loaded trucks), but fewer loads of various types move westbound (hence the unloaded trucks). Pulpwood is also moved at Sites 2 and 3, and general cargo is moved at all three sites.

The number of 5-axle tractor-semitrailers per week increases during the move from Site 1 to Site 3. Site 1 has about 750, Site 2 has about 1,600, and Site 3 has about 1,700 vehicles per week. There are no large 5-axle tractor-semitrailer generators or major intersecting routes between Sites 1 and 3, but there are smaller feeders that account for the change in volume. Consequently, given the long-haul nature of 5-axle tractor-semitrailer operations, it is likely that many of the 5-axle tractor-semitrailers monitored at Site 1 also pass through Sites 2 and 3. Also, the increase in 5-axle tractor-semitrailer traffic between Sites 1 and 2 have the same loading characteristics as those shown at both of those sites, so the weight loading pattern is the same. In analyzing weight data using the distribution of gross weight of 5-axle tractor-semitrailers, a minimum sample of 150 vehicles is recommended.

METHODOLOGY

The study and interpretation of WIM data and the methods used to determine its validity are still in the formative years. One issue that is open for discussion is the calibration of scales and the resulting validity of the weight data that is collected over an extended period—a topic that was discussed in an earlier report (*1*). The reintroduction of one of the key indicators used in that report is useful in interpreting the TH-2 data under examination here. That indicator is the distribution of the gross weight of 5-axle tractor-semitrailers. Of specific concern is the placement of the peaks for the empty and loaded trucks. The empty trucks should peak at about 12.7 to 14.5 Mg (28 to 32 kips), whereas the loaded trucks generally should peak at between 31.7 to 36.3 Mg (70 to 80 kips) on those routes where 36.3 Mg (80 kips) is the legal limit.

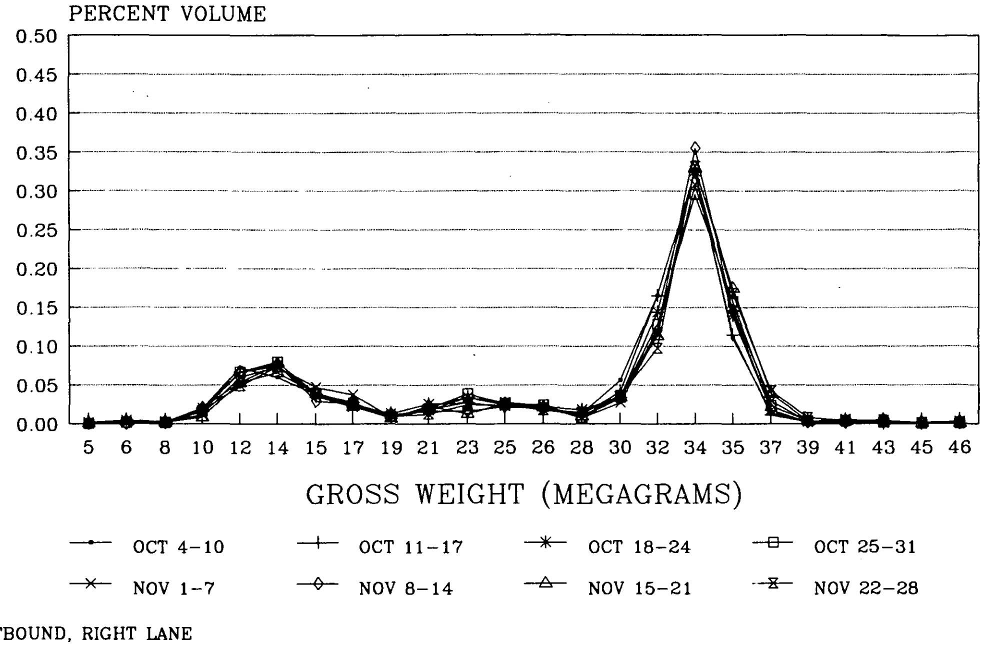


FIGURE 1 Distribution of gross weight of 5-axle tractor-semitrailers for Site 2.

DATA REPEATABILITY AT A SITE

The first step in the analysis of these data is to determine whether weights at a given site repeat week after week. Figure 1 shows the distribution of gross weight of 5-axle tractor-semitrailers at Site 2. This shows weight data from the eastbound lane for 8 consecutive weeks, beginning October 4, 1992. The gross weight is shown in megagrams, and the values shown represent the bottom of the range. For example, 12 represents 12 to 14 Mg (26 to 30 kips). This work was originally done in English and then soft-converted to metrics. Consequently, the weights on the *x*-axis for these figures do not progress smoothly. There are between 1,600 and 1,800 5-axle trucks in each of these weeks. This consistent pattern means that generally the same trucks are traveling this route each week and that they are carrying the same approximate load each week. That is the general nature of cargo movement on

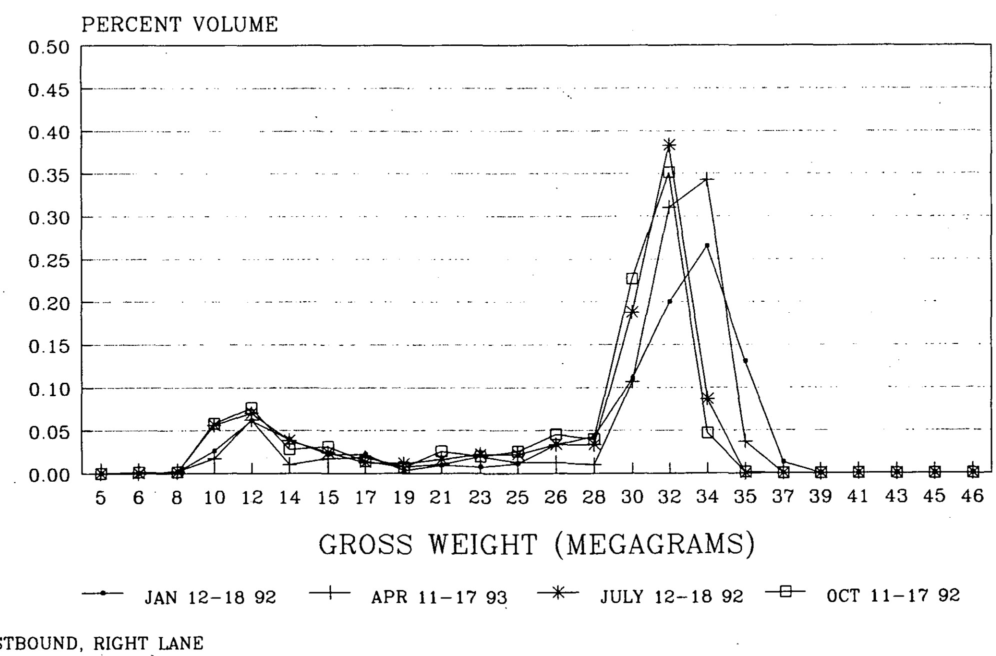
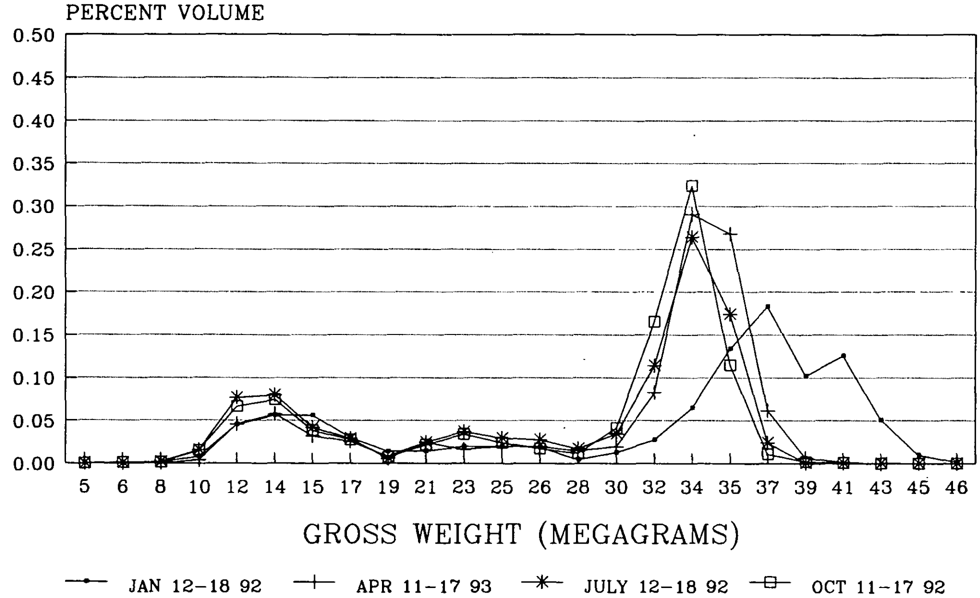


FIGURE 2 Distribution of gross weight of 5-axle tractor-semitrailers for Site 1.



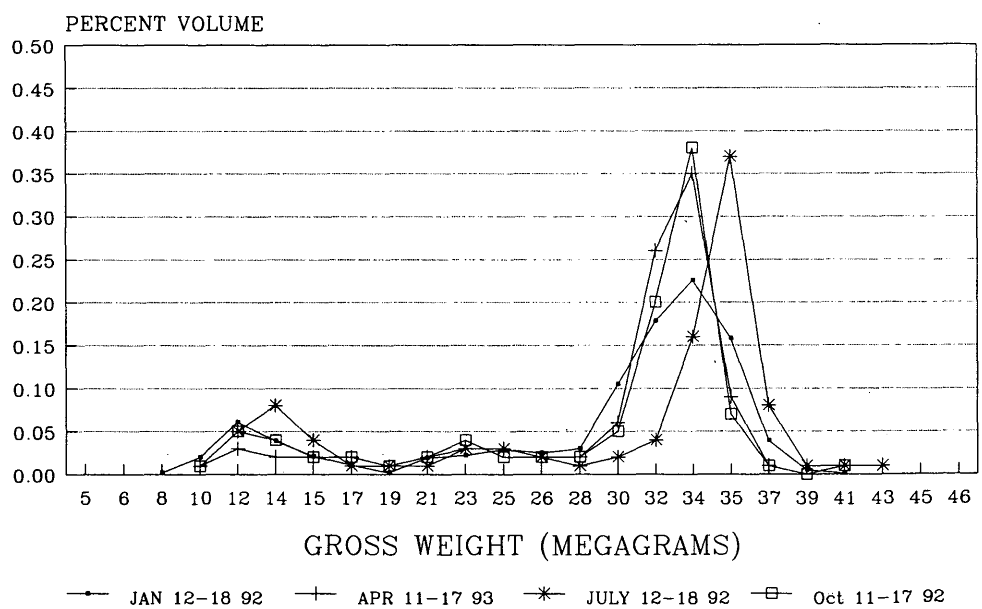
EASTBOUND, RIGHT LANE

FIGURE 3 Distribution of gross weight of 5-axle tractor-semitrailers for Site 2.

moderate- to high-volume truck routes. There is a strong tendency toward repeatability.

DATA REPEATABILITY BETWEEN SITES

Now that the repetitiveness of weight patterns at a specific site has been demonstrated, the next step is to analyze what is happening at the three sites over a period of time. For purposes of analysis in this report, 1 week was selected from each season of the year at each of the sites. This ensures that the data are as comparable as possible from site to site. Figures 2 through 4 show distributions for eastbound traffic for Sites 1 through 3, respectively, whereas Figures 5 through 7 show distributions for westbound traffic for those same respective sites. Three of the weeks are from 1992 and the other is from 1993. The week from 1993



EASTBOUND, RIGHT LANE

FIGURE 4 Distribution of gross weight of 5-axle tractor-semitrailers for Site 3.

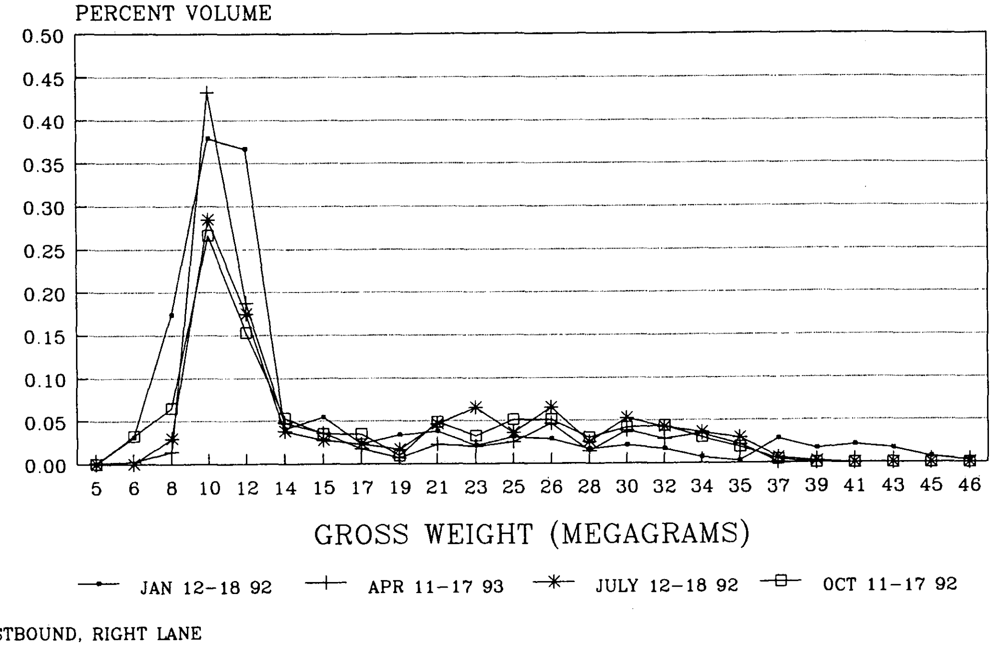


FIGURE 5 Distribution of gross weight of 5-axle tractor-semitrailers for Site 1.

(April 11–18) was included because not all three sites were operating in April 1992. Generally, these plots demonstrate that the same pattern exists over both time and space. They exist over time in that for each specific site throughout a year the same general pattern is repeated. They exist over space in that this same pattern repeats from site to site, spanning the 200 km (125 mi) between Sites 1 and 3. A more detailed examination of the data shown in these figures helps to interpret some of the seeming apparent inconsistencies in the data. In Figures 2 through 4, one of the larger observed differences occurs in Figure 3 during the week of January 12 through 18. The peak for the loaded trucks has shifted quite sharply to the right. There is a slight shift for that week in Figure 2 and no shift for that week in Figure 4. Although Minnesota allows trucks to haul an additional 10 percent during the winter, it is not clear if that additional hauling was taking place during that week in January because the data are inconsistent.

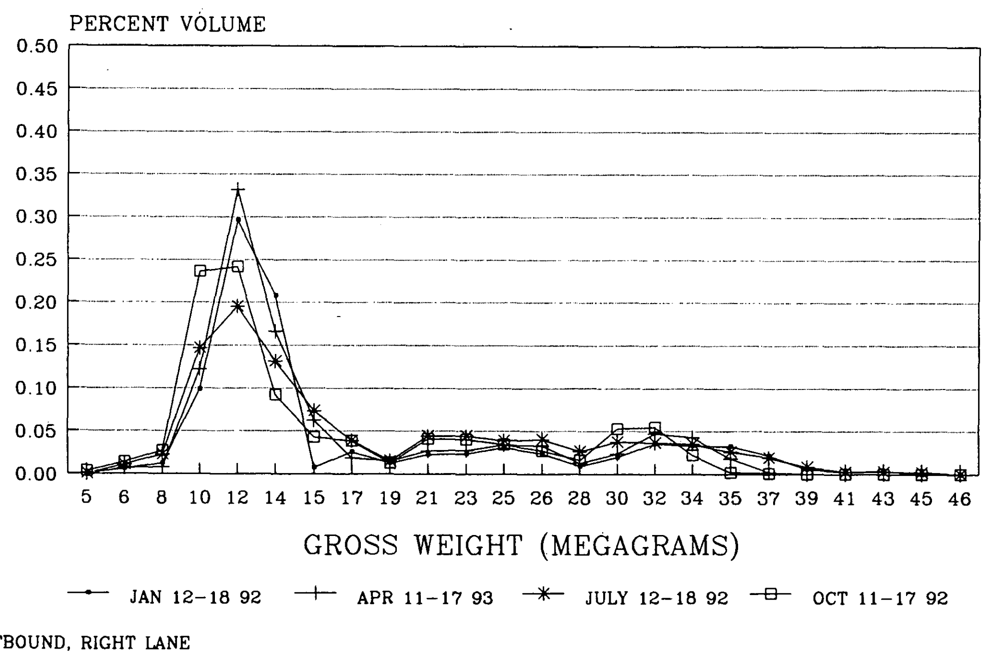


FIGURE 6 Distribution of gross weight of 5-axle tractor-semitrailers for Site 2.

A look at the peak for the empties for that week in Figure 3 shows a shift to the right, as was previously observed for the loaded trucks. Because both peaks for the January data in Figure 3 shifted and since there was no corresponding appreciable shift at the other sites, one can conclude that there was likely a drift in calibration that took place at Site 2 during that week.

A shift in the same direction for both peaks at a site likely means that there was a change in the calibration. Given that condition, if there is, for example, a 1.8-Mg (4-kip) shift for the empties, there will be about a 4.5-Mg (10-kip) shift in the peak for the loaded trucks. The percentage shift will be about the same for both peaks. A shift in one peak and not the other could be interpreted to mean that the data were valid. Although it is less pronounced, the same phenomenon occurs in Figure 4 during the week of July 12 through 18. The peaks for the empty and loaded both shifted to the right, whereas the other two sites did not show a shift in either peak.

In Figures 5 through 7, the most striking inconsistency is the week in October in Figure 7. The peak for the empty vehicles for that week differs from that of the other 3 weeks at that site. The peak for the loaded vehicles is also slightly different. Both peaks shifted in the same direction. The data appear to indicate a problem with calibration.

SHIFTS IN CALIBRATION

As already noted earlier, the calibration probably has been off for some of the lanes in this data set. By focusing on the peak for the weights of the empty vehicle, some differences are observable from one figure to another. Intuitive judgment supported by static weight data indicates that the peaks for empty 5-axle tractor-semitrailers should be in the range of 12.7 to 14.5 Mg (28 to 32 kips) (*1*). Using this criterion, Figures 2–4, 6, and 7 are properly calibrated, with the exceptions of the weeks previously discussed. Figure 5 is off quite sharply for 3 of the 4 weeks, with the weights peaking between 10 and 12 Mg (22 and 26 kips).

To simplify the issue as much as possible, the patterns in only two of the weeks (April and July) for Figures 5 through 7 will be examined. As has been pointed out earlier, because the scales are probably monitoring many of the same 5-axle tractor-semitrailers at these three sites, it is not surprising that the patterns are the same. Consequently, the empty vehicle peaks for April and July in Figure 5 should be the same in Figures 6 and 7. They are not. The former peaks between 10 and 12 Mg (22 and 26 kips), whereas the latter peak between 12 and 14 Mg (26 and 30 kips). To accept the weights from those 2 weeks as being valid at all three sites (Figures 5–7), it would have been necessary for the empty vehicles to secure 1.8-Mg (4-kip) loads between Sites 1 and 2 and for those loads to remain constant between Sites 2 and 3. The probability of there being 1.8-Mg (4-kip) loads available for most of those empty trucks between Sites 1 and 2 during those 2 weeks is highly unlikely. This difference has to be attributed to a drift in calibration.

Figure 8 illustrates another example of drifts in calibration. This figure shows 3 weeks of eastbound traffic at Site 3 in late 1991. Both the peaks for the empty and loaded vehicles shifted, and the shifts were all in the same direction. In this example, the peaks for November 3–10 were to the left, for December 15–22, in the middle, and for November 10–17, to the right. Loads carried by trucks can and do change. However, what typically takes place is that loaded trucks take on even larger loads, whereas empty trucks locate small loads. The weight of empty vehicles should not change appreciably. This means that there was a drift in calibration.

CONCLUSIONS

Two important observations can be made about the data examined here. The first is that in certain cases weight data collected at one

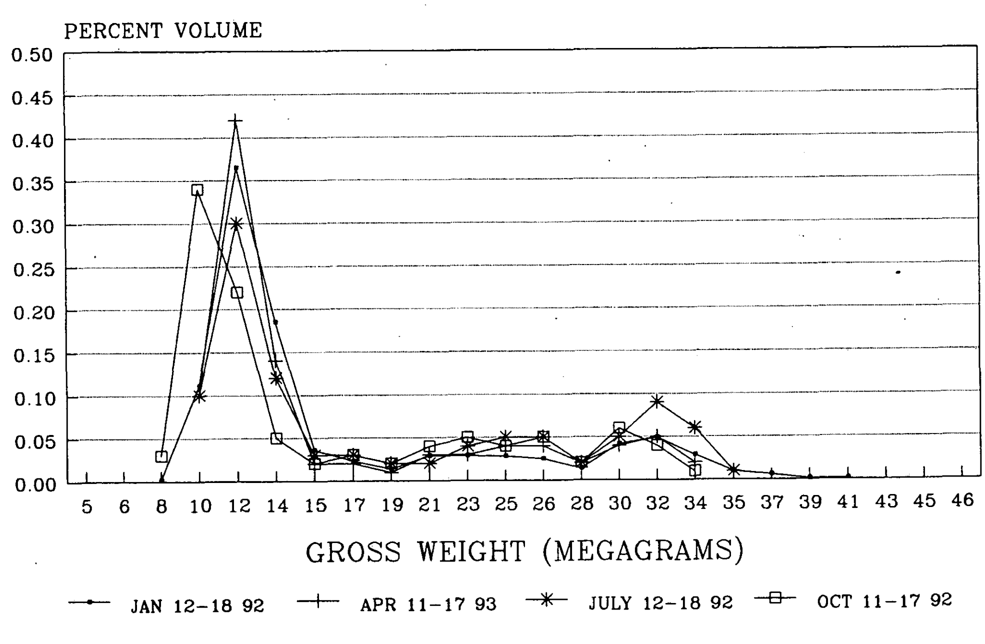


FIGURE 7 Distribution of gross weight of 5-axle tractor-semitrailers for Site 3.

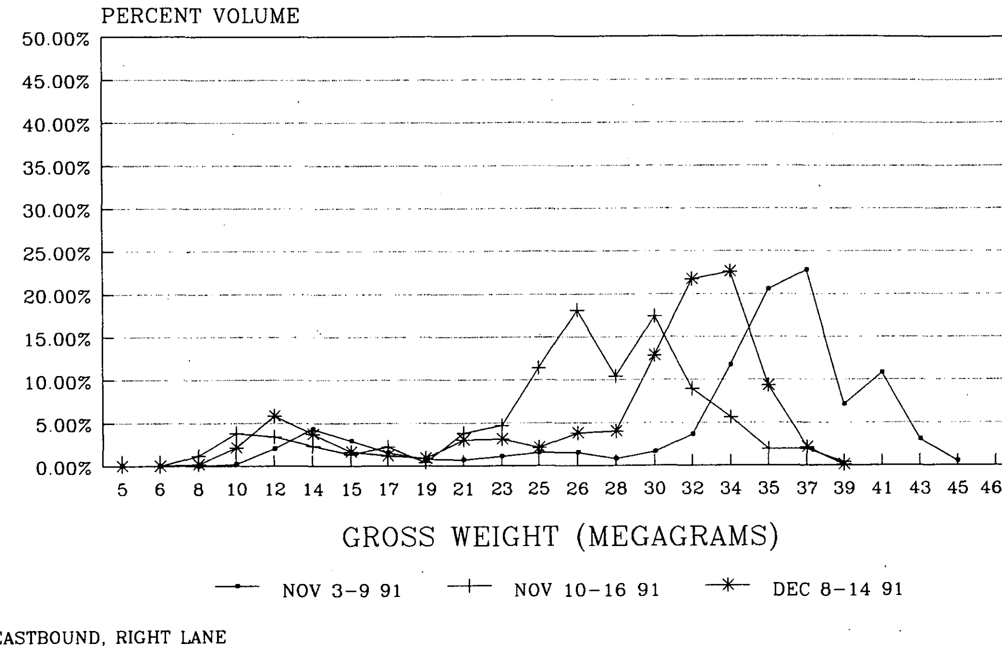


FIGURE 8 Distribution of gross weight of 5-axle tractor-semitrailers for Site 3.

site on a given route could quite confidently be used, perhaps by a traffic forecaster, at the other sites on that route. The directional patterns observed at these three sites were all similar. In fact, given some knowledge of the commodities hauled on the route and the origins and destinations of those commodities, the forecaster can probably apply those weight data to the entire length of TH-2 in Minnesota. Furthermore, it probably could be applied to other parallel routes in the area that have the same loading characteristics. For some projects, where it is known that the vehicle loading characteristics discussed earlier are similar, forecasters will be able to quite confidently use weight data collected at sites other than the specific location where they are stationed.

The second point is that by observing weight data in the format used here, it is possible to determine when there are probable drifts in the calibration. Even seemingly small drifts in calibration are significant because of the fourth-power relationship between weight and ESALs. This analysis can be done by comparing data from one site with those from another and also by looking at data from one site over time. Data that were collected during a drift in calibration should be set aside and not processed. A considerable amount of data should be collected and analyzed before a judgment is made about validity. Otherwise, any conclusions drawn may be erroneous. The exception would be in those instances where the system kept on collecting data during a major malfunction (*1*). The analyst needs to be as certain as possible that data that are in fact valid are not labeled as being invalid and vice versa. Experience in dealing with the data will be essential in eventually making the proper judgments.

Examination of data from three sites on the same route has shown that drifts in calibration do occur and that they are observable. Because this trend has been established, the analyst can apply the same techniques used here to data collected at other individual sites. There is no need for multiple sites on the same route to make this application. A sufficient amount of data collected at one site over a period of time plus time for analysis and consideration of the possible explanations for variations in the patterns provides what is needed.

REFERENCE

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