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# New Research on Pavement Damage Factors

Numerous factors contribute to deterioration of pavements and the consequent need to reconstruct, rehabilitate, or repair these pavements. These include environmental (weather) influences, dynamic interactions between pavements and vehicle speeds, numbers of tires per axle, tire pressures and suspension characteristics, and the frequency, spacing and magnitude of axle loads. Sub-base soil and terrain characteristics, as well as maintenance practices and the structure, materials, depth and construction quality of the initial pavement also play a role in determining pavement life.

The available research indicates that of these factors, by far the most important are the frequency, spacing and magnitude of axle loads. These are therefore the primary factors, along with environmental influences, considered in assessing responsibility for pavement deterioration.

Over the years, various sets of equivalence factors have been developed to compare the pavement stress imposed by different types and weights of vehicles. This article briefly compares the load-related damage factors from previous research with those from the new National Pavement Cost Model (NAPCOM) research.

## Previous Research

The pavement damage equivalence factors used in highway cost allocation, truck size and weight, and other pavement studies prior to the mid-1990s were based on the results of the American Association of State Highway Officials (AASHO) Road Test of the late 1950s and early 1960s. The results of this research were used to develop equivalent single axle load (ESAL) factors relating the pavement stress imposed by an axle of any given weight to that imposed by an 18,000-pound single axle. This weight was selected as the benchmark axle weight because it was the maximum legal weight of a single (dual-tired) axle at the time of the AASHO Road Test.

This research indicated that, on average, pavement wear increases at approximately the fourth power of increases in axle weight. Doubling the weight on an axle, in other words, results in an approximately 16-fold (i.e., two to the fourth power, or 2x2x2x2) increase in the amount of stress applied to pavements. The AASHO Road Test research and resulting ESAL factors were also the basis for the often-quoted statement that it takes 9,600 automobiles to do the same pavement damage as one fully-loaded, 80,000-pound, five-axle truck.

## New Research

For highway cost allocation studies (HCASs), the older AASHO Road Test results have now been replaced by those from the newer NAPCOM research. NAPCOM is a complex simulation model developed by the Federal Highway Administration in 1992 that further refines the deterioration-based method employed in the 1982 Federal HCAS. It uses information on specific, representative highway sections supplied by the states through the Highway Performance Monitoring System. NAPCOM models eleven different pavement

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***This issue of Policy Notes was written by John Merriss, Policy Section Manager, ODOT Policy Section, and does not necessarily reflect the views of the Oregon Department of Transportation or the Policy Section. Author can be reached by email at John.S.Merriss@odot.state.or.us or call (503) 986-3474.***

**Oregon Department of Transportation, Policy Section**
John Merriss, Policy Section Manager
555 13th Street NE, Suite 2, Salem, Oregon 97301-4178
(503) 986-3466

distresses such as faulting, fatigue cracking, thermal cracking, rutting and loss of skid resistance to estimate when pavement restoration will be required and determine expected pavement condition at the end of each year of the analysis.

The NAPCOM results and load equivalence factors (LEFs) developed from these results have been used in the 1997 Federal HCAS and the most recent national Truck Size and Weight Study, as well as the 1999, 2001, and 2003 Oregon HCASs. The NAPCOM results differ from those of the older AASHO Road Test research in two major ways:

1. Unlike the approximately fourth-power relationship established by the earlier research, NAPCOM estimates separate pavement wear relationships for each different distress modeled. For most, the exponent is considerably less than four. While the precise relationship differs depending on the type of pavement and distress being considered, the NAPCOM research suggests, on average, the exponent relating pavement deterioration to increases in axle weight is closer to 2.5 than 4. This means a doubling of axle weight results in an approximately 6-fold, rather than 16-fold, increase in load-related pavement damage.

   As with the older ESAL factors, separate LEFs have been developed for rigid (Portland cement concrete) and flexible (asphaltic concrete) pavements. Using a weighted average reflecting the overall mix of Oregon pavement types (about 93% flexible and 7% rigid) suggests it takes roughly 750 automobiles weighing 3,800 pounds each to do the same pavement damage as one fully-loaded, 80,000-pound truck. This is substantially lower than the 8,000-10,000 to one relationship derived from the older ESAL factors.

2. The second major finding of the NAPCOM research, which has received less attention than the first, is that weather and other non-load-related factors play significantly less of a role in pavement deterioration than suggested by the earlier research. This largely offsets the impact of the lower exponential relationship between pavement wear and axle weight, so that the overall responsibility of trucks and other heavy vehicles for pavement costs is approximately the same as under the older research.

   Use of the newer LEFs instead of the older ESAL factors in a HCAS, in other words, results in a shift of responsibility for pavement costs within the heavy vehicle classes, specifically from the heavier axle weight classes to the lighter and medium-weight axle classes, but does not materially change the overall responsibility of heavy vehicles for pavement costs. This is illustrated by the fact the 2003 Oregon HCAS found heavy vehicles, as a group, to be responsible for approximately 70% of pavement reconstruction and rehabilitation costs, a result generally similar to those of the past several Oregon studies.

**Summary**

New research on the relationship between vehicle weight and pavement deterioration finds this relationship to be less extreme than previously thought. This research suggests that, on average, the exponent relating pavement damage to increases in axle weight is closer to 2.5 than 4. At the same time, this research indicates weather and other non-load-related factors play less of a role in pavement deterioration than suggested by the earlier research. The combined effect of these two findings is to leave the overall responsibility of trucks and other heavy vehicles for pavement costs relatively unchanged, but to shift more of this responsibility from heavier axle weight vehicles to lighter and medium-weight axle vehicles. These findings have been reflected in the results of the 1997 Federal HCAS and the past three Oregon HCASs.