AN ECONOMIC ANALYSIS OF THE APPROPRIATE FEE AND FINE STRUCTURE FOR OVERLOADED VEHICLES: ECONOMIC INCENTIVE TO OVERLOAD VERSUS ROAD DAMAGE CAUSED BY OVERLOADING

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INTRODUCTION

The transportation system serving the producers and consumers of the United States and the state of Washington is an effective, efficient and productive system. An integral part of that system, some would say the integral part, has been the highway and road system, both rural and urban. This highway system, even as it continues to expand in some areas, is experiencing deterioration of its infrastructure. This degradation arises for many reasons: the age of the infrastructure, increased traffic volumes, heavier vehicles, different vehicle configuration, etc. One contributing factor to the deterioration of highways is the damage associated with loads above the legal weight limit on these roads.

A complex system of fines and fees have been legislated in the United States, with a great deal of variation among states, to control or recapture the damage caused by overloading on the highways. But, this fine structure may or may not be effective in controlling the damage to roads of such activity. The penalty charges collected for a particular payload may either not be sufficient to recover the damage associated with the extralegal weight movement or may not be large enough in magnitude to deter the trucker from overloading.

When benefits to truckers are greater than costs (fee or fine as a price surrogate), overloading will occur and probably increase, with attendant increases in road deterioration. Conversely, loss to society occurs whenever the premature damage to roads (costs to repair) is greater than the revenue (fee or fine received). The basic problem of this research effort was to determine the effectiveness and equity of the Washington fee/fine structure relative to the goal of controlling damage to the roads. Notice the goal is not to minimize the damage because some damage, when paid for by the truckers, does contribute a positive economic impact to the economy and society. Critical variables include the financial impacts on highways of overloads, the decision-making process of trucking firms and the fee/fine structure that will produce a cost-effective control of damage to the highways.

1. OBJECTIVES

The overall purpose of this paper is to evaluate the effectiveness and equity of the existing motor vehicle permit and penalty (fee and fine) structure of the state of Washington. Specific objectives are to:

1. Develop a conceptual approach to evaluating the equity (fee and fine versus damage imposed) of the truck fee and penalty structure.
2. Preliminarily determine impact on highway pavements of differing overload weights moved for different distances.
3. Review and evaluate the benefit/cost situation of overloading for individual owner-operators or truck firms.
4. Develop recommendations for the structure of the Washington fee and fine system, and determine recommendations for implementation of that system.

2. STUDY APPROACH

The main analytical tasks of this study form the analytical component of this paper. They dealt with the methodologies of determining the economic incentive (cost or rate savings) to overload by carriers and the damage caused by various combinations of weight/distance movements by truckers. The economic incentives were based on various movements, via a typical axle configuration, of a generic trucking firm. The damage function analysis relied on a modification of the standard pavement deterioration function developed by the American Association of State Highway Officials (AASHO), with price (cost) estimates derived from previous studies in Washington using the Pavement Management Systems (PMS) of WSDOT (Casavant and Lenzi) to generate preliminary estimates of expected or typical damage values, inflated to 1990 levels.

Arising from the multiple tasks within this research effort was an understanding of the real world implementation of the fee and fine schedule recommended in this paper. As such, some thoughts relative to enforcement efforts, allocation of fees and fines, etc., are included in the final section.

3. CONCEPTUAL FRAMEWORK

The goal of this study was to examine the efficiency and equity of the Washington overweight fee and fine system. Efficiency entails recovering pavement damages, when it is privately economic to overload, or forestalling pavement damage that is more socially costly than the private firm benefits of overloading. Equity is concerned with designing a system that relates magnitude of damage by a particular firm (or overload factor) to the penalty or fee paid by the perpetrator of that damage.

The force inflicted on a pavement depends on gross vehicle weight (GVW), per axle weight and the distance between axles (measured by the bridge formula), or axle configuration. The general relationship between vehicle axle weight and damage is shown in Figure 1. What is quickly evident is the increasing impact felt at the higher weights and the impact of axle configuration. The overall impact of the increased weight, especially overweight, and traffic volume on pavement life is shown in Figure 2. The shaded area reflects the increased maintenance and reconstruction costs necessary to achieve the designed road life. It is this impact that is generated by the increased incidence of ESALs (weight loads) and related environmental effects on the state highways and county roads in the state of Washington.

Given the form of this damage function it is conceptually reasonable, with the goals mentioned earlier, that the fee and fine structure should be responsive to weight, distance and axle configuration. The system should generally reflect the 4th power function of the AASHTO (originally AASHO) tests with differing base points for single axle, tandem axle and the bridge formula. The relationship identified in Figure 3 is conceptually a fee or fine structure that would produce equity in application.

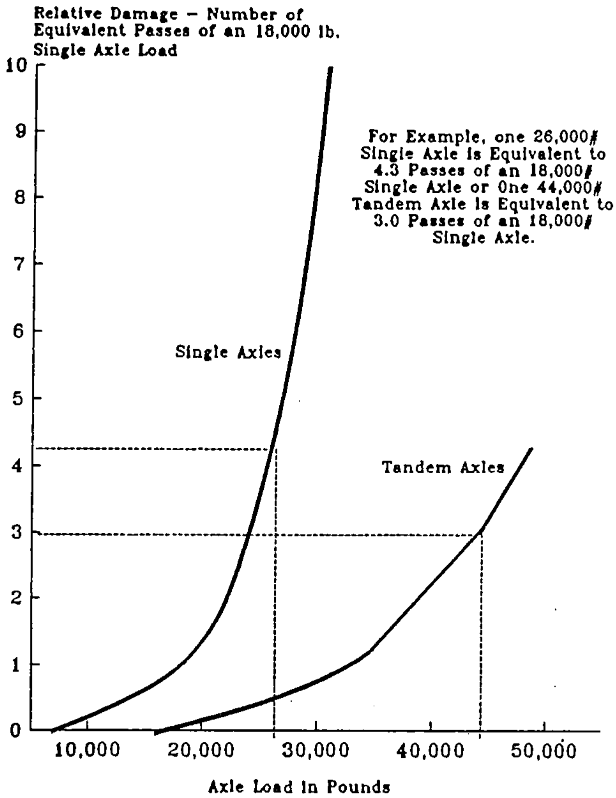
The economic incentive to overload can be conceptually viewed as either the cost savings realized by eliminating some truck mileage to move a certain volume or the extra value of a load defined as the rate (tariff) received per unit times the number of extra (over legal) units carried (incidentally, higher valued commodities can be expected to generate higher rates). The cost savings become a lower bound conservative estimate of the benefits to a trucker of overloading while the value of the extra revenue becomes an upperbound on such benefits. Obviously, if there is no profit margin, the two estimates in the long run would be identical. Conversely, in the short run, variable costs of a load can be expected to be lower than the average; thus cost savings (benefits) are smaller from that short run perspective. Finally, the cost per ton mile, divided by realized payload of the vehicle, gives a straightforward estimate of the per unit cost savings of each extra unit on a truck per movement.

Given these relationships the resultant conceptual structure is that identified in Figure 4. Consider the following:

If D is the damage magnitude at a given weight,
EI is the economic incentive (savings) at a given weight, and
F is the fee or fine at a given weight.

Then the operative fee or fine (OF) at each weight should be:

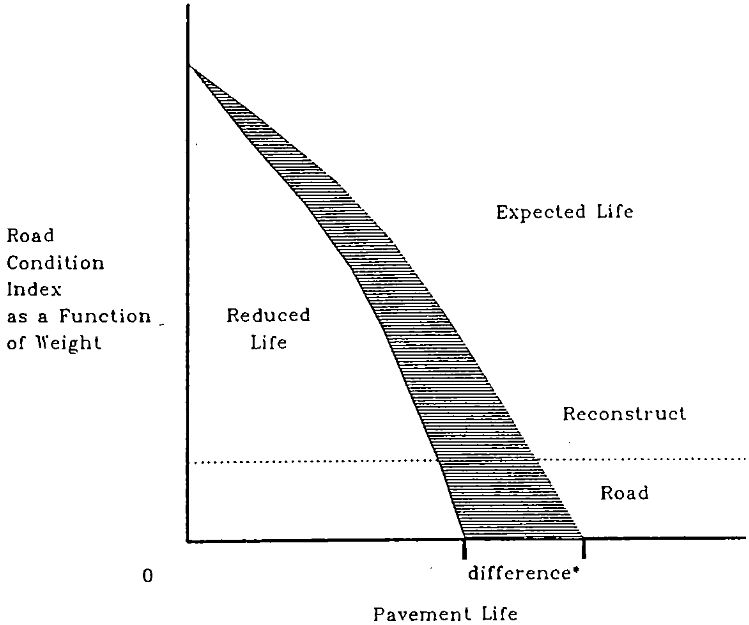
Figure 1. Typical Relative Damage Caused by Different Sized Axles--From the AASHO Road Test



If D > EI > F, then OF should be increased to EI
If D < EI > F, then OF should be increased to D
If D < EI < F, then OF should be decreased to D
If D > EI < F, then OF should be decreased to EI

It is not necessary to set OF equal to the D when D is greater than EI; eliminating the economic incentive will eliminate the occurrence of damage. Conversely, if EI is greater than D, the OF should be set to recover the damage caused by the overloading while still allowing the trucker, and society, to capture the economic benefits of overloading. Figure 4 is a graphical depiction of that relationship with the hatched area reflecting the resultant appropriate schedule.

Figure 2: Weight and Pavement Life.



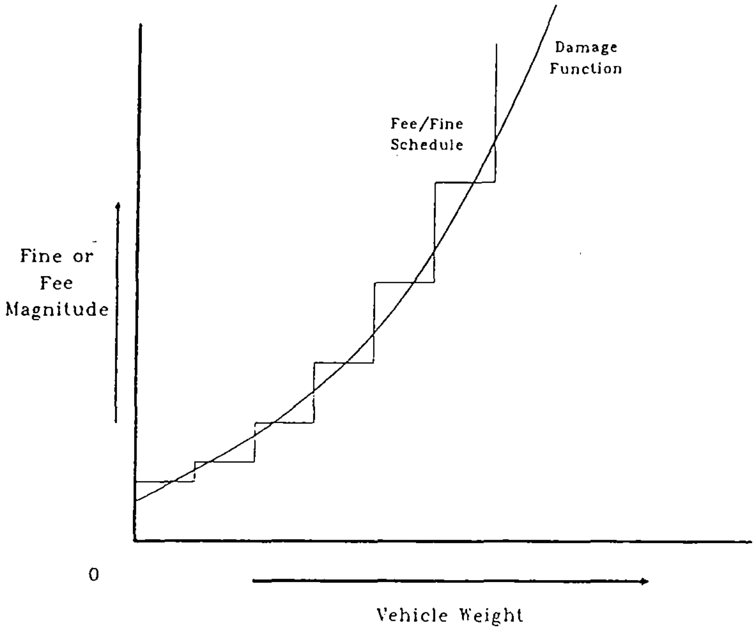
* Premature and unprogrammed pavement wear.

Included in Figure 4 is a net fine function, reflecting the real world experience of enforcement success (or failure). Differing estimates exist as to the percentage of overloaded vehicles that are actually "captured" and cited, but in most cases the estimates range from 1% to 20%. From the private trucker's viewpoint, if the potential fine for a given load is F, and only one out of ten loads receives a citation, then the net fine to be used in decisions about overloading is F • (probability of capture) or, for example, if probability is 10%, the net fine is F • (.10) or F/10; thus, instead of a $200 paper fine, the net operative fine is only $20.

4. EFFECTIVENESS AND EQUITY OF WASHINGTON FEE AND FINE STRUCTURE

To test the effectiveness of the overweight fee and fine system in Washington in either deterring overweight movements or recovering damage caused by such movements, it was necessary to determine the potential damage to roads at various Kip mile combinations and the economic incentive to overload for each Kip mile

Figure 3. Conceptual Fee/Fine Structure.



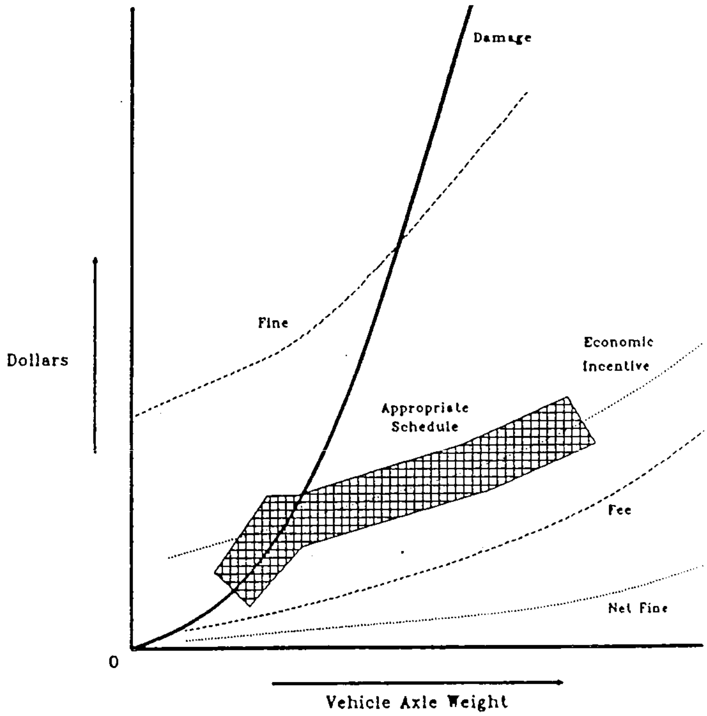
combination. These are then compared to the fee and/or fine associated with each movement. Equity considerations involve comparing, across distance and weight, the relationship among these variables.

4.1. Economic Incentive to Overload

The economic incentive to overload arises from the cost savings associated with the extra legal weight. As vehicle weight increases, some item costs may increase but the average cost per unit hauled decreases. In this analysis the cost per ton mile was derived by dividing the cost per loaded mile by the payload. This was then converted to cost per Kip mile by putting it on a 1,000 pounds basis. Then, for each distance/Kip combination resultant Kip miles were multiplied by the cost per Kip mile.

The cost per running mile, including fixed and variable costs (essentially long run average costs) were assumed to be $1.10 per running mile, based on updates of earlier studies done by Casavant and the American Trucking Association (ATA) reported cost data on various truck configurations and products. The payload for

Figure 4. Conceptual Relationship.



this analysis was assumed to be 25 tons or 50 Kips and, due to the longer haul nature of some of the product movements in Washington, a 10% empty mileage was figured. This resulted in a $1.21 per loaded mile cost estimate which, when divided by the payload of 25 tons yielded a ton-mile cost of $0.0484. On a Kip mile basis this resulted in a $0.0242 cost estimate and the results in Table 1.

Table 1. Economic Incentive for Washington Truckers to Overload.

	KIPs Overweight			
	3	5	10	30
30 Miles	$ 2.20	$ 3.60	$ 7.30	$ 21.80
100 Miles	7.30	12.10	24.20	72.60
300 Miles	21.80	36.30	72.60	217.80

4.2. Damage Analysis

Costs to society of this overloading activity arise because of the damage to the infrastructure caused by the overloaded vehicle. Pavement deterioration models or damage functions serve as the means to estimate the financial magnitude of overloading. These functions relate the decline in pavement serviceability to the traffic or axle passes. The general relationship is expressed by:

$$D = (\#/N)^B$$

where D = Index of pavement serviceability

\# = number of passes of an axle group of specified weight

N = number of passes of the axle weight configuration before serviceability reaches zero

B = shift coefficient

The change in D is a reflection of the impact of weight (overloads) on the pavement condition (Tolliver). This general function was translated in the AASHO studies conducted in 1958 and 1960 to the following general form: $D = KX \text{ (axle load)}^4$ where K = number of axles. The effect of this fourth-power function is to create tremendous increases in damage as the axle loading increases. This test has been attacked in many fashions; most complaints suggest the fourth power function is too large in magnitude because it ignores the effect of environment, tire pressure, etc.

Accordingly, a modified power function was used in this study to estimate the damage associated with overloaded vehicles. The economic or financial impact was derived from Washington studies of 80,000-pound vehicles (Casavant and Lenzi) and the cost of reconstruction associated with varying traffic levels, as projected by the Washington Pavement Management System (in that study actual expenditures were found to closely approximate the PMS estimates). Those case studies yielded estimates of damage per ton-mile ranging on state highways of one to six cents; county road costs were 50% higher. A weighted average of five cents per ton mile, determined in that study, was updated to 1990, resulting in a base cost of $0.05275 per ton-mile at the 80,000 weight. Since, as the payload per vehicle increases, the number of axle passes decreases to move a given volume of product, the function was modified to yield the results in Table 2. It is realized that these estimates do not consider tire characteristics and use, pavement surface thickness, subgrade support, etc. They are simply generic representations, preliminary in nature, of the consumption of Washington's average roadway caused by overloaded vehicles. Higher quality roads could be expected to suffer less damage; such analyses are beyond these preliminary evaluations.

Table 2. Damage Estimates for Washington Highways.

	KIPs Overloaded			
	3	5	10	30
30 Miles	$ 2.50	$ 4.40	$ 11.20	$ 74.40
100 Miles	8.30	14.60	37.20	248.00
300 Miles	24.80	43.90	111.60	744.10

4.3. Comparative Analyses

The comparative evaluation of these variables, fee-fine-damage-economic incentive, is presented in Tables 3-5 for 30-, 100- and 300-mile movements of varying weights. The fees and fines reflect the existing structure in Washington. The four state average for fees and fines is for the states of California, Idaho, Oregon and Washington. First consider the relationship between road damage estimates and the economic incentive to overload. It is very evident that in all cases the economic incentive is smaller than is the damage to roads, although given the preliminary nature of these estimates, the two variables are quite close at the lower overweight figures. Because of the increasing (power) function for damage and the linear function for economic incentive the two estimates quickly diverge. This holds for all trip lengths, with the divergence increasing in magnitude as trip distance increases. This indicates that any mathematical refinement of the damage function, while intuitively appealing, may not be necessary for policy prescriptions since the economic incentive quickly becomes the relevant policy variable.

Table 3. Comparative Evaluation, 30-Mile Movement.

	KIPs Overloaded			
	3	5	10	30
Damage	$ 2.50	$ 4.40	$ 11.20	$ 74.40
Economic Incentive	2.20	3.60	7.30	21.80
Fee	14.00	14.00	14.00	18.90
Fine	140.00	200.00	350.00	950.00
Fee (4 State Average)	14.10	14.20	14.40	16.60
Fine (4 State Average)	70.00	141.30	682.50	2,737.50
Net Fine (10% Capture)	14.00	20.00	35.00	95.00

Table 4. Comparative Evaluation, 100-Mile Movement.

	KIPs Overloaded			
	3	5	10	30
Damage	$ 8.30	$ 14.60	$ 37.20	$ 248.00
Economic Incentive	7.30	12.10	24.20	72.60
Fee	14.00	14.00	14.00	63.00
Fine	140.00	200.00	350.00	950.00
Fee (4 State Average)	16.70	17.00	17.50	32.00
Fine (4 State Average)	70.00	141.30	682.50	2,737.50
Net Fine (10% Capture)	14.00	20.00	35.00	95.00

Table 5. Comparative Evaluation, 300-Mile Movement.

	KIPs Overloaded			
	3	5	10	30
Damage	$ 24.80	$ 43.90	$ 111.60	$ 744.10
Economic Incentive	21.80	36.30	72.60	217.80
Fee	21.00	21.00	42.00	189.00
Fine	140.00	200.00	350.00	950.00
Fee (4 State Average)	25.90	36.60	33.50	76.20
Fine (4 State Average)	70.00	141.30	682.50	2,737.50
Net Fine (10% Capture)	14.00	20.00	35.00	95.00

Consider next the relationship between the existing fee and fine levels. As identified in the legislative history developed in the overall study (Casavant), the Washington fine is far greater than the fee at any weight level and, even though the fine is not related to distance, even at longer movements it is still over 500% greater (5,000% at the shorter distances). If, and if is important, the probability of receiving a citation every time a trucker overloaded were equal to one, the fine would quickly force profit maximizing trucking firms to move only under a paid fee basis. However this simply is not the case.

The fee, at the shorter distance, more than eliminates any economic incentive to overload for the smaller overload weights. As the distance increases the existing Washington fee at low to medium overloads does seem to track the economic incentive quite well, capturing most of that cost savings, and probably eliminating the damage that would have occurred. It does appear that, with a small adjustment at the higher levels to supplement the recent legislative increase (40%) in 1990, the

Washington legislature could eliminate much of the road damage--at least based on these preliminary figures and if all truckers paid fees.

Fines, at the existing levels in Washington, are significantly above the economic incentive to overload for all weights and lengths of haul. But the fee and fine structure is only functional and effective if it succeeds in causing truckers to use fees because the alternative of fines is too expensive. If the capture rate were 100%, e.g., every truck or trucker that overloaded would be caught each time, that relationship would hold. But if the capture rate is only 10% then, for example, for a 300-mile, 30-Kip overload, the nominal fine of $950 would only experience a $95 net fine (fine times the probability of getting a citation) while fees for such a load and distance are $189, economic incentive is about $218 and the road damage estimate is $744. In such a case, the fee is inoperative, economic incentive is not eliminated and road damage could be expected to occur. Except for the 30-mile movement, a 10% capture rate would not eliminate the economic incentive, thus road damage would be massive.

The four state average (Washington, Idaho, Oregon and California) is also presented in the tables. Washington's present fee magnitude is slightly above the average at most levels and is significantly so for the highest levels; this is noticeable for movements of 100 and 300 miles. The fine level is also above the average for the four states at the three and five Kip overload weight, irrespective of distance, but is significantly below the average at the higher levels.

4.4. Recommendations and Institutional Effectiveness

This research has suggested the redesign of an appropriate fee and fine structure for the state of Washington. Under present conditions the fine structure is already at a level to eliminate any economic incentive to overload, even if a 10% capture rate is the best achieved in the enforcement process. The existing fee structure does need an increase at the heavier levels of overload, possibly a 50% increase at 10 Kips and a 15% at 30 Kips. At longer distances, fees should be increased at even lower Kip levels of overload.

Calibrating the structure to reflect the results indicated above would produce a system that was equitable (large damages or economic incentives pay large fees or fines) and effective (damage is eliminated or compensated for by revenue to the state). But this is a theoretical relationship that has serious problems when implementation in the institutional format of Washington is attempted.

Assumptions inherent in the redesigned system above are: the fines are effective 100% of the time, and revenue generated by fines go directly to repair the damaged pavement. These assumptions are institutionally incorrect because: (1) there may be a capture rate in Washington of 10% or less (no studies or experiences currently exist to document the actual performance); (2) tolerances to overloads in enforcement introduce sloppiness in capturing damage costs; (3) the revenue returned from the fines does not go to the road fund but is deposited in the Washington State Public Service Education Account; and (4) local courts ultimately determine the actual fine magnitude and usually local court costs are subtracted from that amount so the net return to the state is even lower.

This study was not designed as an enforcement evaluation research effort. But the importance of this area is painfully evident. It is obvious and recommended that enforcement effort and success in Washington and the U.S. must be increased. Since increased fines would encourage truckers to pay fees (or risk larger fines), that increased revenue should be dedicated directly to the weight enforcement effort. Similarly, increased research and educational efforts with local courts and magistrates should identify the benefits to society, local and state, of an effective and equitable fee and fine system. Otherwise, the system developed in this paper is only an academic exercise. The search for and design of the appropriate fee/fine schedule simply cannot be divorced from the enforcement of that schedule.

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