Research Report
KTC-94-5

PROPOSAL FOR DEVELOPMENT OF A RESOURCE AND COMMODITY HIGHWAY SYSTEM

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Kentucky Transportation Cabinet
Commonwealth of Kentucky

January 1994

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EXECUTIVE SUMMARY

In 1986, the Kentucky General Assembly established the Extended Weight Coal and Coal By-Products Haul Road System. This system includes approximately 3,200 miles of the most significant coal-haul roads in the state and permits coal trucks to carry much larger payloads than trucks with other commodities. In many ways, the extended-weight system has been very successful. Coal-transportation productivity has been substantially increased, and Kentucky coal continues to remain competitive in the marketplace. At the same time, infrastructure costs have risen substantially--to considerably greater levels than the increase in revenue produced by the requisite coal decal fees--and the extended-weight system has proven to be difficult to manage. Moreover, there is a fundamental inequity in the preferential treatment that has been extended to coal haulers and to the specific regions in which they travel.

In pursuit of its goal of providing the best possible transportation system to all citizens of the Commonwealth and its recognition of the key influence of transportation productivity on the national and international competitiveness of Kentucky industry, the Kentucky Transportation Cabinet recently initiated an evaluation of the extended-weight system and an identification of ways in which the extended-weight system might evolve into a comprehensive trucking network that would effectively serve the entire Commonwealth. Key considerations in forming future alternatives included the necessity for 1) limited mileage in order to contain costs; 2) permanency to promote efficient management; 3) more lenient weight limits for commodities other than coal; 4) statewide service; and 5) a connected, continuous trucking network.

The study, conducted by the Kentucky Transportation Center, concluded that development of a statewide trucking network, herein named the Resource and Commodity Highway System, was both feasible and desirable. To accommodate coal trucks currently operating with decals on the extended-weight system while at the same time limiting the wear on newly added highways to more reasonable levels required a two-tiered system which distinguishes coal roads from the remainder of the system. Weight limits on the coal-road component would initially be larger than elsewhere and truckers carrying other commodities would also be allowed to operate at the higher limits on coal roads. The eventual goal would be to phase out this distinction and to treat all components of the system identically.

The study recommended that the system be designated by administrative regulation. Although detailed study would be required before specific recommendations could be justified, some consideration has been given to identifying a reasonable point of beginning. Routes that stand out as primary candidates include those within 1) the current extended-weight system, 2) the Designated Truck Network, 3) the proposed National Highway System, 4) the Parkway System, 5) the Appalachian Regional Development Highways, and 6) the Ashland-Alexandria Highway. Interstate highways must be excluded because their size and weight limitations have been set by Congress. After eliminating county roads and short (less than five miles) segments of extended-weight highways, the initial network totals 4,350 miles of the most important trucking corridors within the state. Refinements to the system would recognize the distribution of major natural resource, agricultural, and industrial areas within the state; the distribution of rail and motor-freight terminals and river ports; the physical compatibility of the roads and bridges with the operating characteristics of large trucks; and network considerations including connectivity and continuity.

Access to the system would be provided by designated access routes. It is proposed that any state-maintained road within 10 miles of the system would be eligible for such designation. Truckers or shippers would be responsible for identifying needed access routes and for petitioning to have these routes so designated. A detailed engineering study would be a required component of the petition process. Truck weights and speeds would be restricted as necessary based on the detailed study, and the route would be posted as an access route: any necessary operating restrictions would be posted as well. Cost sharing would require the petitioner to pay for the cost of the engineering study, the cost of the posting, and the cost of any necessary intersection improvements. Additional cost sharing would be permitted if the petitioner desired other improvements which would relax or eliminate any special operating restrictions.

In establishing appropriate weight limits for the system, the focus shifted from the traditional gross truck weight limits to axle weights and wheelbases because infrastructure damage is directly linked to the magnitudes of the axle weights and the wheelbase "span" within which they are concentrated. In general the search for replacement limits was driven by the desire to maximize the allowable payload while minimizing infrastructure wear. More specifically, consideration was given to:

- Equalizing the various types of trucks in terms of their bridge impacts (measured in terms of bridge formula overload) and pavement impacts (measured in terms of equivalent single axle loads per payload ton);
- Selecting limits of the various axles and axle groups such that 1) pavement wear is minimized and 2) loading patterns (proportion of load on each axle or axle group) of the current truck population are accommodated;
- Accommodating all trucks legally operating on Interstate and "AAA" trucking highways; and
- Accommodating as reasonably as possible the coal trucks currently operating with decals on the extended-weight system.

A gross weight cap of 130,000 pounds was added because of concern that more heavily laden vehicles might not be able to safely stop under current highway and traffic conditions. Specific recommendations are summarized in the following table.

Proposed Limit		Base System	Coal Roads
Steering Axle (lbs)		20,000	20,000
Single Axle (lbs)		20,000	23,000
Tandem Axle (lbs)		37,000	47,000
Tridem Axle (lbs)		55,000	70,000
Gross Weight to Wheelbase Ratio (lbs/ft)	Straight Truck	3,200	3,900
	Combination with One Trailer	2,450	3,000
	Combination with Two Trailers	1,700	2,100
Gross Weight Cap (lbs)		130,000	130,000

These increased weight limits would be applicable only to trucks with appropriate permits operating on the Resource and Commodity Highway System. Trucks without appropriate permits would not be permitted to operate at these increased weights, and weight limits on other state roads would not be increased.

Bridge and pavement wear impacts of the proposed axle weight and wheelbase limits are summarized as follows:

Truck Type	Number of Axles	Gross Weight with Tolerance (lbs)		Percent Change in Gross Weight	Percent Change in Bridge Overstress	Percent Change in Pavement Wear
		Current	Proposed			
Base System						
Straight Truck	2	42,000	42,000	0.0	3.9	0.0
	3	56,700	59,850	5.6	6.6	13.5
	4	71,400	78,750	10.3	5.6	56.5
Combination Truck With One Trailer	4	77,700	80,850	4.0	7.8	16.3
	5	80,000	98,700	23.4	33.7	121.8
	6	80,000	117,600	47.0	47.4	254.4
Combination Truck With Two Trailers	5	80,000	105,000	31.2	32.2	120.4
	6	80,000	122,850	53.6	44.2	306.1
	7	80,000	130,000	62.5	49.8	---
Coal Roads						
Straight Truck	2	42,000	45,150	7.5	15.9	49.2
	3	94,500	70,350	-25.6	-24.1	-61.5
	4	105,000	94,500	-10.0	-13.2	-47.2
Combination Truck With One Trailer	4	77,700	94,500	21.6	28.1	123.6
	5	126,000	119,700	-5.0	-0.8	-23.4
	6	126,000	130,000	3.2	6.3	14.4
Combination Truck With Two Trailers	5	80,000	117,600	47.0	54.5	230.1
	6	80,000	130,000	62.5	63.0	415.2
	7	80,000	130,000	62.5	62.9	---

This tabulation documents increased bridge stress and increased pavement wear on the base system but some reductions on the coal-road portion. Reductions on coal roads result primarily from placing axle weight limits on three- and four-axle straight trucks, two particularly damaging trucks when loaded to the exceptionally lenient, extended-weight limits.

Considerable attention was given to assuring that increased weight limits would not jeopardize highway safety. Almost certainly, any reductions in the number of trucks on Kentucky's roadways due to payload increases, any improvements to the infrastructure to adequately accommodate large trucks, and any shifts of trucks from inferior facilities to the system would eventually enhance highway safety. In addition, specific recommendations to enhance safety have been advanced concerning

1) conformity with state and federal safety requirements, 2) operator certification that braking and safety standards will be met, 3) revocation of permits because of serious safety and weight violations, 4) tire load and pressure limits, and 5) driver safety training. Additionally, weight and safety violations should be reduced by the diversion of a substantial portion of the permit fees to enforcement activity. Finally, trucks carrying hazardous materials would not initially be permitted to operate at increased weights.

Implementation of the Resource and Commodity Highway System demands a long-term commitment to develop an improved trucking highway network that is fully compatible with the dimensions and operating characteristics of large trucks. As a result, the system would command a significant portion of future highway budgets--just as its individual road segments collectively do now--but the payoffs in transportation efficiency would be substantial. Large trucks would not be the only beneficiaries, as an improved highway system would make travel safer, faster, and more comfortable for other highway users as well.

The allowable weight increases proposed herein are intended in part to encourage the use of those types of trucks that are less damaging to pavements and bridges and, hopefully, less threatening to other motorists. Success in this endeavor would eventually mean greater use of tractor-semitrailer-trailer combinations where they are permitted to operate and a greater number of axles on each truck. As roadway improvements are implemented, further increases in truck payloads and further shifts to less damaging trucks would be expected.

ACKNOWLEDGEMENTS

The assistance, support, and encouragement of many within the Kentucky Transportation Cabinet contributed to the successful completion of this investigation. Thanks are especially extended to Sandy Pullen and Gary Sharpe for their initiative and leadership and for their will to quickly move this investigation to its successful completion. Others whose assistance is gratefully acknowledged include:

Roy Back, Assistant State Highway Engineer, Construction
Bill Crace, Division of Maintenance
Joe England, Division of Motor Vehicle Enforcement
Don Herd, Division of Maintenance
Jim King, Division of Bridges
Bill Monhollon, Assistant State Highway Engineer, Operations
Charles Raymer, Assistant State Highway Engineer, Preconstruction
Rolands Rizenbergs, Division of Specialized Programs
Bruce Siria, Division of Planning
David Smith, Assistant State Highway Engineer, Planning
Richard Sutherland, Division of Bridges
Ken Watson, Division of Maintenance
Greg Witt, Division of Planning
Jim Wood, Division of Maintenance

Also to be acknowledged are the key contributions of support personnel within the Kentucky Transportation Center including David Cain, Carla Crossfield, John Fleckenstein, and Kurt Godshall.

Finally and most importantly, the support of the Secretary of Transportation, Don C. Kelly, the State Highway Engineer, J.M. "Mac" Yowell, and the Director of the Kentucky Transportation Center, Calvin G. Grayson, is also gratefully acknowledged. Under their leadership and vision, Kentucky is poised to move to the forefront in developing a progressive statewide transportation system.

FIGURES

FIGURES (contd.)

TABLES

TABLES (contd.)

INTRODUCTION

Today's economic climate in the United States and around the world has created a very competitive commercial market. These competitive market conditions demand that individuals and corporations operate on increasingly smaller profit margins, thus placing more stringent demands on operating costs in the transportation industry. To keep these costs as low as possible, it is important that productivity be maximized. One important way of increasing productivity is to permit greater payloads per haul trip. Because of current and anticipated future competitive markets, it appears that (at this time) the Commonwealth of Kentucky is presented with an opportunity to greatly assist the shipping and hauling industry that operates within its borders.

One way to take advantage of this opportunity would be to develop a statewide trucking highway network on which shippers and haulers would be permitted to carry increased payloads. The creation of such a network would undoubtedly increase productivity, and in many ways, promote safer travel on the network.

There is worldwide precedent for permitting heavier payloads on trucks hauling bulk commodities. For example, maximum permissible axle loads on vehicles among the European countries are 28,660 pounds on a single axle (compared with 20,000 pounds in Kentucky), 46,300 pounds for a tandem axle (compared to 34,000 pounds in Kentucky), and 52,900 pounds on a tridem axle (compared to 48,000 pounds in Kentucky). European roads are built to accommodate these larger loads, and European industry is more competitive because of the reduced costs of transportation.

There is also precedent in Kentucky for the development of a trucking network on which haulers are permitted to carry heavier payloads than are normally permitted on other highways. In 1986, an Extended Weight Coal and Coal By-Products Haul Road System was established by the Kentucky General Assembly. Under this legislation, coal haulers on the extended-weight system have been permitted to carry gross weights far in excess of the 80,000-pound limit that is the maximum permitted on other highways such as the Interstate system and the "AAA" highway trucking system.

The extended-weight system has proven difficult to manage, for a variety of reasons. The method of defining the system (based on tons of coal transported each year) has resulted in a system that lacks sufficient access provisions and connectivity and does not properly consider the adequacy of route geometry and structural components. The fact that the system changes from year to year interferes with effective budgeting and programming, management, and enforcement. The decal system is designed primarily to collect fees, thus missing the opportunity to control the characteristics and operation of permit vehicles that impact highway safety. Further clouding the management issue is the fact that the extended-weight system includes non-state-maintained roads.

The relaxed weight limits on the extended-weight system have permitted truckers who haul coal to greatly increase productivity by carrying considerably greater payloads per haul trip. Clearly this greater productivity translates into increased profits for the hauler. However, permitting only coal to be transported in vehicles with heavier weights has created an inequity for the haulers of other commodities.

To help alleviate this inequity, to permit haulers of all bulk and high-density commodities to increase productivity, and to provide for more effective management of the highway system in the Commonwealth, it is proposed to develop a Resource and Commodity Highway System. To accomplish this, it is proposed to increase permissible axle weights and gross weights beyond limits currently permitted on the "AAA" highway trucking system, and to do this on a statewide network of selected state-maintained highways. At the same time, it is proposed to make some adjustments to permissible truck weights on the current coal-haul system to reduce the large rates of pavement wear and bridge overstress.

A number of factors must be considered in developing a Resource and Commodity Highway System. What are the characteristics of the highway segments that are to be a part of the system (by what criteria would they be chosen)? What should be the magnitudes of the permissible axle weights on individual vehicles? How would these loads affect pavement and bridge performance? What would be the effects on highway maintenance and construction costs? What would be the effects on costs to highway users?

Other considerations include the effects of this system on safety. Are the present designs of the highway segments sufficient to permit safe operations of heavy trucks without endangering other motorists? Are braking systems on heavy trucks sufficient to stop them in a safe distance? Are drivers adequately trained to operate heavier trucks?

Considerable emphasis should be placed on the administration and management of the system. The nature and organizational structure of the management agency should be defined. The permitting procedures must be determined and a fee schedule for various use levels should be set. A means of ensuring an equitable allocation of monetary resources generated by the payment of fees must be determined. In addition, all users must in some way share in the cost of the use of the system. Finally, questions concerning enforcement of the various provisions associated with the Resource and Commodity Highway System must be addressed.

The proposal presented herein attempts to address most of the concerns listed above in promoting the idea of a new, integrated system of trucking highways that permits bulk haulers of resources and commodities to obtain greater productivity by hauling greater payloads per trip.

CONCEPT

The Kentucky Transportation Cabinet, in recognition of the importance of Kentucky's agricultural and natural resources to the state's economy, has proposed development of a Resource and Commodity Highway System in order to significantly enhance transportation productivity while, at the same time, promoting safe travel and preventing premature wear of the highway infrastructure. Trucks with greater-than-normal payloads would be permitted to operate within the system, and the system would be managed and developed in anticipation of use by these large trucks. The new system would be of limited mileage in order to hold anticipated infrastructure cost increases to reasonable levels and to permit systematic upgrading.

The existing extended-weight system, currently used to transport coal and coal byproducts, would be replaced by the Resource and Commodity Highway System, with the majority of extended-weight mileage being incorporated into the new system. The coal-road portion of the system would be reduced from about 3,200 miles to about 2,600 miles to allow the limited highway resources to be focused on the more important and more productive routes of the system. The reduced mileage would also allow improved system management and enforcement. Existing weight limits would be fine-tuned to assure more even pavement and bridge wear among the various types of coal-decal trucks and to eliminate excessive loading likely to induce premature failure. The standard for comparison would be the six-axle tractor-semitrailer loaded to a nominal level of 126,000 pounds (maximum legal weight including tolerance). More liberal weight limits would be developed for types of trucks not now permitted to carry increased loads, and eligible commodities would not be limited to coal and coal byproducts.

A maximum of approximately 2,500 additional miles of state-maintained roadways would also be included in the Resource and Commodity Highway System. These roadways would be carefully selected to provide a coherent network connecting Kentucky's primary agricultural, manufacturing, and natural-resource regions with major markets and intermodal transfer facilities. Truck weights on this portion of the system would initially be more liberal than current Interstate limits but more limited than those on coal roads. The standard for comparison would be Kentucky's five-axle tractor-semitrailer. The goal would be to develop axle-weight limits such that the equivalent single axle loads (ESALs) per payload ton are of similar magnitude for the various types of trucks and that all trucks are loaded to similar levels with respect to federal bridge-formula limits. The increased weight limits would not be restricted to specific commodities.

The heavier trucks would require special permits in order to operate at the increased weights. The purpose of special permitting is to insure that the necessary safety and other standards are met and to assist in effectively managing the system. Permits would be required and fees would be set to partially offset the costs of system administration, management, and enforcement. Fees for individual types of vehicles would be approximately proportionate to maximum permissible payload increments.

SYSTEM CHARACTERISTICS

One of the most important tasks in developing and implementing the Resource and Commodity Highway System is to identify the specific highway segments that are to be included. Although the system itself should be defined by administrative regulation, considerable thought has been given to the identification of criteria that should be applied. This section discusses those criteria and identifies a network of primary highways that could serve as an effective point of beginning in defining the final system. This preliminary network is useful in demonstrating the extent to which various areas of the state can be served, given a 5,000-mile system constraint. It is also useful in evaluating the extent to which the state's existing bridges might constrain the rate at which the new weight limits of the Resource and Commodity Highway System might be implemented. This section also addresses highway development standards appropriate for large-truck operations, access requirements for the system, and future implications of the system.

CRITERIA

Numerous criteria must be considered when selecting route segments to be included as a part of the Resource and Commodity Highway System. Conflicting criteria must be balanced among various industries and various areas of the Commonwealth. It is clear that the trucking needs of every potential user of the system cannot be satisfied by any system that would be developed. However, a system that meets the greatest number of needs of the greatest number of users would be the most desirable. In attempting to fulfill these requirements, a number of general criteria immediately present themselves for consideration.

Service is the first criterion that must be considered. All of the major resource areas of the Commonwealth should be reached by the system. These areas most certainly include mining, which is concentrated in the two major coal fields of eastern and western Kentucky. Logging is another major resource in the Commonwealth. Although the location of major logging areas changes more frequently than coal mining areas, it is important to attempt to provide access to the trucking system from these areas. The location of stone and gravel quarries should be considered by attempting to service as many quarries as possible.

Major farm commodity areas should also be served. The distribution of farm commodity producing areas of the Commonwealth is broader than that of other resources or commodities; however, areas where there is considerable hauling of bulk farm products (such as grain) should be given particular consideration.

Service to major industrial and/or manufacturing areas should be considered in the choice of routes. While it is clear that not every individual factory or freight terminal could be reached by one of the routes, counties that have high concentrations of industrial activity should be serviced.

A second important criterion to be considered in route selection is intermodality. Users of the Resource and Commodity Highway System must have access to other modes of transportation. There are numerous barge terminals along the Ohio River. Some of the many Kentucky products that are shipped by barge include coal, sand, slag, steel, iron ore, liquid chemicals, dry bulk fertilizers, salt, and farm products. These ports should be serviced by the system. Major rail yards and rail lines should be connected to the system. Locations of major freight trucking terminals should be investigated when selecting the individual routes on the system.

A third criterion for route selection is connectivity. One of the problems of the current extended-weight coal-haul system is that there are isolated routes that do not connect with other portions of the system. To alleviate this problem on the Resource and Commodity Highway System, all segments of the system should be connected to the remainder of the system by at least one nodal point. This would ensure that a user entering the system at one point would be able to reach all points of the system without having to traverse any highway that was not on the system.

Because the Resource and Commodity Highway System is essentially conceived to be a long-haul system, continuity is also an important criterion. An excessive number of short spur routes or discontinuous routes would not provide an acceptable level of service. For example, a large number of the current extended-weight coal-haul routes are less than five miles in length. It is recommended that any highway segment chosen to be a part of the system should be at least five miles in length. Access routes would compensate for the loss of many of these short segments of the extended-weight system, but operating restrictions would sometimes be necessary and cost sharing would be required.

Physical compatibility of the highway segments with large truck operations is an additional criterion to be considered. Poor highway alignment, both vertically and horizontally, would make some routes unacceptable as candidates for the system. Also, lane widths and shoulder widths must be considered. The number of structurally or functionally deficient bridges must also be used in choosing highway segments.

A sixth important criterion that should be studied in the route selection process is the current distribution of truck traffic or truck volume. Routes that currently carry a high percentage of truck traffic should be given greater consideration in the final selection of highway segments. Likewise, coal-haul routes that meet most of the other criteria and carry a great percentage of coal traffic should be considered as likely candidates for the system.

All routes on the Resource and Commodity Highway System would initially be chosen from current state-maintained highways, and no county roads would be a part of the system. The total number of miles would be limited because of the additional funding required for maintenance of the system and for upgrading the various structural and geometric components of the individual routes in the system.

Urban areas should be avoided wherever possible. This would be accomplished by using bypass routes and/or other trucking routes. This criterion would help alleviate urban congestion and problems with maneuverability of large vehicles on narrow urban streets and intersections.

The last criterion that should be considered is compatibility of the Resource and Commodity Highway System with other existing highway systems. It is recommended that a large portion of the current extended-weight coal-haul system be included as a part of this system. Additionally, all of the proposed National Highway System, all of the Parkway System, most of the Designated Trucking Highway System, and the entire length of the Ashland-Alexandria Highway should be included in the system. All of the Interstate Highway System would be excluded.

PRELIMINARY SYSTEM SELECTION

The first step in identifying a trial Resource and Commodity Highway System was to develop a database containing information on the AAA trucking system, the extended-weight coal-haul system, the designated trucking system, the preliminary National Highway System, and the Appalachian Regional Development Highways. In addition, the Parkway System and the Ashland-Alexandria Highway were included. As would be expected, many of the route segments included in the large database were members of more than one of these highway systems.

The database thus developed included the most important highways in the state and those most likely to satisfy the criteria enumerated earlier. Special considerations in defining the trial system included:

- The extended-weight system is critically important because it currently serves coal transportation in much the same way as the Resource and commodity Highway System is expected to serve Kentucky's total resource and commodity base;

- The Designated Truck Network is important because it defines the set of highways deemed physically most suitable to accommodate the operation of large trucks;

- The preliminary National Highway System is important because it is becoming the focus of federal funding and interstate commerce;

- The Parkway System, the Ashland-Alexander Highway, and the Appalachian Regional Development Highways are important not only because of their generally superior geometric and structural design standards, but also because they were developed, in part, to support economic development and resource recovery within Kentucky; and

- The AAA trucking system is important because it identifies all highways deemed suitable for trucks as heavy as 80,000 pounds.

After several trial-and-error queries of the database, a suitable trial system of 4,350 miles emerged. This selection included approximately 2,600 miles of the extended-weight system of greatest statewide significance[1] and all linked elements of the Designated Truck System, the National Highway System, the Parkway System, the Ashland-Alexandria Highway, and the Appalachian Regional Development Highways--exclusive, of course, of Interstate highways. Many of these systems overlap, resulting in a total mileage for the trial system of 4,350 miles. A summary of mileage by system is presented in Table 1.

Table 1. Mileage Summary

Original System	Total Original System Mileage	Total Mileage Within RCHS	Mileage Shared with Other Systems
Extended Weight Coal Haul System	3,161	2,639	1,103
Designated Truck Network	2,312	2,312	1,664
National Highway System	2,743	1,980	1,647
Total RCHS Mileage	4,350		

Figure 1 shows the trial system as described above. In proposing this system, attempts were made to adhere to the criteria listed earlier in the report as much as possible. In cases where it fails to meet all or some of these criteria, adjustments would be recommended when the final system is chosen. Approximately 400 miles could eventually be added without exceeding the 5,000-mile limitation.

To determine how well the trial system reaches the major resource and commodity areas of the commonwealth, Figures 2 through 6 were compiled. Figure

[1]Excluded portions of the extended-weight system included county roads and state-maintained segments less than five miles long. It is expected that many of these exclusions would be eligible for future designation as access routes and, hence, would continue to serve coal haulers.

2 shows that the two major coal producing areas (top 20 coal producing counties) of the commonwealth are well covered by the system. Figure 3 indicates that most of the top 25 counties that produce primary forest products have direct access to the system. Figure 4 shows the top 20 counties that produce three major bulk farm commodities (corn, winter wheat, and soybeans). Again, coverage of those areas is excellent with only Breckinridge County having no direct access. The 20 top milk producing counties are shown in Figure 5. Four of those counties do not have direct access to the system. Figure 6 indicates that only two of the top 20 counties in manufacturing (ranked by number of manufacturing jobs) have direct access to the system. Those two counties are Scott and Taylor Counties. Figures 2 through 6 also indicate the proximity of the locations of barge terminals along the major waterways to the trial system.

The extent to which the trial system includes major trucking highways within the state is also of interest. To make such a determination, data were collected from more than 900 vehicle classification counts conducted during the period 1990-1992. After eliminating those sites located on Interstate highways, the top half of the sites in volume of truck traffic was identified. That 81 percent of these sites are located on the trial system is evidence that most major facilities are included. As future refinements are made, an attempt should be made to include an even greater proportion of Kentucky's major trucking highways.

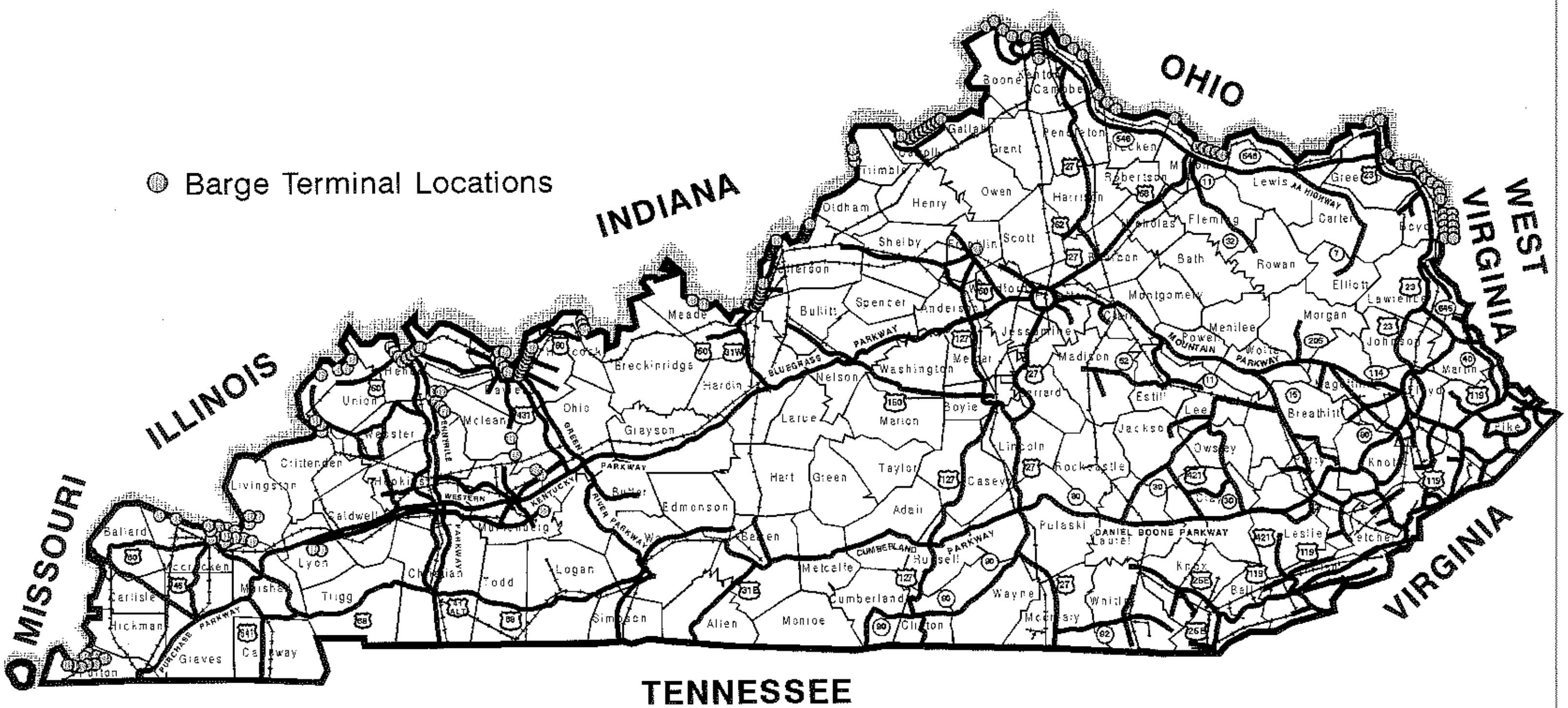

Figure 1. Distribution of Routes on the Trial Resources and Commodity Highway System.

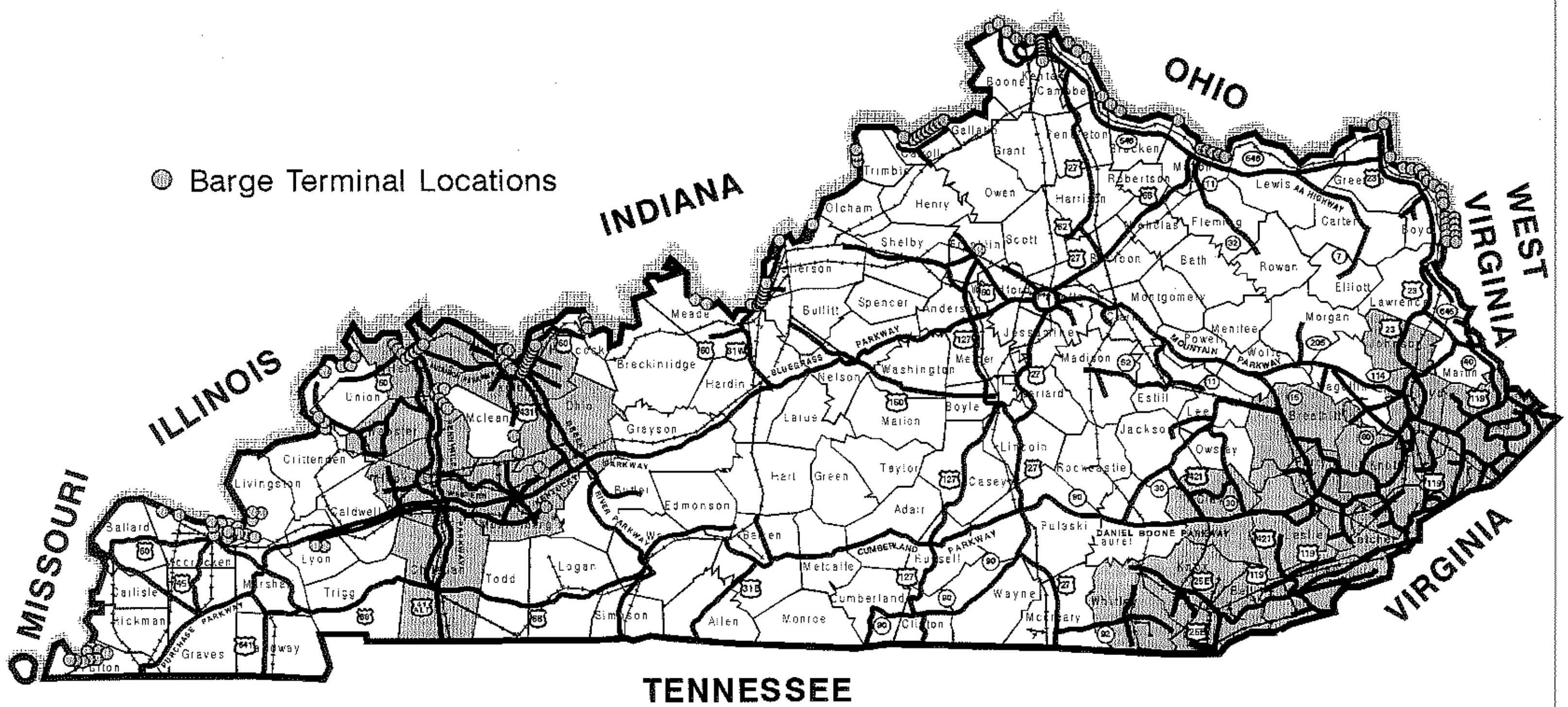

Figure 2. Proximity of Routes on the Trial Resources and Commodity Highway System to the Top 20 Coal-Producing Counties in the Commonwealth

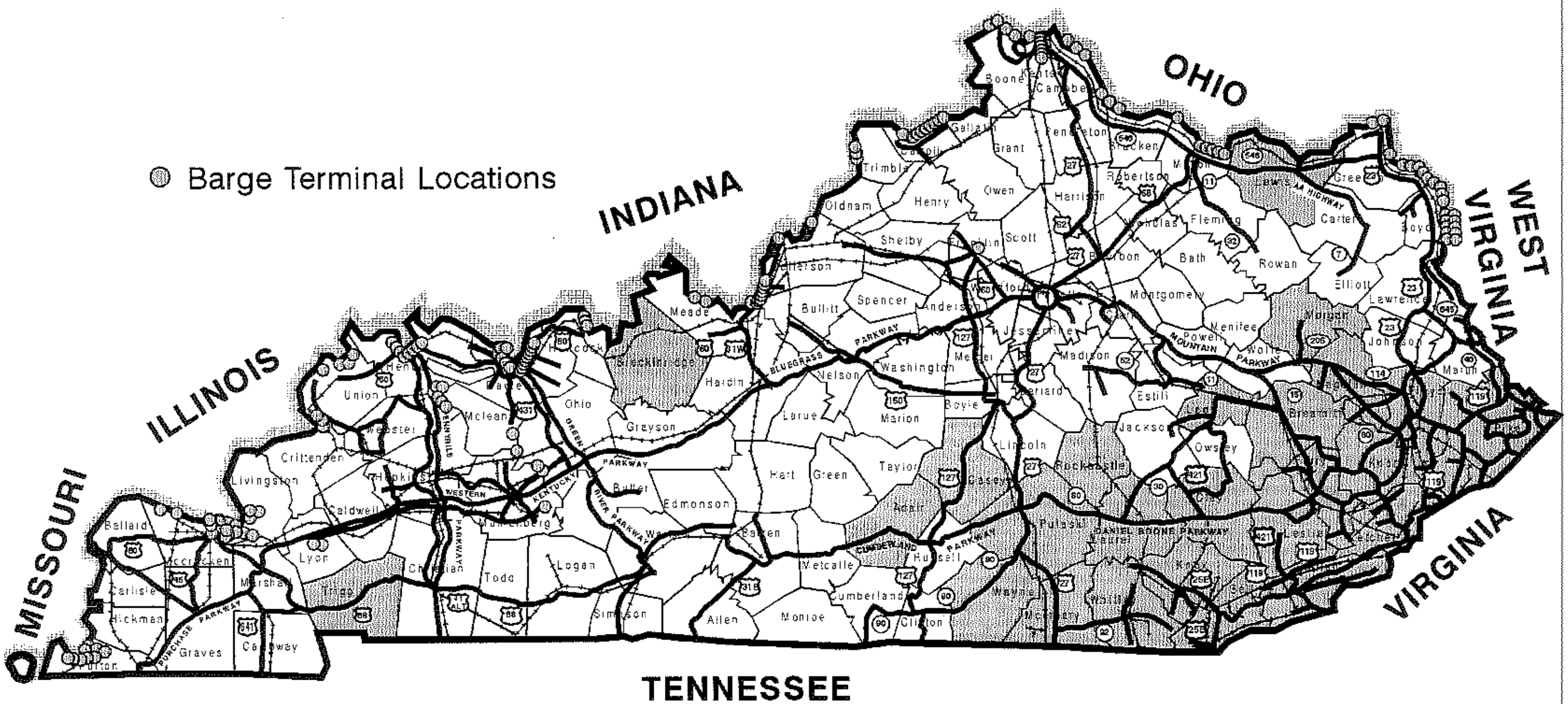

Figure 3. Proximity of Routes on the Trial Resources and Commodity Highway System to the Top 25 Counties Producing Primary Forest Products.

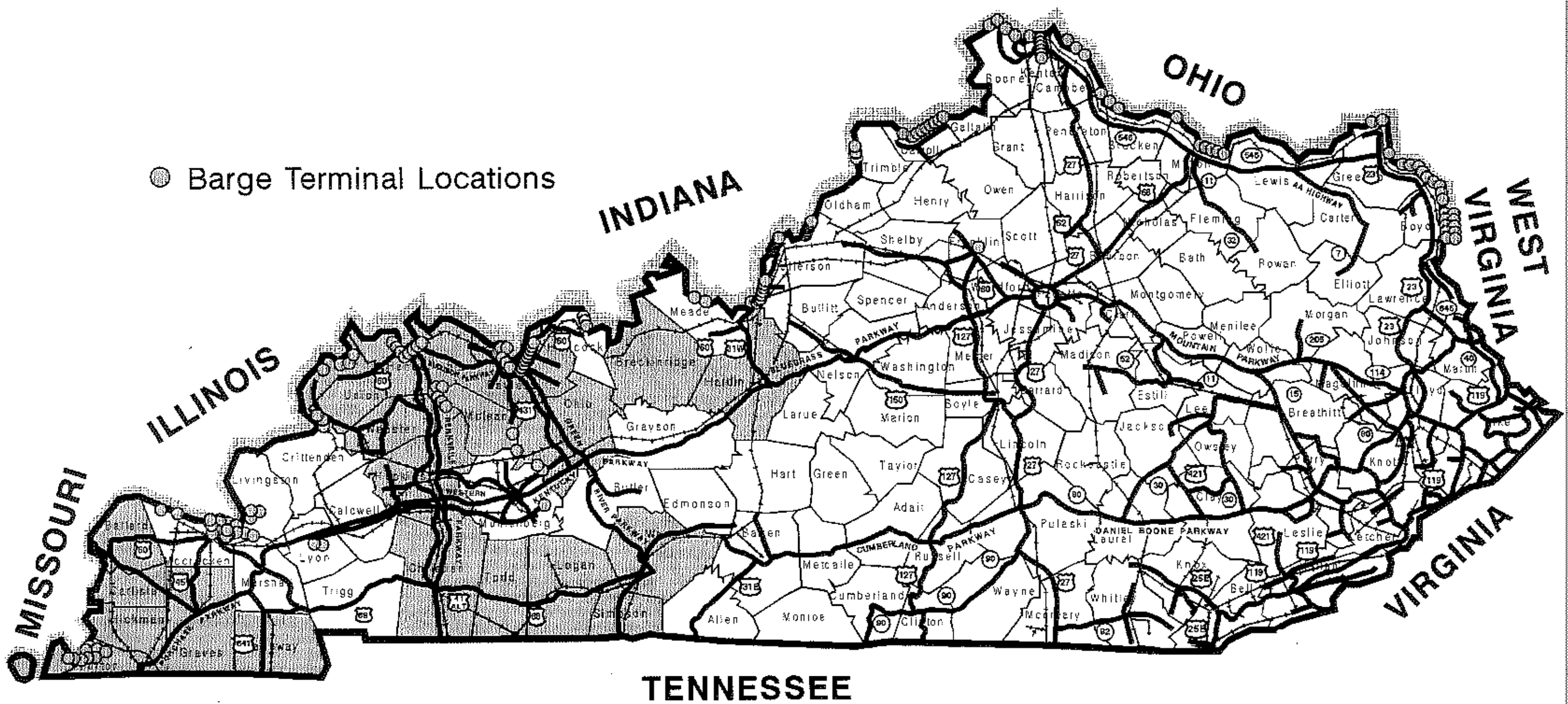

Figure 4. Proximity of Routes on the Trial Resources and Commodity Highway System to the Top 20 Counties Producing Bulk Farm Products (Corn, Winter Wheat, and Soybeans).

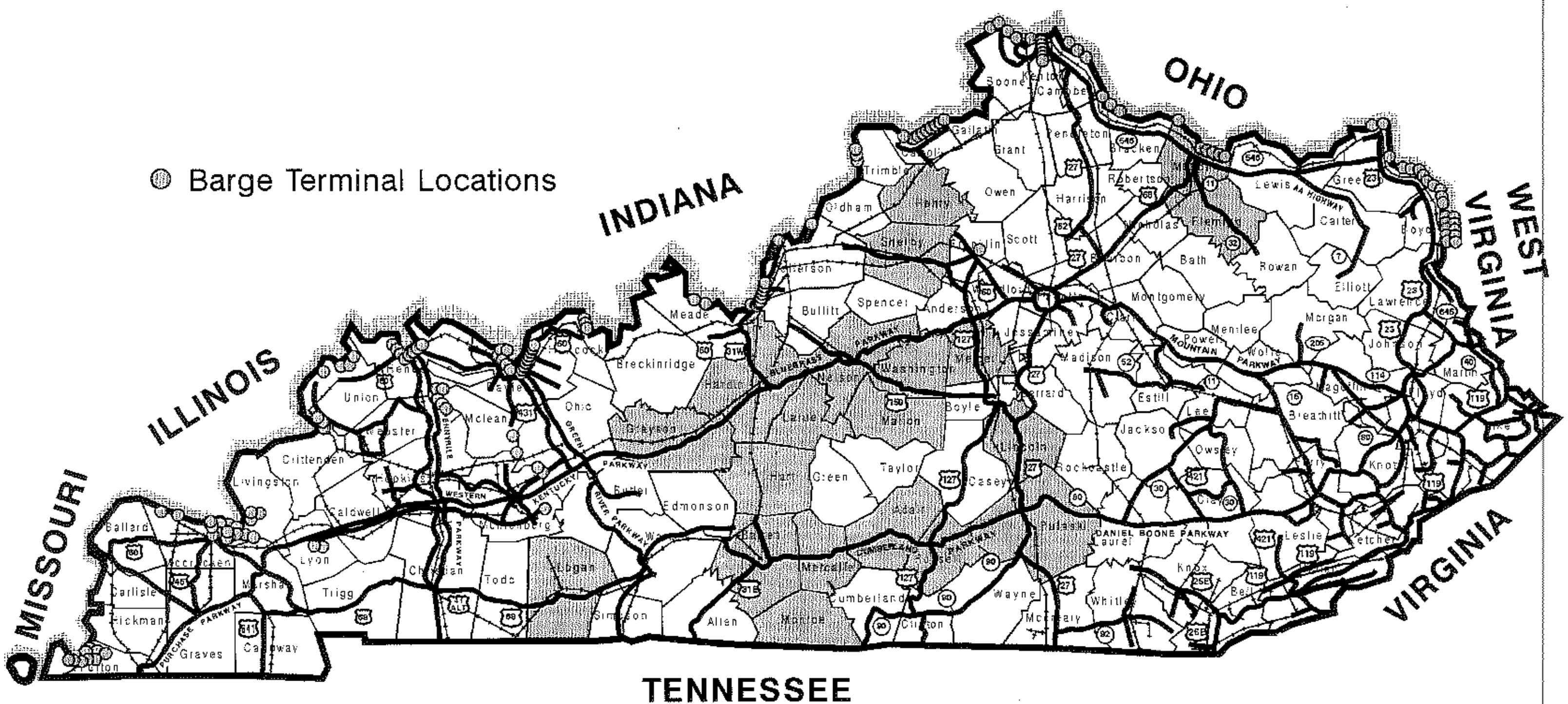

Figure 5. Proximity of Routes on the Trial Resources and Commodity Highway System to the Top 20 Milk-Producing Counties.

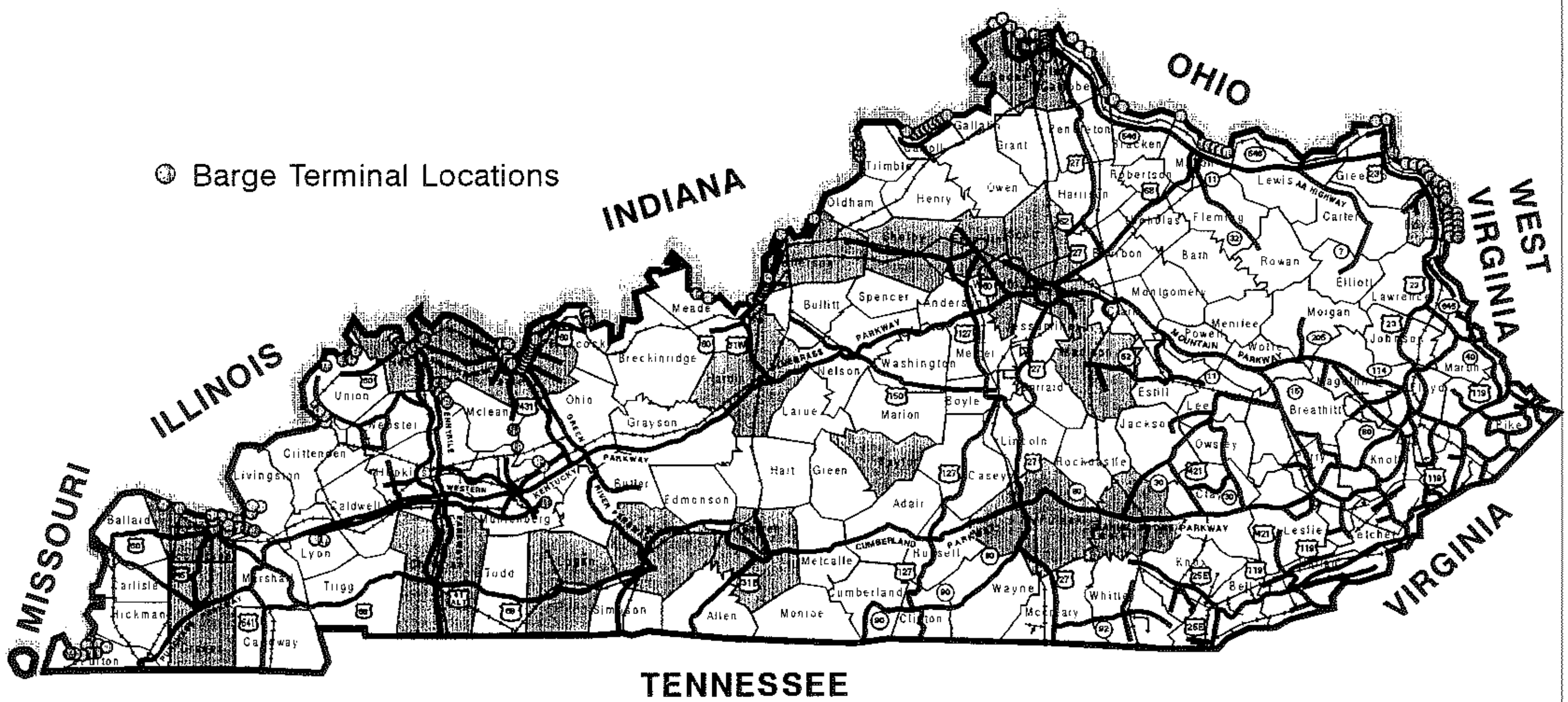

Figure 6. Proximity of Routes on the Trial Resources and Commodity Highway System to the Top 20 Industrial Counties (Ranked by Number of Manufacturing Jobs).

DEVELOPMENT STANDARDS

It is clear that many of the highway segments that would be chosen to be a part of the Resource and Commodity Highway System would not have been designed and constructed to standards that are appropriate for highways that carry large or oversized vehicles or those that are heavily loaded. This is similar to the current situation that exists on the extended-weight coal-haul system. This, of course, affects the capacity of a particular highway segment as well as the degree of safety. A long-term program of development and/or upgrading of the Resource and Commodity Highway System is necessary.

As various portions of the system deteriorate to the point where rehabilitation or reconstruction is required, then redesign of that particular segment of highway to standards that are adequate for the type of traffic the highway would be serving is expected.

Upgrading of all elements of the highway infrastructure would be required. For example, the cross section of the highway would be very important. Large vehicles on narrow roads become a safety hazard, notwithstanding the inconvenience to other users of the highway. All reconstructed segments of the Resource and Commodity Highway System would be redesigned with minimum lane widths and minimum shoulder widths. In addition, truck passing lanes would be required on steep grades.

Poorly aligned highways (both vertically and horizontally) servicing large, heavy vehicles are also a potential safety hazard to the motoring public because of poor sight distances. Poor alignment also reduces average speed of the traffic stream, increasing travel time and reducing productivity. Reconstructed segments of the system would be redesigned with stricter guidelines on maximum curvature and maximum grades.

Pavements would be redesigned and reconstructed to thicknesses that would accommodate the anticipated service loads throughout the design life of the structure. The magnitude of the design load would be equivalent to the largest permitted on the coal-road portion of the system. It is anticipated that eventually all pavements on the system would be constructed to this standard.

Bridges are an extremely important element of the highway infrastructure. Bringing all the bridges on the system up to a level of service that could accommodate the heaviest of loads would be both time consuming and costly. However, bridges on newly reconstructed segments of the system would be designed to carry the much heavier loads of future trucks.

Other elements of the highway infrastructure must also be considered in upgrading the system. Intersections must be properly signalized to accommodate heavy, large, and high-speed vehicles. Turning radii at intersections must be adequate to permit large vehicles to turn without endangering other traffic. Right-of-way clear zones must also be considered in the redesign of these segments of the system.

ACCESS PROVISIONS

For the Resource and Commodity Highway System to reach its maximum potential, carriers must have ready access to it. This is a delicate situation, however, because access routes may be deficient, and, as a result, usage by heavy trucks may be unsafe to other motorists and excessively damaging to pavements and structures. Reasonable access can be provided, however, to those carriers who are willing to share in the cost responsibility and who are willing to operate their vehicles in a safe and prudent manner.

The specific proposal advanced herein would allow, upon petition, any state-maintained roadway within 10 miles of the Resource and Commodity Highway System (exclusive of Interstate highways) to be designated as an access road. Each such road would be posted as such in both directions of travel at the point of its beginning and at one-mile intervals thereafter. The posting would specify any weight restrictions dictated by substandard bridges or pavements and any speed restrictions dictated by substandard geometry, cross section, sight distance, and roadside access or by large traffic volumes.

Submittal of a special impact study by a properly qualified professional engineer (retained and reimbursed by the petitioner) would be required with the initial petition. The impact study would evaluate the adequacy of bridges, pavements, and intersections to physically accommodate large trucks and would also evaluate the safety of their operation. It would recommend appropriate weight restrictions and speed limits consistent with its findings. It would also identify any needed improvements to specific intersections to accommodate turning maneuvers, improve sight distances, and properly control traffic flow. Implementation of these improvements would be a necessary condition for approval of the petition.

Upon approval of the petition, the petitioner would enter into an agreement with the Cabinet to reimburse it for expenses occasioned by the special posting and by intersection improvements. Renewal petitions would be required on an annual basis. Impact studies would be required for renewals only as a result of significant changes in traffic and/or roadway conditions. The costs of maintaining and replacing the sign postings would continue to be the responsibility of the petitioner.

The petitioner could be a single carrier, a group of carriers, or any other responsible entity such as a producer or an industry association. Once a road has been designated as an access route, it would be available for use under posted conditions by any truck with a proper permit.

FUTURE IMPLICATIONS

Implementation of the Resource and Commodity Highway System would bring with it a commitment to develop an improved trucking highway network that is fully compatible with the dimensions and operating characteristics of large trucks. The Resource and Commodity Highway System would command a significant portion of future highway budgets--just as its individual road segments collectively do now--but the payoffs in transportation efficiency would be significant. Large trucks would not be the only beneficiaries as an improved highway system would make travel safer, faster, and more comfortable for other highway users as well.

The allowable weight increases proposed herein are intended in part to encourage the use of those types of trucks that are less damaging to pavements and bridges and, hopefully, less threatening to other motorists. Success in this endeavor would eventually mean greater use of tractor-semitrailer-trailer combinations and a greater number of axles on each truck. As roadway improvements are implemented, further increases in truck weight limits and further shifts to less damaging trucks may be possible.

Whether Kentucky's initiative would eventually spread to other states and to Congress is speculative at this time. Nevertheless, being economically competitive in the worldwide marketplace depends on the achievement of significant gains in transportation productivity. The pressure to improve in the United States is intense. Moreover, the presently deteriorated state of the nation's highway infrastructure provides the opportunity to not only correct current deficiencies but also to implement progressive improvements. The majority of the nation's freight moves on the Interstate System. Thus, the key to unlocking current restraints beyond Kentucky's boundaries is held by Congress, not the states.

TRUCK WEIGHT AND SIZE LIMITS

Vehicle weight limits for travel on public roadways are necessary for a variety of reasons including:

- Efficient use of resources: Excessive pavement and bridge loading leads to premature failure, which means fewer total tons transported over the road per dollar of infrastructure investment. One goal is to control <u>peak</u> loading, so that the total payload transported before failure is as large as possible.

- Safe travel: The mix of vehicles on the roadway, specific characteristics of individual types of vehicles, and compatibility between the vehicles and the roads on which they travel have fundamental influences on traffic safety. Weight limits can influence vehicle size, rollover thresholds, ability to accelerate and climb grades, braking, and a host of other factors that can potentially impact safety.

- Equitable allocation of resources: The objective in part is to insure that all road users not only can share in the use of the road but also have the responsibility to pay their fair share of its cost. If one user shares in the cost of the road, but causes a disproportionate share of the damage, the allocation is no longer equitable.

Although these considerations generally guide the search for new truck limits, more specific objectives of the current effort included the following:

- To enhance the productivity of Kentucky trucking by maximizing the allowable payload per vehicle and
- To preserve Kentucky's pavements by minimizing the ESALs per ton of payload

subject to the following constraints:

- To maintain or enhance the current level of safety on Kentucky's highways,
- To preserve Kentucky's bridges by not unduly accelerating their wear, and
- To forestall investment needs from less maneuverable trucks by assuring adequate turning performance.

This section includes relevant background information and describes the development of recommendations for weight limits suitable for use on the Resource and Commodity Highway System.

CURRENT WEIGHT AND DIMENSION REQUIREMENTS

Fundamental Statute. The basic vehicle weight and size limitations are governed by KRS 189.221. This statute applies to all highways which are operated on the state-maintained system. Provisions are made under KRS 189.222 to allow the Secretary of the Transportation Cabinet to increase these size and weight limits on designated routes by official order.

The maximum limitations as prescribed by KRS 189.221 are as follows:

(1) Height, 11.5 feet
(2) Width, 96 inches
(3) Length
- motor truck, 26.5 feet
- semitrailer truck, 30 feet

(4) Gross vehicle weight, 36,000 pounds

(5) 600 pounds per inch of combined width of tires upon which the vehicle may be propelled, not to exceed 36,000 pounds.

Exceptions:

Any truck hauling building materials to a road construction project on a highway rated less than the maximum weight provided in this section, may haul up to 80,000 pounds gross weight, including load, without a permit.

General Limits of Secretary's Authority. The maximum limitations as prescribed by KRS 189.222 are as follows:

(1) Height, 13.5 feet
(2) Length
- semitrailers, 53 feet
- trailers, 28 feet
- motor trucks, 45 feet
- not to exceed two trailers per truck tractor

(3) No single axle in any arrangement shall exceed 20,000 pounds or 600 pounds per inch of aggregate width of all tires on a single axle, whichever is less.
(4) Total gross weight of the vehicle and load shall not exceed 80,000 pounds.
(5) A tolerance of not more that five percent (5%) per axle weight shall be permitted before a carrier is deemed in violation. The gross vehicle weight shall not exceed 80,000 pounds.
(6) Weights of axle groups are limited as follows:

Axles	Allowable Load (Pounds)	Axle Spacing (Inches)
1	20,000	2 axles less than 42" apart considered a single axle
2	34,000	42 -96
3	48,000	42 - 120

Exceptions:

Vehicles registered under KRS 186.050(4) or 186.050(9) and engaged in transportation of farm or primary forestry products and vehicles transporting ready-mixed concrete shall be excluded from the axle weight provisions, except on Interstate highways, and subject only to the gross weight provisions.

Vehicles registered under KRS 186.050(3)(b) and engaged in the transportation of primary forest products may exceed the axle, or gross weight provisions as set forth in accordance with 189.222(1)(c) by a weight tolerance of ten percent (10%), except on the Interstate highway system.

Except on the Interstate highway system, vehicles engaged exclusively in the transportation of crushed stone, fill dirt and rock, soil bulk sand, coal, phosphate muck, asphalt, concrete, solid waste, tankage or animal residues, livestock, and agricultural products shall be permitted a tolerance of ten percent (10%) of the axle weight provisions before a carrier is deemed in violation of KRS 189.222 (1)(c).

Limits of Secretary's Authority on Federal-Aid and Parkway Systems. KRS 189.222(7) states that the Secretary of the Transportation Cabinet shall not authorize the operation of any motor vehicle or combination of motor vehicles, upon any part of the federal-aid highway system or state parkway system, which exceeds the following dimensions and weights:

(1) The total gross weight of the vehicle and load shall not exceed 80,000 pounds.

(2) The width shall not exceed 102 inches, including any part of the body or load.

(3) Weights of axle groups are limited as follows:

Axles	Allowable Load (Pounds)	Axle Spacing (Inches)
1	20,000	2 axles less than 42" apart considered a single axle
2	34,000	42 -96
3	48,000	42 - 120

Extended-Weight Coal or Coal By-Product Haul Road System (KRS 177.9771). Any vehicle when registered with a declared gross weight of 80,000 pounds and when transporting coal or coal by-products over public highways which are part of the extended-weight coal-haul road system or portions thereof, may be operated at the weights as set forth below in excess of the maximum gross weight prescribed in KRS 189.221 and 189.222 and any other maximum weight limitations on state- or county-maintained systems by entering into a cooperative agreement as provided in KRS 177.979 or by paying the corresponding decal fee.

The extended weight limits are as follows:

Number of Axles	Gross Vehicle Weight (Pounds)	Tolerance (Percent)	Decal Fee (Dollars)
(1) Steering (2) axles in tandem	90,000	5	$160
(1) Steering (3) axles in tridem	100,000	5	260
Tractor-semitrailer combinations with (5) or more axles	120,000	5	360

BRIDGE FORMULA

The federal bridge formula (Formula B) is widely known and understood. It provides one of several limits that have been applied since 1974 to the upper weights of trucks traveling the nation's Interstate highways. Specific weight requirements on Interstate highways include:

- Maximum gross weight of 80,000 pounds,
- Axle limits of 20,000 pounds for single axles and 34,000 pounds for tandem axles, and
- Formula B limits for each and every axle group based on the number of axles in the group and the spacing between the leading and trailing axles in the group.

The bridge formula was designed to avoid exceeding design stresses in HS-20 bridges by more than 5 percent and, in H-15 bridges, by more than 30 percent.

In response to Congressional directive in 1987, the Transportation Research Board (TRB) was charged with conducting a study of the adequacy of the bridge formula and other matters related to federal weight limits for Interstate highways. Its study, published in 1990, effectively critiques the bridge formula as well as the alternatives that have been proposed to replace it.

The TRB critique included the following observations about Formula B:

- "When applied to the Interstate system, the current federal bridge formula is an overly cautious limit on weights for shorter trucks;"
- "When the current bridge formula is applied to vehicles over 80,000 lb, one of the criteria used to develop the bridge formula--that the design stresses for HS-20 bridges not be exceeded by more than 5 percent--may be violated;"
- The bridge formula provides only modest incentive for operating trucks with more axles;
- At weights above 80,000 pounds as permitted by the bridge formula, five-axle doubles perform very poorly in terms of pavement wear per ton of freight;
- The bridge formula provides little incentive to distribute loads evenly among axles and can promote the use of non-load-bearing dummy axles; and
- Enforcement of the bridge formula can be complex and time consuming.

As a result of its investigation, the TRB proposed the following new weight restrictions on Interstate trucking:

- Continue current federal axle-weight restrictions,
- For trucks of 80,000 pounds or less, replace the current bridge formula with the TTI HS-20 formula, and
- For trucks over 80,000 pounds, implement a special permit system and hold gross weights to limits of the current bridge formula for vehicles with up to 9 axles[2].

Weight limitations under the special permit program are illustrated in Table 2. It may be important to note that TRB considered but rejected an approach, designed in part to encourage the use of trucks with more load-bearing axles, which limited axle weights to 15,000 pounds for single axles, 34,000 pounds for tractor drive axles, and 30,000 pounds for other tandem axles.

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[2]In addition to weight restrictions, key features of the states' special permit programs would be designated routes, fee structures, and safety restrictions for permit vehicles.

Table 2. Gross Weights under TRB's Special-Permit Proposal for Interstate Travel

Truck Wheelbase (Feet)	Maximum Gross Weight (1,000 Pounds)			
	5-6 Axles	7 Axles	8 Axles	9 or More Axles
40	82.0	83.5	89.0	94.5
45	84.5	86.5	91.5	97.5
50	87.0	89.0	94.5	100.0
55	89.5	92.0	97.5	103.0
60	92.0	95.0	100.5	106.0
65	94.5	98.0	103.0	108.5
70	97.0	101.0	106.0	111.5
75	99.5	104.0	109.0	114.0
80	102.0	106.5	111.5	117.0
85	104.5	109.5	114.5	120.0
90	107.0	112.5	117.5	122.5
95	109.5	115.5	120.5	125.5
100	112.0	118.5	123.0	128.5
105	114.5	121.5	126.0	131.0

The following rationale was offered for the special permit program:

- Most states that currently allow vehicles over 80,000 lb under grandfather exemptions do so only under special permit programs, with designated networks for permit vehicles.
- A permit process with a carefully designed fee structure provides a mechanism for recovering possible increases in pavement or bridge costs caused by heavier vehicles.
- Permit processes strengthen the hand of the state in enforcing weight and safety regulations. They give states considerable latitude to impose special conditions to make enforcement easier (e.g., special markings on vehicles) and permits can be revoked

for repeated or severe violations.

- Permit processes allow states to require safety-related improvements to vehicle components as a condition for use of more productive trucks.
- If the 80,000-lb limit were eliminated, five-axle doubles could operate at up to 92,000 lb, depending on their length. Such vehicles are undesirable at weights over 80,000 lb, because they cause relatively high pavement wear per unit of freight hauled. Under a permit program, these vehicles could be banned or charged higher permit fees commensurate with the damage they add to pavements. Alternatively, reduced axle weights (such as those envisioned by the Turner Proposal) could be applied to certain permit vehicles.

In summary, despite its limitations, the federal bridge formula provides a reasonable mechanism for evaluating the expected impact of heavy trucks on bridge performance. When used to regulate truck weights, it seems to be too complex to be effectively enforced. As a result, it was not considered herein to be an attractive candidate for setting allowable limits for the weights of Kentucky trucks.

EMPTY WEIGHTS

The thrust of the current approach to developing weight limits is to control the amount of pavement wear for each ton of freight moved. Pavement wear can be approximated by means of the number of equivalent single axle loads (ESALs), that is, the number of 18,000-pound single axle loads to which one passage of the truck is equivalent. ESALs have been used for Kentucky pavement designs for a number of years, and procedures for their calculation are straightforward and commonplace. Estimating the payload that can be carried is somewhat more problematic because it requires determining the empty or tare weights of the vehicles that may eventually evolve from any changes in truck weight limits. Moreover, even trucks of the same type, that is, the same number of trailers and the same number of axles, may vary considerably in empty weight depending upon body style, etc.

The approach to estimating empty weights began by computing the cumulative frequency distribution of gross weights for various types of trucks. Kentucky weigh-in-motion (WIM) data collected by the Division of Planning during the period 1990-1992 were used. Cumulative weight distributions were developed for each type of truck: for comparative purposes, separate distributions were determined for rural Interstates and for the collection of all other highway types (Appendix A). Even a cursory examination of these cumulative distributions reveals that no single best estimate of empty weight can be made. There are many empty or very lightly loaded trucks of somewhat widely varying weights. Fortunately, empty weights that have been used by the Federal Highway Administration (FHWA) in analyzing prior truck data were available, and Kentucky weights at the 2nd-percentile level corresponded rather well with the FHWA weights (Table 3). Because 2nd-percentile weights provide visually appealing estimates of empty weights from the cumulative weight distributions, it seemed reasonable to use the FHWA empty weight estimates here. However, because trucks carrying heavier payloads are also likely to be heavier when empty (due to structural and other increased requirements), payloads reported herein are expected to be somewhat exaggerated. The difference should not be so great, however, as to threaten the validity of the findings.

Table 3. Empty Weights of Kentucky Trucks

Truck Type	Number of Axles	Empty Weights Used by FHWA in Preparing W-3 Tables (Pounds)	2nd-Percentile Weights (Pounds)		Empty Weights Selected for Use in Payload Analysis (Pounds)
			Kentucky Rural Interstates	Other Kentucky Roads	
Straight Truck	2	10,000	10,400	9,700	10,000
	3	16,000	17,400	17,400	16,000
	4 or more	20,000	24,500	43,900	20,000
Combination Truck with One Trailer	4 or less	28,000	---	---	28,000
	5	30,000	30,300	29,300	30,000
	6 or more	34,000	34,600	35,600	34,000
Combination Truck with Two Trailers	5 or less	38,000	37,000	30,400	38,000
	6	42,000	40,300	37,100	42,000
	7 or more	46,000	---	---	46,000

RELATIVE PAVEMENT WEAR

Having selected estimates of empty truck weights, the 1990-1992 WIM data were once again used, this time to determine, for each vehicle passing a scale, the ratio of its relative pavement wear (ESALs) to its payload (tons). The focus was on trucks traveling rural principal arterials because these highways were considered to be most representative of those likely to be included within the Resource and Commodity Highway System.

Results, summarized graphically in Appendix B, demonstrate poor pavement wear efficiency, that is, large ESALs per payload ton, when the vehicle is nearly empty. In this range, the tare weight of the nearly empty vehicle is responsible for most of the pavement wear. As payload and gross weight increase, the pavement wear efficiency is improved until a minimum wear rate is reached. Beyond this point of minimum wear or maximum efficiency, ESALs per ton continue to increase without limit as payload and gross weight increase.

At the larger gross weights, the curves of Appendix B are approximately linear and, accordingly, can be expressed quantitatively by the following relationship:

$$\text{ESALs per Payload Ton} = e^{(a + b * \text{Gross Weight})}$$

where e is the base of the natural logarithms, a and b are constants, and the gross weight is expressed in 1,000 pounds. Normal regression techniques were used to determine the constants of such relationships for use in later phases of the investigation (Table 4). Similar graphs (Appendix C) and calibrations (Table 4) were developed using American Association of State Highway Officials (AASHTO) damage factors. The AASHTO damage factors (and the estimates based therefrom) provide a frame of reference for those subscribing to the AASHTO pavement design and evaluation procedures. For the AASHTO calculations, the damage factors corresponded to flexible pavements having a structural number of five and a terminal serviceability of 2.5.

Table 4. Relationship Between ESALs per Payload Ton and Gross Weight for Rural Principal Arterials

Truck Type	Number of Axles	Range of Calibration (1,000 pounds)	KY ESALs			AASHTO ESALs		
			a	b	R^2	a	b	R^2
Straight Truck	2	20 and more	-5.427455	0.1291982	0.89	-5.530553	0.1181243	0.91
	3	50 and more	-3.967332	0.0395360	0.82	-4.184650	0.0391526	0.87
	4	50 to 70	-5.612613	0.0609250	0.73	-3.627611	0.0280468	0.50
Combination Truck with One Trailer	4	50 to 83	-4.369376	0.0478727	0.64	-4.442055	0.0452170	0.72
	5	80 and more	-5.941586	0.0424060	0.97	-4.601676	0.0291296	0.93
	6	85 and more	-5.377134	0.0336188	0.95	-4.146655	0.0235986	0.96
Combination Truck with Two Trailers	5	75 and more	-4.806603	0.0316514	0.85	-3.934809	0.0235098	0.94
	6	85 and more	-5.338516	0.0327514	0.90	-4.207099	0.0236265	0.84

Using Kentucky damage factors and adding calibrations based on rural Interstate data, gross weights of the various styles of trucks that are equivalent in pavement wear efficiency to the 80,000-pound five-axle tractor semitrailer were determined (Table 5). This table demonstrates very convincingly that gross weight is not an accurate indicator of pavement wear efficiency and, therefore, may not be a very good measure with which to control limiting vehicle weights.

Table 5. Gross Weights of Trucks with Equivalent Pavement Wear

Truck Type	Number of Axles	Gross Weight Equivalent in KY ESALs per Payload Ton to 80,000-Pound 5-Axle Tractor-Semitrailer[a]	
		Rural Interstate	Rural Principal Arterial
Straight Truck	2	22,400	22,300
	3	40,700	35,900
	4	44,800	50,300
Combination Truck with One Trailer	4	40,800	38,000
	5	80,000	80,000
	6	85,800	84,100
Combination Truck with Two Trailers	5	48,500	71,300
	6	66,000	85,200

[a]The 80,000-pound, five-axle tractor-semitrailer imposes approximately 0.084 and 0.078 KY ESALs per ton of payload on rural Interstates and rural principal arterials, respectively.

Also of general interest is a comparison of the pavement wear efficiency of coal trucks loaded to the limits currently permitted on Kentucky's extended-weight system (Table 6). Immediately obvious from this table are the large differences in efficiency among these trucks. Because of their large axle loads, all of these trucks are much more destructive that the typical Interstate carrier (the 80,000-pound five-axle tractor semitrailer), and the advantage of more axles (reduced ESALs per payload ton) is readily apparent.

Table 6. Pavement Wear of Coal-Decal Trucks

Truck Type	Number of Axles	Permitted Gross Weight (Pounds)	KY ESALs Per Payload Ton		Relative Wear Compared to 80,000-Pound 5-Axle Tractor-Semitrailer	
			Rural Interstate[a]	Rural Principal Arterial	Rural Interstate	Rural Principal Arterial
Straight Truck	3	94,500	1.29	0.79	15.4	10.1
	4	105,000	0.95	2.19	11.3	28.1
Combination Truck with One Trailer	5	126,000	0.40	0.55	4.8	7.1
	6	126,000	0.22	0.32	2.6	4.1

[a]Coal-decal trucks are not permitted to operate on the Interstate system under maximum gross weights permitted on the extended-weight system. Therefore, entries for rural Interstate travel are for comparative purposes only.

CANDIDATE TRUCK WEIGHT OPTIONS

A range of truck weight options was considered in this investigation. For the base system[3], the five-axle, tractor-semitrailer truck was selected as the standard for comparison. Candidate gross loads on this "standard" truck varied from 85,000 pounds to 105,000 pounds in increments of 5,000 pounds. Candidate gross loads for other truck types were set, as best possible, so as to yield comparable bridge loading and comparable pavement wear efficiency. For the coal-road system, loadings in excess of current weight limits were not considered to be viable alternatives. Moreover, significantly restricting the loading privileges that had been given to coal haulers also did not seem to be viable. The six-axle tractor-semitrailer, loaded to 126,000 pounds, was considered herein to be the line-haul coal transporter of choice and was selected as the standard for comparison. Gross loads of other trucks were set to yield comparable bridge loading and comparable pavement wear efficiency.

First the weights of "equivalent" trucks for each weight scenario were determined based on both the federal bridge formula (Table 7) and pavement wear efficiency (Table 8). In estimating the basic bridge formula limits for the base system, wheelbases (steering to rearmost axle) were set at 85th percentile levels for

[3]The Resource and Commodity Highway System has two components; a coal-road system which contains the major arteries of the current extended-weight system and a base system which contains key trucking routes with current gross weight restrictions of no more than 80,000 pounds. This distinction is necessary because of the desire to allow decaled coal trucks to continue to operate at or near the current limits of the extended-weight system.

trucks currently operating on rural principal arterials. The 1990-1992 WIM database was used to determine these percentiles. For coal roads, 85th percentile wheelbases were used based on travel on the extended-weight system in coal producing counties for three- and four-axle straight trucks and five- and six-axle combinations and on 85th percentile wheelbases on rural principal arterials for other trucks. Appendices D and E contain graphs of these wheelbase distributions and corresponding bridge formula distributions.

Table 7. Weights of Equivalent Trucks Based on Bridge Formula Limits

Truck Type	Number of Axles	Bridge Formula[a]	Gross Weight of Base Truck (5-Axle Tractor Semitrailer)					Coal Roads[b]
			85,000	90,000	95,000	100,000	105,000	
Straight Truck	2	47,815	48,859	51,733	54,607	57,481	60,355	69,345
	3	52,250	53,391	56,531	59,672	62,812	65,953	77,003
	4	59,638	60,940	64,525	68,109	71,694	75,279	84,500
Combination Truck with One Trailer	4	74,145	75,764	80,220	84,677	89,134	93,590	107,530
	5	83,184	85,000	90,000	95,000	100,000	105,000	119,400
	6	85,497	87,363	92,503	97,642	102,781	107,920	126,000
Combination Truck with Two Trailers	5	90,144	92,112	97,530	102,949	108,367	113,785	130,733
	6	93,980	96,032	101,681	107,330	112,978	118,627	136,297

[a]Based on 85th percentile wheelbases on rural principal arterials.

[b]Adjusted to 126,000-pound, six-axle tractor-semitrailer and based on 85th percentile wheel bases on the extended-weight system in coal producing counties for three- and four-axle straight trucks and five- and six-axle combinations and on 85th percentile wheelbases on rural principal arterials for other trucks.

Table 8. Weights of Equivalent Trucks Based on Average ESALs per Ton of Payload

Truck Type	Number of Axles	Gross Weight of Base Truck (5-Axle Tractor Semitrailer)					Coal Roads[a]
		85,000	90,000	95,000	100,000	105,000	
Kentucky Damage Factors							
Straight Truck	2	23,900	25,500	27,200	28,800	30,500	33,100
	3	41,200	46,600	51,900	57,300	62,700	71,500
	4	53,700	57,200	60,700	64,200	67,700	73,400
Combination Truck with One Trailer	4	42,500	46,900	51,300	55,700	60,200	67,400
	5	85,000	90,000	95,000	100,000	105,000	113,200
	6	90,500	96,700	103,000	109,300	115,700	126,000
Combination Truck with Two Trailers	5	78,000	84,700	91,400	98,100	104,800	115,800
	6	91,600	98,100	104,600	111,100	117,500	128,200
AASHTO Damage Factors							
Straight Truck	2	28,800	30,100	31,300	32,500	33,700	36,900
	3	52,600	56,300	60,000	63,700	67,400	76,900
	4	53,500	58,800	63,900	69,100	74,300	87,500
Combination Truck with One Trailer	4	51,300	54,500	57,700	60,900	64,100	72,300
	5	85,000	90,000	95,000	100,000	105,000	117,700
	6	85,600	91,800	98,000	104,100	110,300	126,000
Combination Truck with Two Trailers	5	77,000	83,100	89,400	95,500	101,700	117,500
	6	88,100	94,300	100,400	106,500	112,700	128,400

[a]Adjusted to 126,000-pound, six-axle tractor semitrailer.

Table 7 demonstrates that all trucks for all weight-limit scenarios exceed federal bridge formula gross weight limits. This means that, regardless of the weight limits ultimately selected for the Resource and Commodity Highway System, bridges on this system will be overstressed in comparison with the standard currently applicable to Interstate bridges. Moreover, in comparing Tables 7 and 8, pavement wear efficiency is seen to yield smaller gross weight equivalency than bridge formula equivalency for all truck types except five- and six-axle tractor-semitrailers.

Next the candidate gross weight of each truck type for each weight scenario was selected as the minimum of the two weights, one for bridge-formula equivalency (Table 7) and the other for pavement-wear equivalency (Table 8). To determine corresponding axle weights, regression equations of the following form were calibrated:

Gross Weight = a + b * NSINGLE + c * NTANDEM + d * NTRIDEM

in which NSINGLE is the number of single axles for the given vehicle type, NTANDEM is the number of tandem axles, and NTRIDEM is the number of tridem axles. The constants, a, b, c, and d, then represent best-fit estimates of the weights of the steering, single, tandem, and tridem axles at the gross weight limits selected by the combination of bridge formula equivalency and pavement wear equivalency. Results are summarized in Table 9.

Table 9 entries would be considered to be viable candidate axle-weight limits were it not for the fact that some, particularly steering-axle and other single-axle weights, are less than currently allowable limits on Kentucky's Interstate highways. In selecting candidate axle-weight limits, a limit of 15,000 pounds on the steering axles of all but coal roads seemed reasonable in recognition of the greatly increased wear under single tires instead of dual tires (according to Kentucky damage factors and other independent investigations), the practical difficulty in loading most truck steering axles beyond this limit, and the regression calibrations completed herein. On coal roads, the steering axle-weight limit was set at the current 20,000-pound maximum for other single axles. For other axle types, axle-weight limits can not be smaller than those currently permitted on Kentucky's Interstate highways, namely, 20,000 pounds on a single axle, 34,000 pounds on a tandem axle group, and 48,000 pounds on a tridem axle group.

Table 9. Maximum Axle Weights in Pounds for Equivalent Trucks

Base Condition	Type of Axle			
	Steering	Single	Tandem	Tridem
Kentucky Damage Factors				
Coal	11,152	24,147	48,994	64,051
105,000	10,717	21,859	43,931	55,127
100,000	8,811	20,828	42,137	53,611
95,000	7,023	19,762	40,281	52,007
90,000	5,209	18,696	38,456	50,414
85,000	3,421	17,630	36,601	48,810
AASHTO Damage Factors				
Coal	19,510	22,375	46,173	62,653
105,000	18,067	19,227	40,244	52,921
100,000	17,301	17,982	38,420	49,429
95,000	16,506	16,770	36,611	45,959
90,000	15,917	15,483	34,653	42,057
85,000	13,821	15,077	33,783	38,838

Overlaying these restrictions onto the entries of Table 9 produces, after suitable rounding, candidate maximum axle weights for each scenario (Table 10). These candidate weights include a 5-percent weight tolerance. Axle-weight limits determined with Kentucky damage factors exceed those determined with AASHTO damage factors by an average of about 500, 3,000, and 1,600 pounds for single, tandem, and tridem axles, respectively. Using Kentucky factors because they provide the basis for pavement design and analysis in Kentucky and removing the 5-percent recommended tolerance yields the candidate axle-weight limits of Table 11.

Table 10. Maximum Axle Weights in Pounds After Adjustment to Current Weight Limits

Base Condition	Type of Axle			
	Steering	Single	Tandem	Tridem
Kentucky Damage Factors				
Coal Road	21,000	24,150	49,350	64,050
105,000	15,750	22,050	44,100	55,650
100,000	15,750	21,000	42,000	53,550
95,000	15,750	21,000	39,900	52,500
90,000	15,750	21,000	38,850	50,400
85,000	15,750	21,000	36,750	50,400
AASHTO Damage Factors				
Coal Road	21,000	22,050	46,200	63,000
105,000	15,750	21,000	39,900	52,500
100,000	15,750	21,000	38,850	50,400
95,000	15,750	21,000	36,750	50,400
90,000	15,750	21,000	35,700	50,400
85,000	15,750	21,000	35,700	50,400

Table 11. Candidate Maximum Axle Weights in Pounds Without Tolerance

Base Condition	Type of Axle			
	Steering	Single	Tandem	Tridem
Coal Road	20,000	23,000	47,000	61,000
105,000	15,000	21,000	42,000	53,000
100,000	15,000	20,000	40,000	51,000
95,000	15,000	20,000	38,000	50,000
90,000	15,000	20,000	37,000	48,000
85,000	15,000	20,000	35,000	48,000

In addition to axle-weight limits, some means must be provided to assure that truck axles are not so closely spaced as to induce undue wear on bridges. This is what the bridge formula seeks to control. However, the bridge formula is too complex for effective understanding and enforcement. A similar effect can be achieved simply by assuring that the density of loading (gross weight per unit of wheelbase length) is not excessive.

Table 12 presents such limits. Entries are based on regressions of the ratio of maximum gross weight (determined by axle-weight limits of Table 11) to the 50th percentile wheelbases with respect to number of trailers. For coal roads, only heavily laden trucks operating on extended-weight systems in coal-producing counties were used in the wheelbase measurements (1991 WIM data). On the base system, the wheelbases were determined from trucks operating on rural principal arterials (using 1990-1992 WIM data).

Table 12. Candidate Maximum Allowable Weight-to-Wheelbase Ratios

System Element	Basis for Proposal	Maximum Allowable Gross Weight Per Foot of Wheelbase (Pounds per Foot)
Coal Roads		3,500 - 750 * Number of Trailers
Other Roads	105,000-Pound, Five-Axle Tractor Semitrailer	3,000 - 600 * Number of Trailers
	100,000-Pound, Five-Axle Tractor Semitrailer	2,900 - 600 * Number of Trailers
	95,000-Pound, Five-Axle Tractor Semitrailer	2,800 - 600 * Number of Trailers
	90,000-Pound, Five-Axle Tractor Semitrailer	2,700 - 550 * Number of Trailers
	85,000-Pound, Five-Axle Tractor Semitrailer	2,600 - 500 * Number of Trailers

Based on the candidate axle-weight limits of Table 11 and the candidate minimum wheelbase spacings for fully loaded trucks that derive from Table 12, Tables 13 through 18 summarize the gross weights of the various truck types resulting from the proposed axle-weight limits and their effects on bridge and pavement wear. In general given a particular style of truck, for example, straight trucks, more axles (and greater load and longer wheelbase) means more bridge wear but less pavement wear.

Table 13. Effects of Candidate Axle Weight Limits for Coal-Road Portion of Resource and Commodity Highway System

Truck Type	Number of Axles	Gross Weight (Pounds)		Minimum Wheelbase at Maximum Weight (Feet)	Percent of Bridge Formula Allowable Gross Weight	KY ESALs per Payload Ton
		Without Tolerance	With Tolerance			
Straight Truck	2	43,000	45,150	12.9	105.2	1.500
	3	67,000	70,350	20.2	137.5	0.305
	4	81,000	85,050	24.3	146.1	0.650
Combination Truck with One Trailer	4	90,000	94,500	34.4	145.5	1.167
	5	114,000	119,700	43.5	159.2	0.421
	6	128,000	134,400	48.9	161.3	0.424
Combination Truck with Two Trailers	5	112,000	117,600	58.8	138.8	0.338
	6	136,000	142,800	71.4	147.4	0.516
	7	160,000	168,000	84.0	154.1	---

Table 14. Effects of Candidate Axle Weight Limits for Resource and Commodity Highway System (Nominal 105,000-Pound Basis)

Truck Type	Number of Axles	Gross Weight (Pounds)		Minimum Wheelbase at Maximum Weight (Feet)	Percent of Bridge Formula Allowable Gross Weight	KY ESALs per Payload Ton
		Without Tolerance	With Tolerance			
Straight Truck	2	36,000	37,800	12.6	88.7	0.580
	3	57,000	59,850	20.0	117.4	0.202
	4	68,000	71,400	23.8	123.4	0.283
Combination Truck with One Trailer	4	78,000	81,900	34.1	126.5	0.638
	5	99,000	103,950	43.3	138.5	0.216
	6	110,000	115,500	48.1	139.4	0.224
Combination Truck with Two Trailers	5	99,000	103,950	57.8	123.6	0.219
	6	120,000	126,000	70.0	131.3	0.298
	7	141,000	148,050	82.2	137.1	---

Table 15. Effects of Candidate Axle Weight Limits for Resource and Commodity Highway System (Nominal 100,000-Pound Basis)

Truck Type	Number of Axles	Gross Weight (Pounds)		Minimum Wheelbase at Maximum Weight (Feet)	Percent of Bridge Formula Allowable Gross Weight	KY ESALs per Payload Ton
		Without Tolerance	With Tolerance			
Straight Truck	2	35,000	36,750	12.7	86.1	0.507
	3	55,000	57,750	19.9	113.4	0.186
	4	66,000	69,300	23.9	119.6	0.249
Combination Truck with One Trailer	4	75,000	78,750	34.2	121.5	0.549
	5	95,000	99,750	43.4	132.8	0.180
	6	106,000	111,300	48.4	134.0	0.195
Combination Truck with Two Trailers	5	95,000	99,750	58.7	117.8	0.192
	6	115,000	120,750	71.0	125.0	0.251
	7	135,000	141,750	83.4	130.5	---

Table 16. Effects of Candidate Axle Weight Limits for Resource and Commodity Highway System (Nominal 95,000-Pound Basis)

Truck Type	Number of Axles	Gross Weight (Pounds)		Minimum Wheelbase at Maximum Weight (Feet)	Percent of Bridge Formula Allowable Gross Weight	KY ESALs per Payload Ton
		Without Tolerance	With Tolerance			
Straight Truck	2	35,000	36,750	13.1	85.3	0.507
	3	53,000	55,650	19.9	109.3	0.171
	4	65,000	68,250	24.4	117.1	0.234
Combination Truck with One Trailer	4	73,000	76,650	34.8	117.6	0.497
	5	91,000	95,550	43.4	127.2	0.151
	6	103,000	108,150	49.2	129.5	0.175
Combination Truck with Two Trailers	5	95,000	99,750	62.3	114.7	0.192
	6	113,000	118,650	74.2	120.4	0.234
	7	131,000	137,550	86.0	124.9	---

Table 17. Effects of Candidate Axle Weight Limits for Resource and Commodity Highway System (Nominal 90,000-Pound Basis)

Truck Type	Number of Axles	Gross Weight (Pounds)		Minimum Wheelbase at Maximum Weight (Feet)	Percent of Bridge Formula Allowable Gross Weight	KY ESALs per Payload Ton
		Without Tolerance	With Tolerance			
Straight Truck	2	35,000	36,750	13.6	84.3	0.507
	3	52,000	54,600	20.2	106.7	0.164
	4	63,000	66,150	24.5	113.4	0.205
Combination Truck with One Trailer	4	72,000	75,600	35.2	115.5	0.472
	5	89,000	93,450	43.5	124.3	0.138
	6	100,000	105,000	48.8	126.1	0.158
Combination Truck with Two Trailers	5	95,000	99,750	62.3	114.7	0.192
	6	112,000	117,600	73.5	119.9	0.226
	7	129,000	135,450	84.6	123.9	---

Table 18. Effects of Candidate Axle Weight Limits for Resource and Commodity Highway System (Nominal 85,000-Pound Basis)

Truck Type	Number of Axles	Gross Weight (Pounds)		Minimum Wheelbase at Maximum Weight (Feet)	Percent of Bridge Formula Allowable Gross Weight	KY ESALs per Payload Ton
		Without Tolerance	With Tolerance			
Straight Truck	2	35,000	36,750	14.1	83.3	0.507
	3	47,000	49,350	19.0	98.2	0.133
	4	63,000	66,150	25.4	112.2	0.205
Combination Truck with One Trailer	4	70,000	73,500	35.0	112.5	0.427
	5	85,000	89,250	42.5	119.7	0.116
	6	98,000	102,900	49.0	123.4	0.147
Combination Truck with Two Trailers	5	95,000	99,750	62.3	114.7	0.192
	6	110,000	115,500	72.2	118.7	0.211
	7	125,000	131,250	82.0	121.7	---

The primary objective of the aforedescribed work was to develop axle-weight and spacing limits that would result in similarity among the various truck types in the extent of bridge overstress as well as pavement wear efficiency. Fundamental differences in the effects of axle weights on bridge overstress (Table 7) and pavement wear efficiency (Table 8) combine with the effects of not allowing axle-weight limits to be below Interstate highway limits to limit the extent to which this objective can be achieved. Nevertheless, an acceptable balance seems to have been reached.

To assist in the evaluation process, Table 19 compares the candidate weight limits with respect to the rate of pavement wear expected from fully loaded vehicles of the various types. In this comparison, the current gross weight limit of trucks with fewer than five axles assumes that the steering axle is loaded to 15,000 pounds (plus a 5-percent tolerance). Pavement wear would increase among all the alternatives but begins to accelerate beyond the nominal 95,000 pound five-axle tractor-semitrailer. Figure 7 verifies this trend graphically. Figure 8 shows that bridge overstress increases in an approximately linear fashion with nominal gross weight.

In order to develop specific recommendations about weight limits, a number of additional factors must be considered. Later sections examine issues such as the extent to which the current truck population would be considered to be overloaded under the various candidate weight limits, the adequacy of existing bridges to carry heavier trucks, and the extent to which heavier trucks might jeopardize highway safety.

Table 19. Increase in Pavement Wear for Candidate Weight Limits

Truck Type	Number of Axles	Percentage of Truck Miles (Federal Aid Primary System)	Current Gross Weight Limit (Pounds)	Nominal Gross Weight of Base Truck (5-Axle Tractor Semitrailer)					Coal Roads
				85,000	90,000	95,000	100,000	105,000	
Gross Weight Limit (Pounds)									
Straight Truck	2	28.72	36,750	36,750	36,750	36,750	36,750	37,800	45,150
	3	8.59	51,450	49,350	54,600	55,650	57,750	59,850	70,350
	4	2.28	66,150	66,150	66,150	68,250	69,300	71,400	85,050
Combination Truck with One Trailer	4	6.76	72,450	73,500	75,600	76,650	78,750	81,900	94,500
	5	47.40	80,000	89,250	93,450	95,550	99,750	103,950	119,700
	6	5.35	80,000	102,900	105,000	108,150	111,300	115,500	134,400
Combination Truck with Two Trailers	5	0.61	80,000	99,750	99,750	99,750	99,750	103,950	117,600
	6	0.18	80,000	115,500	117,600	118,650	120,750	126,000	142,800
Kentucky ESALs per Ton of Payload									
Straight Truck	2		0.507	0.507	0.507	0.507	0.507	0.580	1.500
	3		0.145	0.133	0.164	0.171	0.186	0.202	0.305
	4		0.205	0.205	0.205	0.234	0.249	0.283	0.650
Combination Truck With One Trailer	4		0.406	0.427	0.472	0.497	0.549	0.638	1.167
	5		0.078	0.116	0.138	0.151	0.180	0.216	0.421
	6		0.068	0.147	0.158	0.175	0.195	0.224	0.424
Combination Truck With Two Trailers	5		0.103	0.192	0.192	0.192	0.192	0.219	0.338
	6		0.066	0.211	0.226	0.234	0.251	0.298	0.516
Percentage Increase in Pavement Wear									
Straight Truck	2			0.0	0.0	0.0	0.0	14.4	195.8
	3			-8.3	13.1	17.9	28.3	39.3	110.3
	4			0.0	0.0	14.1	21.5	38.0	217.1
Combination Truck With One Trailer	4			5.2	16.3	22.4	35.2	57.1	187.4
	5			48.7	76.9	93.6	130.8	176.9	439.7
	6			116.2	132.4	157.4	186.8	229.4	523.5
Combination Truck With Two Trailers	5			86.4	86.4	86.4	86.4	112.6	228.2
	6			219.7	242.4	254.5	280.3	351.5	681.8
Average				10.1	17.4	21.7	30.3	51.1	235.1

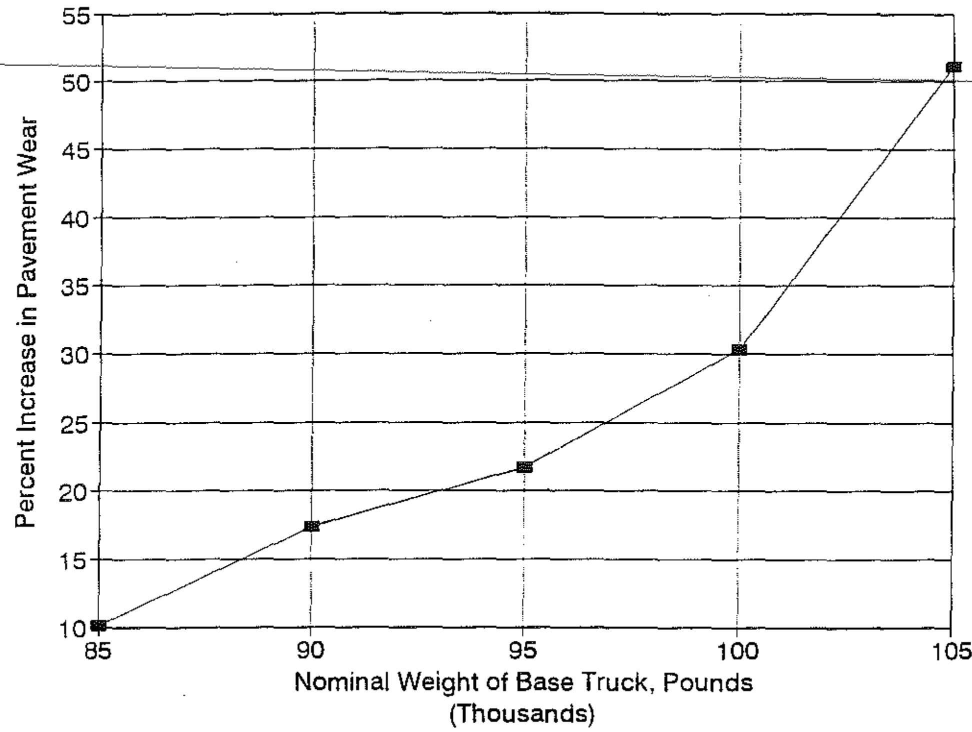

Figure 7. Effect of Nominal Gross Weight on ESALs per Payload Ton

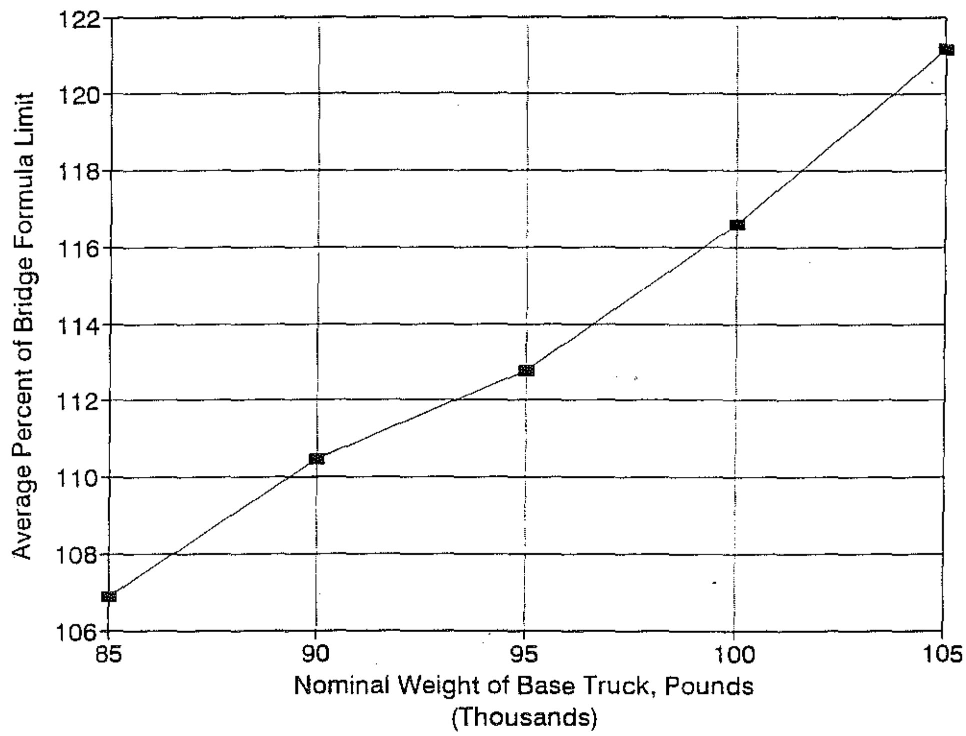

Figure 8. Effect of Nominal Gross Weight on Bridge Overstress

TIRE PRESSURE AND "SUPER SINGLES"

Of all truck size-and-weight matters, one of the currently most important deals with tires and tire loading. There have been tremendous changes in the tire industry in recent years and, as a result, bias-ply tires have been replaced by radials, tire pressures have increased from 85 psi to 120 psi and more, and single tires are becoming much more commonly used as replacements for dual tires. Moreover, across the country, "flexible" pavements are rutting to dangerous levels at escalating rates. The old standard, which simply required that tires be loaded to levels no greater than 600 pounds per lineal inch of width, may no longer be adequate. This requirement has always been difficult, if not impossible, to enforce and can no longer be guaranteed to prevent premature pavement wear.

In 1988 *(Truck Weight Limits, 1990)*, the following ten states imposed less stringent pounds-per-inch requirements than Kentucky:

State	Tire Limit (Pounds per Inch)
Indiana	800
Louisiana	650
Massachusetts	800
Michigan	700
New Jersey	800
New York	800
Ohio	650
Pennsylvania	800
Texas	650
Virginia	650

Thus, although there is precedence for increasing the tire load limit, it is important to recognize that at least seven of these states generally experience cooler temperatures than Kentucky. As a result, rutting of their pavements would not be as severe a problem as it is in Kentucky. The issue is very complex, however, depending additionally on the type of pavement, the total tire and axle weights, etc.

The tire issue demands in-depth investigation of the type that has been impossible during the current study. The 600-pounds-per-inch requirement should be retained until a detailed assessment of other alternatives can be completed and appropriate recommendations developed. The use of "super singles" should be an essential element of this assessment. In Europe, the heavier loads presently are being carried by vehicles using "super single" tires. This appears to be the trend for the future and is a further warrant for in-depth analysis. Meanwhile, from a safety standpoint, efforts should be continued to insure that tire manufacturers' recommendations regarding maximum and minimum inflation pressures and maximum tire loads are followed.

CURRENT TRAFFIC OVERLOADS

To help determine the reasonableness of the candidate weight and wheelbase limits, the extent to which current trucks would be considered to be overloaded by the proposed changes was determined. WIM data collected by the Division of Planning during the period of 1990-1992 provided the basis for the investigation. Two separate analyses were conducted, one for the special coal-road limits and the other for the base-system limits. For the coal-road analysis, WIM data were limited to traffic operating on the existing extended-weight system. For the base-system analysis, WIM data were limited to traffic operating on rural principal arterials but excluding the extended-weight routes.

In addition to the candidate axle-weight and wheelbase limits identified earlier, a gross-weight cap of 130,000 pounds was added to this and subsequent analyses. The gross-weight cap results primarily from safety considerations and not from pavement wear and bridge overload. Its justification is presented later in the section entitled "Large Truck Safety."

The coal-road analysis is summarized in Table 20. Certainly the vast majority of the trucks currently operating would legally meet the proposed load and wheelbase limits. Critical limits involve the four-axle straight truck (steering axle and wheelbase) and the six-axle tractor-semitrailer (tridem axle). In view of considerable pavement damage caused by the single tires of steering axles, relaxing the proposed 21,000-pound (including the 5-percent tolerance) steering axle limit is unreasonable and counterproductive. However, the wheelbase limitation for the four-axle straight truck and the tridem axle weight limitation for the six-axle tractor-semitrailer seem too restrictive. Accordingly, both candidate limitations should be relaxed to reduce overloading to more acceptable percentages.

The base-system analysis is summarized in Tables 21-25. In order to simplify the discussion, the focus will be on the 95,000-pound alternative as summarized by Table 23. Once again the vast majority of the vehicles would be in compliance with the proposed limits. However, that such large proportions of both four-axle straight trucks and six-axle tractor-semitrailers would be considered to be overloaded poses a difficult dilemma. Certainly limits which reject such a large number of existing trucks would not seem to provide sufficient relaxation of existing requirements. However, at the same time, some of these trucks are grossly overloaded at the present time and should not, therefore, be considered to provide a reasonable standard for comparison.

Table 20. Percentage of Overweight Trucks on Extended-Weight System under Candidate Coal-Road Weight Limits

Truck Type	Number of Axles	Sample Size	Percentage of Axle Violations				Percentage of Vehicle Violations		
			Steering (21,000 pounds)	Single (24,150 pounds)	Tandem (49,350 pounds)	Tridem (64,050 pounds)	Gross Weight (130,000 pounds)	Wheelbase	Combined Limits
Straight Truck	2	2,271	0.0	0.8	---	---	0.0	0.0	0.8
	3	1,346	1.9	---	3.0	---	0.0	2.9	4.4
	4	149	14.1	---	---	0.0	0.0	33.6	38.9
Combination Truck with One Trailer	4	826	3.9	0.1	15.8	---	0.0	13.4	14.3
	5	4,924	0.1	---	6.5	---	0.2	1.2	12.0
	6	2,297	0.1	---	2.8	28.0	6.4	8.1	28.2
Combination Truck With Two Trailers	5	58	0.0	0.0	---	---	0.0	3.4	6.9
	6	28	0.0	5.9	5.6	---	3.6	14.2	21.4
	7	---	---	---	---	---	---	---	---

Table 21. Percentage of Overweight Trucks on Rural Principal Arterials under Candidate Weight Limits (Nominal 105,000-Pound Basis)

Truck Type	Number of Axles	Sample Size	Percentage of Axle Violations				Percentage of Vehicle Violations		
			Steering (15,750 pounds)	Single (22,050 pounds)	Tandem (44,100 pounds)	Tridem (55,650 pounds)	Gross Weight (130,000 pounds)	Wheelbase	Combined Limits
Straight Truck	2	2,943	0.0	0.8	---	---	0.0	0.0	0.8
	3	943	9.8	---	0.3	---	0.0	0.7	10.1
	4	171	43.9	---	---	0.0	0.0	40.4	57.3
Combination Truck with One Trailer	4	1,717	1.6	0.7	0.6	---	0.0	1.1	3.0
	5	9,834	0.3	---	3.4	---	0.1	1.8	5.0
	6	2,349	0.4	---	13.2	36.7	8.8	20.9	37.1
Combination Truck With Two Trailers	5	315	0.0	0.0	---	---	0.0	3.5	6.4
	6	46	0.0	17.8	39.6	---	19.6	32.6	54.4
	7	---	---	---	---	---	---	---	---

Table 22. Percentage of Overweight Trucks on Rural Principal Arterials under Candidate Weight Limits (Nominal 100,000-Pound Basis)

Truck Type	Number of Axles	Sample Size	Percentage of Axle Violations				Percentage of Vehicle Violations		
			Steering (15,750 pounds)	Single (21,000 pounds)	Tandem (42,000 pounds)	Tridem (53,550 pounds)	Gross Weight (130,000 pounds)	Wheelbase	Combined Limits
Straight Truck	2	2,943	0.0	1.2	---	---	0.0	0.0	1.2
	3	943	9.8	---	0.8	---	0.0	1.6	10.8
	4	171	43.9	---	---	0.6	0.0	46.2	60.8
Combination Truck with One Trailer	4	1,717	1.6	0.9	0.9	---	0.0	1.3	3.3
	5	9,834	0.3	---	4.1	---	0.1	2.6	5.6
	6	2,349	0.4	---	20.4	39.3	8.8	26.9	39.5
Combination Truck With Two Trailers	5	315	0.0	0.0	---	---	0.0	5.7	7.3
	6	46	0.0	20.0	47.2	---	19.6	39.1	60.9
	7	---	---	---	---	---	---	---	---

Table 23. Percentage of Overweight Trucks on Rural Principal Arterials under Candidate Weight Limits (Nominal 95,000-Pound Basis)

Truck Type	Number of Axles	Sample Size	Percentage of Axle Violations				Percentage of Vehicle Violations		
			Steering (15,750 pounds)	Single (21,000 pounds)	Tandem (39,900 pounds)	Tridem (52,500 pounds)	Gross Weight (130,000 pounds)	Wheelbase	Combined Limits
Straight Truck	2	2,943	0.0	1.2	---	---	0.0	0.0	1.2
	3	943	9.8	---	1.4	---	0.0	2.3	11.0
	4	171	43.9	---	---	3.8	0.0	52.6	63.7
Combination Truck with One Trailer	4	1,717	1.6	0.9	1.0	---	0.0	1.5	3.4
	5	9,834	0.3	---	5.0	---	0.1	3.6	6.5
	6	2,349	0.4	---	27.3	40.1	8.8	32.0	40.7
Combination Truck With Two Trailers	5	315	0.0	0.0	---	---	0.0	7.3	8.2
	6	46	0.0	20.0	54.7	---	19.6	47.8	63.0
	7	---	---	---	---	---	---	---	---

Table 24. Percentage of Overweight Trucks on Rural Principal Arterials under Candidate Weight Limits (Nominal 90,000-Pound Basis)

Truck Type	Number of Axles	Sample Size	Percentage of Axle Violations				Percentage of Vehicle Violations		
			Steering (15,750 pounds)	Single (21,000 pounds)	Tandem (38,850 pounds)	Tridem (50,400 pounds)	Gross Weight (130,000 pounds)	Wheelbase	Combined Limits
Straight Truck	2	2,943	0.0	1.2	---	---	0.0	0.0	1.2
	3	943	9.8	---	2.0	---	0.0	3.5	11.4
	4	171	43.9	---	---	14.5	0.0	59.6	69.0
Combination Truck with One Trailer	4	1,717	1.6	0.9	1.0	---	0.0	1.6	3.4
	5	9,834	0.3	---	5.7	---	0.1	3.9	7.2
	6	2,349	0.4	---	30.6	41.1	8.8	34.0	41.5
Combination Truck With Two Trailers	5	315	0.0	0.0	---	---	0.0	7.3	8.2
	6	46	0.0	20.0	56.6	---	19.6	47.8	65.2
	7	---	---	---	---	---	---	---	---

Table 25. Percentage of Overweight Trucks on Rural Principal Arterials under Candidate Weight Limits (Nominal 85,000-Pound Basis)

Truck Type	Number of Axles	Sample Size	Percentage of Axle Violations				Percentage of Vehicle Violations		
			Steering (15,750 pounds)	Single (21,000 pounds)	Tandem (36,750 pounds)	Tridem (50,400 pounds)	Gross Weight (130,000 pounds)	Wheelbase	Combined Limits
Straight Truck	2	2,943	0.0	1.2	---	---	0.0	0.0	1.2
	3	943	9.8	---	3.2	---	0.0	5.2	12.8
	4	171	43.9	---	---	14.5	0.0	63.2	71.9
Combination Truck with One Trailer	4	1,717	1.6	0.9	1.3	---	0.0	1.6	3.4
	5	9,834	0.3	---	7.3	---	0.1	4.2	9.1
	6	2,349	0.4	---	35.9	41.1	8.8	36.1	41.7
Combination Truck With Two Trailers	5	315	0.0	0.0	---	---	0.0	7.3	8.6
	6	46	0.0	20.0	62.3	---	19.6	47.8	65.2
	7	---	---	---	---	---	---	---	---

The large number of steering-axle overloads for the four-axle combination seems to require returning the steering-axle limit to 21,000 pounds (including tolerance). The percentage of tandem-axle overloads on the six-axle combination seems acceptable: their weight limit of 39,900 pounds (including tolerance) considerably exceeds the current limit of 35,700 pounds (including tolerance). Further relaxation simply to legalize what appears to be current overloading is not justifiable.

Concern with the large percentage of overloads on the tridem axle of the six-axle tractor semitrailer prompted additional computations to determine the optimal loading of the axles of this vehicle. These computations determined that, for steering axles loaded to 15,750 pounds, the minimum ESALs per payload ton resulted when the weight of the tridem axle is about 1.64 times the weight of the tandem axle. The corresponding ratio for the candidate weights is considerably less (about 1.32). Therefore, some increase in the tridem axle limit seems justifiable. Furthermore, some relaxation of the wheelbase restriction is necessary to reduce the incidence of overloading for four-axle straight trucks and six-axle tractor-semitrailers.

After several trial-and-error computations, revised axle-weight limits (Table 26) and revised wheelbase limits (Table 27) were developed that better fit current traffic conditions. Ultimately the tridem weight limits were set to levels approximately 150 percent of the tandem limits. The wheelbase limits were based on 40th percentile wheelbases rather than the 50th percentile wheelbases that had been previously used. Tables 28-33 summarize the percentages of overweight trucks using these modified criteria.

Table 26. Revised Candidate Maximum Axle Weights in Pounds Without Tolerance

Base Condition	Type of Axle			
	Steering	Single	Tandem	Tridem
Coal Road	20,000	23,000	47,000	70,000
105,000	20,000	21,000	42,000	63,000
100,000	20,000	20,000	40,000	60,000
95,000	20,000	20,000	38,000	57,000
90,000	20,000	20,000	37,000	55,000
85,000	20,000	20,000	35,000	53,000

Table 27. Revised Candidate Maximum Allowable Weight-to-Wheelbase Ratios

System Element	Basis for Proposal	Maximum Allowable Gross Weight Per Foot of Wheelbase (Pounds per Foot)
Coal Roads		3,900 - 900 * Number of Trailers
Other Roads	105,000-Pound, Five-Axle Tractor Semitrailer	3,500 - 850 * Number of Trailers
	100,000-Pound, Five-Axle Tractor Semitrailer	3,400 - 800 * Number of Trailers
	95,000-Pound, Five-Axle Tractor Semitrailer	3,300 - 800 * Number of Trailers
	90,000-Pound, Five-Axle Tractor Semitrailer	3,200 - 750 * Number of Trailers
	85,000-Pound, Five-Axle Tractor Semitrailer	3,100 - 700 * Number of Trailers

Table 28. Percentage of Overweight Trucks on Extended-Weight System under Revised Candidate Coal-Road Weight Limits

Truck Type	Number of Axles	Sample Size	Percentage of Axle Violations				Percentage of Vehicle Violations		
			Steering (21,000 pounds)	Single (24,150 pounds)	Tandem (49,350 pounds)	Tridem (73,500 pounds)	Gross Weight (130,000 pounds)	Wheelbase	Combined Limits
Straight Truck	2	2,271	0.0	0.8	---	---	0.0	0.0	0.8
	3	1,346	1.9	---	3.0	---	0.0	0.9	4.0
	4	149	14.1	---	---	0.0	0.0	0.0	14.1
Combination Truck with One Trailer	4	826	3.9	0.1	15.8	---	0.0	13.2	14.0
	5	4,924	0.1	---	6.5	---	0.2	0.1	11.9
	6	2,297	0.1	---	2.8	7.3	6.4	2.2	8.6
Combination Truck With Two Trailers	5	58	0.0	0.0	---	---	0.0	1.7	6.9
	6	28	0.0	5.9	5.6	---	3.6	14.3	14.3
	7	---	---	---	---	---	---	---	---

Table 29. Percentage of Overweight Trucks on Rural Principal Arterials under Revised Candidate Weight Limits (Nominal 105,000-Pound Basis)

Truck Type	Number of Axles	Sample Size	Percentage of Axle Violations				Percentage of Vehicle Violations		
			Steering (21,000 pounds)	Single (22,050 pounds)	Tandem (44,100 pounds)	Tridem (66,150 pounds)	Gross Weight (130,000 pounds)	Wheelbase	Combined Limits
Straight Truck	2	2,943	0.0	0.8	---	---	0.0	0.0	0.8
	3	943	0.2	---	0.3	---	0.0	0.2	0.4
	4	171	5.3	---	---	0.0	0.0	7.6	11.1
Combination Truck with One Trailer	4	1,717	0.2	0.7	0.6	---	0.0	0.5	1.6
	5	9,834	0.0	---	3.4	---	0.1	0.5	4.7
	6	2,349	0.0	---	13.2	18.8	8.8	9.4	21.5
Combination Truck With Two Trailers	5	315	0.0	0.0	---	---	0.0	3.5	6.4
	6	46	0.0	17.8	39.6	---	19.6	32.6	50.0
	7	---	---	---	---	---	---	---	---

Table 30. Percentage of Overweight Trucks on Rural Principal Arterials under Revised Candidate Weight Limits (Nominal 100,000-Pound Basis)

Truck Type	Number of Axles	Sample Size	Percentage of Axle Violations				Percentage of Vehicle Violations		
			Steering (21,000 pounds)	Single (21,000 pounds)	Tandem (42,000 pounds)	Tridem (63,000 pounds)	Gross Weight (130,000 pounds)	Wheelbase	Combined Limits
Straight Truck	2	2,943	0.0	1.2	---	---	0.0	0.0	1.2
	3	943	0.2	---	0.8	---	0.0	0.2	1.0
	4	171	5.3	---	---	0.0	0.0	12.3	16.4
Combination Truck with One Trailer	4	1,717	0.2	0.9	0.9	---	0.0	0.5	2.0
	5	9,834	0.0	---	4.1	---	0.1	0.7	5.3
	6	2,349	0.0	---	20.4	24.2	8.8	11.8	27.2
Combination Truck With Two Trailers	5	315	0.0	0.0	---	---	0.0	3.5	7.3
	6	46	0.0	20.0	47.2	---	19.6	32.6	54.4
	7	---	---	---	---	---	---	---	---

Table 31. Percentage of Overweight Trucks on Rural Principal Arterials under Revised Candidate Weight Limits (Nominal 95,000-Pound Basis)

Truck Type	Number of Axles	Sample Size	Percentage of Axle Violations				Percentage of Vehicle Violations		
			Steering (21,000 pounds)	Single (21,000 pounds)	Tandem (39,900 pounds)	Tridem (59,850 pounds)	Gross Weight (130,000 pounds)	Wheelbase	Combined Limits
Straight Truck	2	2,943	0.0	1.2	---	---	0.0	0.0	1.2
	3	943	0.2	---	1.4	---	0.0	0.2	1.5
	4	171	5.3	---	---	0.0	0.0	18.1	21.6
Combination Truck with One Trailer	4	1,717	0.2	0.9	1.0	---	0.0	0.9	2.3
	5	9,834	0.0	---	5.0	---	0.1	1.1	6.1
	6	2,349	0.0	---	27.3	29.8	8.8	16.7	33.4
Combination Truck With Two Trailers	5	315	0.0	0.0	---	---	0.0	5.7	7.6
	6	46	0.0	20.0	54.7	---	19.6	39.1	60.9
	7	---	---	---	---	---	---	---	---

Table 32. Percentage of Overweight Trucks on Rural Principal Arterials under Revised Candidate Weight Limits (Nominal 90,000-Pound Basis)

Truck Type	Number of Axles	Sample Size	Percentage of Axle Violations				Percentage of Vehicle Violations		
			Steering (21,000 pounds)	Single (21,000 pounds)	Tandem (38,850 pounds)	Tridem (57,750 pounds)	Gross Weight (130,000 pounds)	Wheelbase	Combined Limits
Straight Truck	2	2,943	0.0	1.2	---	---	0.0	0.0	1.2
	3	943	0.2	---	2.0	---	0.0	0.4	2.2
	4	171	5.3	---	---	0.0	0.0	23.4	26.3
Combination Tuck with One Trailer		1,717	0.2	0.9	1.0	---	0.0	1.0	2.4
	5	9,834	0.0	---	5.6	---	0.1	1.4	6.8
	6	2,349	0.0	---	30.6	34.0	8.8	18.5	36.5
Combination Truck With Two Trailers	5	315	0.0	0.0	---	---	0.0	5.7	7.9
	6	46	0.0	20.0	56.6	---	19.6	39.1	63.0
	7	---	---	---	---	---	---	---	---

Table 33. Percentage of Overweight Trucks on Rural Principal Arterials under Revised Candidate Weight Limits (Nominal 85,000-Pound Basis)

Truck Type	Number of Axles	Sample Size	Percentage of Axle Violations				Percentage of Vehicle Violations		
			Steering (21,000 pounds)	Single (21,000 pounds)	Tandem (36,750 pounds)	Tridem (55,650 pounds)	Gross Weight (130,000 pounds)	Wheelbase	Combined Limits
Straight Truck	2	2,943	0.0	1.2	---	---	0.0	0.0	1.2
	3	943	0.2	---	3.2	---	0.0	0.5	3.4
	4	171	5.3	---	---	0.0	0.0	29.8	31.6
Combination Truck with One Trailer	4	1,717	0.2	0.9	1.3	---	0.0	1.1	2.7
	5	9,834	0.0	---	7.3	---	0.1	1.8	8.8
	6	2,349	0.0	---	35.9	36.7	8.8	20.9	39.5
Combination Truck With Two Trailers	5	315	0.0	0.0	---	---	0.0	5.7	8.2
	6	46	0.0	20.0	62.3	---	19.6	39.1	65.2
	7	---	---	---	---	---	---	---	---

BRIDGE DEFICIENCIES

Bridges are vital links in any highway system: a bridge so structurally deficient that it must be posted interrupts normal traffic flow and, for heavy trucks, may necessitate costly detours. Bridges are also one of the most costly components of the highway infrastructure. Therefore, any changes in permissible weight limits must be evaluated for their effects upon the bridges in the system. If a large number of additional bridges warrant posting as a result of the weight-limit changes proposed herein, the effectiveness of the system would be reduced substantially. This section briefly addresses 1) the extent to which structurally deficient bridges are likely to limit the beneficial effects of the proposed weight increases and interrupt the proposed trucking highway system and 2) the likely effect of weight increases on the bridge component of infrastructure costs. Primary concern is for base-system roadways because the weight increases proposed herein do not exacerbate existing problems on coal roads and don't add to the already large infrastructure costs there.

There are 1,198 bridges on the present trial system. Of these, 733 are on the coal-road portion of the system, and 465 are on the base system. Of the 74 bridges currently posted with reduced weight limitations, 57 are on coal roads and 15 are on the base system. These are summarized in Table 34.

Table 34. Bridges Used in Analysis

System Portion	Bridges in Each Portion	Bridges with Capacity Available	Bridges Currently Posted
Coal	733	696	57
Base	465	459	15
Total	1,198	1,155	72

The capacity of existing bridges on the trial system was obtained from the bridge inventory database maintained by the Division of Maintenance of the Kentucky Department of Highways. In that database, the operating rating of a bridge is defined as 75 percent of its ultimate capacity. Also, four load types (Types I through IV) are identified for many of the structures. These load types represent the maximum permissible load on four different types of vehicles. Type IV represents a five-axle tractor-semitrailer. The load magnitude for Type IV loading was always the greatest of any of the four load types. In performing the analysis for this study, the rated capacity of any particular structure was taken to be the greater of the operating rating or the Type IV load. Because 43 structures did not have any capacity information, this analysis is limited to a total of 1,155 bridges.

Cumulative distributions of the rated capacity of all the structures on the base portion of the system and the coal-road portion of the system are plotted in Figures 9 and 10, respectively. Also, in these same figures, cumulative distributions are plotted for three classes of structures--all structures having sufficiency ratings of less than 50, those having sufficiency ratings between 50 and 80, and those having sufficiency ratings from 80 to 100. The sufficiency rating is a composite indicator of structural and functional adequacy. A structure with no deficiencies is awarded a rating of 100, and bridges with ratings of 50 or below are considered to be likely candidates for replacement.

A close examination of Figures 9 and 10 shows that there is not a dramatic difference in the percentage of bridges with sufficiency ratings below 50 between the two portions of the system. However, there is a small increase in the number of bridges within the coal-road portion of the system with sufficiency ratings between 50 and 80 that have reduced capacities when compared to the same group in the base system. For example, the percentage of structures rated less than 90,000 pounds on the coal-road portion of the system is approximately 12 percent, and the percentage of bridges on the base portion rated less than 90,000 pounds is only 10 percent (a difference of only two percent). When comparing all bridges on both portions of the system capable of carrying 90,000 pounds, there is only a one percent difference between the coal-road portion and the base portion.

As the capacity rating increases, the percentage of structurally deficient bridges increases dramatically. For example, as capacity increases to 130,000 pounds, the percentage of structurally inadequate bridges increases to 43 percent and 33 percent on the coal-road portion and the base portion of the system, respectively. This is a significant 10-percent difference between coal roads and other system highways.

The two previous examples argue that small increases in the permitted gross loads on vehicles do not dramatically increase the number of deficient bridges: however, as loads on vehicles continue to increase, a disproportionate number of bridges become deficient.

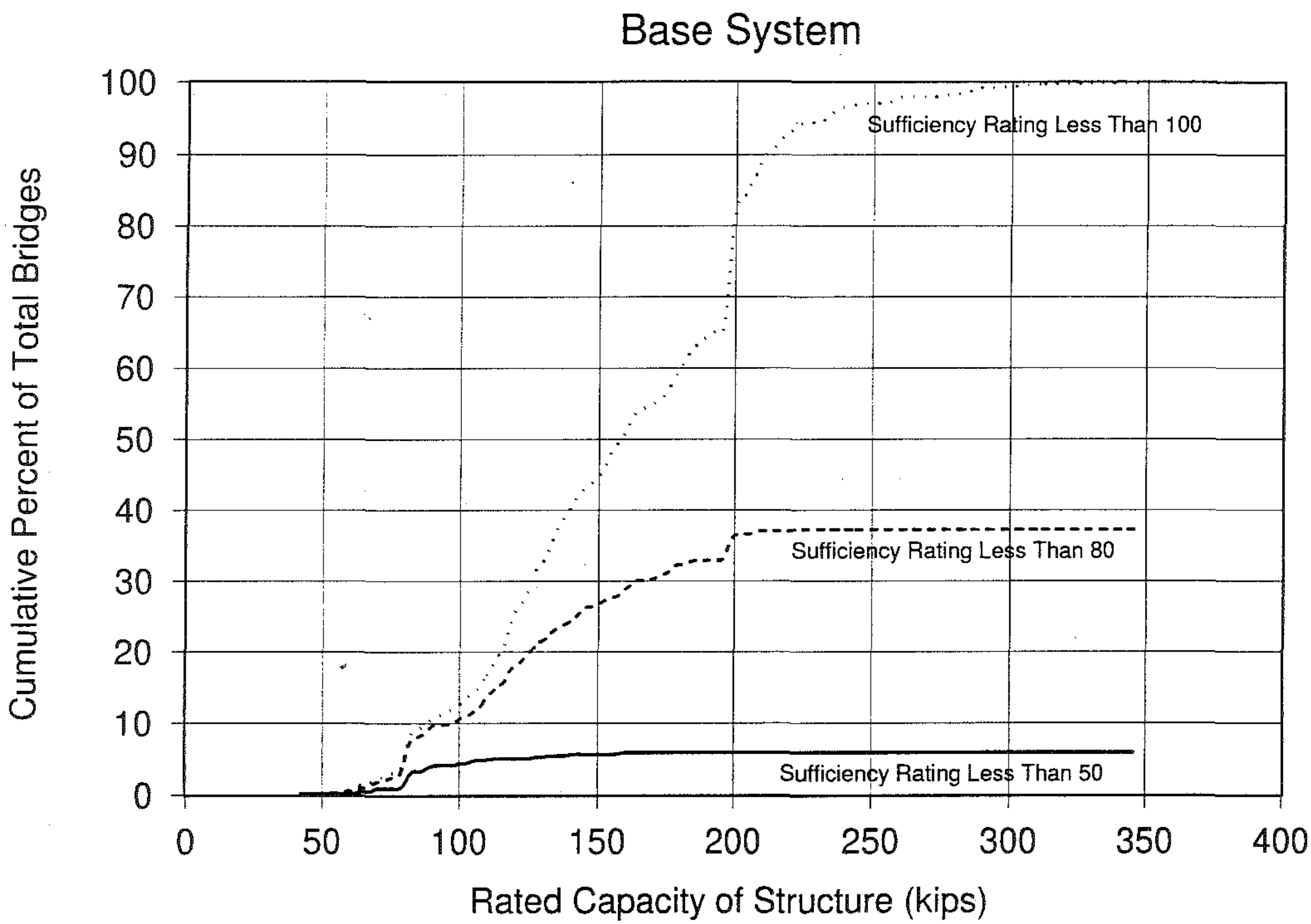

Figure 9. Cumulative Distribution of Rated Capacity of Bridges on Base Portion of Resource and Commodity Highway System.

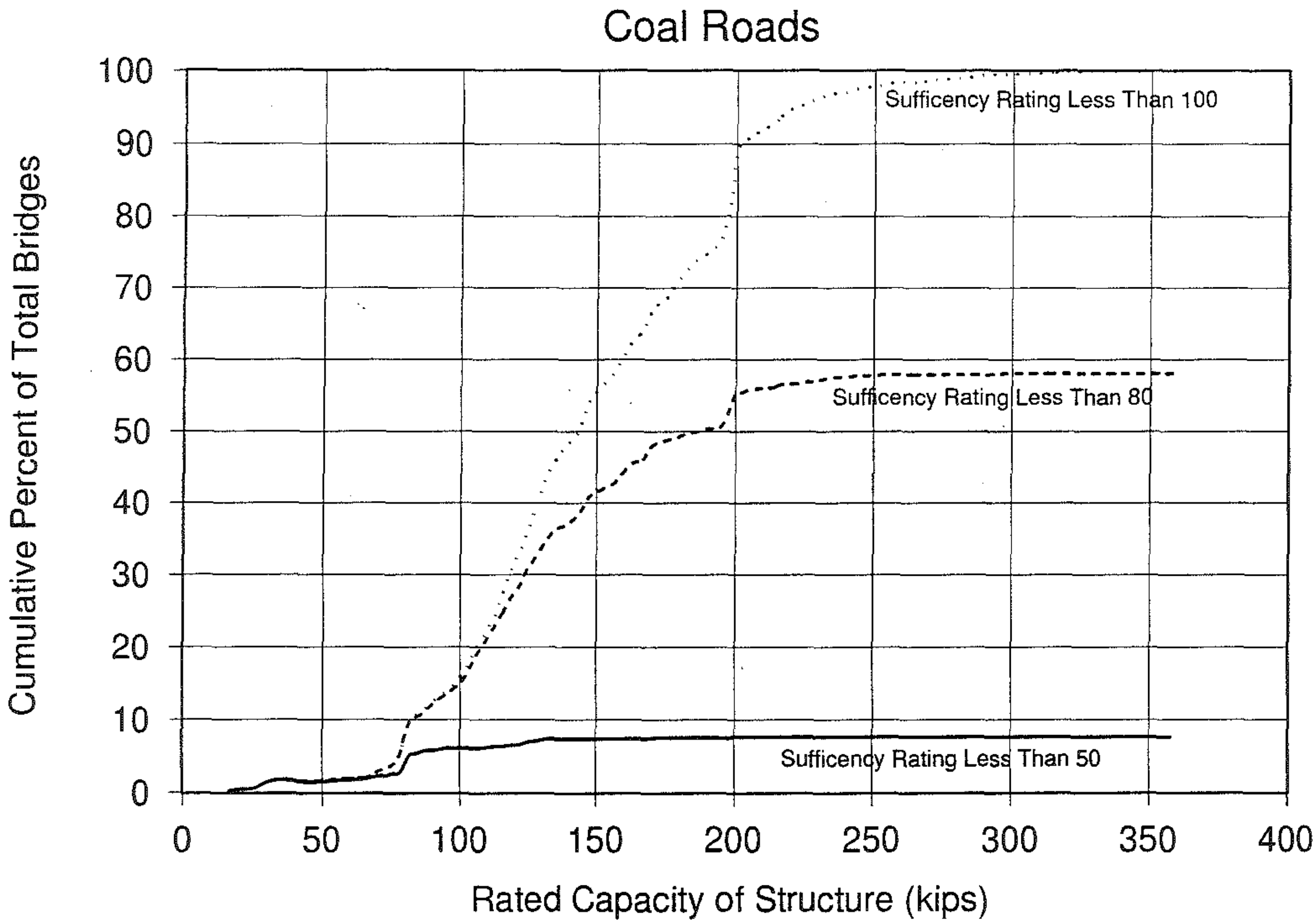

Figure 10. Cumulative Distribution of Rated Capacity of Bridges on Coal-Road Portion of Resource and Commodity Highway System.

The *"Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges,"* published by the Federal Highway Administration, indicates that, when the legal load limit is greater than the defined operating rating, the bridge should be posted. Using this criterion, the number of bridges on the base system that should be posted under the current 80,000-pound limit is approximately 7.6 percent or 35 bridges (from Figure 9)[4]. If the maximum gross load of 117,600 pounds on a six-axle tractor-semitrailer on the base system (using axle limits from Table 26 for 90,000-pound scenario and adding 5-percent tolerance) is permitted, then the number of bridges that must be posted would be approximately 20 percent, or 91 bridges. Since 35 bridges already should be posted by the previously defined criterion, this would be an increase of only 56 bridges.

Nevertheless, 91 deficient bridges out of the total of 465 bridges might seriously limit the overall effectiveness of the Resource and Commodity Highway System and, if these bridges were replaced, considerably increase infrastructure costs as well. Three important findings emerge. First, the system will obviously incorporate routes with bridges that must be posted (at least initially). Even with posting, however, most trucks will achieve substantial weight gains. For example, only 58 bridges could not accommodate loads up to 98,700 pounds, the maximum weight permitted on five-axle tractor-semitrailers (using axle limits from Table 26 for 90,000-pound scenario and adding 5-percent tolerance). Moreover, even at a 98,700-pound limit, six-axle tractor-semitrailers would receive a substantial payload boost. Second, future system refinements must consider the location of structurally deficient bridges and, where possible, alternate routes without such limitations should be sought. Third, any bridge with a serious load deficiency and so located as to unavoidably interrupt system connectivity should be among the first programmed for replacement or upgrade.

Many of the bridges that are structurally deficient in carrying the increased weights proposed herein have low sufficiency ratings. This means that, even under current weight limits, these bridges have structural and/or functional inadequacies that limit their utility. A low sufficiency rating identifies a bridge as a likely candidate for replacement, and, accordingly, sufficiency rating is one of the elements considered in programming and budgeting bridge replacements. To the extent, then, that bridges with low sufficiency ratings are likely to become prime candidates for replacement (with or without the weight increases proposed herein), their full replacement costs cannot logically be fully attributed to the weight-limit increases proposed herein.

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[4]As indicated earlier, only 15 bridges on the base system are actually posted. The criteria used for posting bridges as described in this report were used only for this study. The actual policies for posting bridges are determined and set by the Kentucky Transportation Cabinet.

The following summarizes the principal findings of the bridge analysis:

- The majority of bridges on the trial system can accommodate gross truck weights of up to about 100,000 pounds. Beyond that point, the percentage of deficient bridges begins to increase rapidly.

- Initially the system would incorporate routes with structurally deficient bridges. Despite these deficiencies, most trucks should still be able to realize significant payload gains.

- The percentage of bridges that are structurally unable to support gross loads of 100,000 pounds is somewhat greater on coal roads than on the base system. However, the costs of eventually upgrading bridges on coal roads cannot logically be attributed to the weight-limit changes proposed herein: they result instead from the 1986 legislation that created the extended-weight system.

- Many of the bridges that are structurally inadequate to accommodate gross loads of 100,000 pounds have sufficiency ratings less than 50. Such low ratings often justify bridge repair or replacement. As a result, the full costs of replacing bridges with low sufficiency ratings also cannot logically be attributed to the weight-limit changes proposed herein.

- Future refinements of the trial system must consider specific locations of functionally and structurally deficient bridges with the objectives of 1) minimizing the number of deficient bridges within the system and 2) assuring, insofar as possible, that no deficient bridge be allowed to interrupt system connectivity.

- Any deficient bridge which unavoidably interrupts system connectivity should be programmed for immediate replacement or upgrade.

SIZE RESTRICTIONS

Kentucky currently limits its semitrailers in tractor-semitrailer combinations to 53 feet in length and its semitrailers and trailers in tractor-semitrailer-trailer combinations to 28 feet. Moreover, truck width for the largest trucks is presently limited to 102 inches. A key question when weight restrictions are eased is whether size restrictions may prevent full utilization of the weight gains. This study has been unable to completely address this issue. However, retaining the 53-foot maximum semitrailer length is considered to be absolutely essential because of turning considerations, particularly at intersections. Although adding vehicle width (to the wheel treads of both tractor and towed units) adds stability and reduces overturning tendencies, wider vehicles may increase the safety risk particularly on more narrow roadways. Until more definitive information is available, therefore, an increase in the width allowance is not warranted.

The 28-foot limitation on the length of semitrailers and trailers in tractor-semitrailer-trailer combinations may produce an unwarranted impediment to achieving desired productivity gains. Although the 45-foot trailers of the turnpike double configuration appear to be completely unsuitable until substantial system upgrades are in place, 33-foot units appear to be an acceptable compromise. Whether double-trailer combinations would be attractive to the trucking industry is an open question at this point. Nevertheless, allowing the use of 33-foot units in double-trailer combinations should impose no added safety risk and should create no special turning or maneuvering problems[5].

RECOMMENDATIONS

To minimize damage to pavements and bridges, the best way to carry heavier payloads is to add additional axles thereby spreading the load over a longer span and avoiding highly concentrated loading. However, some increase in axle-weight limits and removal of the 80,000-pound cap should prove advantageous to Kentucky haulers without severely threatening the integrity of the highway plant. Meanwhile, improvements to the system can be initiated to improve the compatibility between heavier trucks and the line-haul highways on which they operate.

For coal-road portions of the Resource and Commodity Highway System, only one weight limit scenario has been investigated herein. That scenario was designed to endorse currently legal practice to the maximum practical extent while bringing some degree of rationality to weight regulation and restraining the use of particularly destructive trucks. It replaces the current gross weight limits for coal-decal trucks with axle-weight and wheelbase limits, and it extends the larger weight-limit privileges to all haulers regardless of commodity.

For base-system portions of the Resource and Commodity Highway System, five weight-limit scenarios have been investigated. The best of these scenarios represents a compromise between the competing objectives of maximizing transportation productivity and minimizing infrastructure costs. The nominal 90,000-pound alternative (as modified) seems to be a logical choice for the following reasons:

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[5]The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 restricts the operation of commercial motor vehicle combinations with two or more cargo carrying units on the National Network to the type of vehicles in use on or before June 1, 1991, subject to whatever State rules, regulations, or restrictions were in effect on that date. This would prevent Kentucky from allowing 33-foot units in double-trailer combinations on those highways that are part of the National Network.

- It offers quite significant productivity gains to current truckers but does not reach levels of diminishing return, that is, levels where large changes in axle weight limits are necessary to achieve even small productivity gains (see later section, "Trucking Productivity and Infrastructure Costs");

- It is not so large that it requires major truck retrofits or replacements of existing fleets or that it permits overloading of existing trucks to dangerously unsafe levels;

- It limits the degree to which "weak" bridges will initially limit system continuity (see section, "Bridge Deficiencies");

- It prevents axle weights from becoming so large that pavement wear escalates rapidly; and

- It allows the flexibility for future weight increases as may be justified by experience or by detailed analysis, particularly of infrastructure costs.

Tables 35 and 36 identify vehicle weights and wheelbases permitted by these recommendations and summarize their effects on bridges and pavements.

Table 35. Effects of Recommended Axle Weight and Wheelbase Limits for Resource and Commodity Highway System

Truck Type	Number of Axles	Gross Weight (Pounds)		Minimum Wheelbase at Maximum Weight (Feet)	Percent of Bridge Formula Allowable Gross Weight	KY ESALs per Payload Ton
		Without Tolerance	With Tolerance			
Base System						
Straight Truck	2	40,000	42,000	13.1	97.4	0.999
	3	57,000	59,850	18.7	119.6	0.202
	4	75,000	78,750	24.6	134.8	0.443
Combination Truck With One Trailer	4	77,000	80,850	33.0	126.3	0.607
	5	94,000	98,700	40.3	134.9	0.173
	6	112,000	117,600	48.0	142.0	0.241
Combination Truck With Two Trailers	5	100,000	105,000	61.8	121.2	0.227
	6	117,000	122,850	72.3	126.2	0.268
	7	130,000	130,000	76.5	124.3	---
Coal Roads						
Straight Truck	2	43,000	45,150	11.6	108.6	1.491
	3	67,000	70,350	18.0	142.0	0.305
	4	90,000	94,500	24.2	162.5	1.156
Combination Truck with One Trailer	4	90,000	94,500	31.5	150.0	1.167
	5	114,000	119,700	39.9	164.1	0.421
	6	130,000	130,000	43.3	162.5	0.365
Combination Truck with Two Trailers	5	112,000	117,600	56.0	141.7	0.340
	6	130,000	130,000	61.9	142.6	0.340
	7	130,000	130,000	61.9	135.3	---

Table 36. Comparison of Bridge and Pavement Wear Impacts Due to Current and Proposed Weight Limits

Truck Type	Number of Axles	Gross Weight with Tolerance (lbs)			Percentage of Bridge Formula Limit			Pavement Wear (ESALs/Ton)		
		Current	Proposed	% Change	Current	Proposed	% Change	Current	Proposed	% Change
Base System										
Straight Truck	2	42,000	42,000	0.0	93.7	97.4	3.9	0.999	0.999	0.0
	3	56,700	59,850	5.6	112.2	119.6	6.6	0.178	0.202	13.5
	4	71,400	78,750	10.3	127.6	134.8	5.6	0.283	0.443	56.5
Combination Truck With One Trailer	4	77,700	80,850	4.0	117.1	126.3	7.8	0.522	0.607	16.3
	5	80,000	98,700	23.4	100.9	134.9	33.7	0.078	0.173	121.8
	6	80,000	117,600	47.0	96.3	142.0	47.4	0.068	0.241	254.4
Combination Truck With Two Trailers	5	80,000	105,000	31.2	91.7	121.2	32.2	0.103	0.227	120.4
	6	80,000	122,850	53.6	87.5	126.2	44.2	0.066	0.268	306.1
	7	80,000	130,000	62.5	83.0	124.3	49.8	---	---	---
Coal Roads										
Straight Truck	2	42,000	45,150	7.5	93.7	108.5	15.9	0.999	1.491	49.2
	3	94,500	70,350	-25.6	187.2	142.0	-24.1	0.793	0.305	-61.5
	4	105,000	94,500	-10.0	187.3	162.5	-13.2	2.191	1.156	-47.2
Combination Truck With One Trailer	4	77,700	94,500	21.6	117.1	150.0	28.1	0.522	1.167	123.6
	5	126,000	119,700	-5.0	165.5	164.1	-0.8	0.550	0.421	-23.4
	6	126,000	130,000	3.2	152.8	162.5	6.3	0.319	0.365	14.4
Combination Truck With Two Trailers	5	80,000	117,600	47.0	91.7	141.7	54.5	0.103	0.340	230.1
	6	80,000	130,000	62.5	87.5	142.6	63.0	0.066	0.340	415.2
	7	80,000	130,000	62.5	83.0	135.3	62.9	---	---	---

The following summarizes specific recommendations regarding weight limits on the Resource and Commodity Highway System.

1. A combination of axle-weight limits and wheelbase limits should be substituted for fixed gross weight limits as the means for controlling the loading of properly certified vehicles.

2. The following weight and wheelbase limitations should be applied to vehicles properly certified to operate within the entirety of the Resource and Commodity Highway System:

    - Axle-weight limits

        - Steering axle: 20,000 pounds
        - Single axle: 20,000 pounds
        - Tandem axle: 37,000 pounds
        - Tridem axle: 55,000 pounds
        - Allowable axle-weight tolerance: Five percent

    - Maximum ratio of gross weight to wheelbase

        - Straight trucks: 3,200 pounds per foot
        - Combination trucks with one trailer: 2,450 pounds per foot
        - Combination trucks with two trailers: 1,700 pounds per foot
        - No tolerance on weight-to-wheelbase ratio

3. The following weight and wheelbase limitations should be applied to vehicles properly certified to operate at larger weights within the coal-road portion of the Resource and Commodity Highway System:

    - Axle-weight limits

        - Steering axle: 20,000 pounds
        - Single axle: 23,000 pounds
        - Tandem axle: 47,000 pounds
        - Tridem axle: 70,000 pounds
        - Allowable axle-weight tolerance: Five percent

    - Maximum ratio of gross weight to wheelbase

        - Straight trucks: 3,900 pounds per foot
        - Combination trucks with one trailer: 3,000 pounds per foot
        - Combination trucks with two trailers: 2,100 pounds per foot
        - No tolerance on weight-to-wheelbase ratio

    - Three- and four-axle straight trucks should be permitted to operate--if issued the proper permit--on the coal-road portions of the Resource and Commodity Highway System under current provisions of the extended-weight system for a transition period of four years.

- If Recommendation 3 is not adopted, it is recommended that the limits on coal trucks which are now permitted on the extended-weight system be retained and that other trucks be allowed to operate under general provisions applicable to the entirety of the Resource and Commodity Highway System.

4. In computing axle-weight and wheelbase limits, no allowance should be made for any retractable or variable load suspension (VLS) not meeting the following criteria[6]:

   - All controls must be located outside of and be inaccessible from the driver's compartment.

   - The gross axle weight rating of all VLS devices must conform to the expected loading of the suspension and should in no case be less than 9,000 pounds.

   - Axles of all retractable or VLS devices manufactured or mounted on a vehicle after July 1, 1994 should be engineered to be self-steering in a manner that would guide or direct the VLS mounted wheels through a turning movement without tire scrubbing or pavement scuffing.

   - Tires in use on all such axles should conform in load rating capacity with relevant Kentucky regulations or with Federal Motor Vehicle Safety (FMVS) standards or with both as is deemed appropriate.

5. All axle group suspension systems should at all times distribute the load equally among all axles of the group[7]. "Equally" means no single axle weight deviates more than approximately $\pm$ 5 percent from the theoretical maximum average axle weight of the group and specifically interpreted as follows:

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[6]This recommendation is taken from AASHTO's *Guide for Maximum Dimensions and Weights of Motor Vehicles and for the Operation of Nondivisible Load Oversize and Overweight Vehicles*.

[7]This recommendation is an interpretation of a similar recommendation in AASHTO's *Guide for Maximum Dimensions and Weights of Motor Vehicles and for the Operation of Nondivisible Load Oversize and Overweight Vehicles*.

Type of Facility	Maximum Load Difference Between Heaviest and Lightest Axle of Axle Group (Pounds)	
	Tandem Axles	Tridem Axles
Coal Roads	2,500	2,000
Other Roads	2,500	2,000

Failure to achieve equal weight distribution should result in reduction of the allowable load. If any axle of the group exceeds the single-axle weight limit, the allowable load on the entire axle group should be the single-axle weight limit.

6. The allowable length of semitrailers and trailers in tractor-semitrailer-trailer combinations should be increased from 28 to 33 feet where permitted by federal authority.

7. Tire loads should continue to be limited to 600 pounds per lineal inch of width. However, an investigation should be undertaken to examine issues involving permissible tire loading, to study the impacts of replacing dual with single tires including "super singles," and to develop, as appropriate, recommendations for future legislation.

TRUCK MANEUVERABILITY

The Surface Transportation Assistance Act of 1982 (STAA) specifically prohibited Kentucky and other states from limiting the length of a semitrailer in a tractor-semitrailer combination to less than 48 feet, or the length of each trailer in a combination vehicle with two trailers to less than 28 feet on designated highways. The STAA also specified that states could not prohibit the use of twin trailers on the designated highways. In addition, states were prohibited from enacting any overall length limit on tractor-semitrailers or twin-trailer trucks, and truck width requirements were liberalized to allow 102-inch wide vehicles on designated highways with 12-foot lanes.

The Kentucky Transportation Cabinet has established a length limitation of 53 feet for semitrailers of combination vehicles operating on highways designated as the Increased Dimension-Twin Trailer System (IDTT). This system is included in the highways which were identified as the designated truck network (DTN).

One result of allowing increased lengths of combination vehicles was that it resulted in increased offtracking for larger trucks. The required turning path for a given design vehicle is necessary for the design of intersections and ramps. If the offtracking distance is increased, this will have an effect on the geometric design requirements of these facilities.

In a recent study, data were developed to allow turning templates to be produced for critical design vehicles *(Agent and Pigman, 1991)*. This included information concerning truck turning radii and offtracking for larger trucks with varying wheelbases operating in Kentucky. Data were produced for design vehicles ranging from a passenger car to a combination truck with a 53-foot trailer. The simulation model used was the Truck Offtracking Model (TOM) developed by the California Department of Transportation. The data obtained from the truck offtracking simulation program show that it can be used to develop turning templates that are consistent with those developed by AASHTO.

The maximum low-speed offtracking and swept width was found for the tractor-semitrailer combination with a 53-foot trailer (AASHTO designation WB-67). No vehicle should be allowed to operate on the Resource and Commodity Highway System which has a configuration which would result in low-speed offtracking greater than the WB-67. Allowing greater offtracking increases the safety risk as large trucks maneuver to make turns in restricted areas and threatens damage to roadside appurtenances as trailing wheels track beyond paved surfaces during tight turns. The WB-67 should be the design truck for establishing standards for the Resource and Commodity Highway System and, hence, should be the standard against which all future trucks are compared.

LARGE TRUCK SAFETY

While one of the primary goals of the Resource and Commodity Highway System is to enhance transportation productivity, care must be taken to assure that the new system does not adversely impact traffic safety. Traffic safety is a paramount concern in all considerations related to truck size and weight regulation. Heavy trucks are commonly perceived to pose a threat to traffic safety and, although the evidence is mixed, research inquiries do pinpoint vehicle characteristics (including weight) that could contribute to the likelihood of crash involvement. Certainly, the weight of an accident-involved truck can affect the severity of the accident.

One of the more significant prior studies investigated the influence of truck size and weight on the stability and control properties of heavy vehicles *(Ervin et al., 1986)*. Axle weight and gross vehicle weight were two of the variables considered. Each was found to have a strong influence on yaw stability in a turn and on static roll stability, a moderate influence on stopping distance, and a slight influence on stability during braking and the response of the tractor to steering. One particularly significant finding was that, for trucks having the "representative, as-designed" type of brake system behavior, increased axle loading resulted in small reductions in stopping distance. However, for trucks with brake systems which, either through design or lack of maintenance, exhibited limitations in torque output (such that wheel lockup cannot be attained), increased axle loading resulted in increases in stopping distance. If all of the brakes on a vehicle are torque-limited, the stopping distance would increase approximately in proportion to the change in total gross weight. Other findings were that increases in axle-weight limit, implemented by simply increasing the load carried on non-steering axles, consistently result in a reduction in the understeer quality of trucks and tractors and that the rollover threshold is reduced by increases in axle-weight limit (a 10-percent increase in axle-weight limit yielded an average of 0.025 g reduction in the rollover threshold).

Of perhaps greater relevance to the current proposal, a recent study of the impacts of the existing Extended Weight Coal and Coal By-Products Haul Road System in Kentucky included an accident analysis *(Crabtree et al., 1993)*. The analysis found no evidence of a higher overall accident rate on the extended-weight system versus comparable, non-extended-weight routes. However, the fatal accident rate was significantly higher on the extended-weight system. When comparing truck and non-truck accidents, trucks were found to have: 1) a larger percentage of fatal accidents, 2) an overrepresentation of fixed object, sideswipe, and "vehicle overturned" accidents, and 3) a larger percentage of accidents involving obstructed view, road construction, improper passing, defective brakes, tire failure, and improper or oversize load.

Fortunately, while highway crashes can not be eliminated, several measures are available for mitigating most of the potentially harmful effects of heavy trucks. Traffic accidents are caused by one or, more commonly, a combination of factors in three general areas. These areas relate basically to the vehicle, the driver, and the roadway. Safety-related recommendations typically deal with any or all of these areas.

Regarding the vehicle, it is imperative that truck braking systems meet the appropriate Federal Motor Vehicle Safety standards (FMVS) and KRS requirements given the maximum gross vehicle weight allowed. In addition to on-the-road inspections and other activities designed to assure proper braking performance, operators should be required--at the time permits are purchased--to certify that their vehicles meet all applicable braking and safety standards appropriate to the loads they carry. In addition, trucks carrying hazardous materials (HAZMAT) should not initially be permitted to carry the increased payloads being proposed herein.

Experience with heavy truck operations in Kentucky is limited to legal loads of 126,000 pounds. While trucks carrying such loads have generally been operated successfully, the accident pattern suggests that additional experience is warranted before legalizing much heavier trucks. Accordingly, an allowable gross weight cap of 130,000 pounds (with no tolerance permitted) is recommended for all routes on the Resource and Commodity Highway System.

As weights are increased, determinations should be made that the truck has the capacity to carry the increased load. The lowest load capacity for either the axle housing, suspension, brakes, wheel rims, or tires becomes the limiting load for an axle. This value is stamped on the identification plate attached to the tractor and trailer. Tire manufacturers are required to certify the load carrying capacity for each tire design manufactured. A part of this rating involves tire inflation pressure coupled with the load capacity for the specified wheel rim. Increasing the inflation pressure allows the load carrying capacity of the wheel rim to hold the tire. Manufacturers publish tire pressure limits. Tire pressures can be checked against these limits but care must be taken to determine whether the cold or hot inflation pressures are measured.

Other vehicle safety enhancements could be considered, including anti-lock brakes, vehicle activity recorders (mechanical tachographs or electronic recorders), underride protection (particularly rear underride and lower bumpers), air suspension systems, tires (tire pressure monitors), vehicle proximity alerts, and on-board weigh scales *(AASHTO Ad Hoc Group on Truck Size and Weight Research and Policy, 1990).* Although some of these measures would undoubtedly be helpful, it is difficult to make persuasive arguments for mandatory requirements.

Regarding the driver, additional driver safety training is warranted for drivers of the trucks permitted herein. Drivers must be fully aware of the effect that increased payloads could potentially have on the braking and handling characteristics of the truck and should be fully informed about proper driving and maintenance procedures. Recent contacts with two Kentucky trade associations, Coal Operators and Associates, Inc. and the Kentucky Manufactured Housing Institute, Inc., suggest a sensitivity to the value of special training for drivers of large and heavy trucks. While special training mandated by statute may ultimately prove to be necessary, it seems premature at the present time. The industry should be encouraged, however, to support special training activities and assisted in their efforts to implement them. It should also be encouraged to develop a certification program to recognize appropriately trained drivers and to encourage member firms to assign certified drivers to heavy truck operations. Appendix F outlines the type of training that ought to be included.

Regarding the roadway, development of the Resource and Commodity Highway System provides a unique opportunity for channeling heavy vehicles onto the types of highways that can most safely accommodate them. Physical characteristics to be considered include horizontal curvature and superelevation, length and percent of grade, sight distances, intersection design, roadway and lane widths, shoulder width, and bridge load limits and widths. Other factors related to the roadway environment which should be considered include traffic volume and composition, accident history, and roadside design features. Selection of specific routes to be included within the Resource and Commodity Highway System must include consideration of such safety-related factors. Moreover, new design standards must be developed for the system to insure that future construction and reconstruction activities produce highways of the highest possible standards for safely supporting commodity transportation.

Documented evidence highlights the difficulty in stopping heavily loaded trucks approaching signalized intersections (particularly on downgrades and where approach speeds are high). Trucks require traffic-signal change intervals between 40 and 110 percent longer than passenger cars, depending on approach speed, approach grade, and intersection width. Appropriate traffic control measures must be taken at intersections where a potential problem is identified.

One final, but important, point is that larger payloads mean fewer trucks on the roadways. Although the effect could be reduced by commodity shifts from other modes, fewer miles of truck travel translate into fewer opportunities for crashes. This effect could ultimately reduce the state's accident toll. When combined with a superior highway plant and careful monitoring of vehicle and driver, the net safety effect of the Resource and Commodity Highway System is expected to be a beneficial one.

The above information is based in part on the cited references and in part on the personal experience and knowledge of the authors. Additional information resulted from interviews, both telephone and personal, with representatives of other states, the province of Ontario, various manufacturers of trucks or parts manufactured separately, and others. Documentation of selected interviews is compiled in Appendix G.

TRUCKING PRODUCTIVITY AND INFRASTRUCTURE COSTS

The primary force that drives maximum permissible truck weights upward is an economic one. Larger payloads mean greater transportation productivity which potentially translates into greater earnings for carriers, cost savings for shippers, and reduced prices for consumers. The economic price that is paid is an increase in infrastructure costs in order to accommodate the larger and heavier trucks. Notwithstanding the potential safety threat of heavier vehicles and the economic threat to competing modes, particularly the railroads, the primary issue may well be who bears the primary cost responsibility for the infrastructure.

The Transportation Research Board's recent report *(Truck Weight Limits, 1990)* clearly describes the issue:

> The impact analyses conducted for this study support findings from previous congressionally mandated truck size and weight studies that increasing truck weights can significantly reduce the cost of goods movement and that cost savings because of more efficient trucks generally exceed the additional pavement and bridge costs incurred by highway agencies. At the same time, other study findings suggest the need for caution in implementing increases in truck weights. Unless the

> revenues required to cover additional pavement and bridge costs were provided to highway agencies, the condition of the highway system would deteriorate, thereby increasing vehicle repair costs, lowering fuel economy, increasing travel delays and accidents, and adversely affecting driver and passenger comfort.

The report proceeds by briefly summarizing possible effects on safety and traffic operations.

> Also, increasing truck weights has both positive and negative effects on safety and traffic operations. On one hand, reduced truck traffic serves to decrease truck-related accidents and congestion. On the other, simply allowing more weight on existing trucks could adversely affect truck operating characteristics and increase accident rates. Further, if user charges did not increase in step with truck costs, inefficient levels of rail diversion might occur. This new truck traffic could cause net losses for the transportation system as a whole if added pavement and bridge costs resulting from diversion exceed savings in transport costs.

The remainder of this section describes some of the general implications of the weight increases proposed herein on trucking productivity and infrastructure costs. The dictates of time and limitations of other resources prevented the development of specific, quantified findings.

TRUCKING PRODUCTIVITY

Possible Beneficiaries. The Resource and Commodity Highway System is not expected to have significant impact on interstate commerce. It excludes the Interstate System which serves as the backbone for interstate highway freight movement, and its proposed weight limits are well above those of adjacent states. Its liberalization of weight limits would primarily affect transporters of weight-limited commodities, typically bulk commodities such as coal, lumber, and grain and other high density commodities as well including construction materials, raw materials, and perhaps some manufactured products. Its primary impact would be on transporters who don't have to <u>replace</u> significant portions of their existing fleet in order to carry the added payload. Over time, however, intrastate transporters can be expected to make fleet replacements that can capture the significant productivity gains of greater payloads.

The Resource and Commodity Highway System would be limited to a maximum of 5,000 miles of the total of approximately 28,000 miles of state-maintained highways in Kentucky. Although it would thus include a significant percentage of the state's most important arterials and would be selected to connect its major resource, agricultural, and industrial areas to suitable destinations, it would not serve all potential users as a collection-distribution system and would not serve all possible origin-destination pairs. Use would, therefore, be denied to some, and others would have to adopt special systems for collection-distribution and transsshipment in order to take full advantage of the system.

Productivity Gains. A productivity study of the impact of the proposed weight limits on Kentucky trucking has not been conducted. However, productivity studies typically show gross-weight increases mean slight increases in the cost of truck operations on a per vehicle mile basis but rather dramatic decreases in the cost per ton mile of freight hauled. Figure 11, based on estimates made by the FHWA in 1990, is illustrative of the kind of data available *(Truck Configuration Loadings and Costs Chart, 1990)*. Operating costs of several longer combination vehicles are shown to be significantly reduced by increases in gross weight. Although the type of truck is obviously important, increasing the gross weight from 80,000 pounds to 110,000

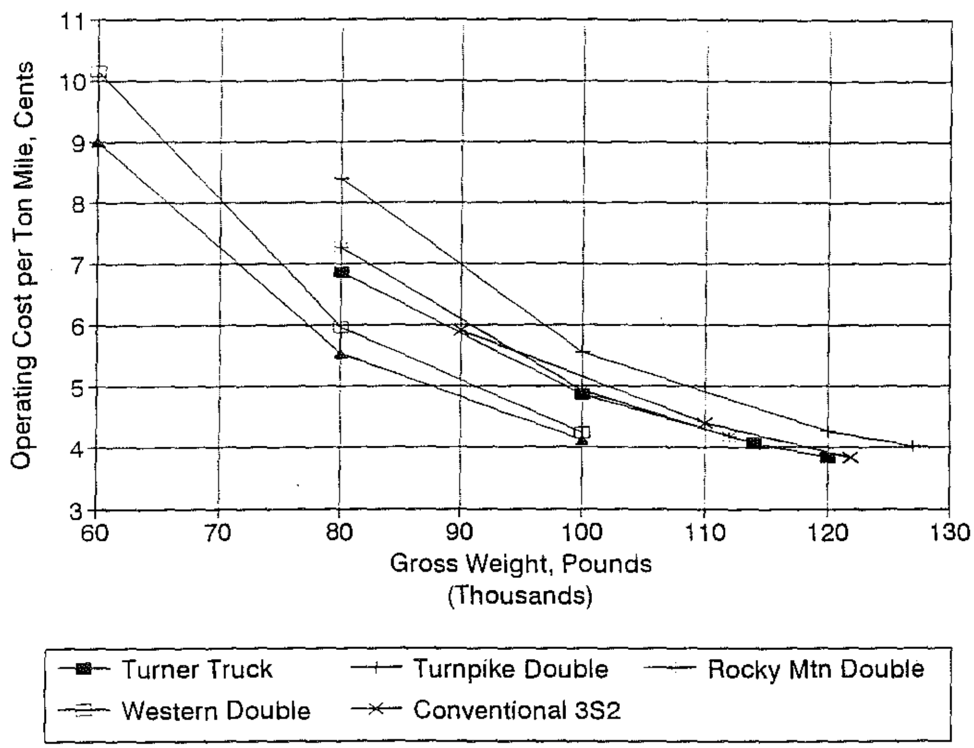

Figure 11. Effect of Gross Weight on Operating Cost per Ton Mile

pounds reduces the operating cost by as much as 2.5 cents per ton mile. The net effect is obviously somewhat less substantial, however, as a result of partial hauls and empty backhauls. Figure 11 also demonstrates that the rate of decrease in transportation costs diminishes as gross weight increases. For the types of trucks that are illustrated, there seems to be a point of diminishing returns after which even quite significant gross weight increases yield only modest improvements in productivity.

INFRASTRUCTURE COSTS

Truck characteristics have a dominant influence on the highway plant. Standards of acceptable design depend on the size, weight, power, turning radii, and other important characteristics of the truck population. Trucks cause much greater wear than other vehicles, particularly of pavements and shoulders and, to a somewhat lesser extent, bridges as well. As a result, maintenance and repair strategies and their costs depend on the nature of the truck population. Trucks utilize more of the available capacity than cars and, as a result, cause greater congestion and necessitate earlier replacement or expansion of the highway plant. Traffic control must recognize the presence of trucks, and special activity is required to assure not only that truck size and weight regulations are enforced but also that trucks are properly registered and all fees and taxes are paid.

In examining the current proposal, it is useful to point out that Kentucky currently has 3,200 miles of heavy-duty roads on its extended-weight system. A commitment--in intent, money, or both--has previously been made to provide for heavy-truck movements on these roads. Under the current proposal, some savings may in fact be realized by reducing the extent of this system to approximately 2,600 miles. Although costs on these 2,600 miles may increase as volumes of heavy trucks increase, any increase in infrastructure costs is not expected to be dramatic. The weight limits for heavy trucks on coal roads would not be increased by the proposal and, for some trucks, permissible weights would actually decrease. Moreover, increased enforcement enabled by the proposed dedication of permit revenue[8] is expected to reduce overweight violations and, as a direct consequence, decrease infrastructure costs. Volumes of permitted heavy truck traffic are already large on many coal roads, and increases resulting from the extension of increased weight limits to other commodities are not expected to be large in comparison to existing coal traffic.

Infrastructure costs would undoubtedly increase across the board on the remaining approximately 2,400 miles of the proposed system. However the following considerations bear on the evaluation of these increases.

- These roads are currently among the major arterials of the state and already command a significant portion of the state highway budget.

- Bringing bridges up to the requisite standard is likely to be one of the largest infrastructure cost items. To the extent that some of these bridges may soon need rehabilitation or replacement anyway, the full cost of bridge upgrades cannot accurately be assessed against the Resource and Commodity Highway System.

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[8]See the later section of this report entitled "System Administration, Management, and Enforcement."

- In addition to heavy trucks, other road users would benefit from the wider lanes and shoulders, the reduced grades, and other improvements that would eventually characterize the Resource and Commodity Highway System.

The 1994 draft report, *Allocation of Highway Costs and Revenues*, estimates the cost responsibility of the various classes of highway users on a per-vehicle-mile basis. Although these estimates provide a very useful means for determining the extent to which cost responsibility is in balance with revenue contributions, they are not proper measures of the marginal costs associated with incremental increases in allowable weight limits. Nevertheless, they are useful in conclusively demonstrating that heavier vehicles have added cost responsibilities and in assessing an order-of-magnitude impact of the influence on costs of increases in gross weight.

For six common truck types, the graphs of Appendix H demonstrate the effects of truck registration weight on the cost responsibility per vehicle mile. The cost responsibility varies a great deal between truck types not only because of weight and size differences but also because of differences in their volumes and in the roads on which they operate. For example, the cost responsibility of five-axle tractor-semitrailers is relatively small because of the very large volumes that operate on Interstate highways and the correspondingly large volumes of cars, also operating on the Interstates, with whom they share the costs. Nevertheless, for each class of truck, the cost responsibility escalates with increases in registered weight.

Regression equations, fit to the curves of Appendix H, enable estimates of percentage changes in unit cost responsibility under the allowable weight recommendations proposed herein. Meaningfulness of the results depends upon an unknown factor, that is, the extent to which the unit cost vs. registered weight curves parallel similar unit cost vs. maximum allowable gross weight curves. Results, nevertheless, are summarized on Table 37. Figure 12 is a graphic portrayal of the average percentage increases, weighted by the percentage of truck miles on the Federal Aid Primary System. In general, the cost increases determined this way seem reasonably small for base-system scenarios but, of course, considerably larger for coal roads.

Table 37. Percentage Increase in Unit Cost Responsibility for Selected Trucks

Truck Type	Number of Axles	Percentage of Truck Miles (Federal Aid Primary System)	Nominal Gross Weight of Base Truck (5-Axle Tractor-Semitrailer)					Coal Roads
			85,000	90,000	95,000	100,000	105,000	
Straight Truck	2	28.72	0.00	0.00	0.00	0.00	3.10	27.70
	3	8.59	-5.31	8.53	11.53	17.79	24.40	63.43
	4	2.28	0.00	0.00	6.92	10.56	18.21	82.61
Combination Truck with One Trailer	4	6.76	1.73	5.27	7.08	10.81	16.65	43.23
	5	47.40	12.21	18.24	21.37	27.89	34.76	63.97
	6	5.35	80.27	90.27	106.34	123.76	149.30	305.45
Average			9.83	14.70	17.61	22.54	29.25	65.46

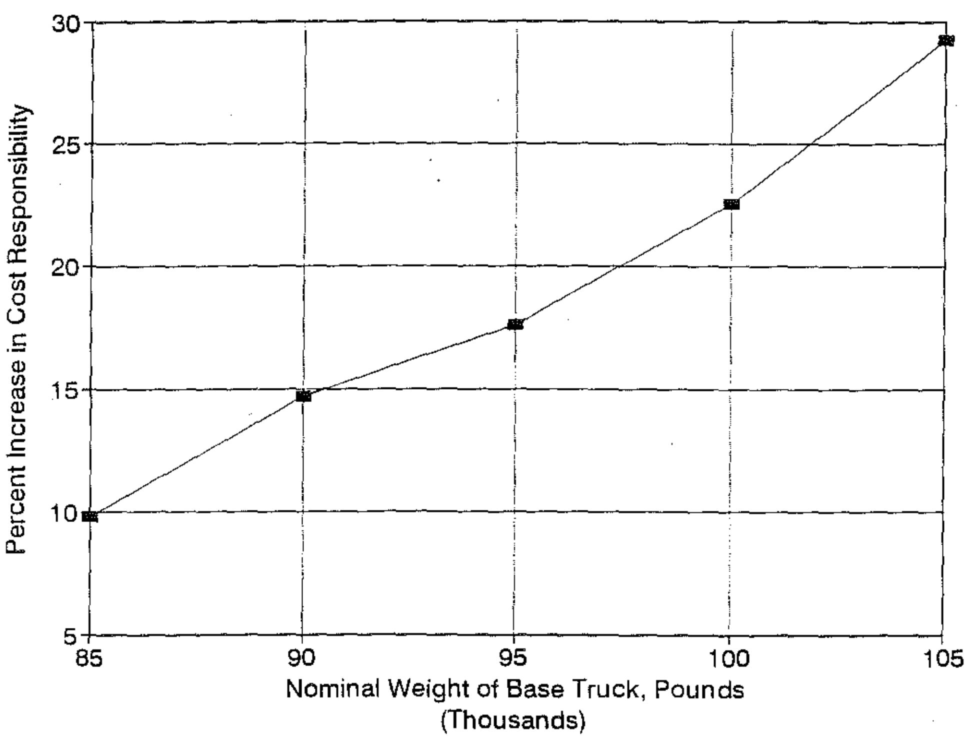

Figure 12. Effect of Nominal Weight of Base Truck on Average Percent Increase in Unit Cost Responsibility

In summary, although estimates of the infrastructure costs of implementing the Resource and Commodity Highway System have not been possible, the incremental change is not expected to be great because:

- Cost increases will be limited to the approximately 2,400 miles not currently included on the extended-weight system. Costs on the entire 3,200-mile extended-weight system may even be reduced as a result of reduced weight allowances on these facilities.

- The very heavy overloads which cause great damage and result in large costs will likely be reduced as a result of better management and intensified enforcement.

- Considerable upgrading of system roadways will be required in future years with or without designation of the Resource and Commodity Highway System. The incremental costs associated with improving these roadways to system standards rather than more normal standards in unlikely to be large.

- Proposed increases in permissible axle loads are modest, and care has been taken to insure that loads have not reached levels of rapidly escalating pavement costs.

- Relatively modest numbers of trucks are expected to take advantage of the new limits. The new limits will be attractive primarily to haulers of bulk commodities and other high density cargo. No commodity is likely to generate nearly the same volume of traffic as coal, and incremental costs of coal movement are negligible because its high costs are already charged against the existing extended-weight system. Furthermore, virtually no interstate carrier will be able to take advantage of the new weight limits.

FINDINGS AND CONCLUSIONS

1. An increase in allowable gross weight is expected to increase trucking productivity. However, the increase must be of the type and extent that can be utilized by the industry in terms of the types of commodities it transports, its underutilized weight capacity in the current truck fleet, and/or its ability to modify or replace the fleet as may be necessary to accommodate the increased weights.

2. At least for some types of large trucks, there seems to be a point of diminishing returns after which even quite significant gross weight increases yield only modest improvements in productivity.

3. An increase in allowable gross weight is also expected to increase the costs of constructing, operating, and maintaining the highway infrastructure.

4. Others *(Truck Weight Limits, 1990)* have found that, when expressed in dollars, the benefits from increased trucking productivity are often much greater than the infrastructure costs. Economically, the matter of increased weight limits may depend largely upon the level and source of revenue needed for the infrastructure.

5. Although market surveys and interviews of truckers have not been conducted, it is difficult to visualize that large numbers of trucks (beyond those currently operating with coal decals) will be able to benefit from operating at increased weights on the Resource and Commodity Highway System. As a result, pavements and bridges are not expected to deteriorate at a greatly increased rate nor would wear-related costs. The primary infrastructure cost impacts are likely to involve the bridge replacements and geometric upgrades that would be necessary to provide, in the long run, a first-class trucking highway network.

SYSTEM ADMINISTRATION, MANAGEMENT, AND ENFORCEMENT

If the objectives of the Resource and Commodity Highway System are to be achieved, it is essential that the system be effectively managed and administered and that motor carrier regulations be effectively enforced on the system. In considering how these tasks can best be accomplished, important lessons can be learned from the Extended Weight Coal and Coal By-Products Haul Road System, which was established by the Kentucky General Assembly in 1986. That system has proven difficult to manage, and it is worthwhile to briefly discuss the reasons for the difficulties.

The extended-weight system is defined based upon tons of coal transported. Any road segment which carries more than 50,000 tons of coal (or coal by-products) during a given calendar year is included in the system for the following year[9]. This method of defining the system gives inadequate consideration to access provisions and system connectivity, which results in extended-weight loads being carried on non-extended-weight routes. In addition, there is no consideration of route geometry and the adequacy of structural components in selection of extended-weight routes. Many bridges on extended-weight routes are posted for lower weight limits, which presents a dilemma for coal haulers operating on those routes.

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[9]Road segments that meet the 50,000-ton criterion may be excluded from the system or posted at lower weight limits under specific circumstances, when recommended by a fiscal court or local government.

The fact that the extended-weight system changes from year to year has many implications on system management and enforcement. Any attempts to upgrade the system over time are confounded by a changing system, as are budgeting and programming activities. Enforcement is hindered by confusion (among truckers and enforcement personnel) over which routes are actually on the system. Further complicating the state's efforts to manage the system is the fact that approximately eight percent of the system is made up of county roads.

Although decals are issued for trucks using the extended-weight system, this appears to be primarily a means to collect fees rather than to exercise control over which trucks can transport increased weights. This represents a significant missed opportunity, since a properly designed permit program can greatly enhance system safety and enforcement (for example, the extended-weight legislation contains no provision for revocation of permits due to gross or repeated safety or weight violations). In general, the overall enforcement system for the extended-weight roads appears to be weak.

ADMINISTRATION AND MANAGEMENT

As previously stated, effective administration and management is essential to accomplishing the objectives of the Resource and Commodity Highway System. Toward this end, an office should be established within the Transportation Cabinet with overall responsibility for administering and managing the system. Although the various duties associated with managing the system would likely be distributed among various divisions within the Transportation Cabinet, the responsibility for coordinating these activities to accomplish system objectives would rest with the office created to manage the system (hereinafter referred to as the "system management office"). Specific activities to be carried out (or coordinated) by the system management office would include: issuing of permits and collection of fees; allocation and accounting of funds from permit fees; collection and dissemination of data on the system, its condition, and its performance; preparation and updating of system databases, maps, etc.; access route management; and periodic reviews of the system to determine if road segments should be added to or deleted from the system.

Specific aspects of system administration, management, and enforcement are discussed in the following sections.

PERMIT SYSTEM

A special permit would be required for any truck to be operated at the larger weights allowed on the system. The fees charged for these permits would not recover the cost of providing and maintaining the infrastructure, but would provide funds for system administration, management, and enforcement. Specific activities to be funded from the permit fees would include the issuing of permits and collecting the fees, periodic reviews and updates of the system, ongoing monitoring of system condition and safety performance, training of drivers, and enforcement of weight limits and other motor-carrier regulations on the system.

Two types of permits should be available. The first type (RCHS Permit) would allow a truck to operate at the base weight limits on any part of the Resource and Commodity Highway System (including the coal-road portion). The second type (Coal-Road Permit) would allow a truck to operate at the higher coal-road-portion weight limits while on the coal-road portion of the system and at the base weight limits on any other part of the system. Purchase of a Coal-Road Permit and operation at the coal-road-portion weight limits would not be limited to coal haulers; transporters of other commodities would be eligible as well.

The fee structure would be based on the benefit (i.e., increase in allowable payload) realized by the truck operator. Table 38 shows the maximum gross weights (including tolerances) that would be allowed on the Resource and Commodity Highway System with and without a permit. These gross weights, with the exception of the 80,000-pound and 130,000-pound gross weight caps, were calculated by assuming the maximum allowable weight on each axle grouping. Table 39 shows the additional payload gained by the purchase of a permit. Table 40 shows the proposed fee structure, which is based on a fee of $150 for every 10,000-pound increase in payload.

In addition to purchasing a permit, trucks operating at increased weight limits would need to be registered in the appropriate category for the maximum weight at which they would operate (all extended-weight trucks are currently required to register in the 80,000-pound category). Because the maximum declared gross weight for registration is 80,000 pounds, the registration category is only an issue for straight trucks that have four or fewer axles.

An analysis of the revenue implications of the proposed fee structure, compared to the existing extended-weight fee structure, is presented in Table 41. This analysis considers only the Coal-Road Permits (not RCHS Permits) and assumes that the same number of trucks would be equipped in the future with Coal-Road Permits as were previously equipped with extended-weight permits. The analysis considers both permit sales and incremental revenue from registration fees. As shown in the table, the new permit fee structure results in an additional $650,000 in revenue from permit sales, and a loss of $150,000 in incremental registration fees, for a modest net gain of $500,000.

As stated previously, the revenues shown in Table 41 do not include additional permit sales for the non-coal portion of the system, nor do they include increased Coal-Road Permit sales due to opening up the coal-road portion to other commodities. Another major factor that was not included in this analysis is the impact of truck weight limit changes on overall registration fee revenue. Allowing larger payloads reduces the number of trucks required to haul a specified quantity of goods. Thus, larger payloads can result in fewer trucks being registered, which reduces revenue from truck registration fees. The potential dollar value of this impact has not been estimated.

Table 38. Weight Limits with and without Permits on Resource and Commodity Highway System (Including Tolerances)

Truck Type	Number of Axles	Maximum Weight Without Permit (Pounds)	Maximum Weight with Permit (Pounds)	
			Base System	Coal Roads
Straight Truck	2	42,000	42,000	45,150
	3	56,700	59,850	70,350
	4	71,400	78,750	94,500
Combination Truck with One Trailer	4	77,700	80,850	94,500
	5	80,000	98,700	119,700
	6	80,000	117,600	130,000
Combination Truck with Two Trailers	5	80,000	105,000	117,600
	6	80,000	122,850	130,000
	7	80,000	130,000	130,000

Table 39. Additional Payload Gained by Purchase of Permit

Truck Type	Number of Axles	Additional Payload with Permit (Pounds)	
		Base System	Coal Roads
Straight Truck	2	0	3,150
	3	3,150	13,650
	4	7,350	23,100
Combination Truck with One Trailer	4	3,150	16,800
	5	18,700	39,700
	6	37,600	50,000
Combination Truck with Two Trailers	5	25,000	37,600
	6	42,850	50,000
	7	50,000	50,000

Table 40. Proposed Permit Fees

Truck Type	Number of Axles	Proposed Annual Permit Fee	
		Base System	Coal Roads
Straight Truck	2	---	$50
	3	$50	$200
	4	$150	$350
Combination Truck with One Trailer	4	$50	$250
	5	$300	$600
	6	$600	$750
Combination Truck with Two Trailers	5	$400	$600
	6	$650	$750
	7	$750	$750

(Based on a fee of $150 for every 10,000-pound increase in payload)

Table 41. Revenue Implications of Proposed Permit Fee Structure

Truck Type	Number of Axles	Number of Decals Issued	Current Extended-Weight Coal Haul System					Proposed Resource & Commodity Highways (Coal Road Portion)				
			Permit Fee	Increm. Registr. Fee	Permit Revenue	Increm. Registr. Revenue	Total Revenue	Permit Fee	Increm. Registr. Fee	Permit Revenue	Increm. Registr. Revenue	Total Revenue
Straight Truck	2	---	---	---	---	---	---	$50	$0	$0	$0	$0
	3	1,071	$160	$716	$171,360	$766,836	$938,196	$200	$581	$214,200	$622,251	$836,451
	4	141	$260	$135	$36,660	$19,035	$55,695	$350	$135	$49,350	$19,035	$68,385
Combin. Truck with One Trailer	4	---	---	---	---	---	---	$250	$0	$0	$0	$0
	5	1,920	$360	$0	$691,254	$0	$691,254	$600	$0	$1,152,090	$0	$1,152,090
	6	339	$360	$0	$121,986	$0	$121,986	$750	$0	$254,138	$0	$254,138
Combin. Truck with Two Trailers	5	---	---	---	---	---	---	$600	$0	$0	$0	$0
	6	---	---	---	---	---	---	$750	$0	$0	$0	$0
	7	---	---	---	---	---	---	$750	$0	$0	$0	$0
	Totals===>				$1,021,260	$785,871	$1,807,131			$1,669,778	$641,286	$2,311,064

SYSTEM UPDATES AND CHANGES

Because the Resource and Commodity Highway System is intended to be a "permanent" system of limited mileage, it is not expected to change greatly from year to year. Significant annual changes in the system would disrupt the continuity of the system, confound the management task, and interfere with the objective of gradually building the system up to higher standards. Thus, changes to the system would be made only by administrative regulation, and only when determined to be in the best interests of the Transportation Cabinet with regard to accomplishing the system objectives.

ENFORCEMENT

Enforcement is a key element in the successful achievement of the system's objectives. If trucks are allowed to operate at the system's higher weight limits without permits, then the incentive for other truckers to purchase permits is removed. If trucks (with or without permits) are allowed to violate the higher weight limits, then rapid and serious deterioration of the pavements and structures would occur, resulting in major public expenditures. Thus, particular emphasis should be given to enforcement to ensure that:

1. Those who purchase permits are the only ones allowed to operate at the larger weight limits;
2. The pavements and structures are not prematurely damaged by gross violations of the larger weight limits; and
3. Trucks operating on the system are in a condition to safely transport the weights at which they are being operated.

Because of the importance of enforcement, 75 percent of the revenue from permit sales should be allocated to enforcement. These funds would be directed (through the system management office) to the Division of Motor Vehicle Enforcement of the Department of Vehicle Regulation. All funds would be placed in a special account to be used for additional personnel, equipment, and resources dedicated to enforcement of motor carrier regulations on the Resource and Commodity Highway System. The system management office would oversee enforcement activities and would coordinate with the Division of Motor Vehicle Enforcement in ensuring the most effective possible use of the funds.

DRIVER SAFETY TRAINING

A driver safety training program should be established and coordinated by the system management office. This program should be established in partnership with motor carrier organizations and other representatives of the trucking community. It should provide safety-related training to drivers of trucks that would be operated at the higher weight limits allowed on the Resource and Commodity Highway System. The training would concentrate on the effects of heavy loads on the handling and braking characteristics of the vehicle. The trucking community should be encouraged to actively support the training program and incorporate it into driver certification programs. The feasibility of incorporating such training into Commercial Driver's License requirements should be investigated.

PENALTIES AND FINES

As previously discussed, effective enforcement is needed if the objectives of the Resource and Commodity Highway System are to be achieved. Penalties and fines are a critical element of the enforcement process. It is essential that a system of stiff penalties and fines be established for violators of weight limits or other motor carrier regulations. Fines for weight violations should be graduated, with heavier fines for more severe violations. This would prevent over-penalizing the slight or inadvertent violator, but would provide a significant deterrent against gross violations.

Documentation of serious and/or repeated safety violations, repeated size- and/or weight-related violations, or assignment of a less-than-satisfactory safety fitness rating by the FHWA should be cause to revoke all permits to operate vehicles at the increased weight limits of the Resource and Commodity Highway System and to deny future applications to operate at such limits.

RECOMMENDATIONS

The motivation for reexamining the way Kentucky's highway plant is being used for the transport of its natural resource, manufacturing, and agricultural commodities is a compelling one. This investigation supports the initiative for rather dramatic change which would explicitly create a coherent trucking highway network, the Resource and Commodity Highway System, replace current weight limits on system highways with more rational and more liberal ones, and extend the advantages of larger legal payloads to the transport of all commodities. As a result of this proposal, the costs of providing and maintaining the highway infrastructure would indisputedly increase, but transport productivity is expected to receive a substantial boost as well. Importantly, implementing the proposal may have two other significant benefits. First, highway safety may be enhanced because of fewer trucks on the road, the careful selection and eventual improvement of a limited-mileage system, and other safety-related measures proposed herein. Second, the incidence of flagrant overloading should be reduced as a result of the increase in enforcement activity. Specific recommendations of this investigation include the following:

RESOURCE AND COMMODITY HIGHWAY SYSTEM

1. There should be developed a Resource and Commodity Highway System to promote the efficient transport of Kentucky's natural resources, agricultural commodities, and manufactured products while, at the same time, protecting public investment in the highway infrastructure and promoting traffic safety. The extended-weight coal-haul system should be abolished as a separate entity and most of its mileage should be absorbed by the new system.

2. The total length of the Resource and Commodity Highway System should be limited to a maximum of no more than 5,000 miles. The total miles of the coal-road portion of the system should be approximately 2,600.

3. The Resource and Commodity Highway System should be a continuous network. All routes on the system should connect to the remainder of the system by at least one nodal point: no isolated segments should be permitted.

4. The major portion of the Resource and Commodity Highway System should be comprised of highway segments best meeting the stipulated criteria and currently within the Extended Weight Coal Haul System, the Designated Truck Network, and the National Highway System. Because proposed truck weight limits exceed federal requirements for the Interstate system, Interstate highways must be excluded from the Resource and Commodity Highway System.

   Excepting Interstate highways, the preliminary system proposed for initial evaluation is a 4,350-mile network containing all state-maintained routes within the Extended Weight Coal Haul System that are 5 miles or longer, all of the Designated Truck Network, all of the proposed National Highway System, all of the Appalachian Development Highway System, all of the Parkway System, and the Ashland-Alexandria highway.

5. Only state-maintained highways should be included within the Resource and Commodity Highway System.

6. The Resource and Commodity Highway System should extend, where possible, to all major resource areas, to all major farm commodity areas, and to all major industrial and/or manufacturing areas.

7. To insure intermodal accessibility to other forms of transportation, the Resource and Commodity Highway System should connect to rail lines and barge terminals.

8. The final selection of the individual highway segments that are to be a part of the Resource and Commodity Highway System should be made and established by administrative regulation.

9. Appropriate design standards should be developed and adopted for the Resource and Commodity Highway System to insure that future construction and reconstruction activities produce highways of the highest possible standards for safely supporting commodity transportation. Such standards must include:

   - Bridge design,
   - Pavement loading,
   - Cross sectional elements, and
   - Horizontal and vertical geometry.

10. Reasonable access should be provided to the Resource and Commodity Highway System by allowing the designation of any state-maintained highway within 10 miles of the system as an access road following petition, detailed analysis, and posting as may be necessary. Costs of necessary intersection improvements, posting, and engineering analysis should be assessed against the petitioner.

11. Because of the long expected life of highway bridges, they should be designed and built to standards that allow wide latitude in the weights and dimensions of future trucks that can be accommodated. Because much of the cost of constructing many highway bridges is not affected by traffic loading, the incremental costs of more flexible bridge designs is expected to be small.

TRUCK WEIGHT AND SIZE LIMITS

1. A combination of axle-weight limits and wheelbase limits should substitute for fixed gross weight limits as the means for controlling the loading of properly certified vehicles operating on the Resource and Commodity Highway System.

2. The following weight and wheelbase limitations should be applied to vehicles properly certified to operate within the Resource and Commodity Highway System:

   - Axle-weight limits

     - Steering axle: 20,000 pounds
     - Single axle: 20,000 pounds
     - Tandem axle: 37,000 pounds
     - Tridem axle: 55,000 pounds
     - Allowable axle-weight tolerance: Five percent

   - Maximum gross weight: 130,000 pounds without tolerance

   - Maximum ratio of gross weight to wheelbase

- Straight trucks: 3,200 pounds per foot
- Combination trucks with one trailer: 2,450 pounds per foot
- ~~Combination trucks with two trailers: 1,700 pounds per foot~~
- No tolerance on weight-to-wheelbase ratio

3. The following weight and wheelbase limitations should be applied to vehicles properly certified to operate at larger weights within the coal-road portion of the Resource and Commodity Highway System:

   - Axle-weight limits

     - Steering axle: 20,000 pounds
     - Single axle: 23,000 pounds
     - Tandem axle: 47,000 pounds
     - Tridem axle: 70,000 pounds
     - Allowable axle-weight tolerance: Five percent

   - Maximum gross weight: 130,000 pounds without tolerance

   - Maximum ratio of gross weight to wheelbase

     - Straight trucks: 3,900 pounds per foot
     - Combination trucks with one trailer: 3,000 pounds per foot
     - Combination trucks with two trailers: 2,100 pounds per foot
     - No tolerance on weight-to-wheelbase ratio

   - Three- and four-axle straight trucks should be permitted to operate--if issued proper permits--on the coal-road portions of the Resource and Commodity Highway System under current provisions of the extended-weight system for a transition period of four years.

   - If Recommendation 3 is not adopted, it is recommended that the limits on coal trucks which are now permitted on the extended-weight system be retained and that other trucks be allowed to operate under general provisions applicable to the entirety of the Resource and Commodity Highway System.

4. In computing axle-weight and wheelbase limits, no allowance should be made for any retractable or variable load suspension not meeting the following criteria:

   - All controls must be located outside of and be inaccessible from the driver's compartment.

   - The gross axle weight rating of all VLS devices must conform to the expected loading of the suspension and should in no case be less than

9,000 pounds.

- Axles of all retractable or VLS devices manufactured or mounted on a vehicle after July 1, 1994 should be engineered to be self-steering in a manner that would guide or direct the VLS mounted wheels through a turning movement without tire scrubbing or pavement scuffing.

- Tires in use on all such axles should conform in load rating capacity with relevant Kentucky regulations or with Federal Motor Vehicle Safety (FMVS) standards or with both as is deemed appropriate.

5. All axle group suspension systems should at all times distribute the load equally among all axles of the group. "Equally" means no single axle weight deviates more than approximately $\pm$ 5 percent from the theoretical maximum average axle weight of the group and specifically interpreted as follows:

Type of Facility	Maximum Load Difference Between Heaviest and Lightest Axle of Axle Group (Pounds)	
	Tandem Axles	Tridem Axles
Coal Roads	2,500	2,500
Other Roads	2,000	2,000

Failure to achieve equal weight distribution should result in reduction of the allowable load. If any axle of the group exceeds the single-axle weight limit, the allowable load on the entire axle group should be the single-axle weight limit.

6. The allowable length of semitrailers and trailers in tractor-semitrailer-trailer combinations should be increased from 28 to 33 feet where permitted by federal authority.

7. Tire loads should continue to be limited to 600 pounds per lineal inch of width. However, an investigation should be undertaken to examine issues involving permissible tire loading, to study the impacts of replacing dual with single tires including "super singles," and to develop, as appropriate, recommendations for future legislation.

SYSTEM ADMINISTRATION, MANAGEMENT, AND ENFORCEMENT

1. A special permit should be required for any truck to be operated on the Resource and Commodity Highway System at the system's larger weight limits. Two types of permits should be available. The first type (RCHS Permit) would allow a truck to operate at the base RCHS weight limits on any part of the Resource and Commodity Highway System (including the coal-road portion). The second type (Coal-Road Permit) would allow a truck to operate at the higher coal-road-portion weight limits on the coal-road portion of the system and at the base weight limits on any other part of the system. Purchase of a Coal-Road Permit and operation at the coal-road-portion weight limits would not be limited to coal haulers; transporters of other commodities would be eligible as well.

2. Fees should be charged for permits to operate at increased weight limits on the Resource and Commodity Highway System. The proposed fee structure, approximately proportionate to the benefit (i.e., increase in allowable payload) available to the truck operator, is as follows:

Truck Type	Number of Axles	Proposed Annual Permit Fee	
		Base System	Coal Roads
Straight Truck	2	---	$50
	3	$50	$200
	4	$150	$350
Combination Truck with One Trailer	4	$50	$250
	5	$300	$600
	6	$600	$750
Combination Truck with Two Trailers	5	$400	$600
	6	$650	$750
	7	$750	$750

3. Fees from sales of permits should be allocated to a special fund for administration and management of the Resource and Commodity Highway System and for enforcement activities on the system. Initially, 25 percent of the funds would be set aside for system administration and management, with the remaining 75 percent supporting enforcement activities. The existing Resource Recovery Road Fund would be eliminated, and no funds from permit sales would be allocated to the counties.

4. In the event that Recommendation 3 (above) is deemed to be unacceptable, the recommended alternative is to continue to allocate some funds from permit sales to the Resource Recovery Road Fund and to the counties. Under this alternative, each permit fee would consist of two portions; one dedicated to support system administration, management, and enforcement and the other dedicated to the Resource Recovery Road Fund and to the counties as currently prescribed. Funds dedicated to the Resource Recovery Road Fund and to the counties would be set at approximately current levels. County funds would no longer be restricted to county portions of the extended-weight system but would be available more generally to maintain and develop county coal-haul roads at the discretion of the counties. The formula for allocating county funds to the various counties would be revised to reflect production tonnage and ton miles of coal travel.

5. An appropriate system of fines and penalties should be established for violations of weight limits or other motor carrier regulations on the Resource and Commodity Highway System. Penalties for weight violations should vary with the severity of the violation, so that more extreme violations result in more severe penalties.

6. Specific activities to be funded under the general heading of system administration and management include: issuing permits and collecting fees; periodic reviews and updates of the system; ongoing monitoring of system roadway conditions and safety performance; and training of drivers for safe operation of heavier trucks. Enforcement activities funded would include enforcement of weight limits and other motor carrier regulations on the Resource and Commodity Highway System.

7. No changes are recommended to the existing truck registration requirements and fees. Trucks operating at increased weight limits would be registered in the appropriate category for the maximum gross weight at which they would operate. Trucks operating at weights in excess of 80,000 pounds would register in the 80,000-pound category.

8. An office should be established within the Transportation Cabinet with the responsibility for overseeing, managing, and administering the Resource and Commodity Highway System. That office should carry out (or coordinate) all activities required for proper management of the system, including: issuing of permits and collection of fees; allocation and accounting of funds from permit fees; collection and dissemination of data on the system, its condition, and its performance; preparation and updating of system databases, maps, etc.; access-route management; and periodic reviews of the system to determine if road segments should be added or deleted.

9. The Resource and Commodity Highway System should be developed as an essentially static and permanent system. Changes in the system mileage from

year to year should be minimized. Addition or removal of roadway segments to or from the system should be accomplished by administrative regulation when the Transportation Cabinet determines that such changes enhance or accelerate the accomplishment of system objectives.

10. Funds allocated to system enforcement (75 percent of permit fee revenue) should be directed to the Division of Motor Vehicle Enforcement of the Department of Vehicle Regulation. All such funds should be placed in a special account to be used for enforcement of motor carrier laws and regulations on the Resource and Commodity Highway System. The system management office should coordinate with the Division of Motor Vehicle Enforcement to oversee enforcement activities and to ensure efficient and effective utilization of funds.

SAFETY[10]

1. Trucks with appropriate permits and operating on the Resource and Commodity Highway System should conform to applicable portions of the Federal Motor Vehicle Safety Standard contained in CFR Part 571.105 relating to braking systems.

2. At the time of permit purchase, operators should be required to certify that their vehicles will meet all applicable braking and safety standards--including the Federal Motor Vehicle Safety standards, appropriate sections of the Code of Federal Regulations (CFR), and KRS and KAR requirements--appropriate to the loads they carry as they operate within the Resource and Commodity Highway System.

3. Documentation of serious and/or repeated safety violations, repeated size- and/or weight-related violations, or assignment of a less-than-satisfactory safety fitness rating by the FHWA should be cause to revoke all permits to operate vehicles at the increased weight limits of the Resource and Commodity Highway System and to deny future applications to operate at such limits.

4. In accordance with CFR Part 393.75, no vehicle should be operated with any tire that carries a greater weight than specified for it; nor should it be operated on a tire which has a cold inflation pressure (or its equivalent) less than that specified for the load being carried or a tire whose inflation pressure exceeds

[10]The primary safety feature of the current proposal is the Resource and Commodity Highway System itself. In identifying the system, one of the primary concerns is to insure that the system would incorporate Kentucky's safest highways--those most compatible with large truck operations. Ultimately, though, the objective is to upgrade all elements of the system to improved standards driven, in large part, by truck requirements.

the manufacturer's tire inflation limits.

5. Trucks carrying hazardous materials (HAZMAT) should not initially be permitted to carry the increased payloads being proposed herein.

6. A driver safety training program should be established and coordinated by the system management office. This program should be established in partnership with motor carrier organizations and other representatives of the trucking community. It should provide safety-related training to drivers of trucks that would be operated at the higher weight limits allowed on the system. The training would concentrate on the effects of heavy loads on the handling and braking characteristics of the vehicle. The trucking community should be encouraged to actively support the training program and incorporate it into driver certification programs. The feasibility of incorporating such training into Commercial Driver's License requirements should be investigated.

TRUCK MANEUVERABILITY

The maximum low-speed offtracking and swept width for a truck currently operating in Kentucky has been determined for the tractor-semitrailer combination with a 53-foot trailer (AASHTO designation WB-67). No vehicle should be granted a permit to operate on the Resource and Commodity Highway System which has a configuration resulting in greater low-speed offtracking than the WB-67.

OTHER

The following miscellaneous recommendations are also advanced:

1. AASHTO's *Guide for Maximum Dimensions and Weights of Motor Vehicles and for the Operation of Nondivisible Load Oversize and Overweight Vehicles* should be consulted as a "standard" guide for preparation of legislative proposals.

2. Kentucky statutes provide for numerous exemptions and exceptions to the basic truck size and weight regulations. A review should be conducted to determine the relevancy of such exemptions and exceptions under the fundamental changes proposed herein.

3. The Resource and Commodity Highway System should be given special recognition and treatment in the following ISTEA-mandated management systems: traffic congestion, highway safety, bridges, intermodal transportation facilities and systems, highway pavements, and public transportation facilities and equipment.

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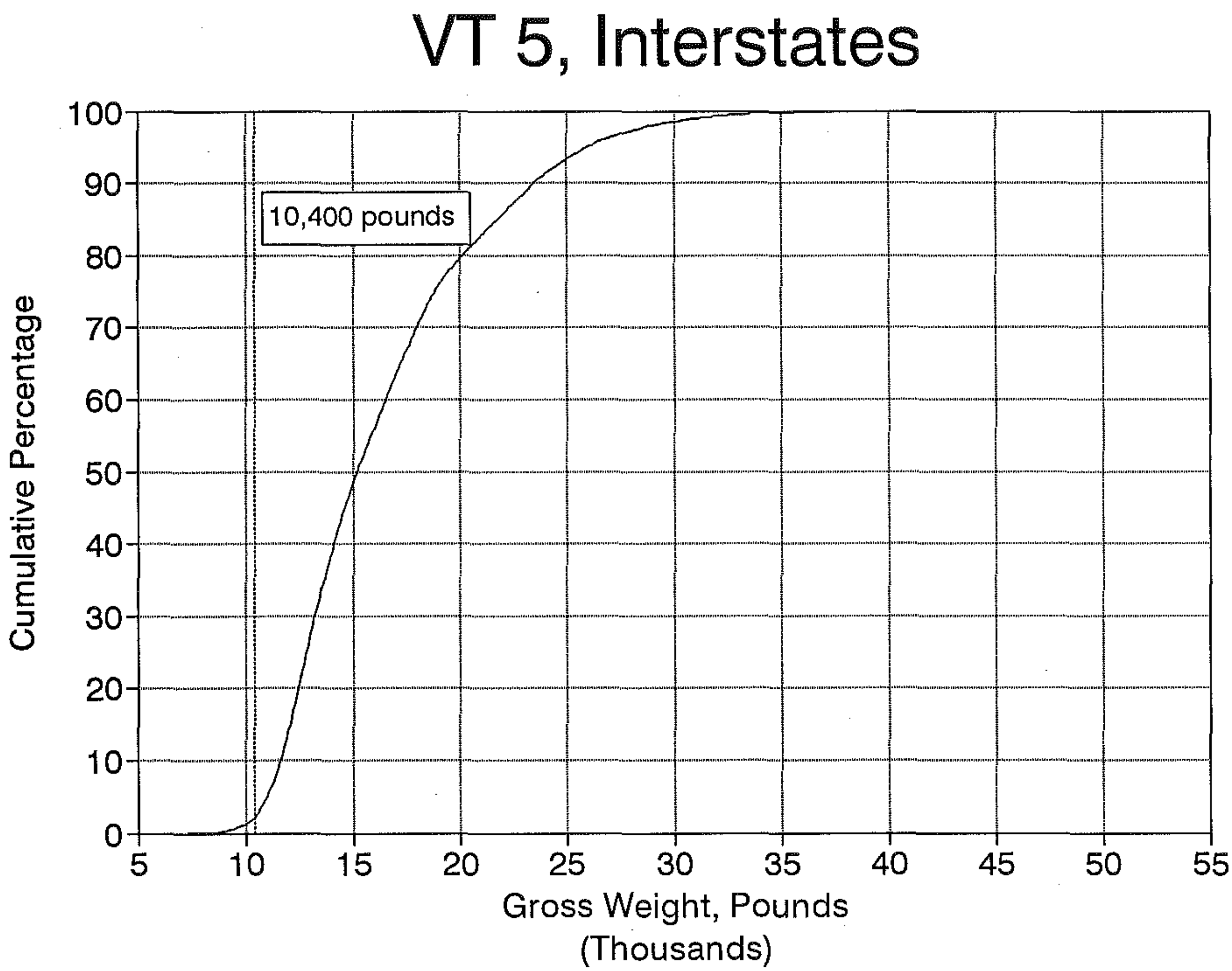
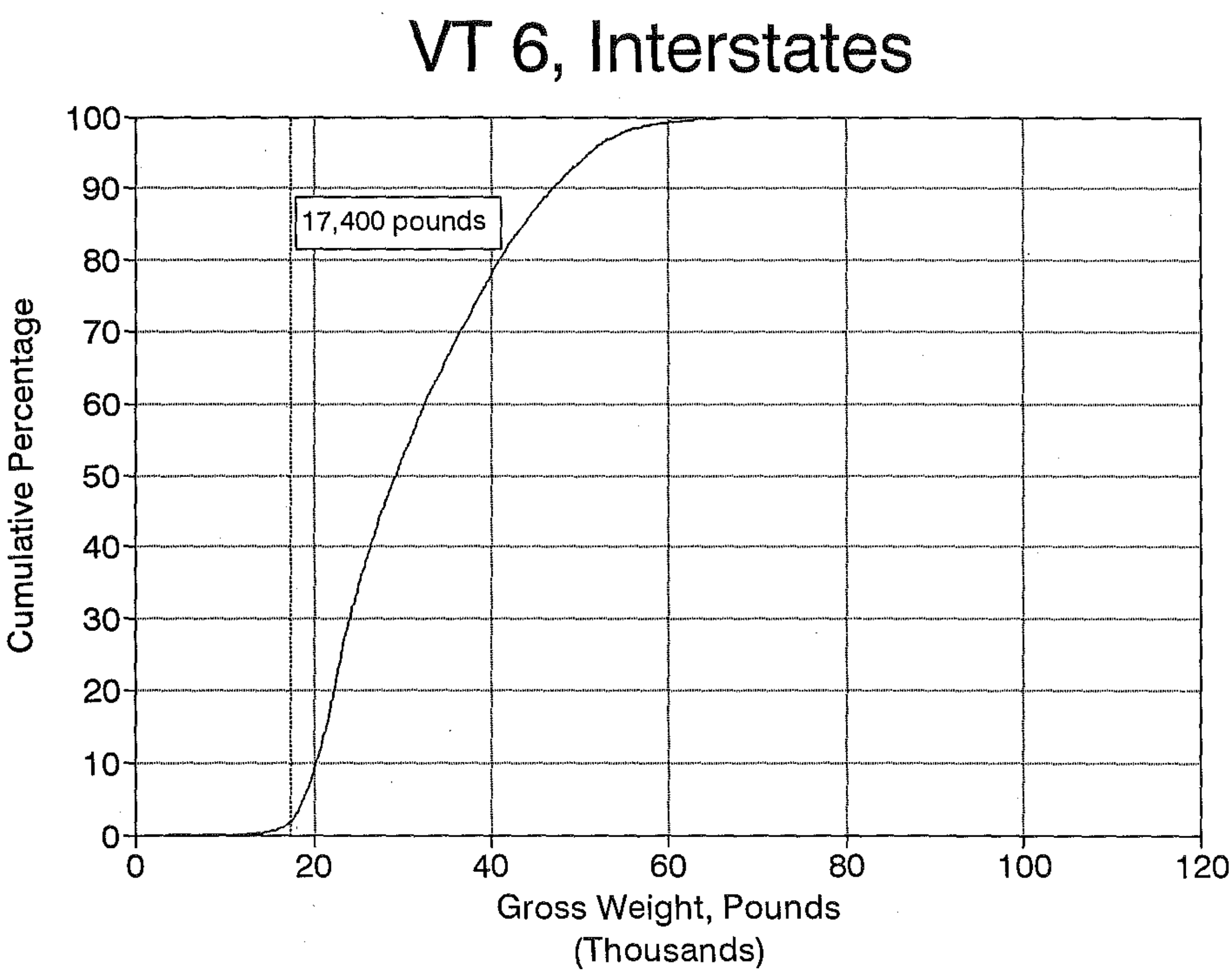
Appendix A

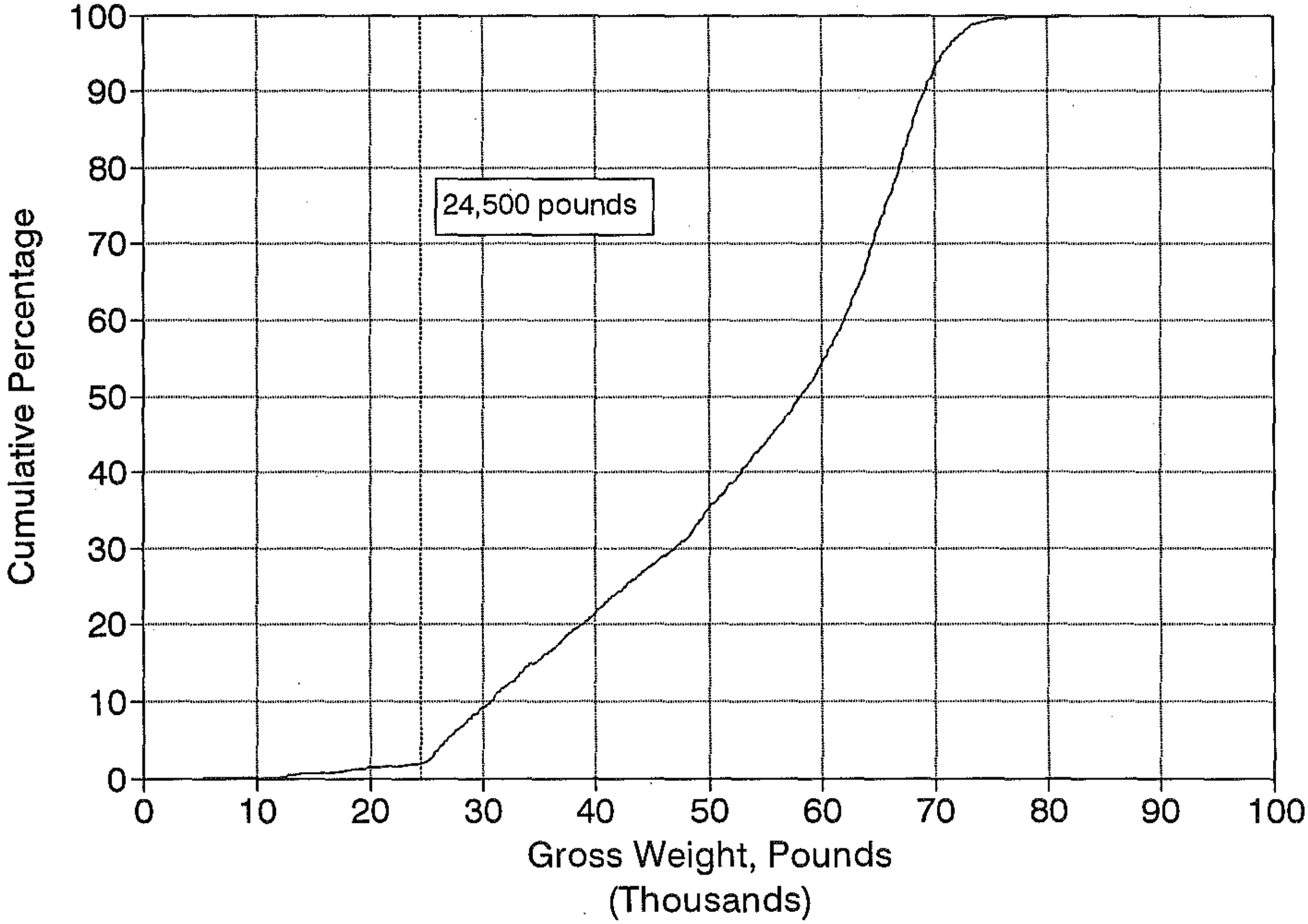
Gross Weight Distributions for Kentucky Trucks


VT 5, Interstates
10,400 pounds
Cumulative Percentage
100
90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
30
35
40
45
50
55
Gross Weight, Pounds
(Thousands)

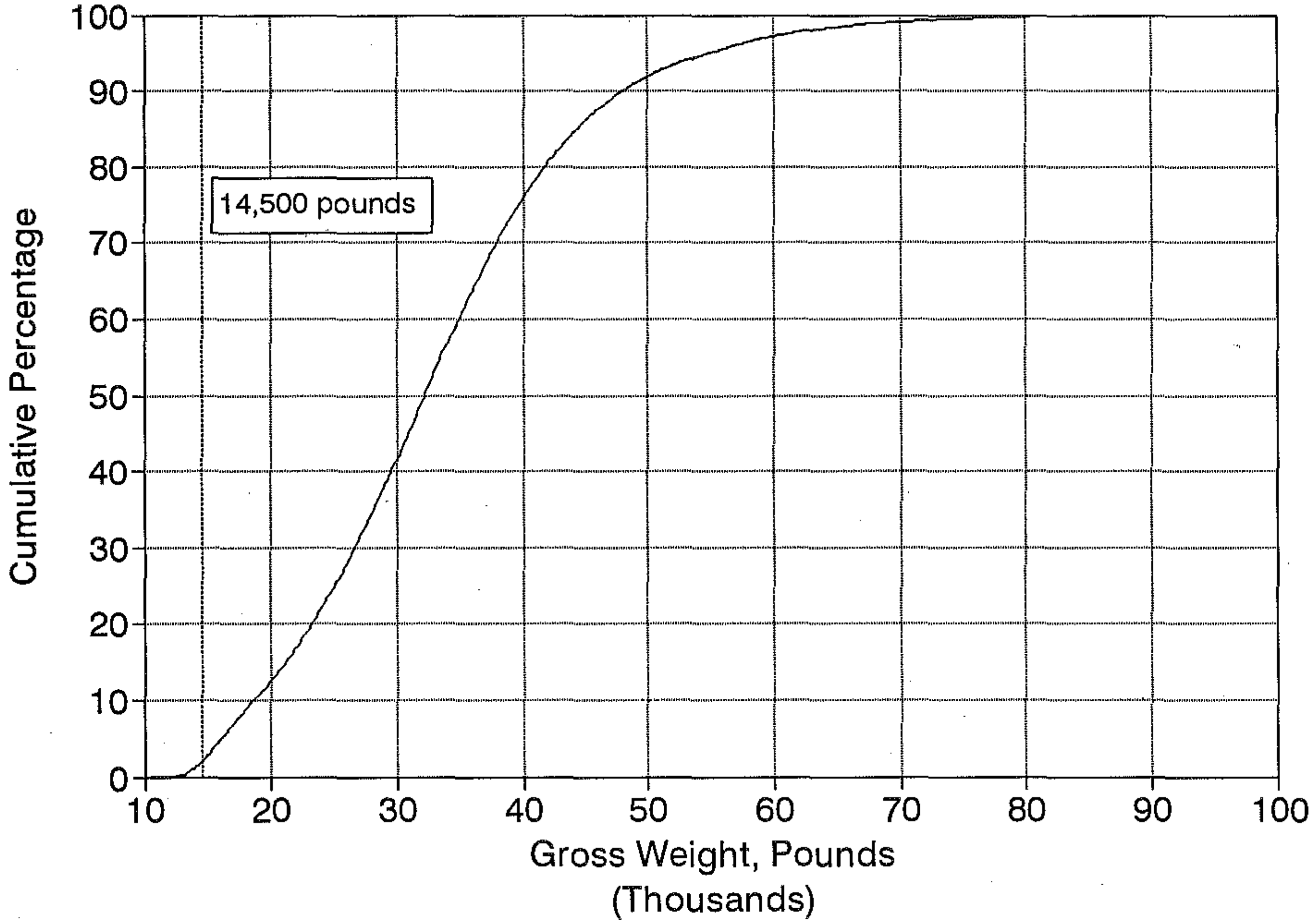


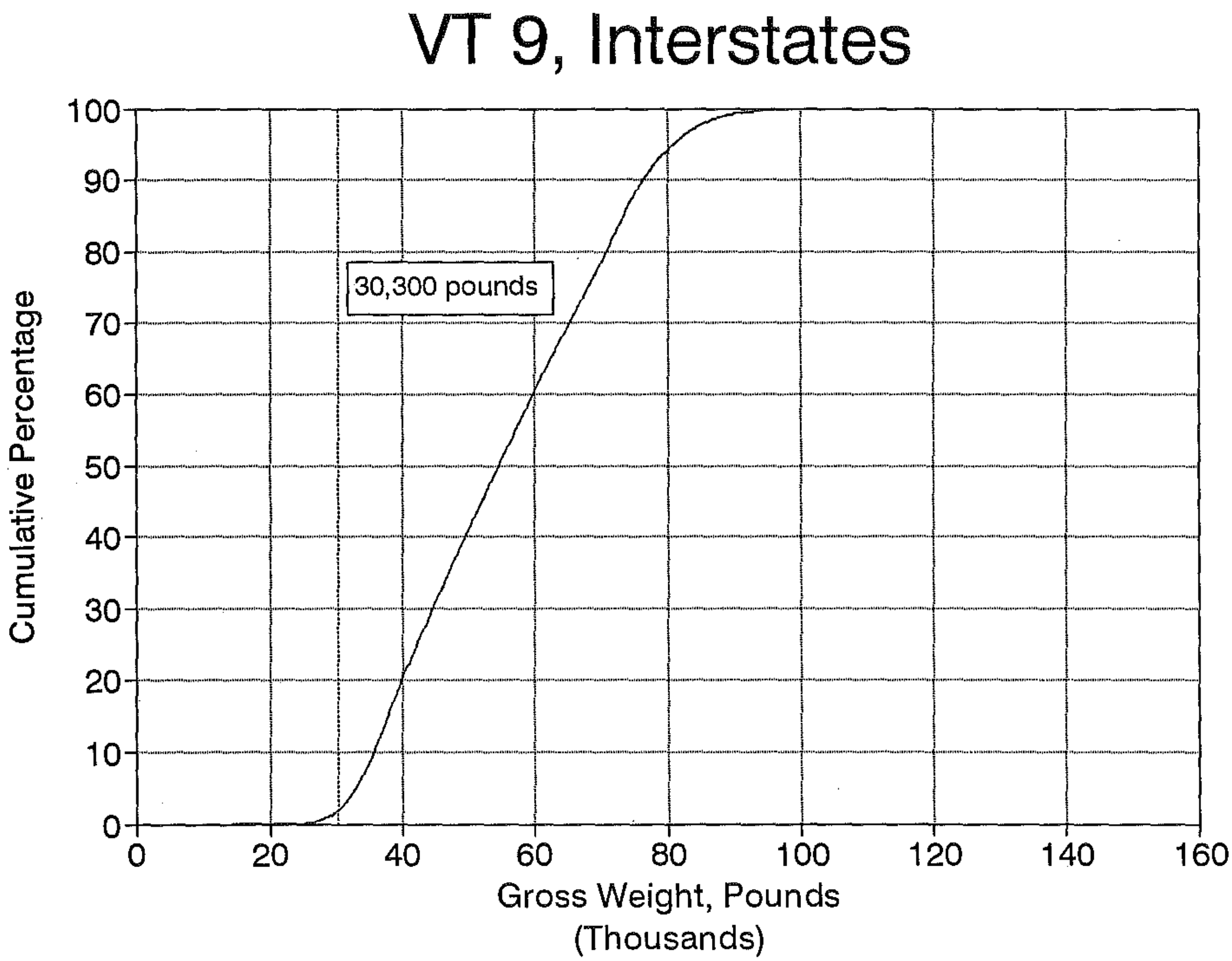
VT 6, Interstates
17,400 pounds
Cumulative Percentage
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Gross Weight, Pounds
(Thousands)

VT 7, Interstates

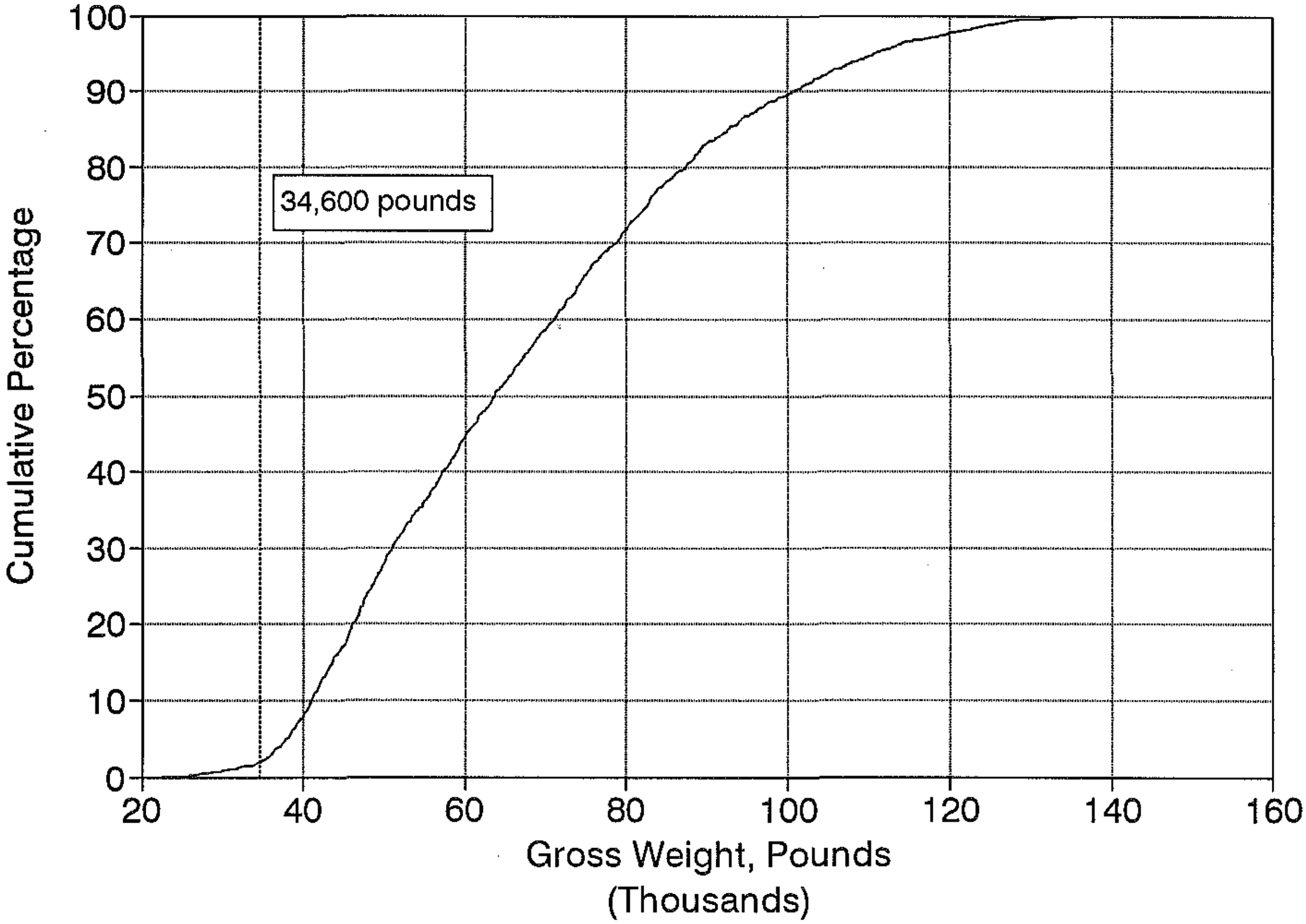


VT 8, Interstates

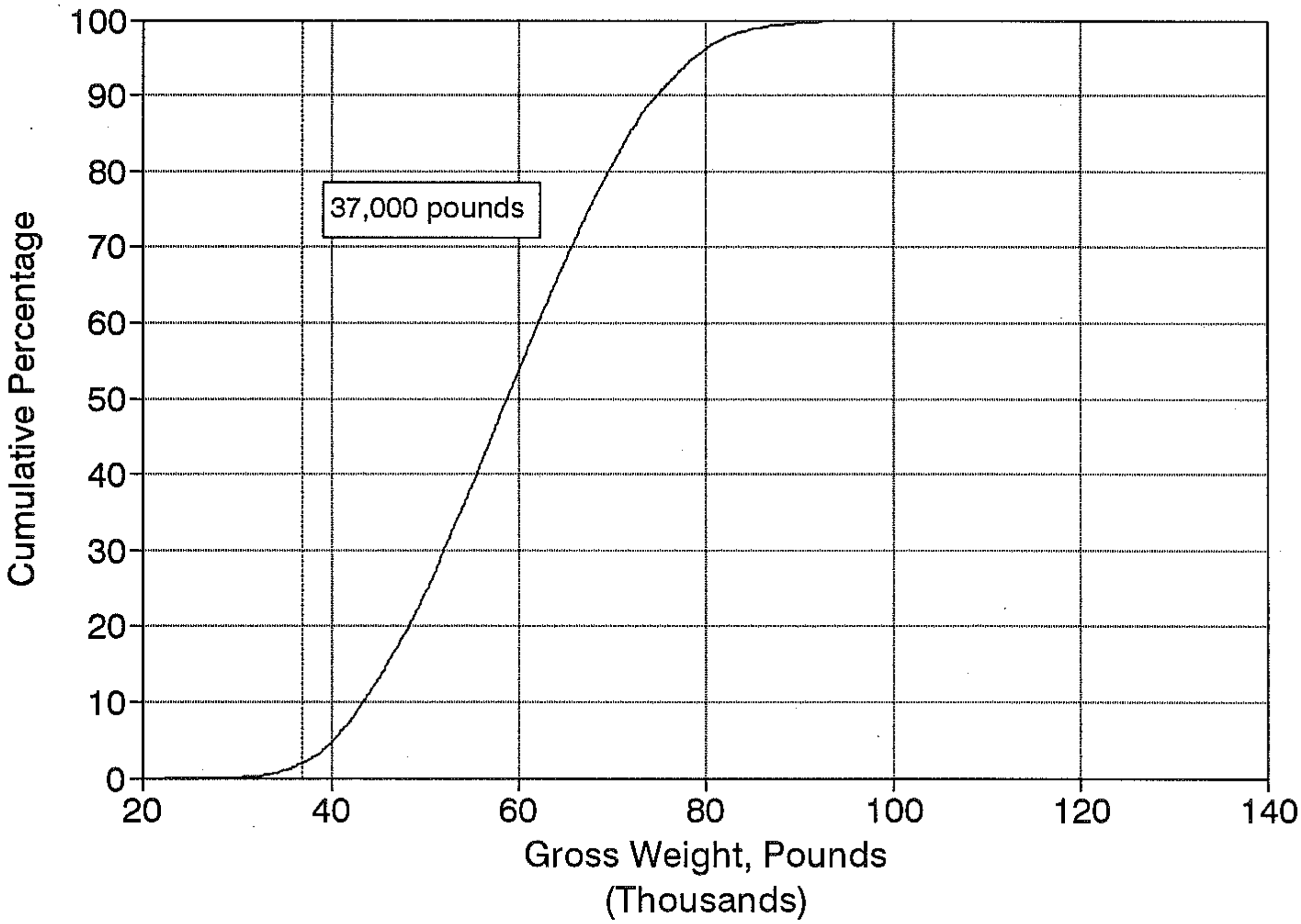


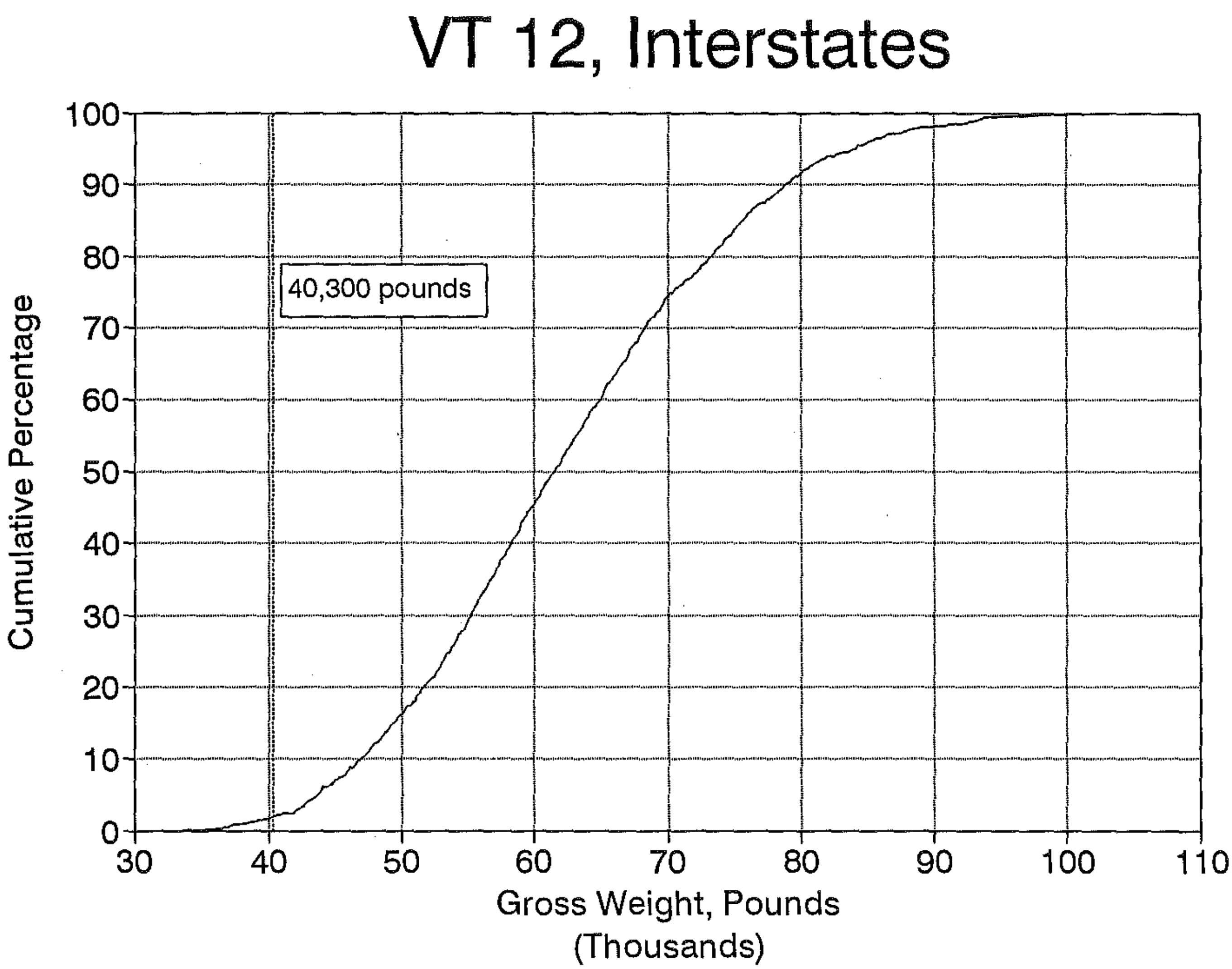

VT 9, Interstates
30,300 pounds
Cumulative Percentage
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
Gross Weight, Pounds
(Thousands)

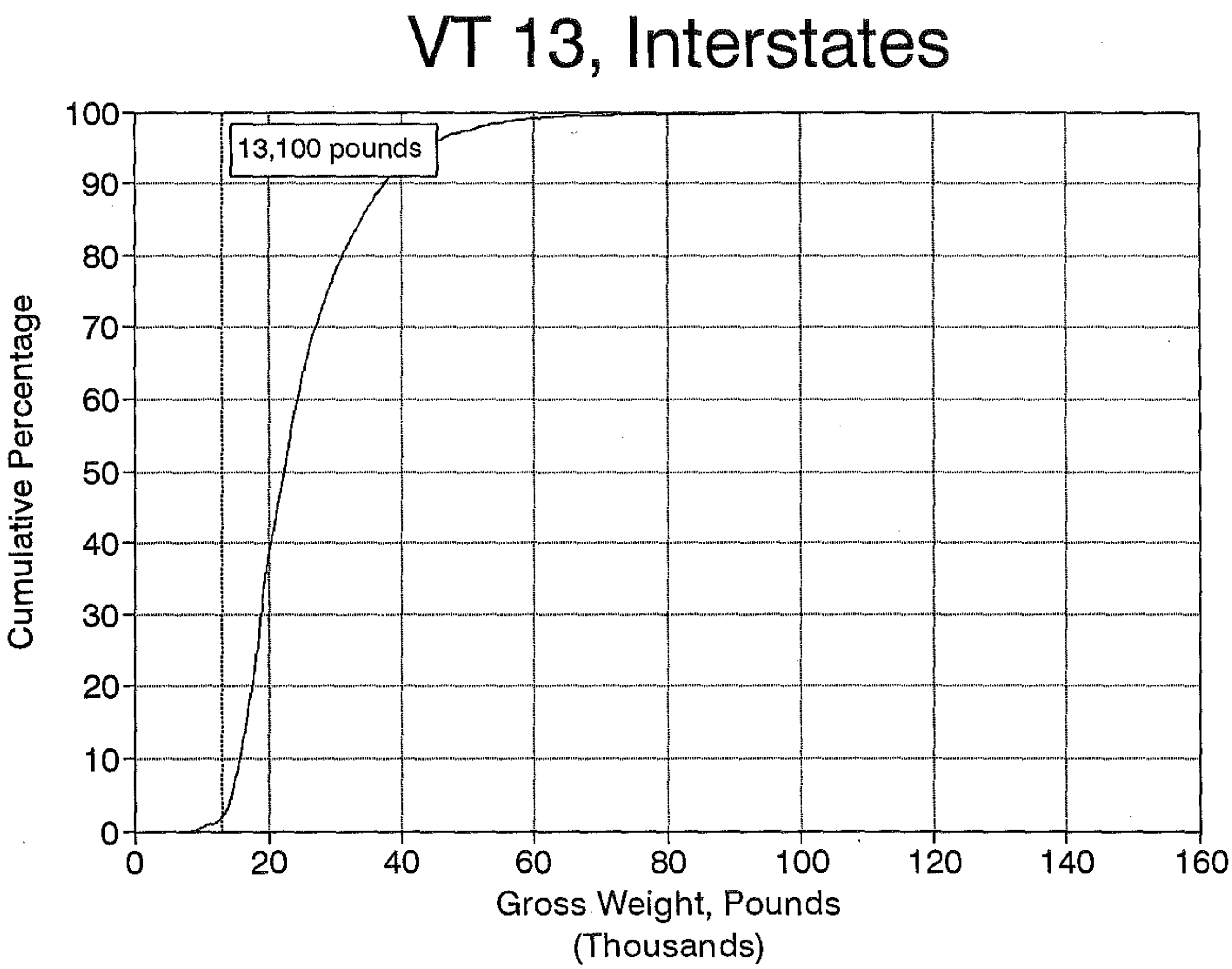
VT 10, Interstates



VT 11, Interstates

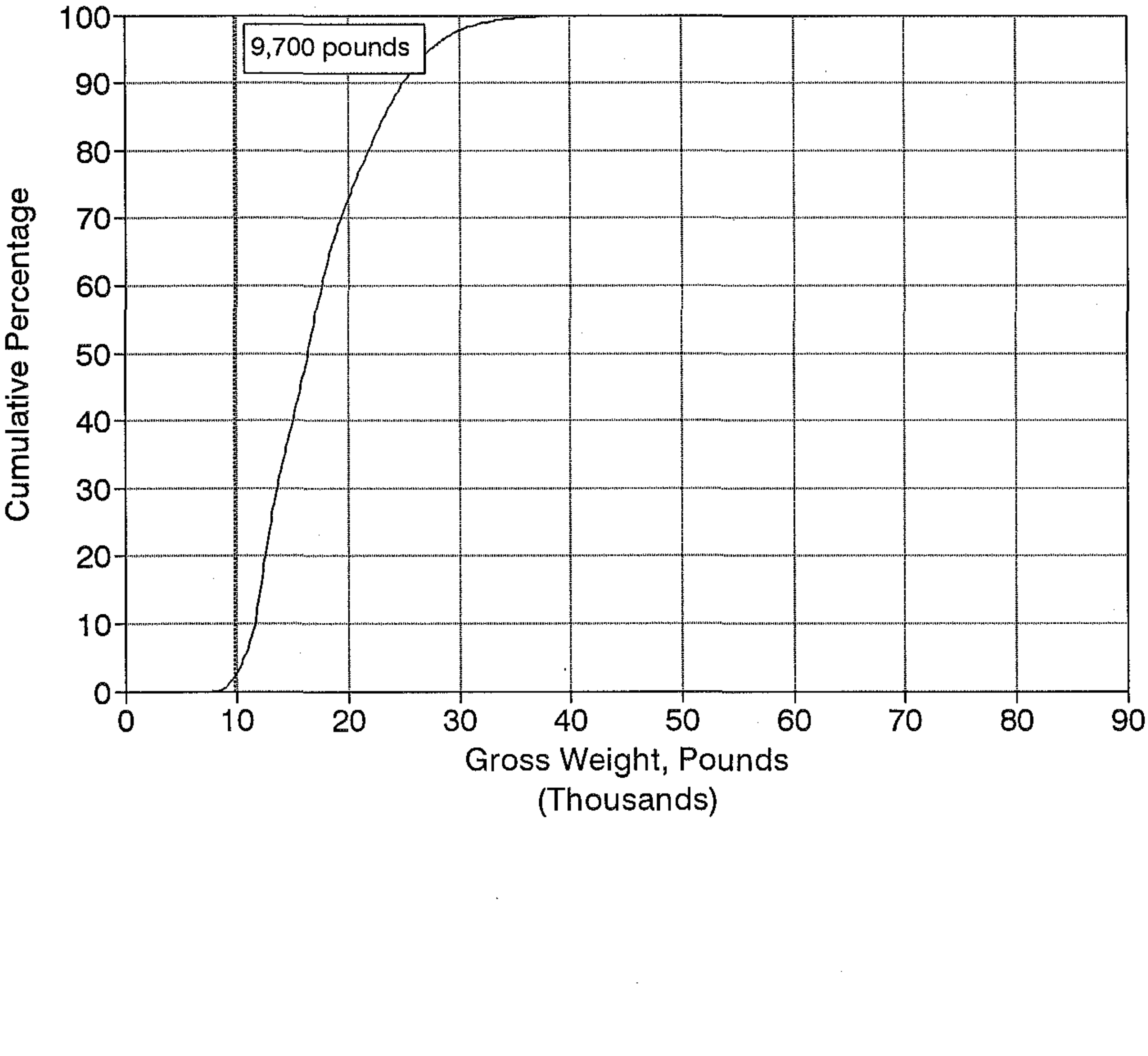


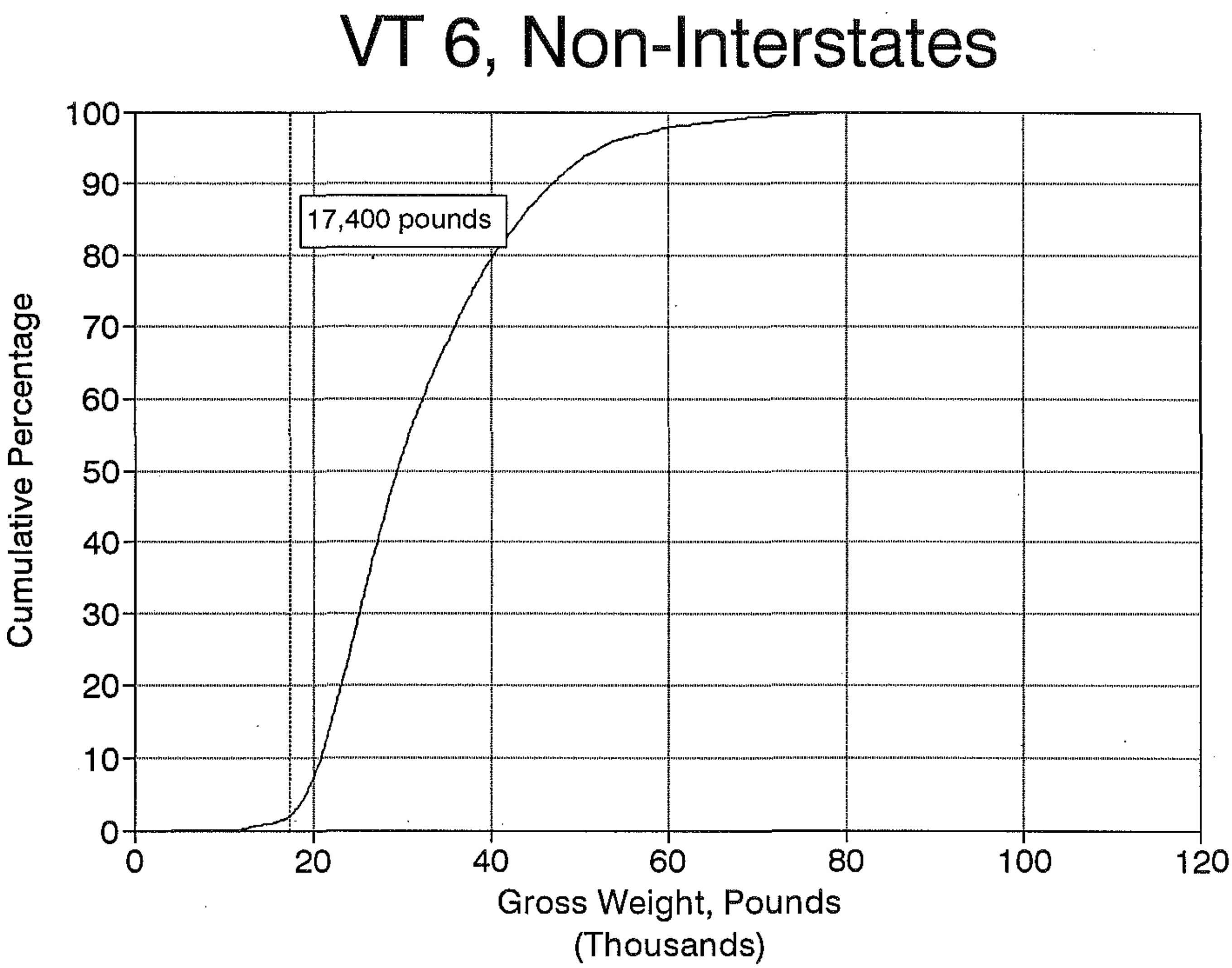

VT 12, Interstates
Cumulative Percentage
100
90
80
70
60
50
40
30
20
10
0
40,300 pounds
30
40
50
60
70
80
90
100
110
Gross Weight, Pounds
(Thousands)

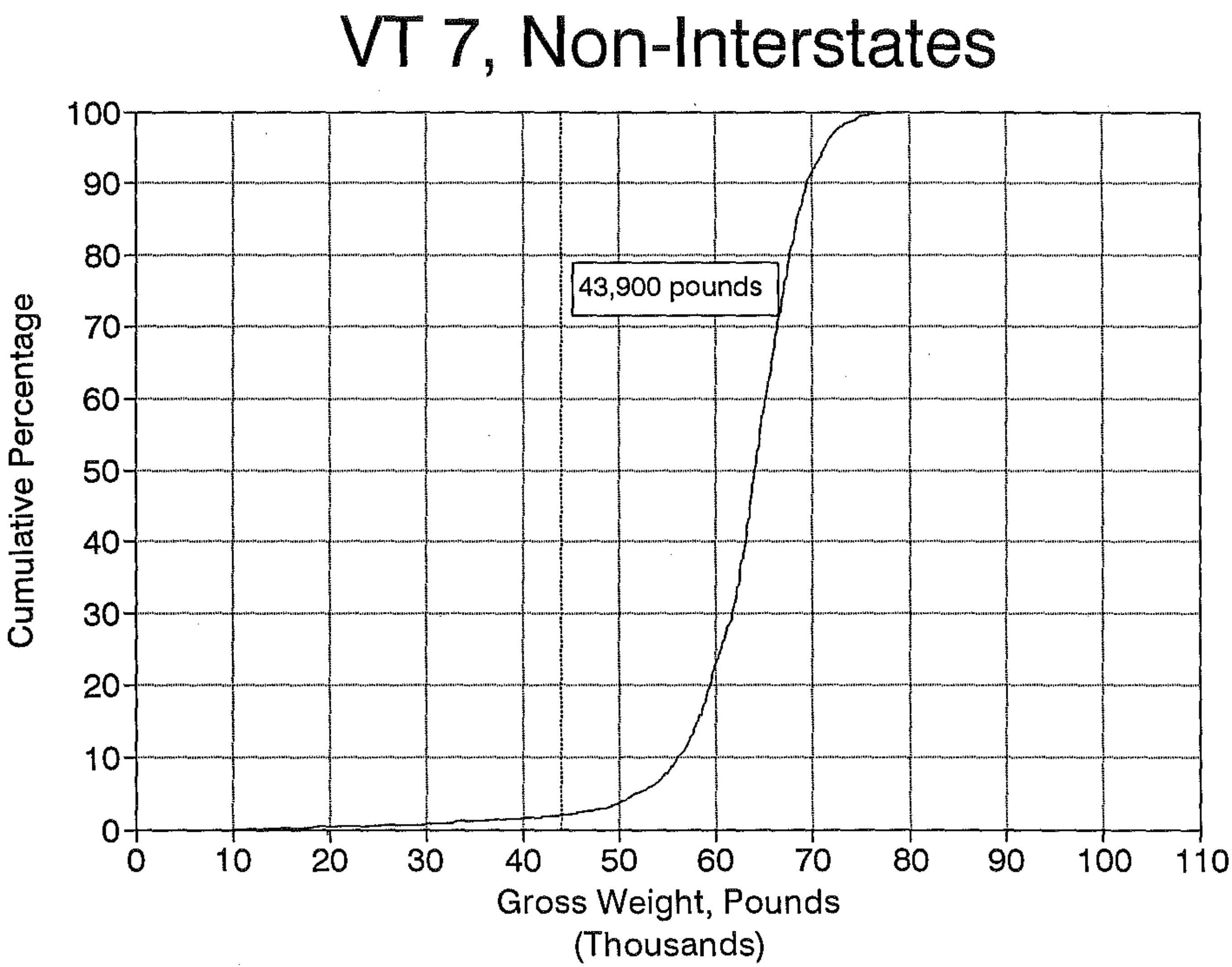


VT 13, Interstates
13,100 pounds
Cumulative Percentage
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
Gross Weight, Pounds
(Thousands)

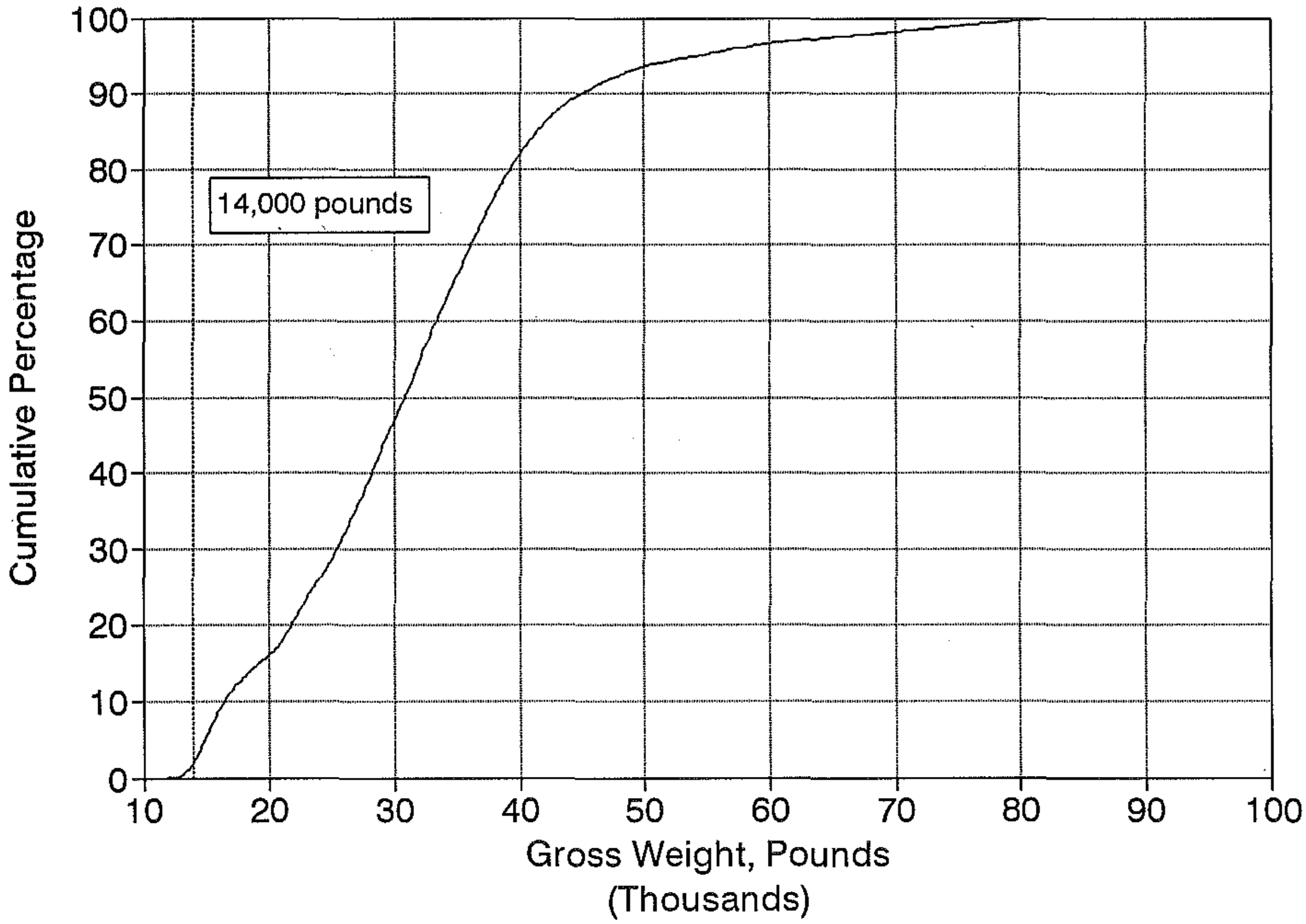
VT 5, Non-Interstates

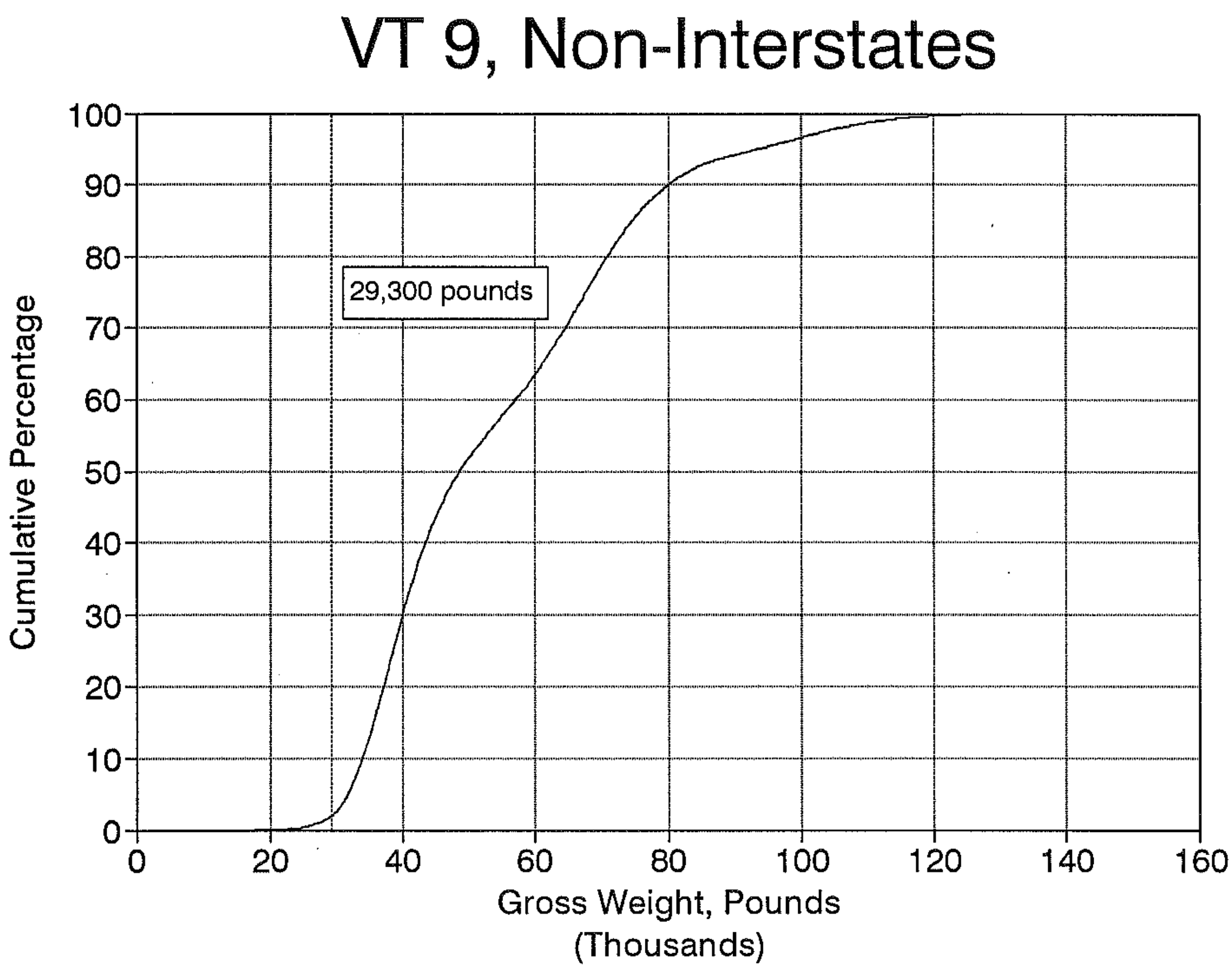



VT 6, Non-Interstates
17,400 pounds
Cumulative Percentage
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
Gross Weight, Pounds
(Thousands)

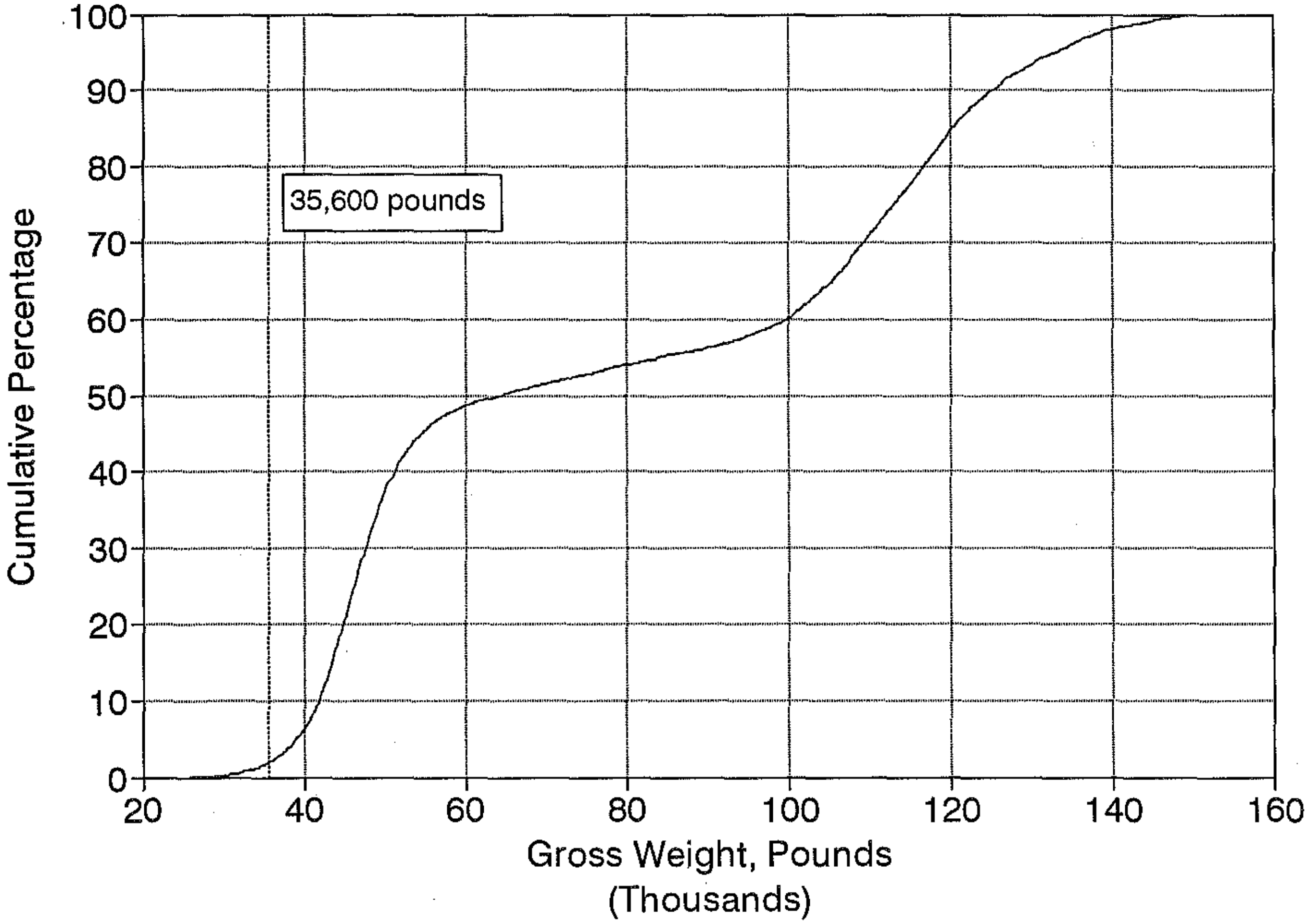

VT 7, Non-Interstates
100
90
80
70
60
50
40
30
20
10
0
Cumulative Percentage
43,900 pounds
0
10
20
30
40
50
60
70
80
90
100
110
Gross Weight, Pounds
(Thousands)

VT 8, Non-Interstates

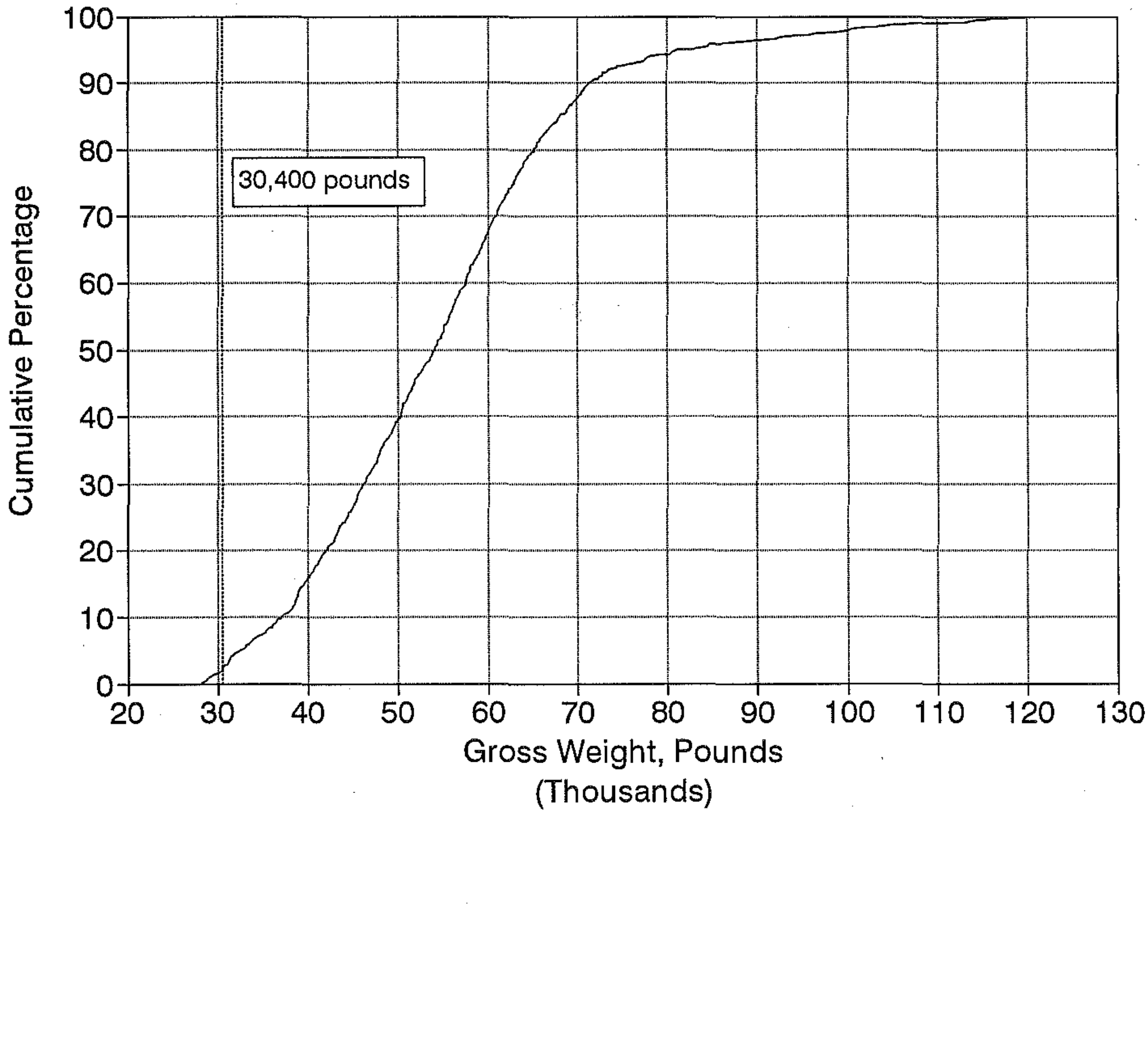


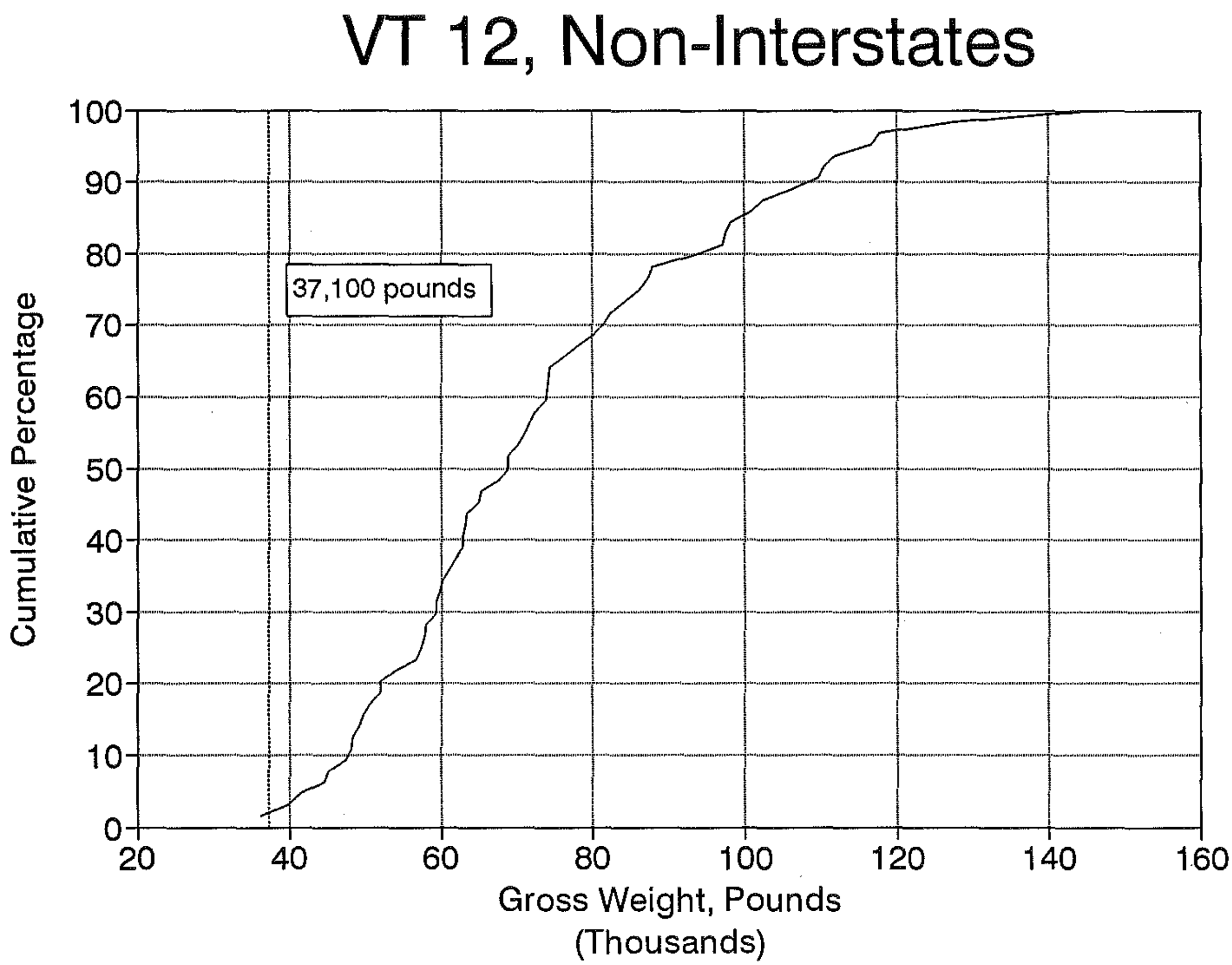

VT 9, Non-Interstates
29,300 pounds
Cumulative Percentage
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
Gross Weight, Pounds
(Thousands)

VT 10, Non-Interstates

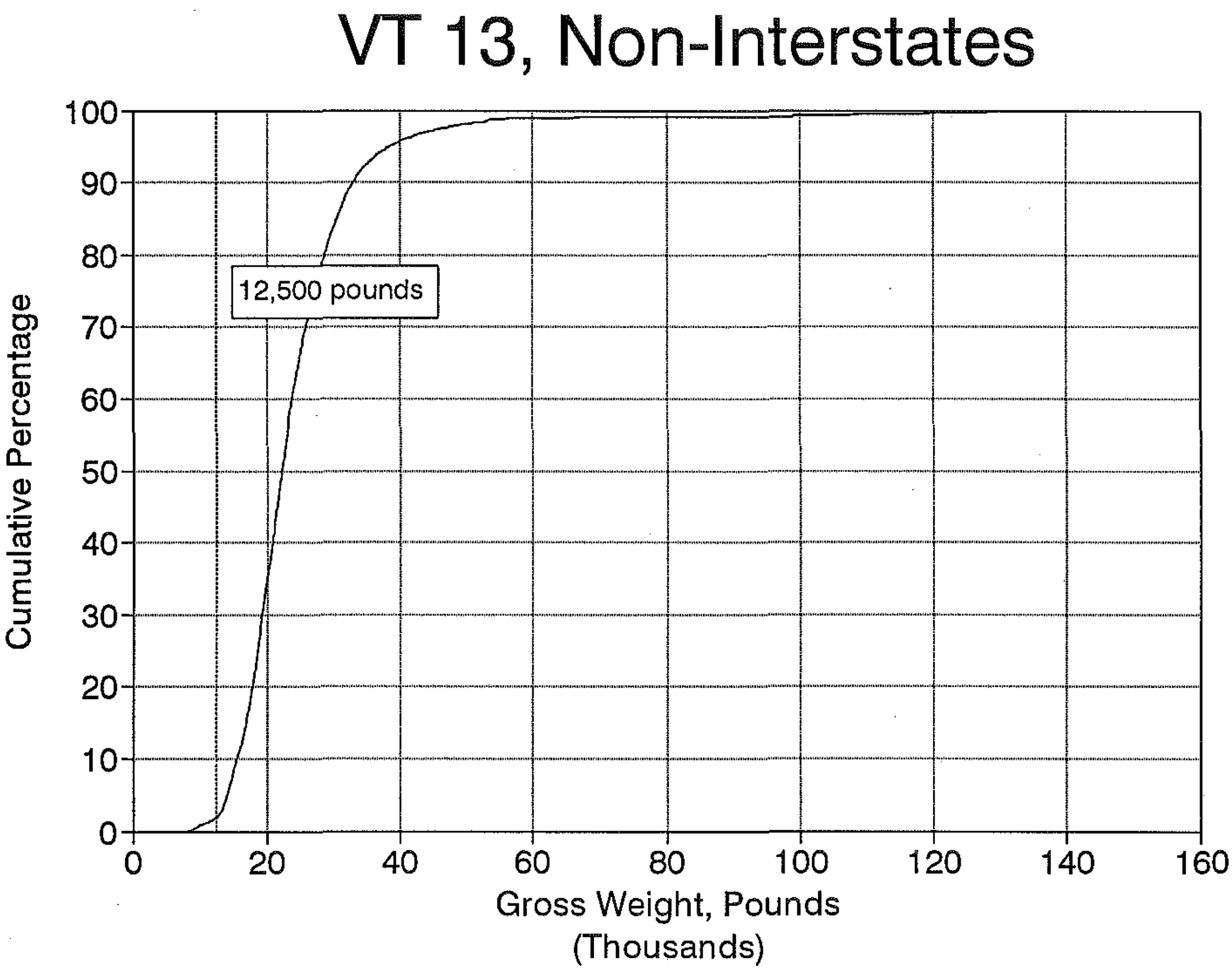


VT 11, Non-Interstates





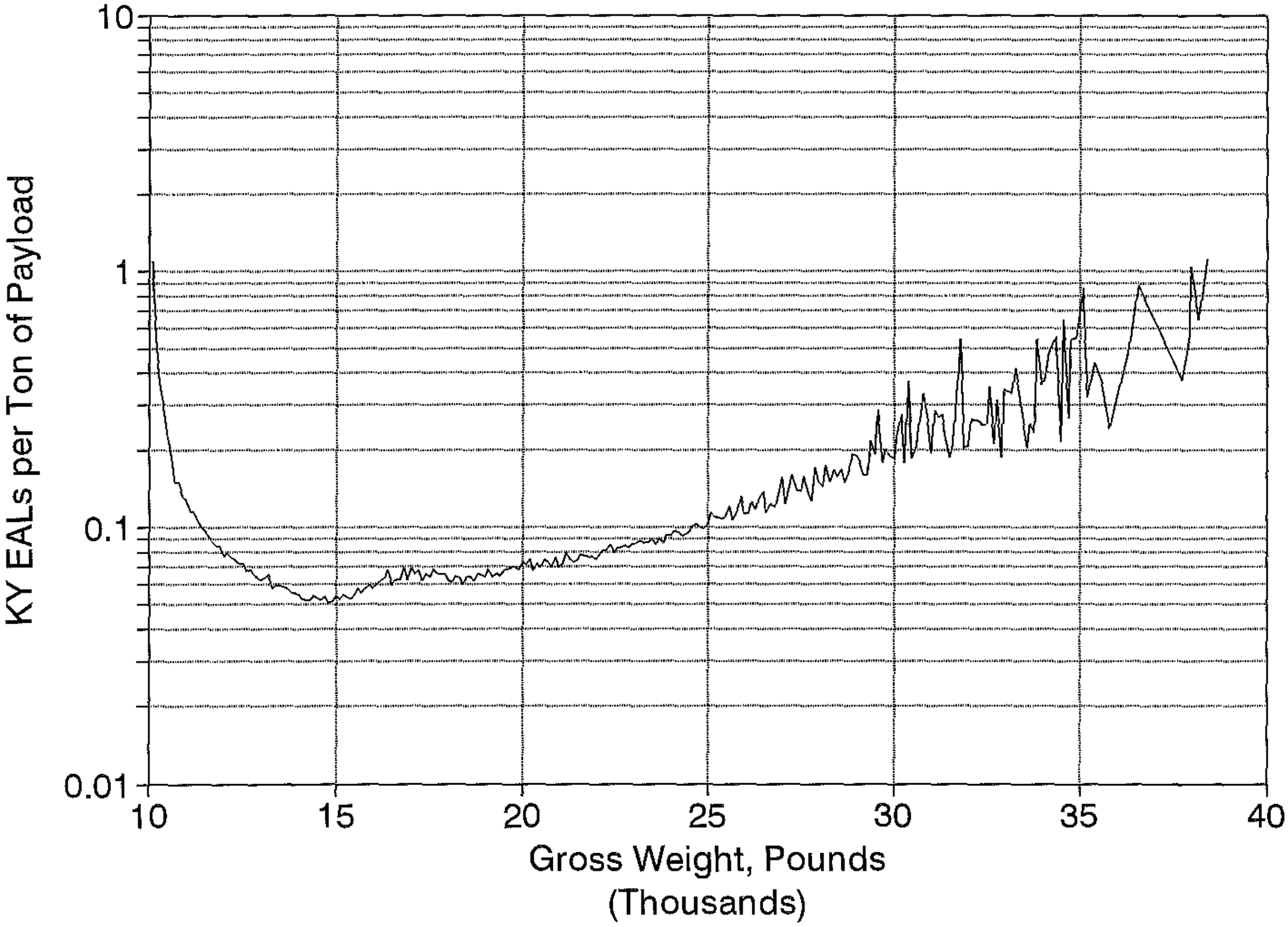
VT 12, Non-Interstates
37,100 pounds
Cumulative Percentage
0
10
20
30
40
50
60
70
80
90
100
20
40
60
80
100
120
140
160
Gross Weight, Pounds
(Thousands)


VT 13, Non-Interstates
100
90
80
70
60
50
40
30
20
10
0
Cumulative Percentage
12,500 pounds
0
20
40
60
80
100
120
140
160
Gross Weight, Pounds
(Thousands)

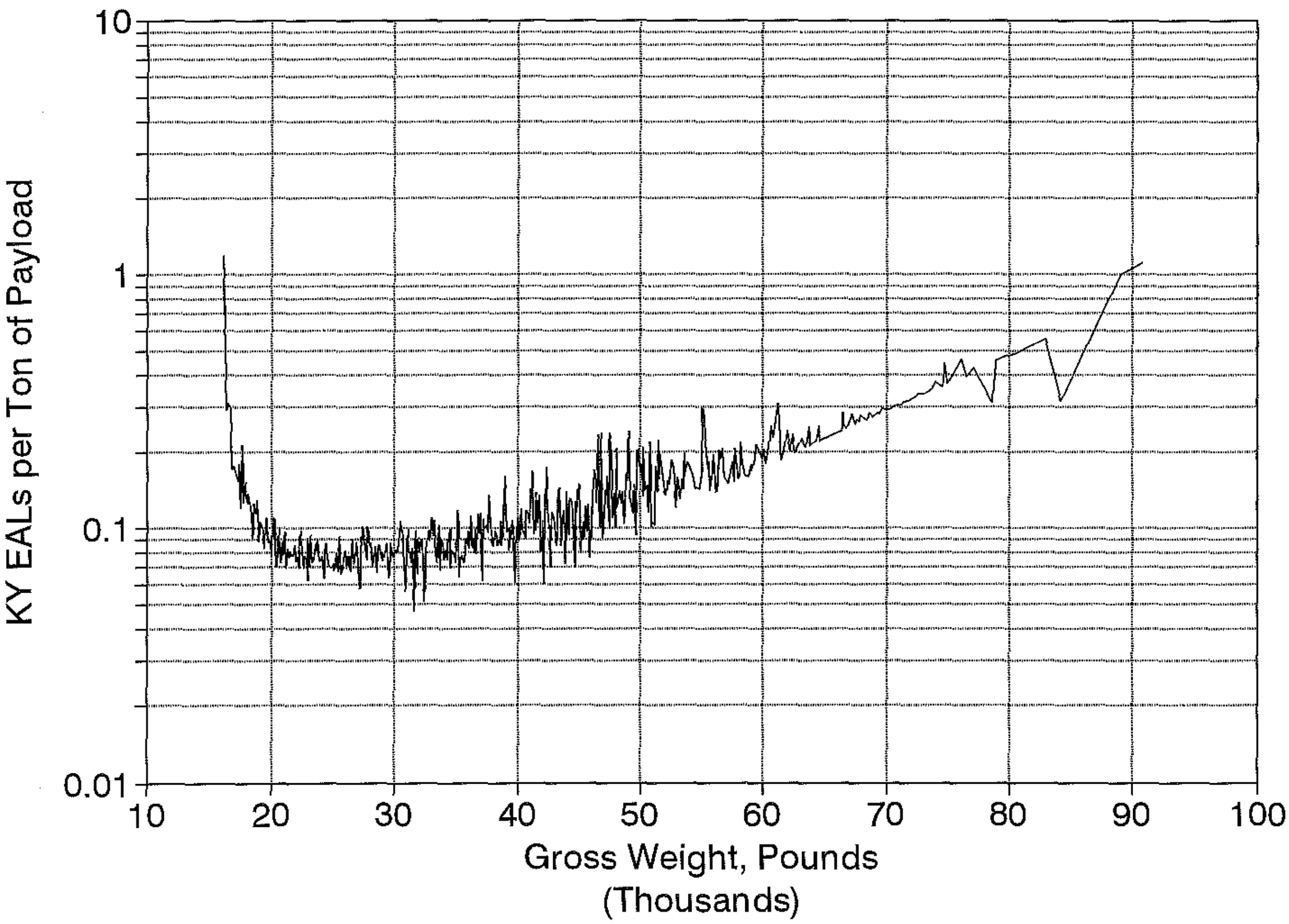
Appendix B

Pavement Wear Rates With Kentucky Damage Factors

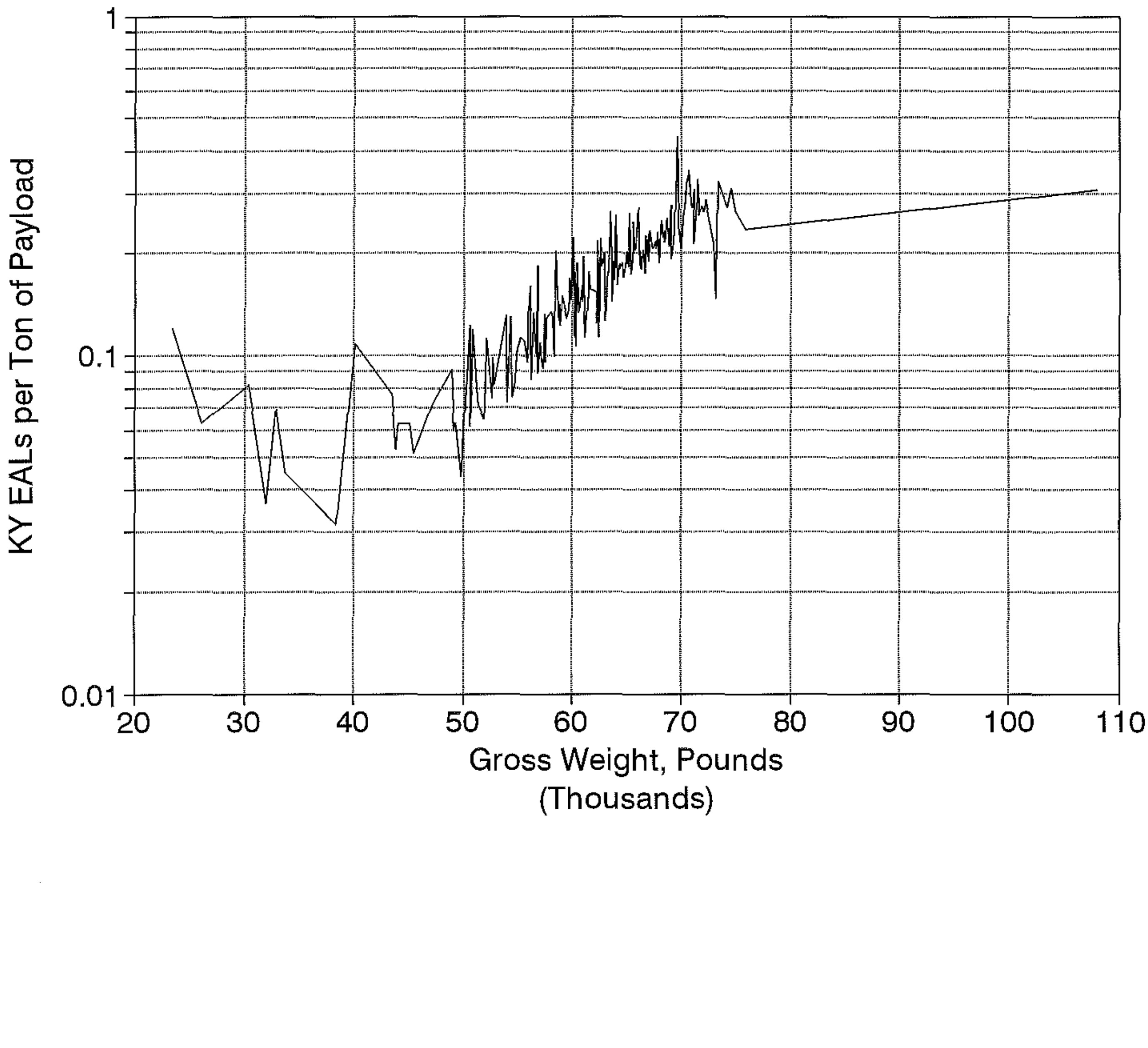
VT 5, Rural Principal Arterial



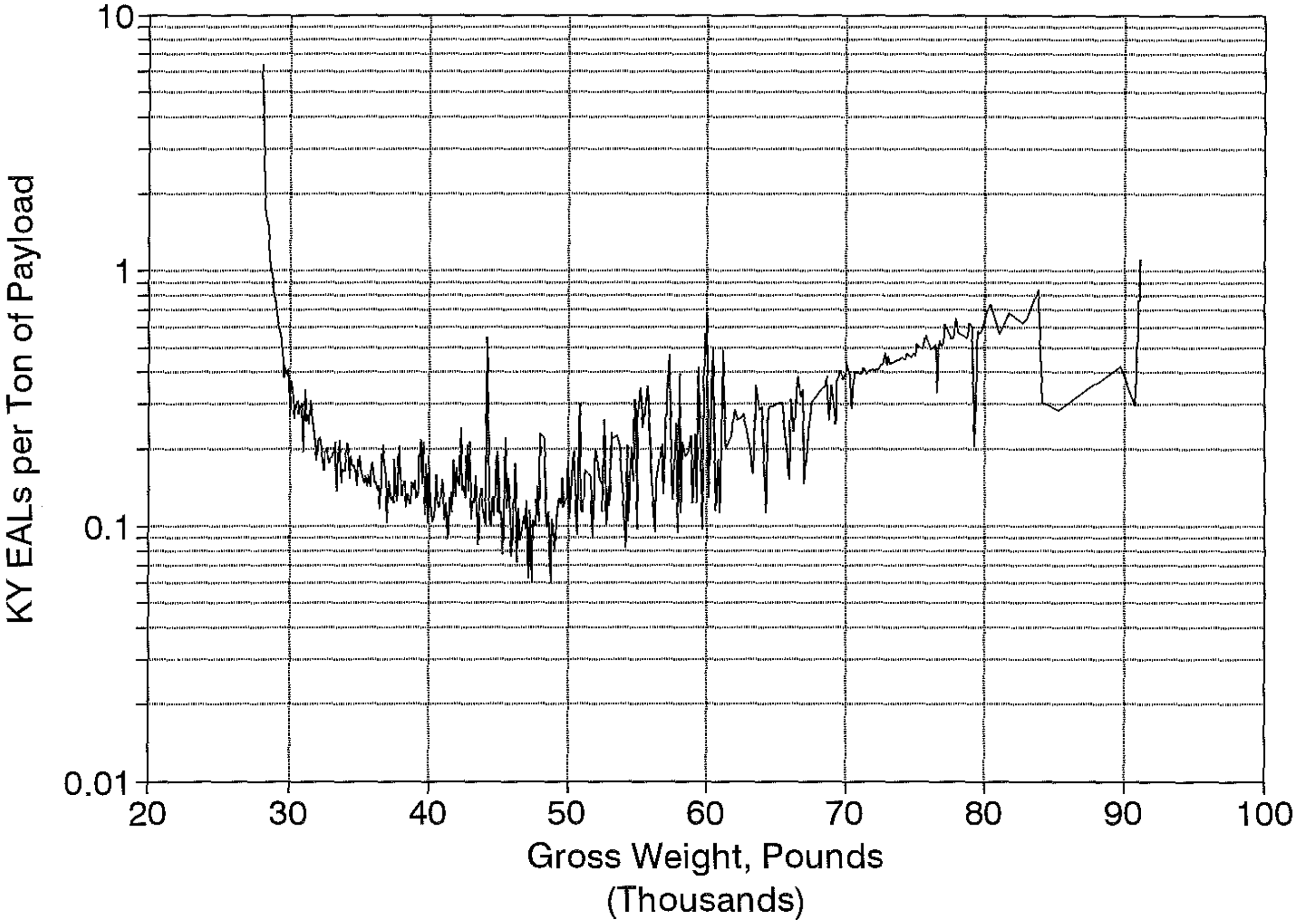
VT 6, Rural Principal Arterial



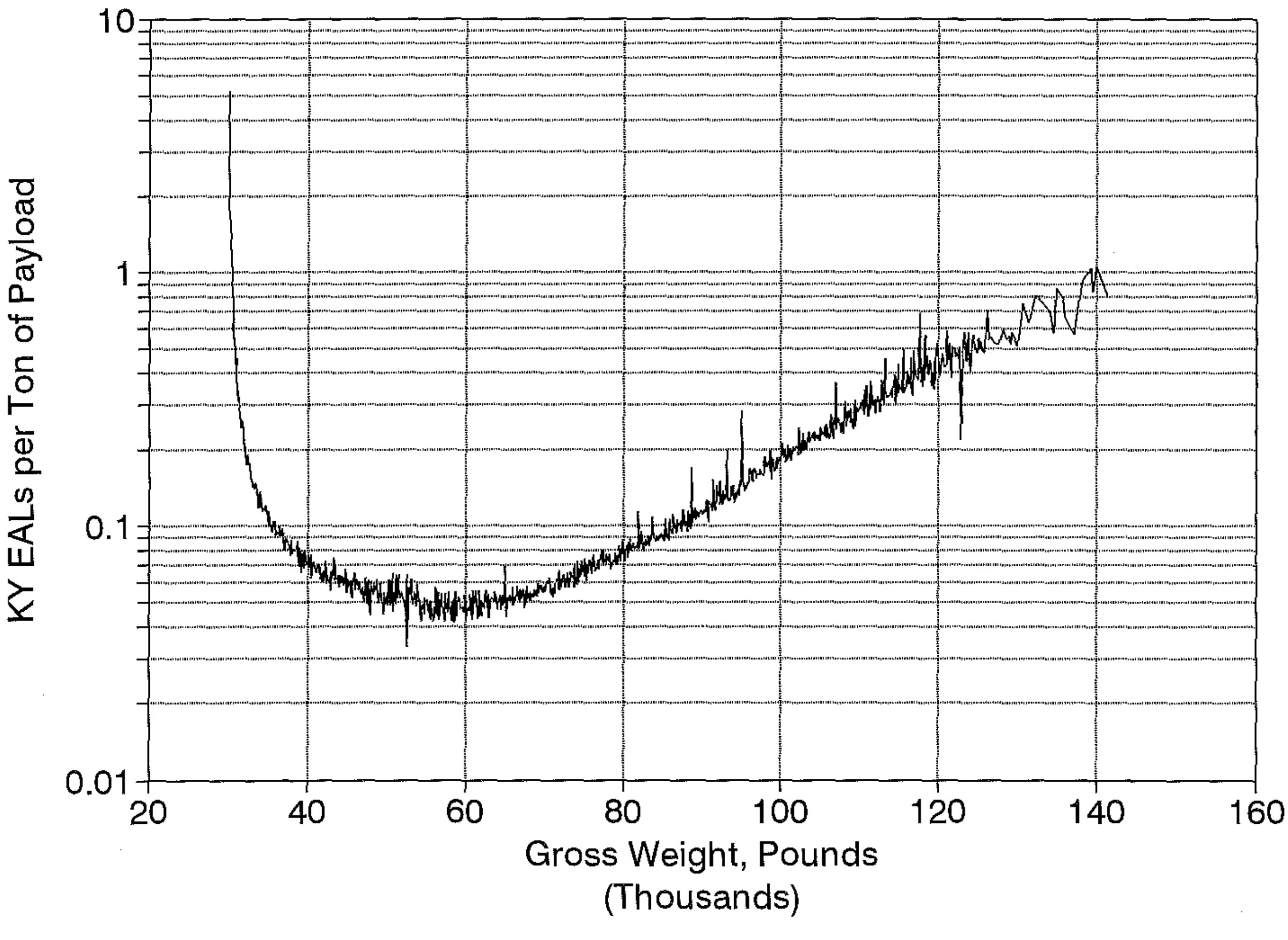
VT 7, Rural Principal Arterial



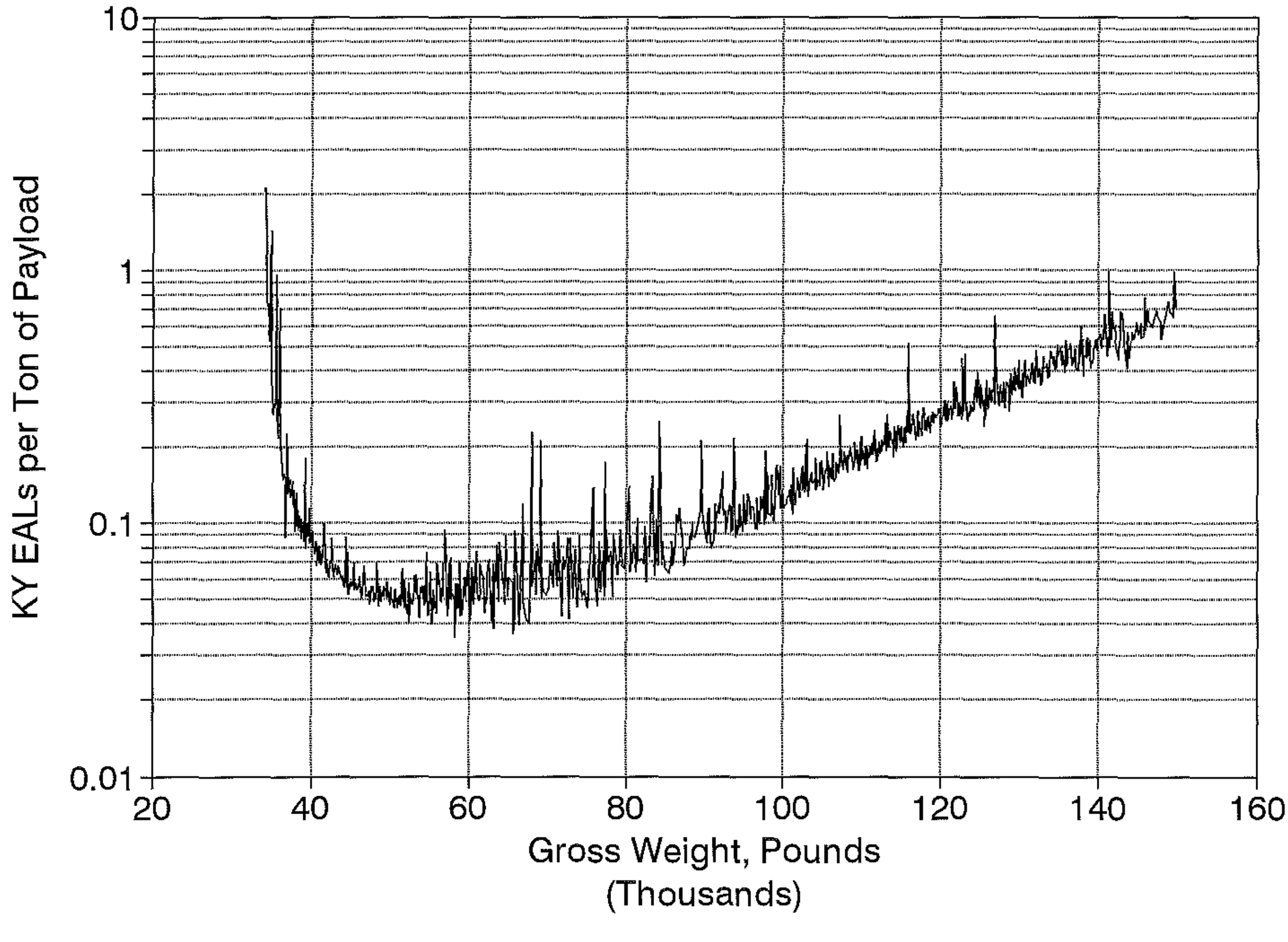
VT 8, Rural Principal Arterial



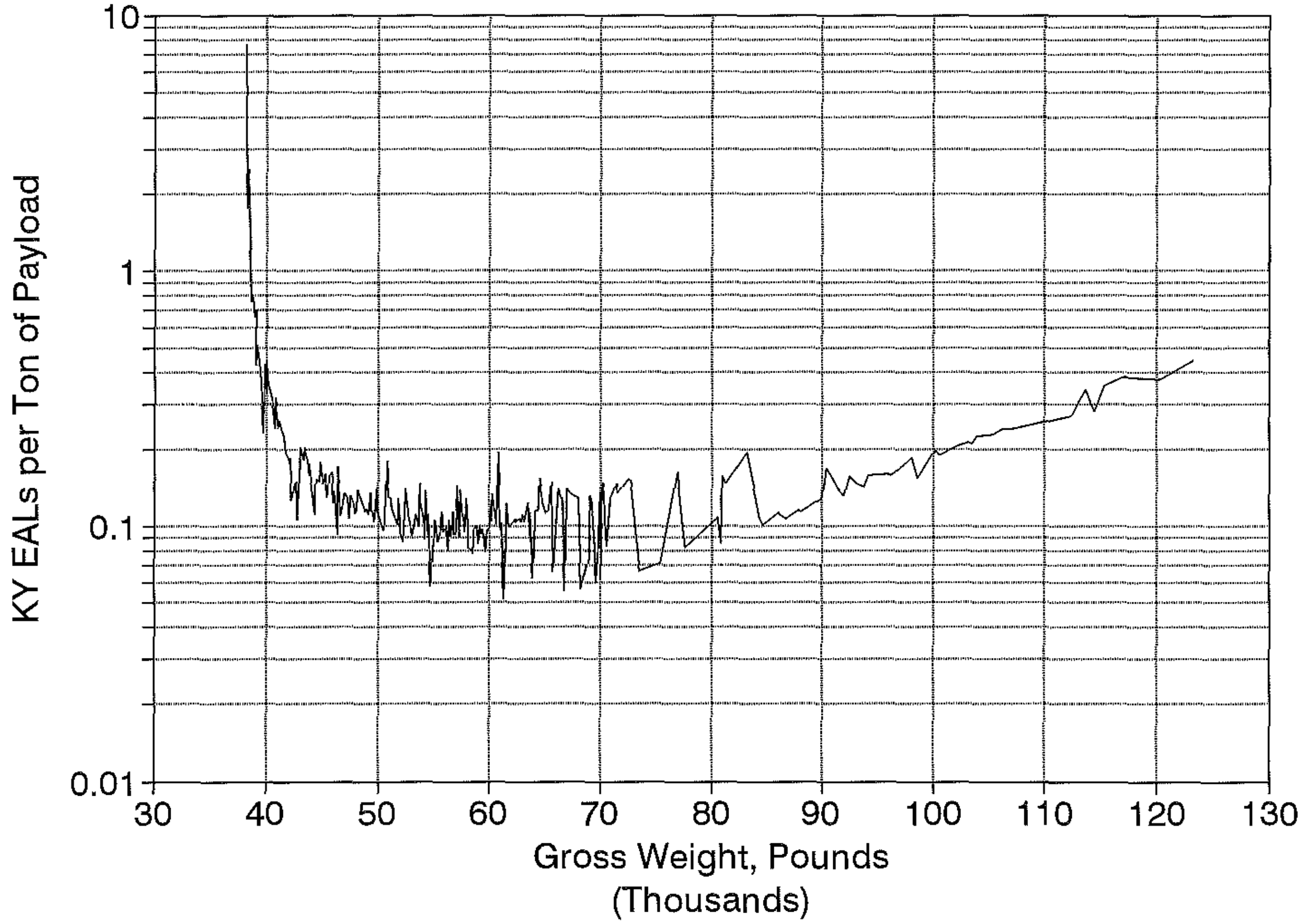
VT 9, Rural Principal Arterial

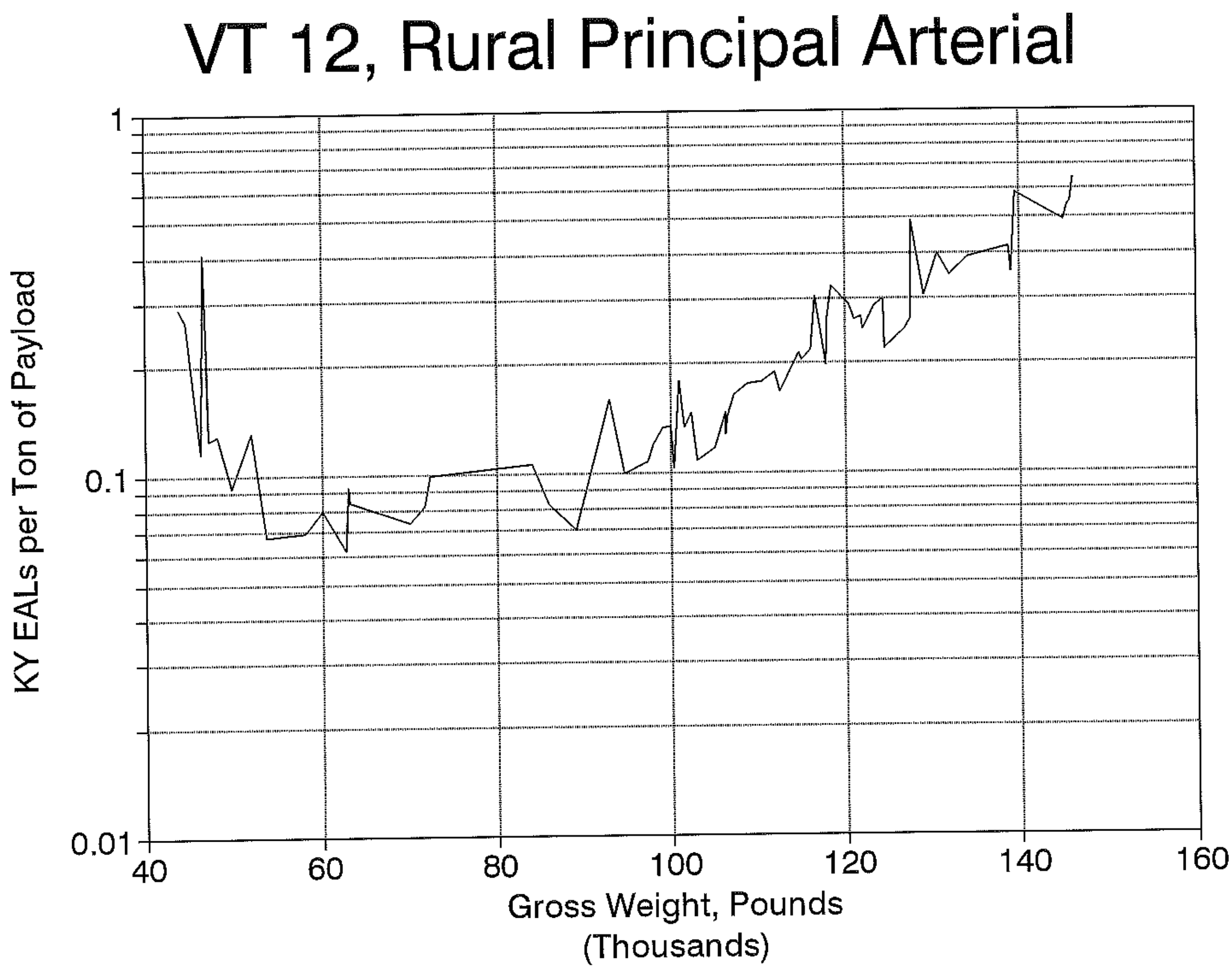


VT 10, Rural Principal Arterial



VT 11, Rural Principal Arterial

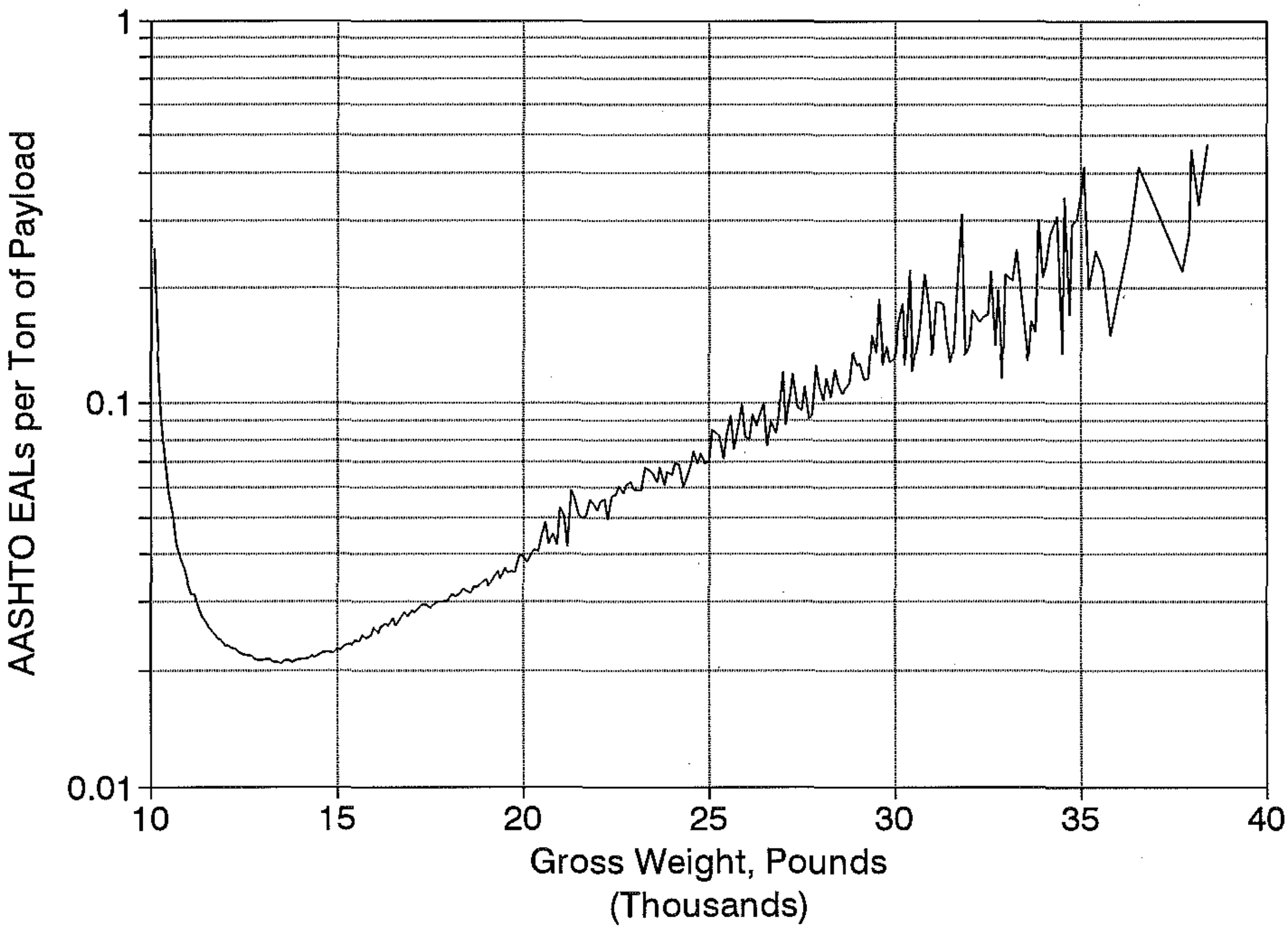



VT 12, Rural Principal Arterial
1
0.1
0.01
KY EALs per Ton of Payload
40
60
80
100
120
140
160
Gross Weight, Pounds
(Thousands)

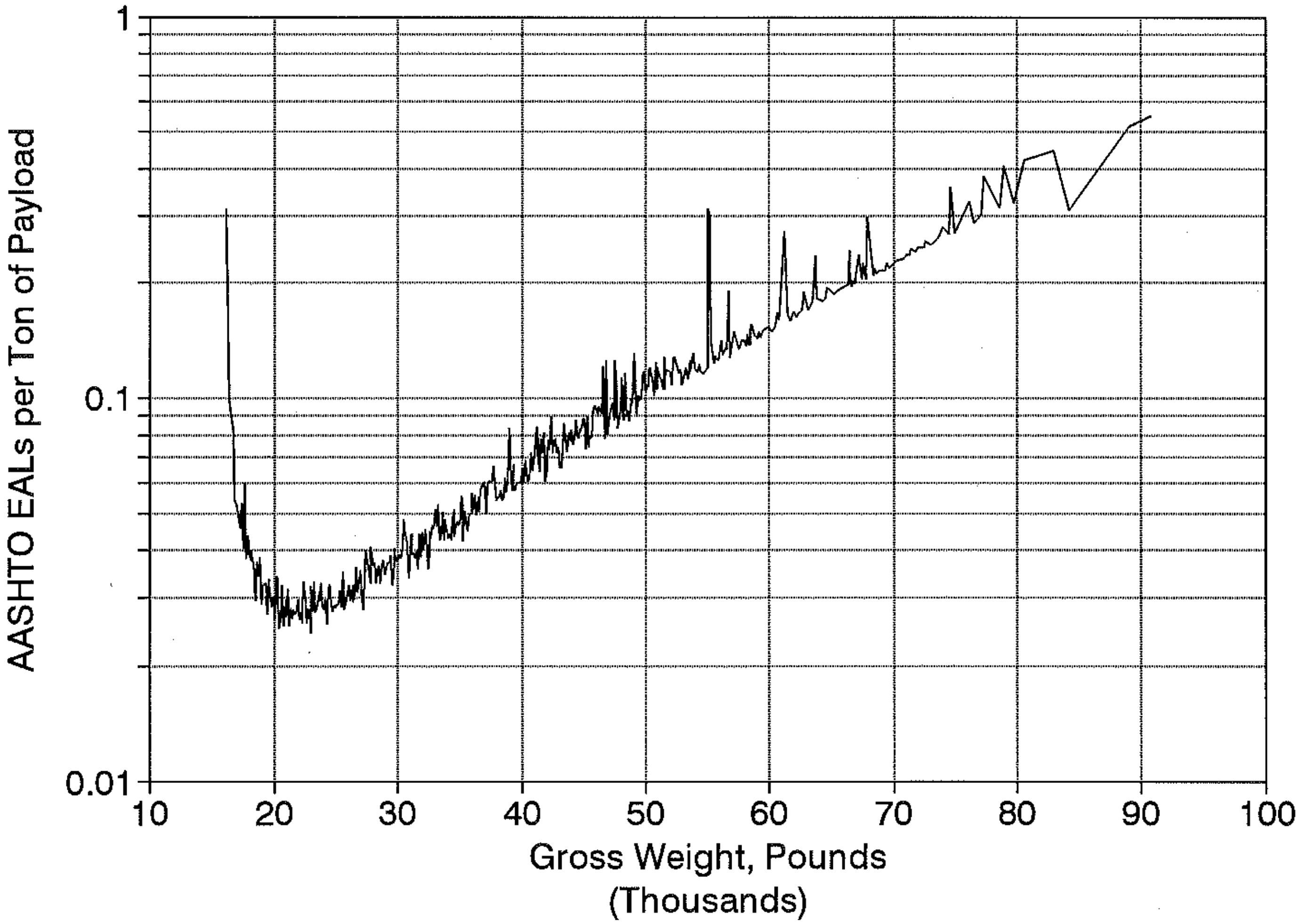
Appendix C

Pavement Wear Rates With AASHTO Damage Factors

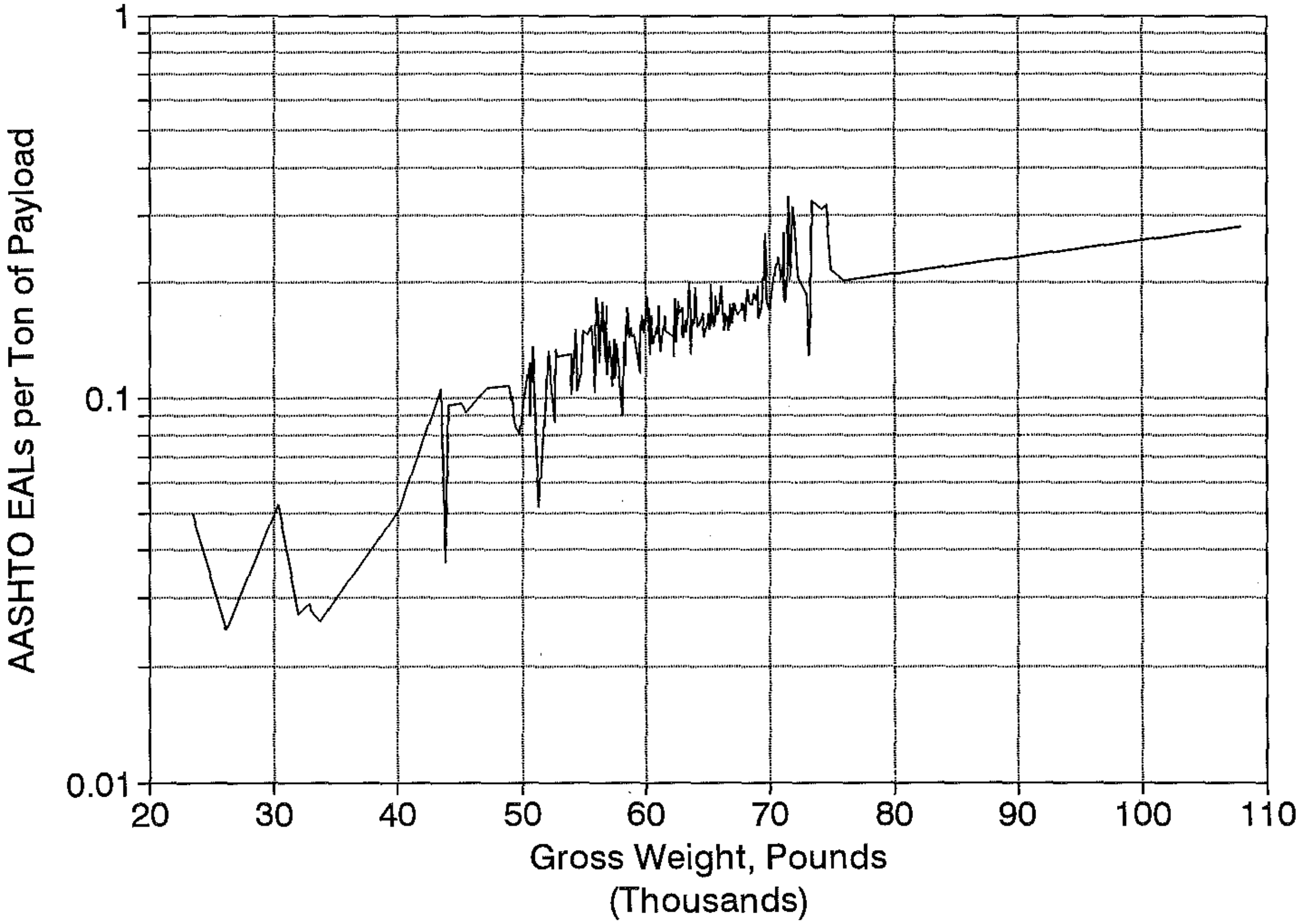
VT 5, Rural Principal Arterial

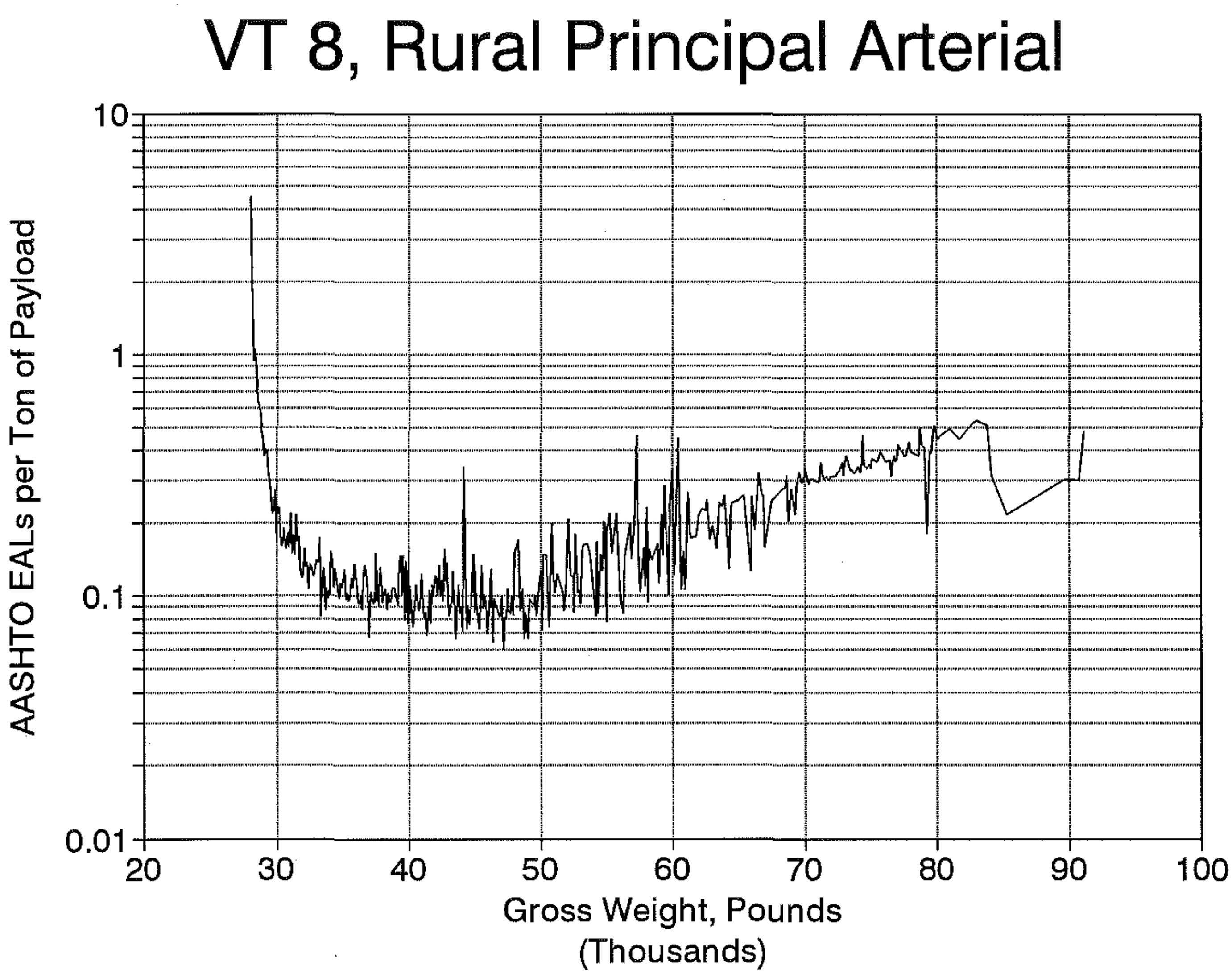


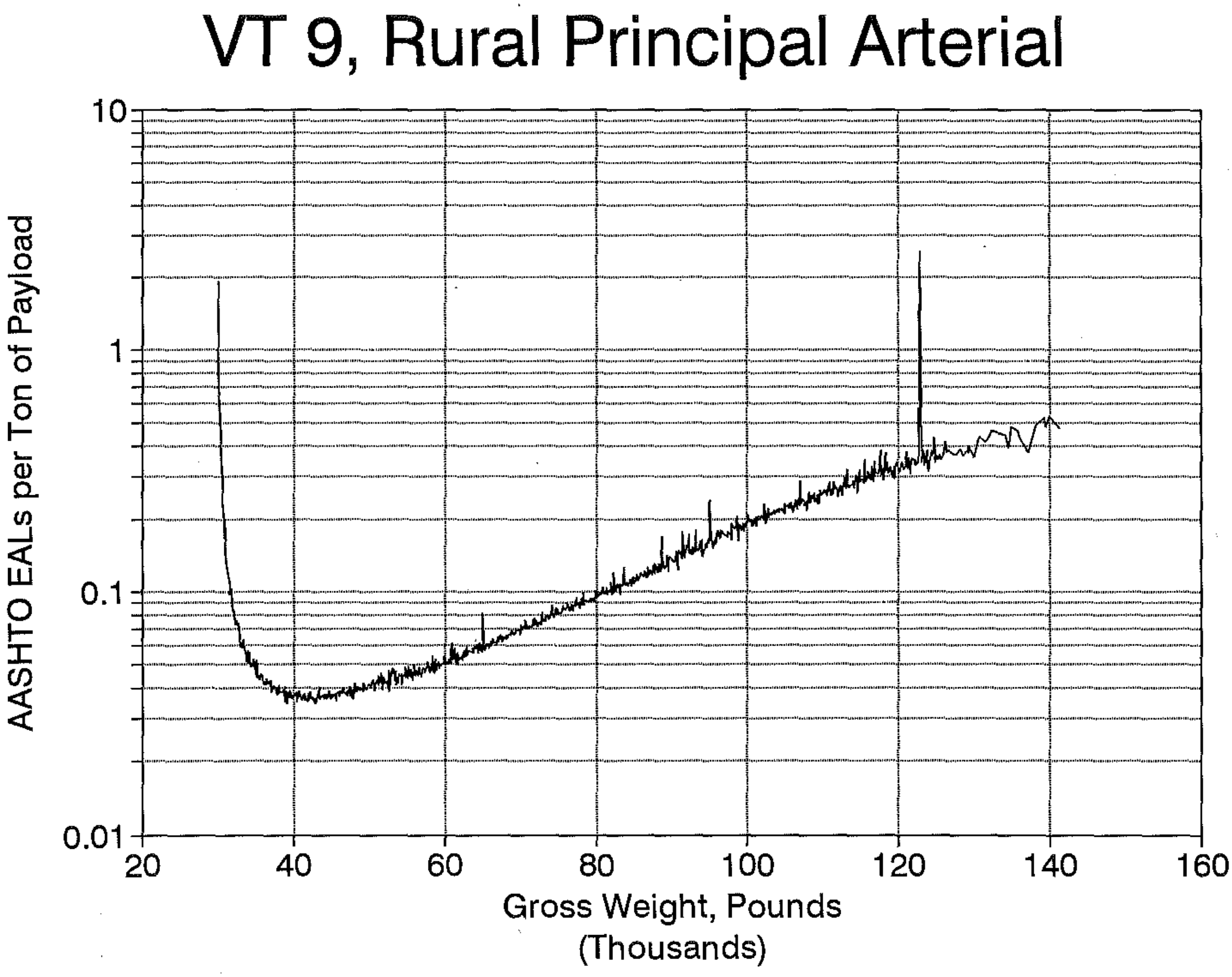
VT 6, Rural Principal Arterial



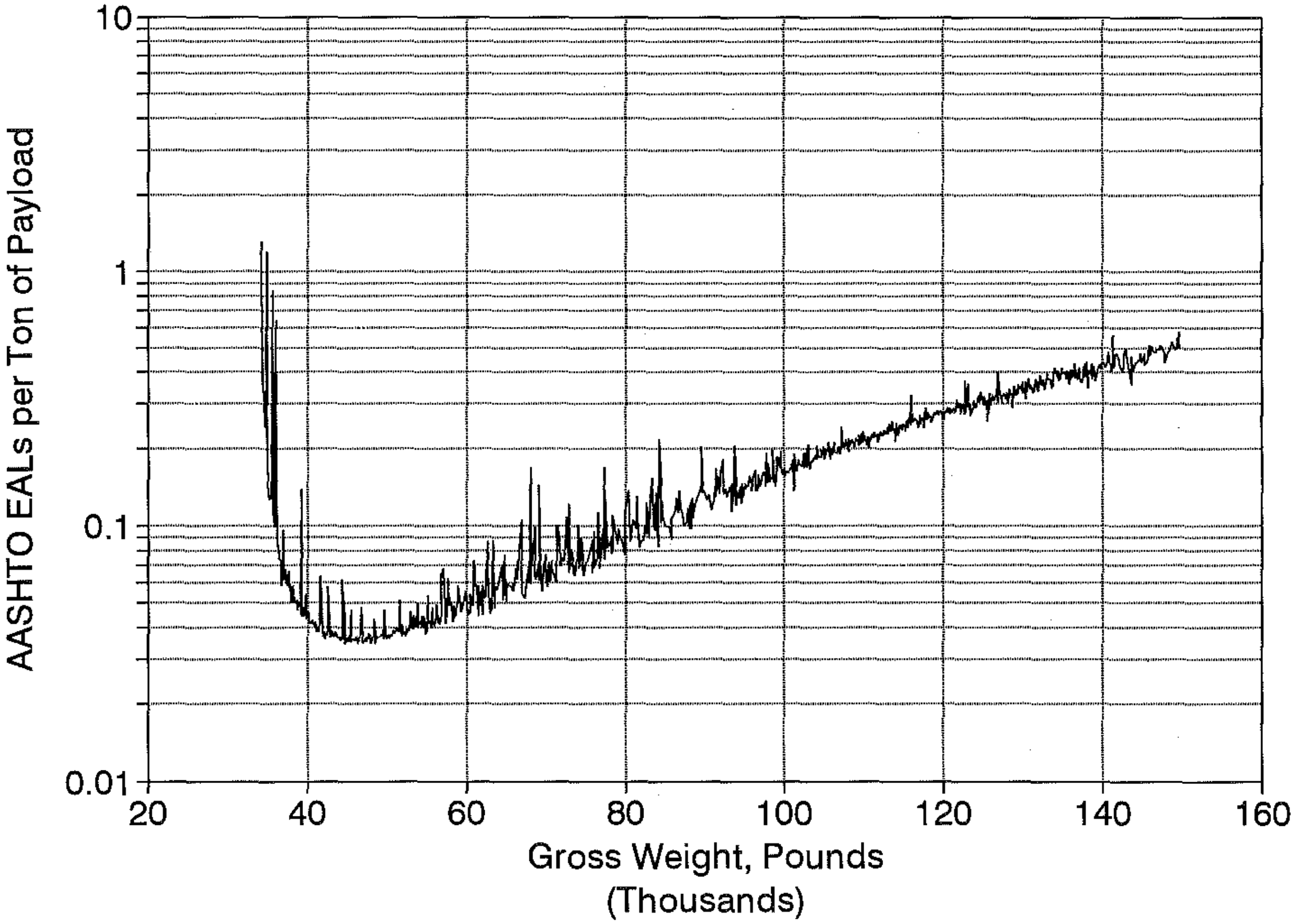
VT 7, Rural Principal Arterial



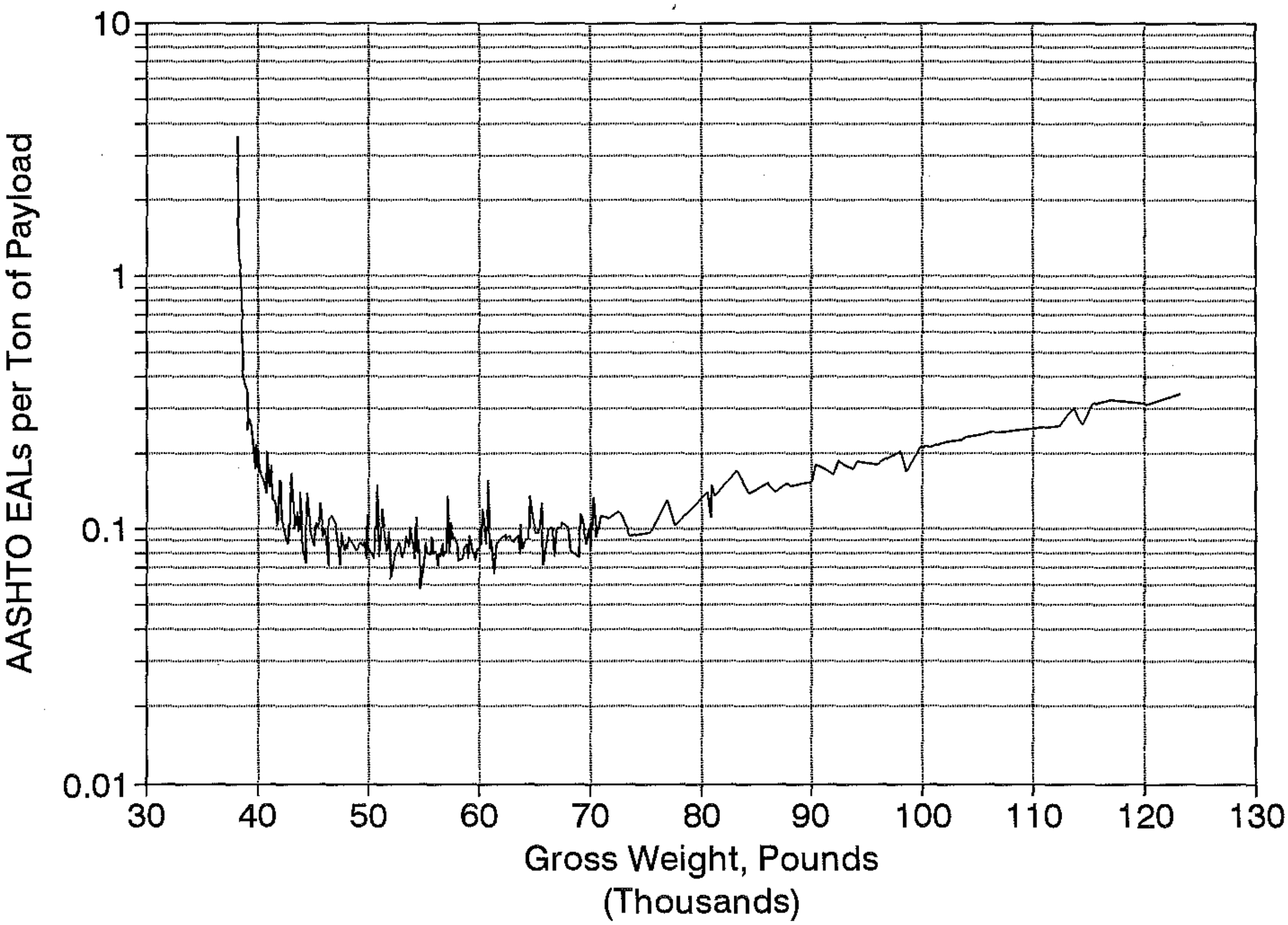

VT 8, Rural Principal Arterial
AASHTO EALs per Ton of Payload
10
1
0.1
0.01
20
30
40
50
60
70
80
90
100
Gross Weight, Pounds
(Thousands)

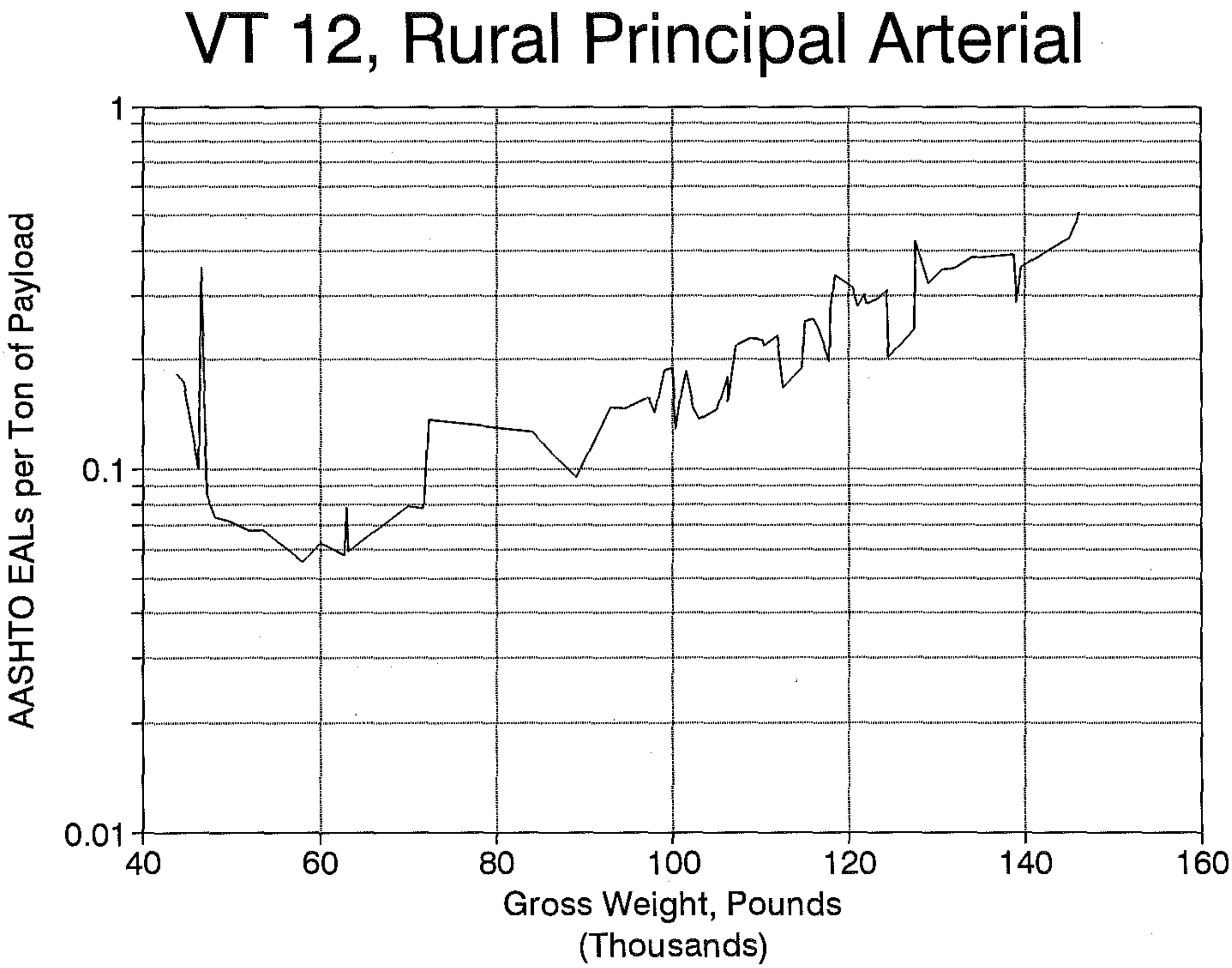

VT 9, Rural Principal Arterial
AASHTO EALs per Ton of Payload
10
1
0.1
0.01
20
40
60
80
100
120
140
160
Gross Weight, Pounds
(Thousands)

VT 10, Rural Principal Arterial



VT 11, Rural Principal Arterial

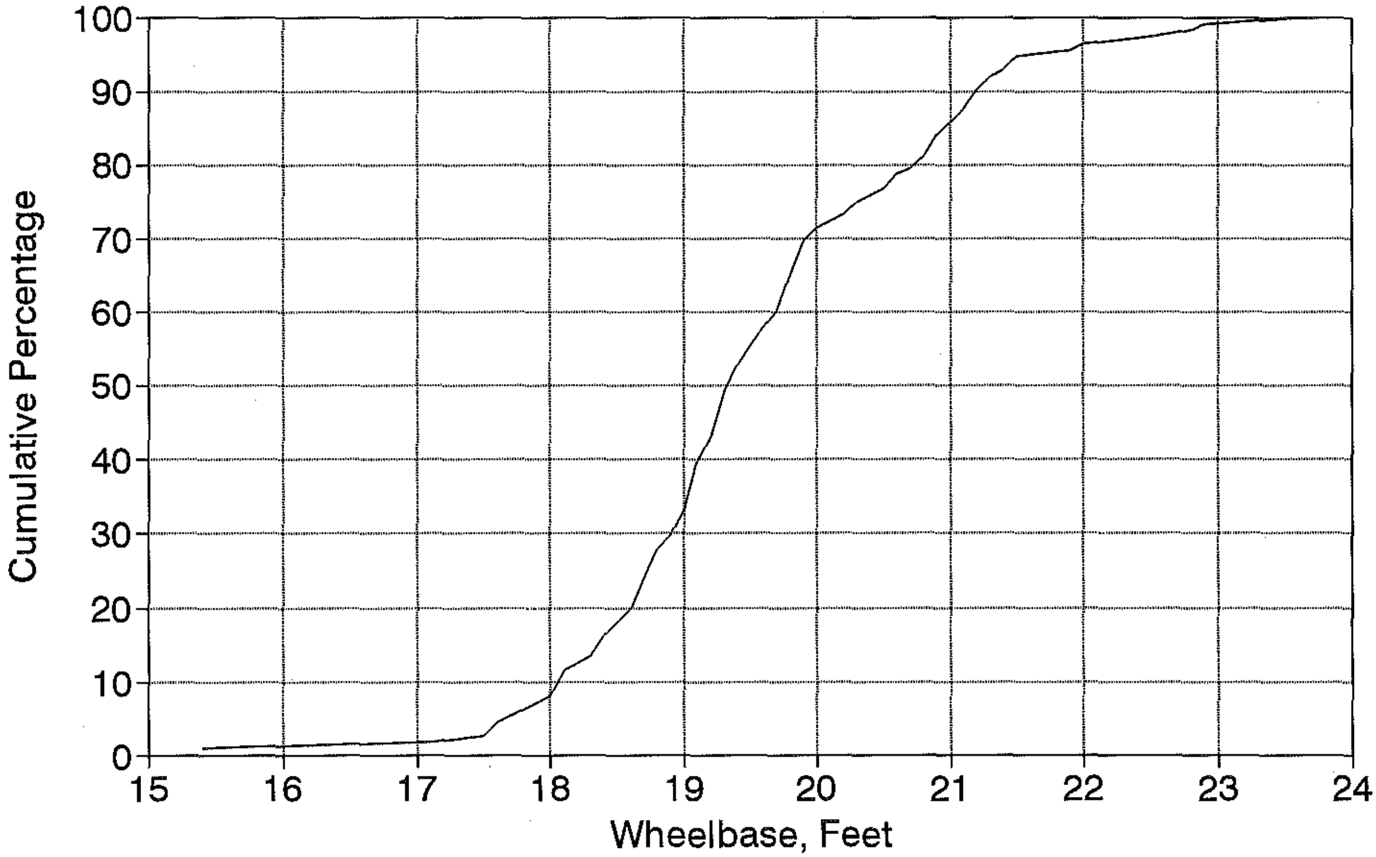



VT 12, Rural Principal Arterial
AASHTO EALs per Ton of Payload
1
0.1
0.01
40
60
80
100
120
140
160
Gross Weight, Pounds
(Thousands)

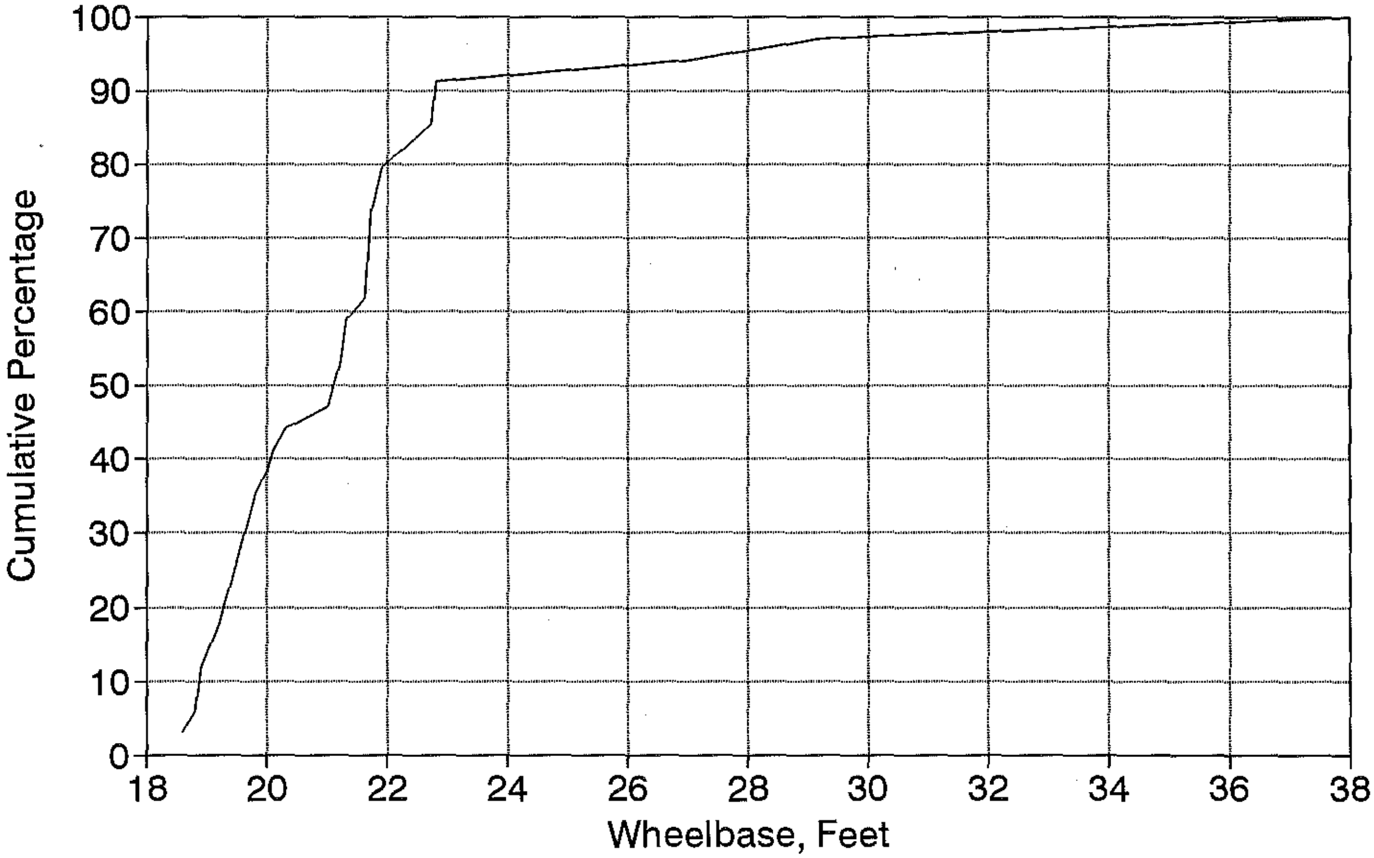
Appendix D

Wheelbase and Bridge Formula Gross Weight Distributions for Coal Trucks

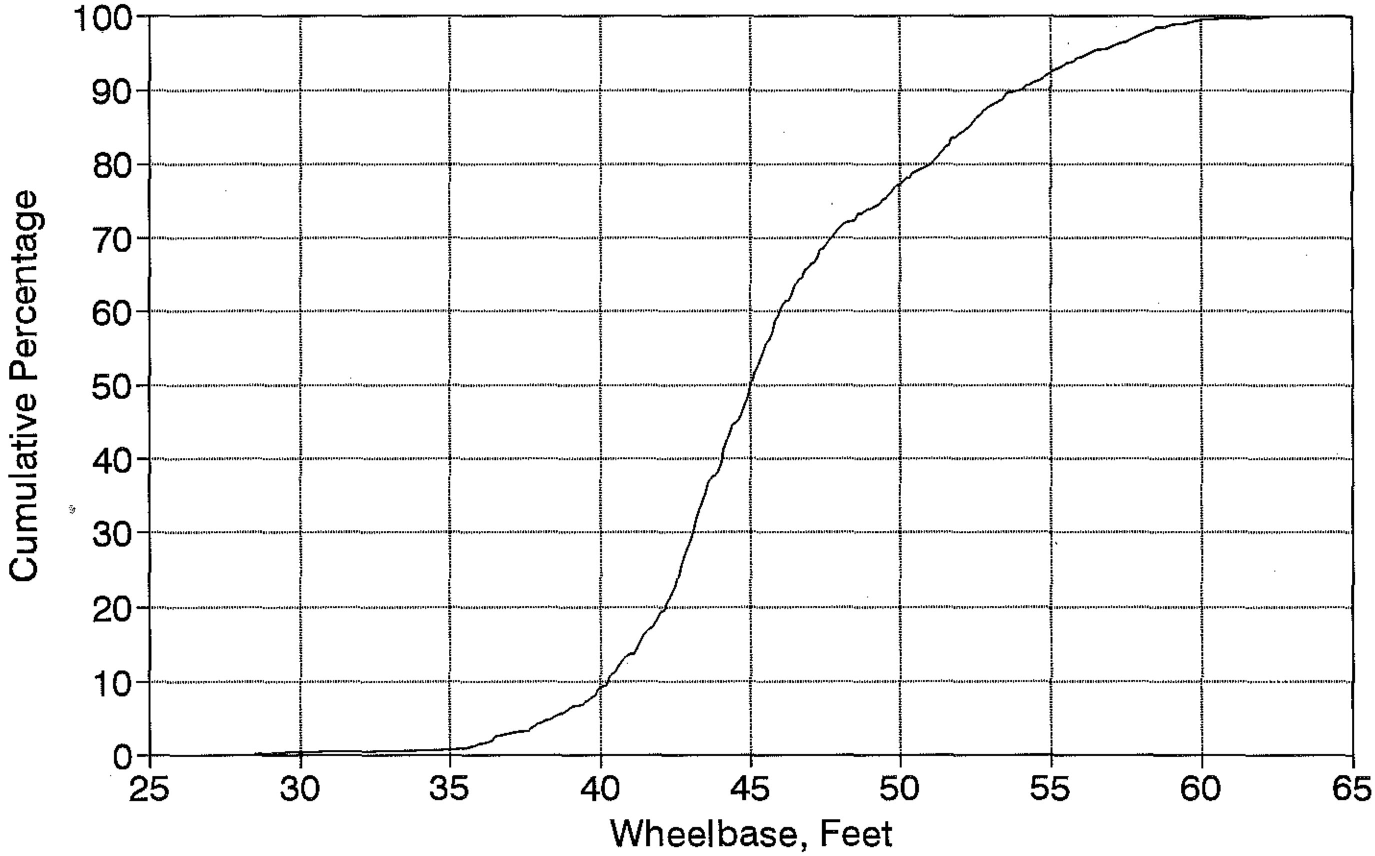
VT 6 (Heavy), Rural Principal Arterial
(Extended Weight, Coal Producing)



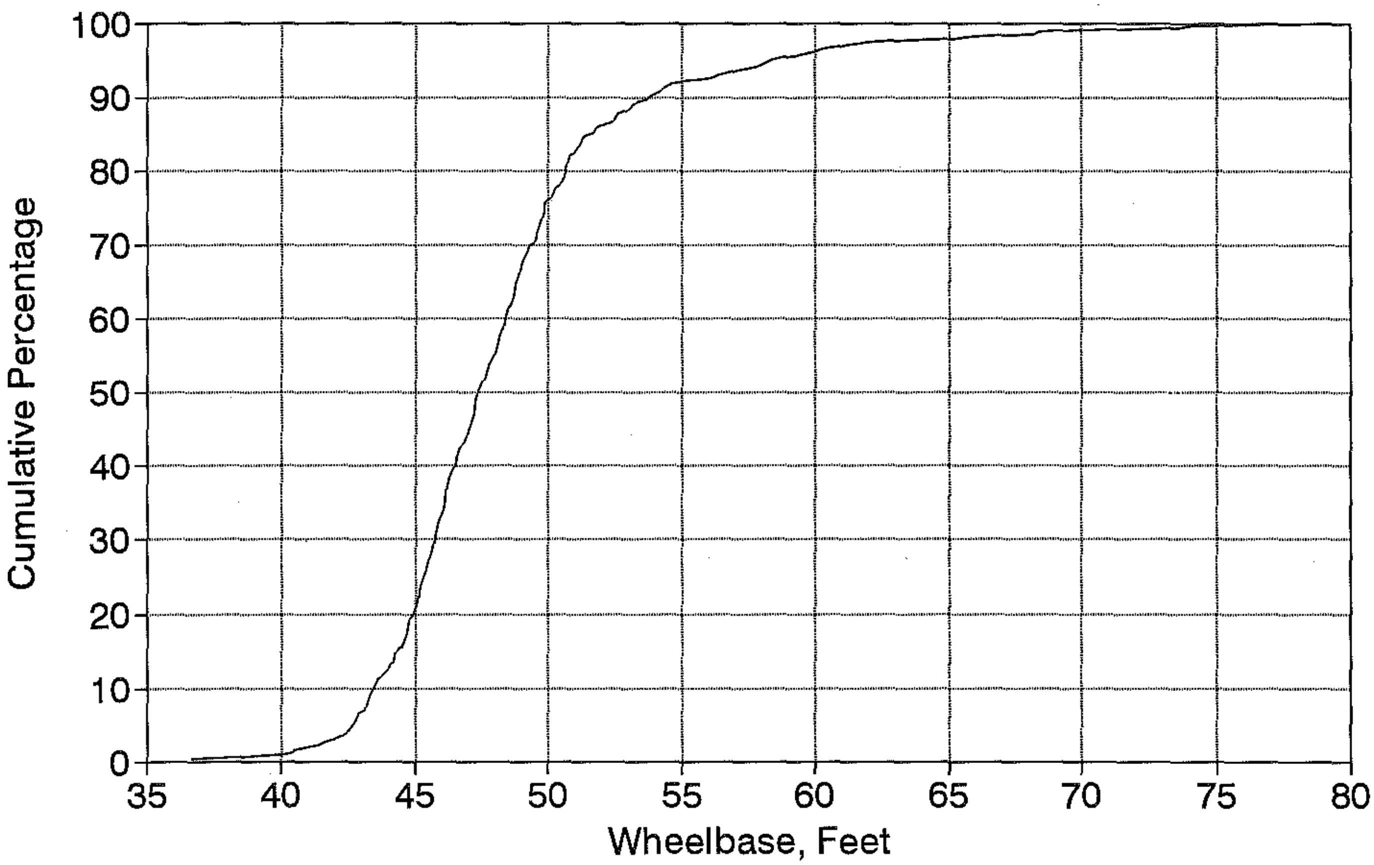
VT 7 (Heavy), Rural Principal Arterial
(Extended Weight, Coal Producing)

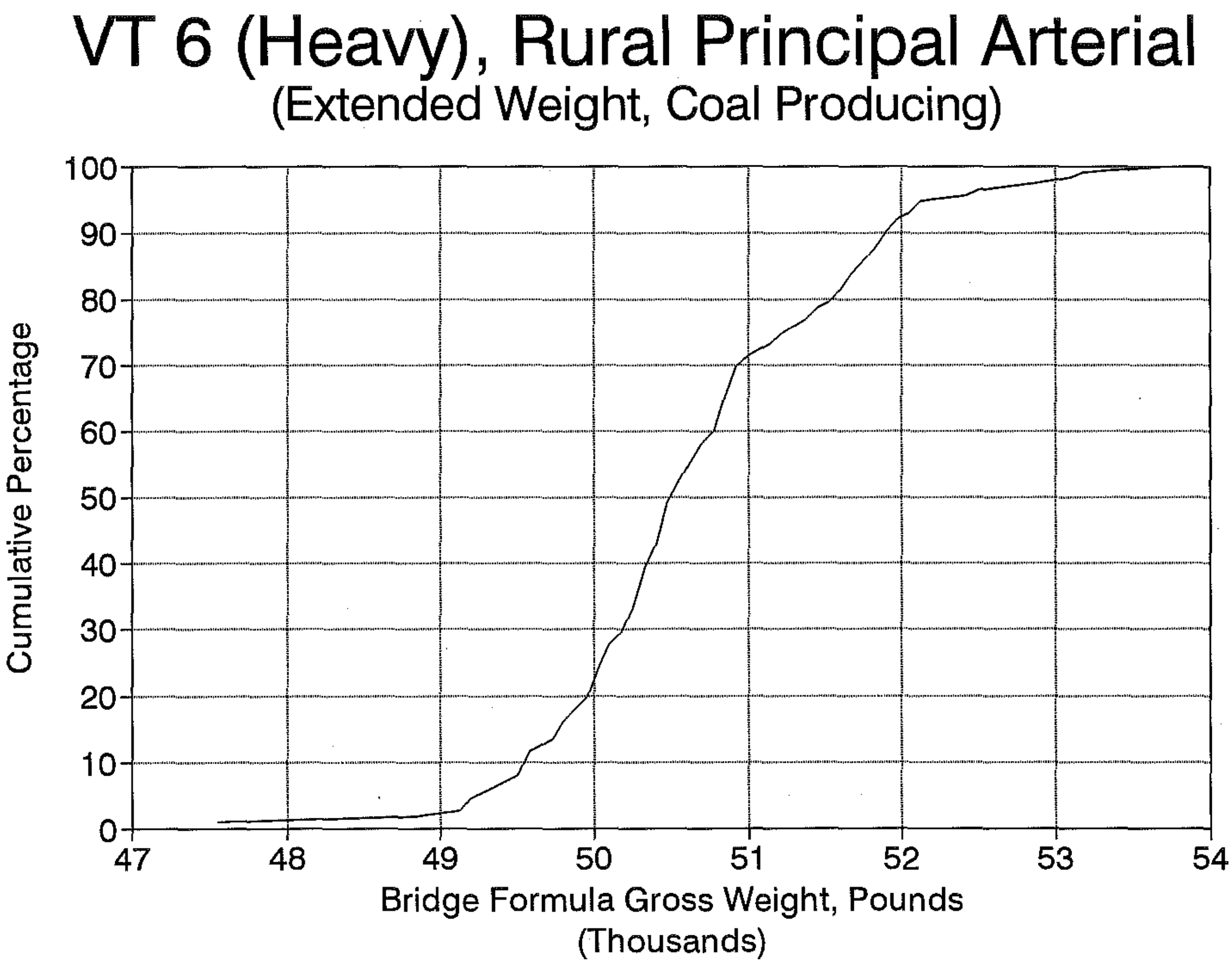


VT 9 (Heavy), Rural Principal Arterial
(Extended Weight, Coal Producing)



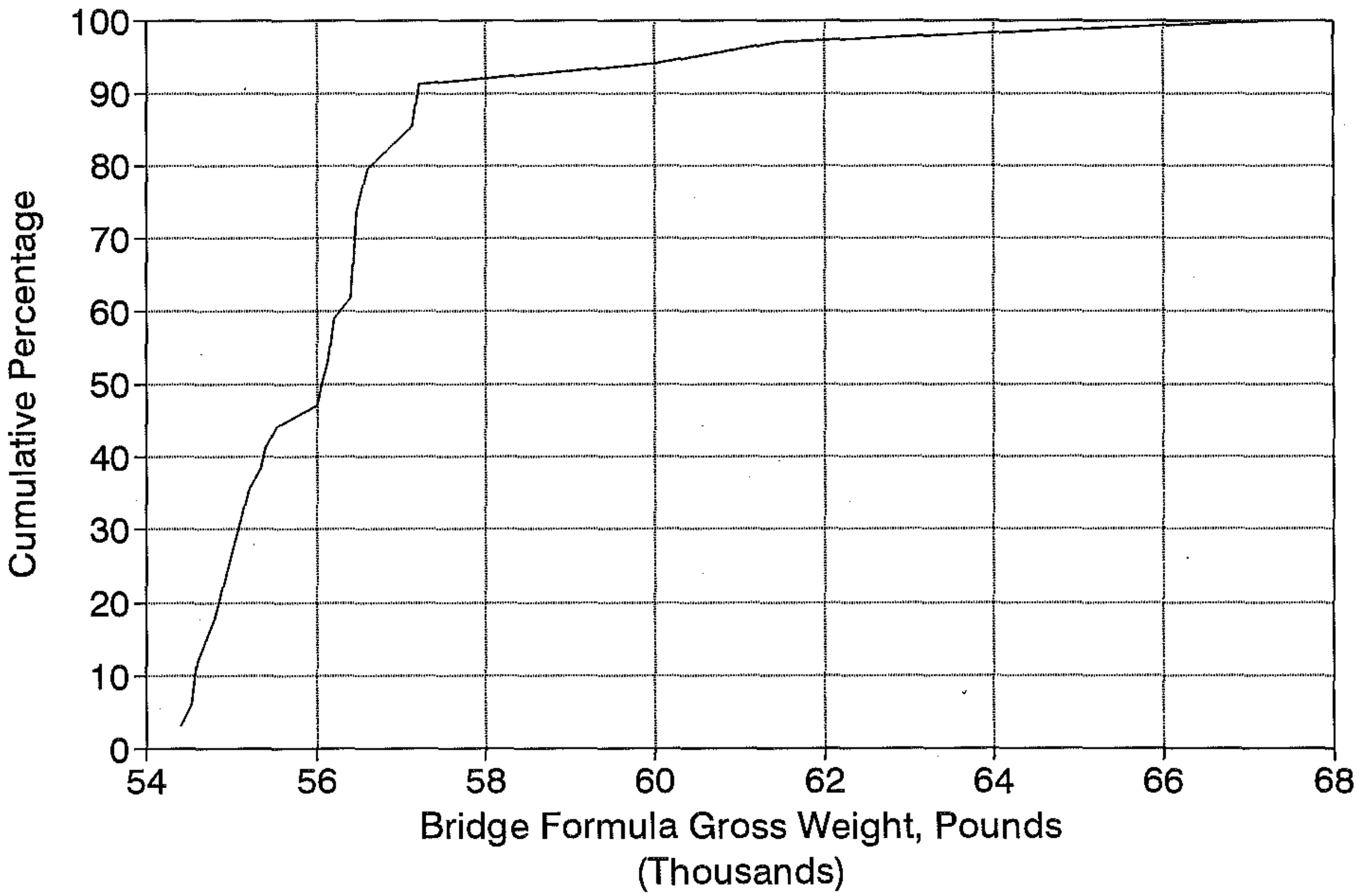
VT 10 (Heavy), Rural Principal Arterial
(Extended Weight, Coal Producing)



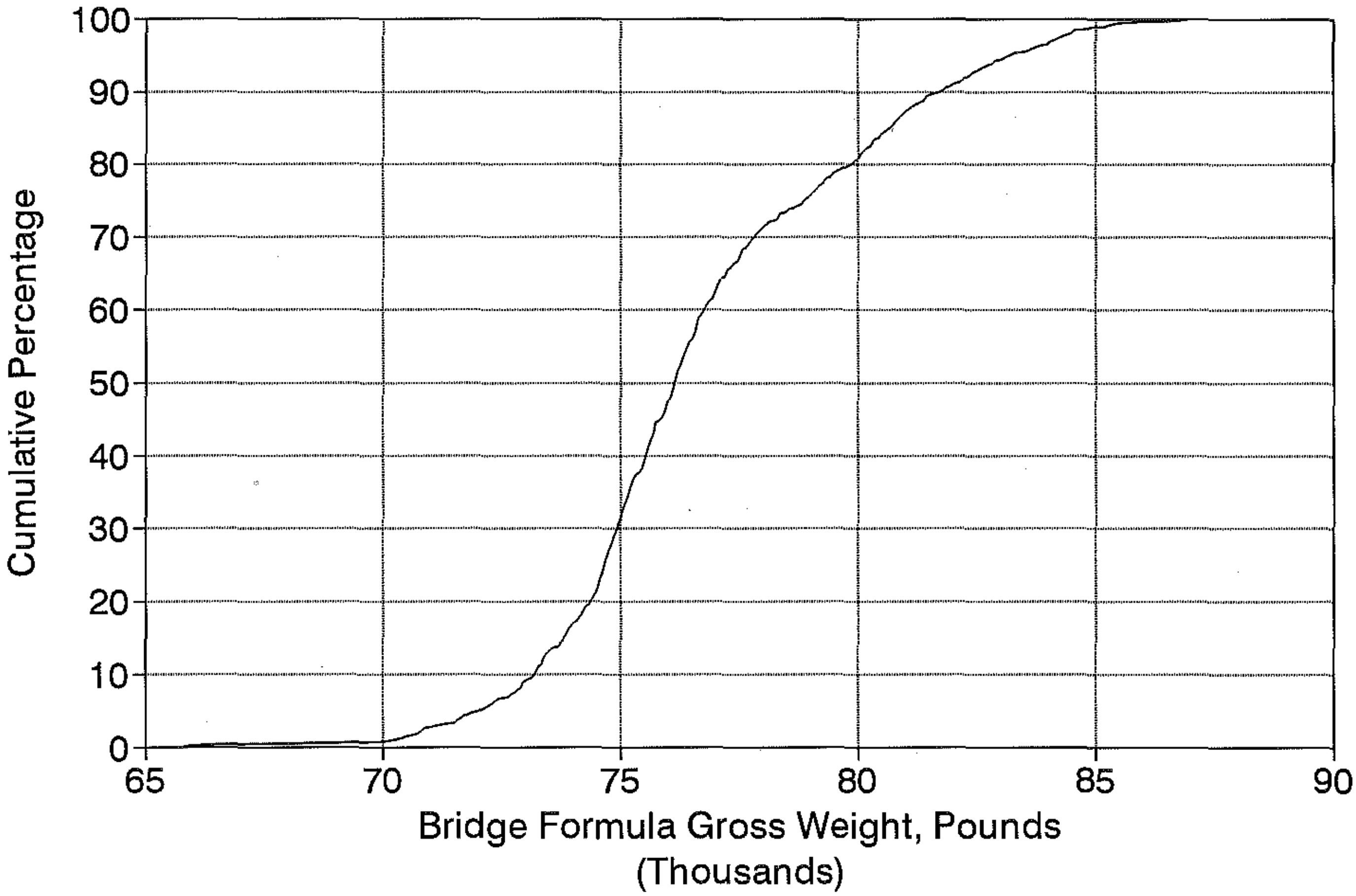

VT 6 (Heavy), Rural Principal Arterial
(Extended Weight, Coal Producing)
Cumulative Percentage
100
90
80
70
60
50
40
30
20
10
0
47
48
49
50
51
52
53
54
Bridge Formula Gross Weight, Pounds
(Thousands)

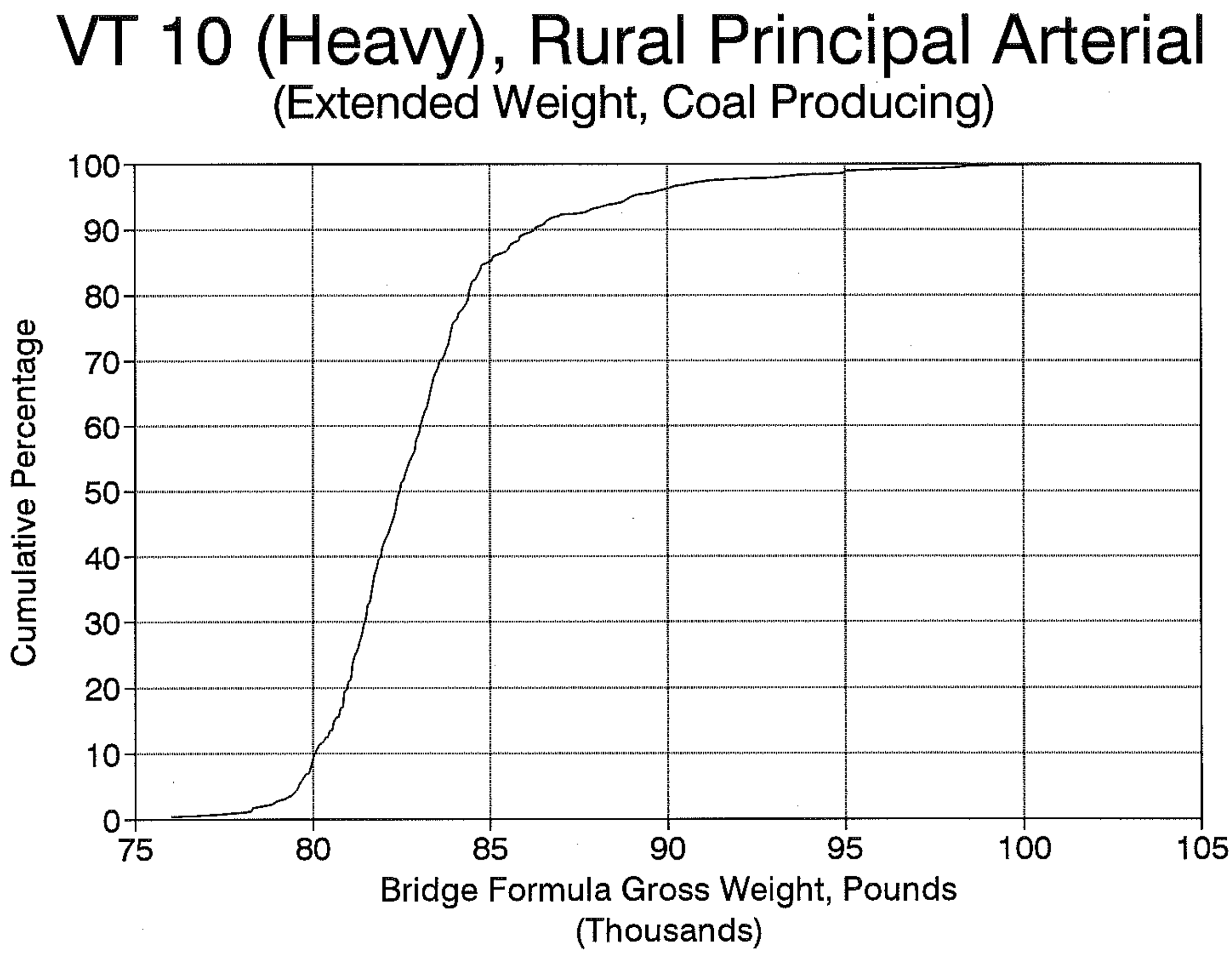
VT 7 (Heavy), Rural Principal Arterial

(Extended Weight, Coal Producing)



VT 9 (Heavy), Rural Principal Arterial
(Extended Weight, Coal Producing)

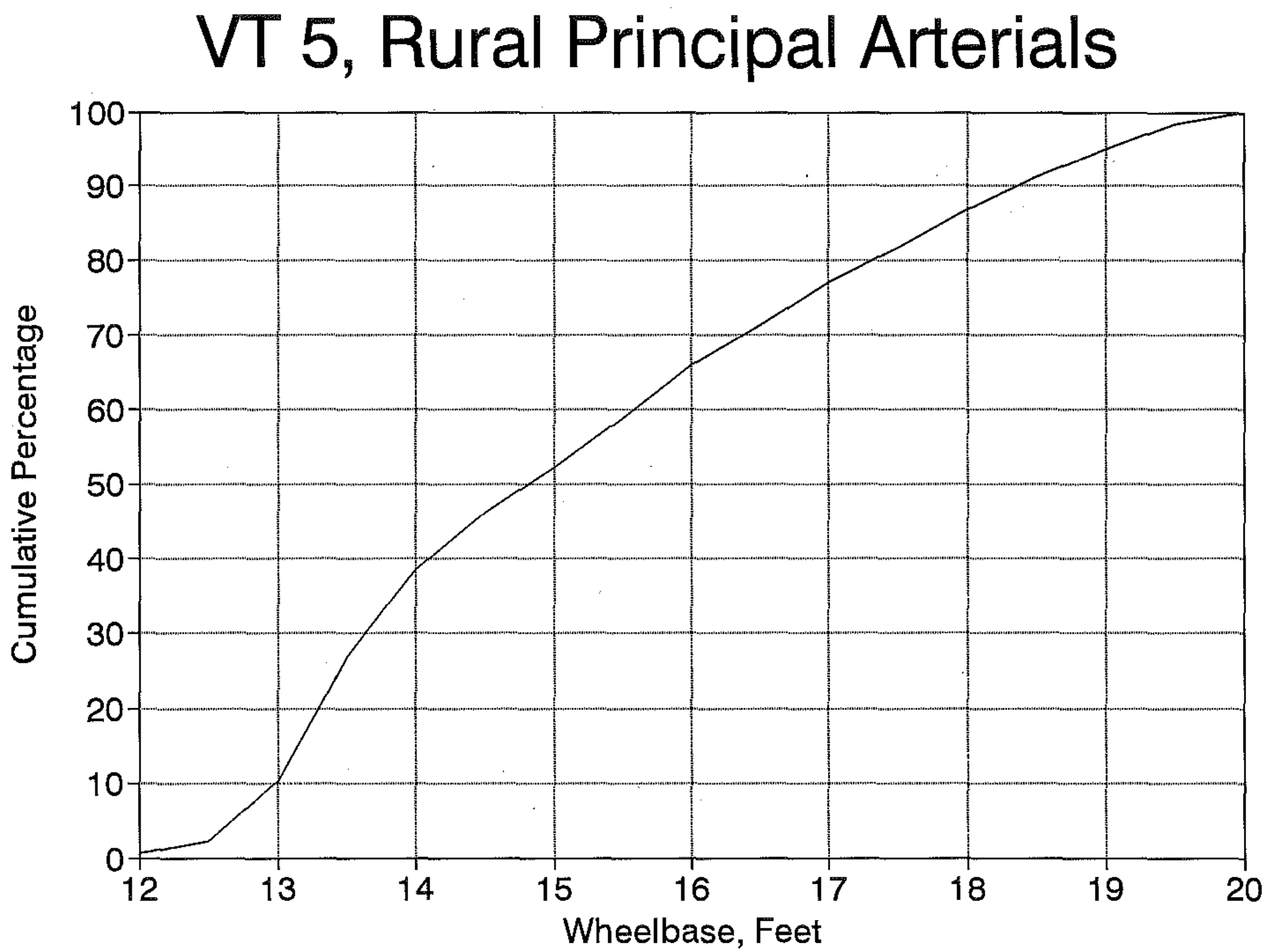




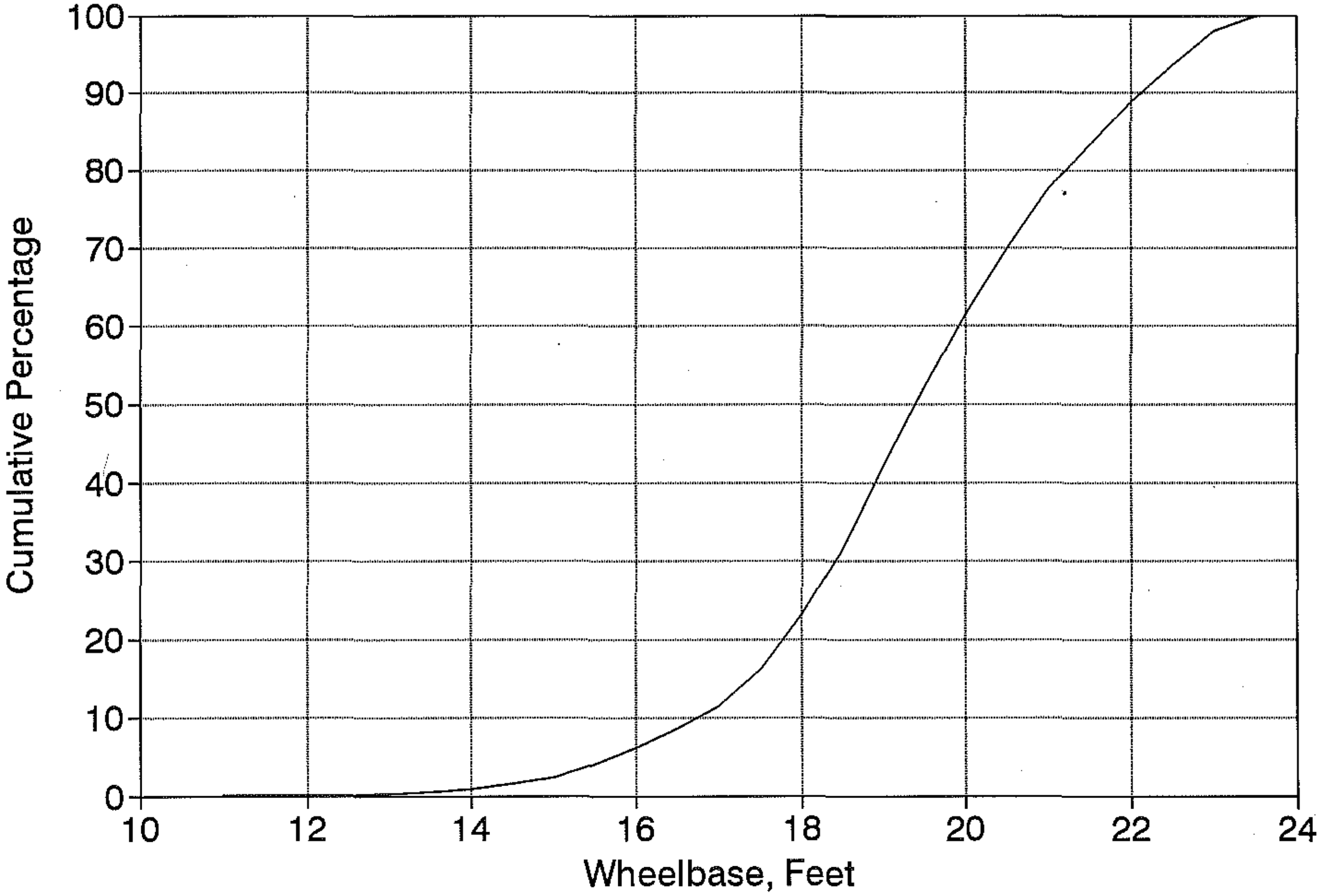
VT 10 (Heavy), Rural Principal Arterial
(Extended Weight, Coal Producing)
Cumulative Percentage
100
90
80
70
60
50
40
30
20
10
0
75
80
85
90
95
100
105
Bridge Formula Gross Weight, Pounds
(Thousands)

Appendix E

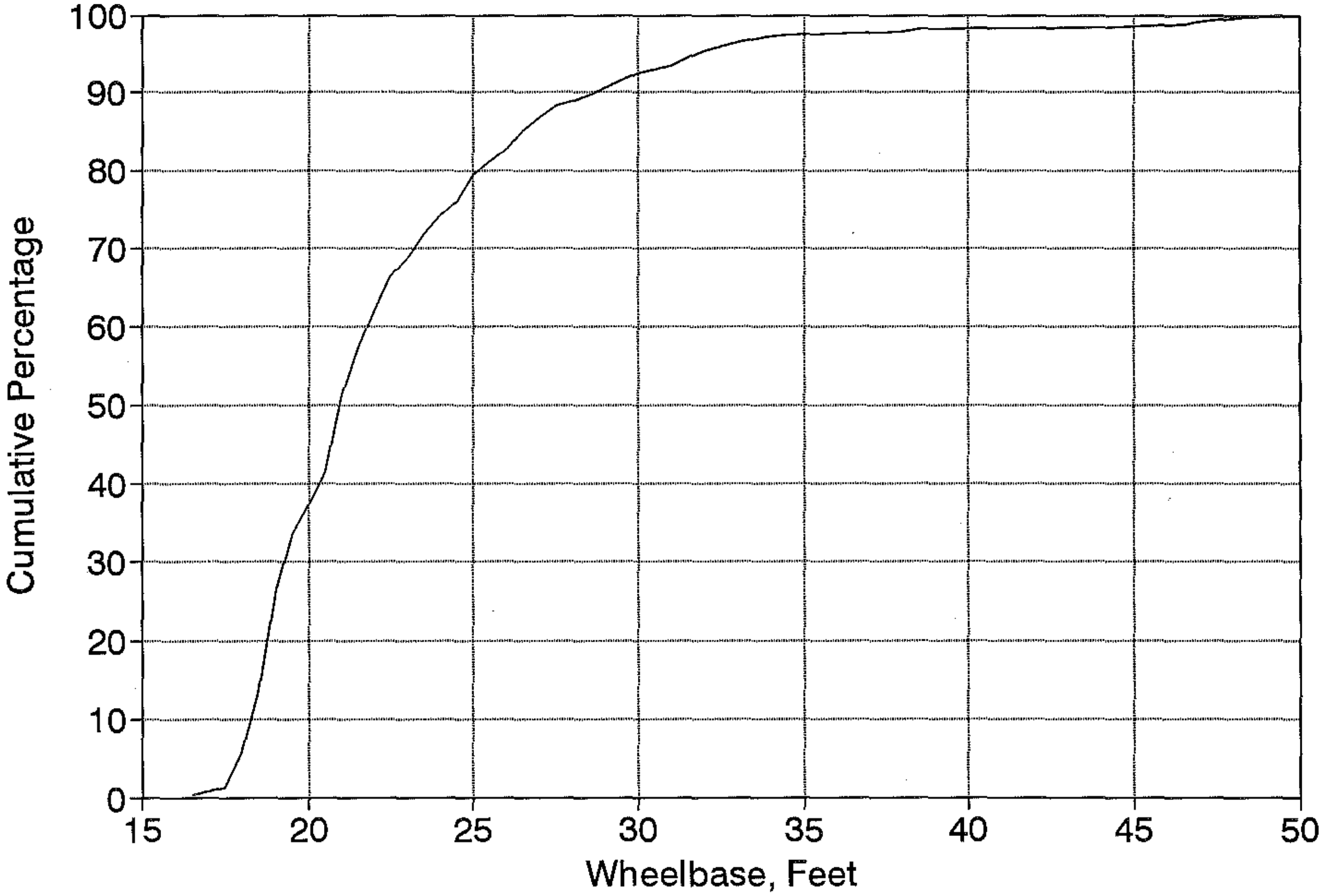
Wheelbase and Bridge Formula Gross Weight Distributions for the General Truck Population

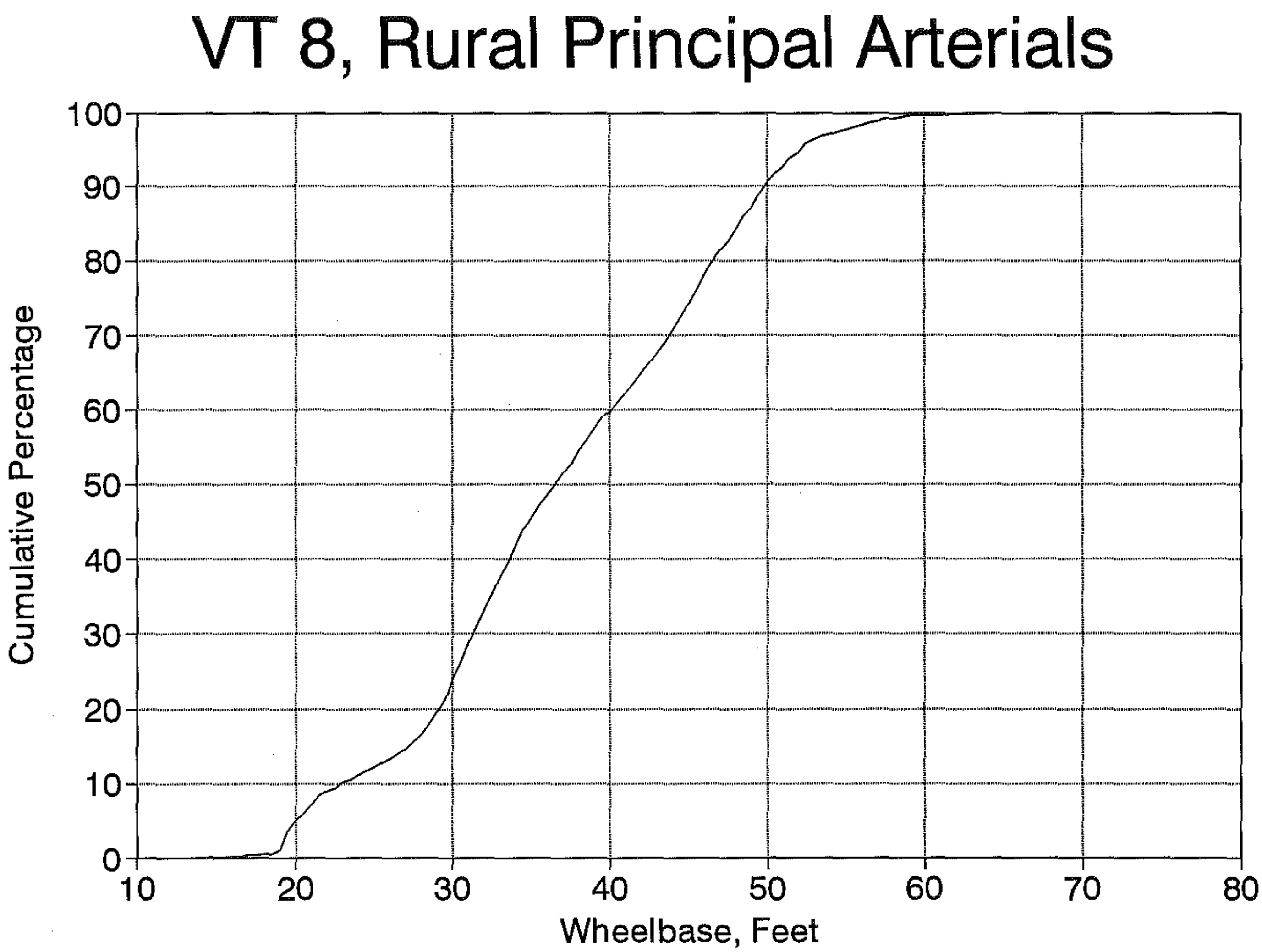

VT 5, Rural Principal Arterials
Cumulative Percentage
100
90
80
70
60
50
40
30
20
10
0
12
13
14
15
16
17
18
19
20
Wheelbase, Feet

VT 6, Rural Principal Arterials



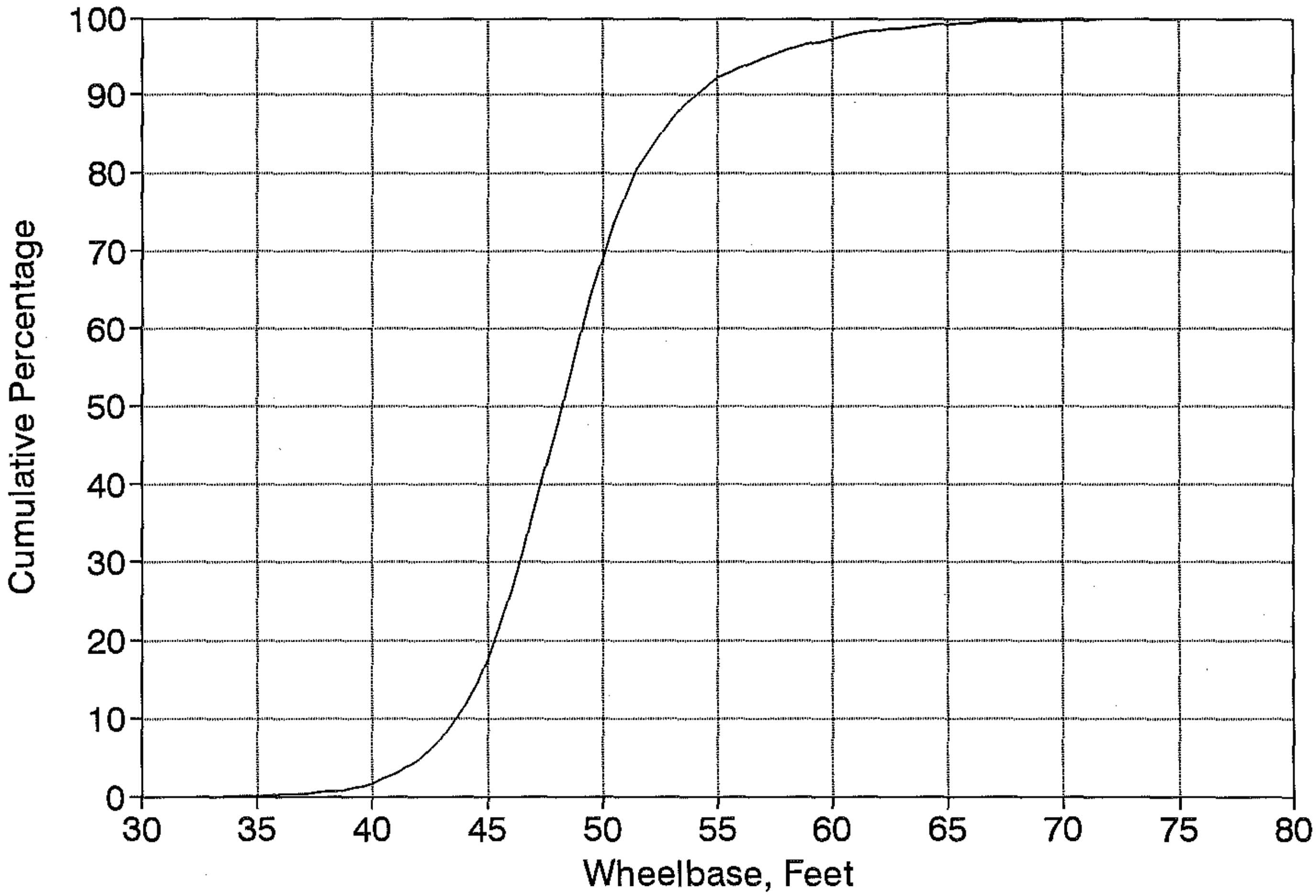
VT 7, Rural Principal Arterials

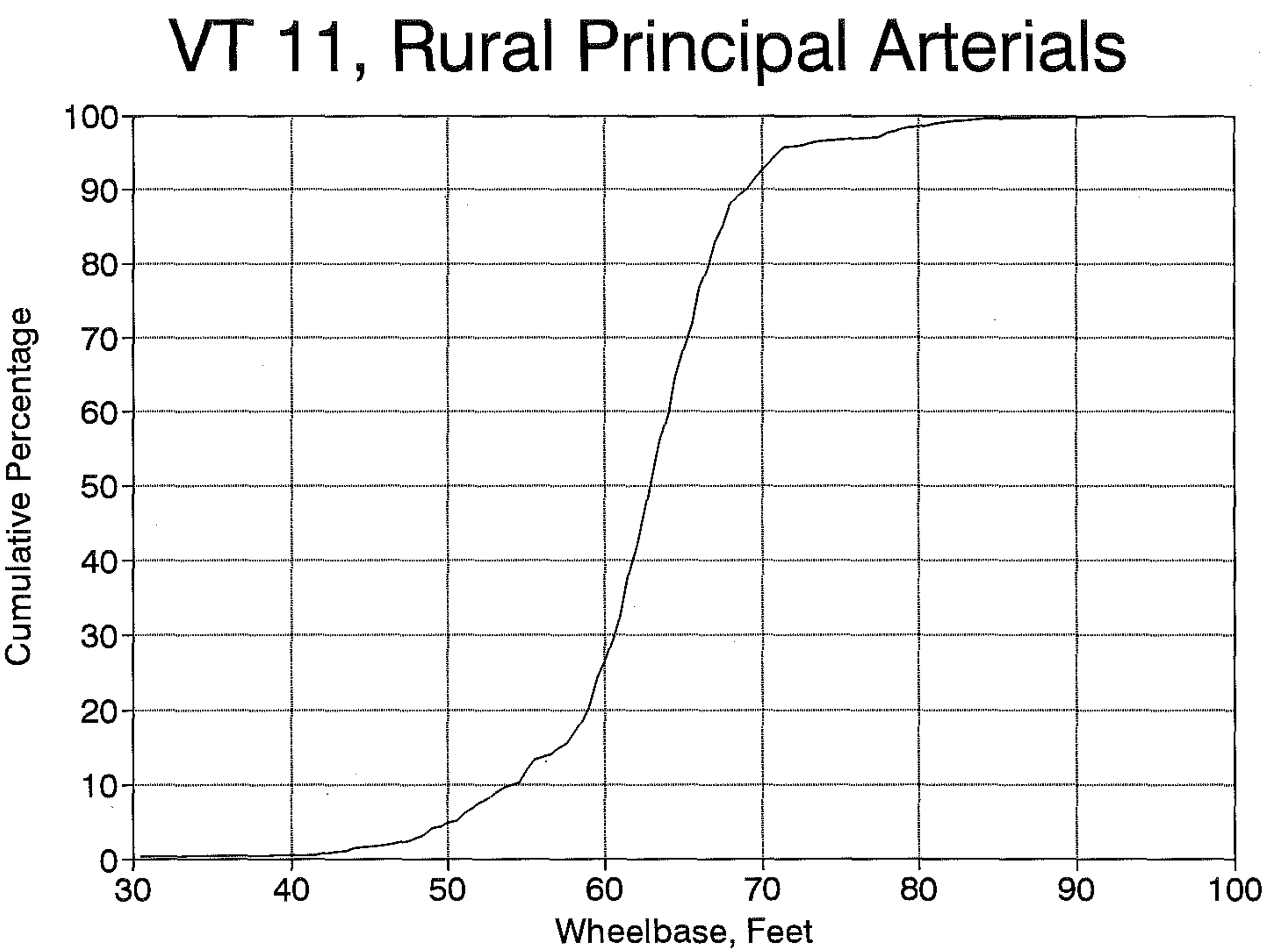



VT 8, Rural Principal Arterials
100
90
80
70
60
50
40
30
20
10
0
Cumulative Percentage
10
20
30
40
50
60
70
80
Wheelbase, Feet

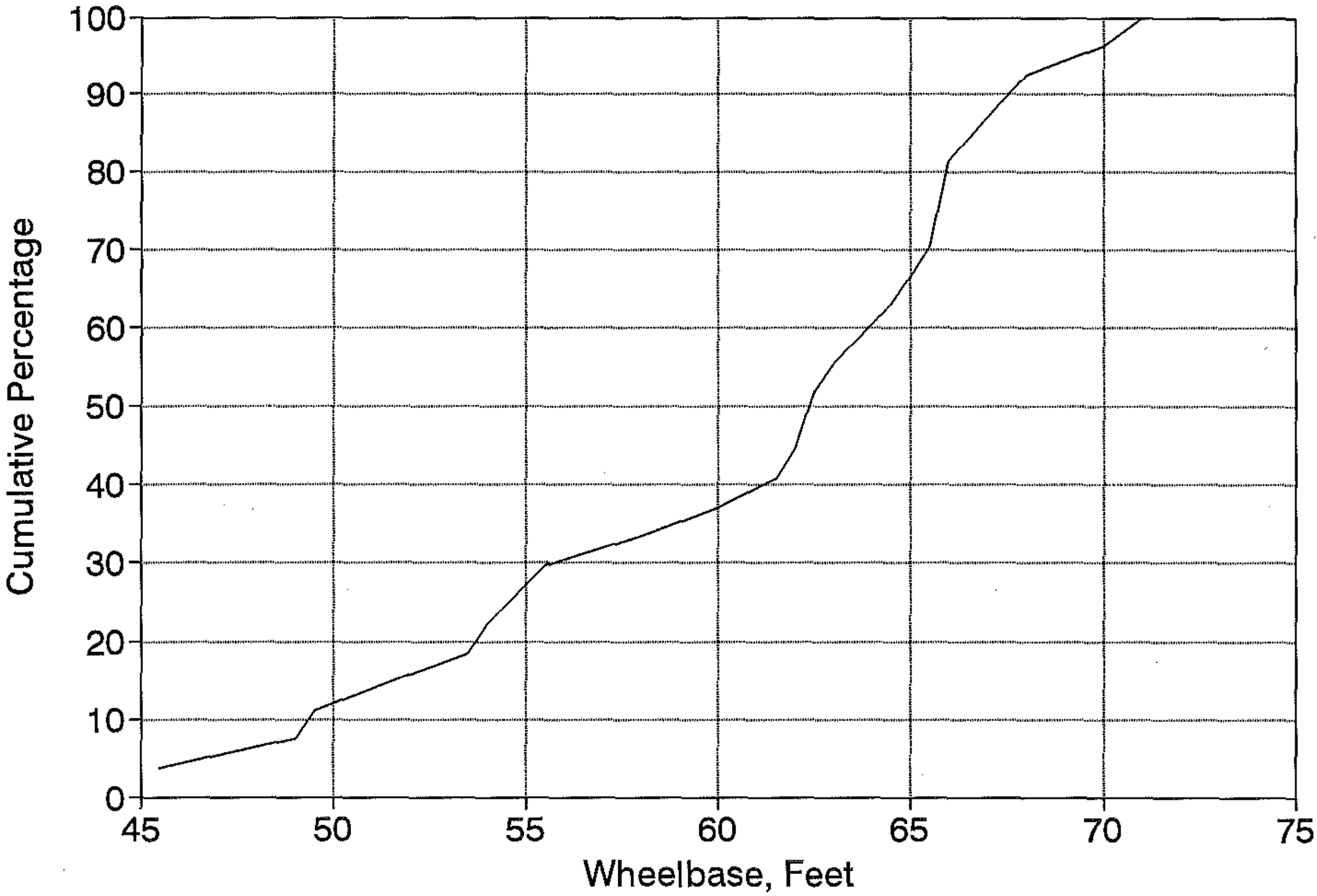
VT 9, Rural Principal Arterials

VT 10, Rural Principal Arterials

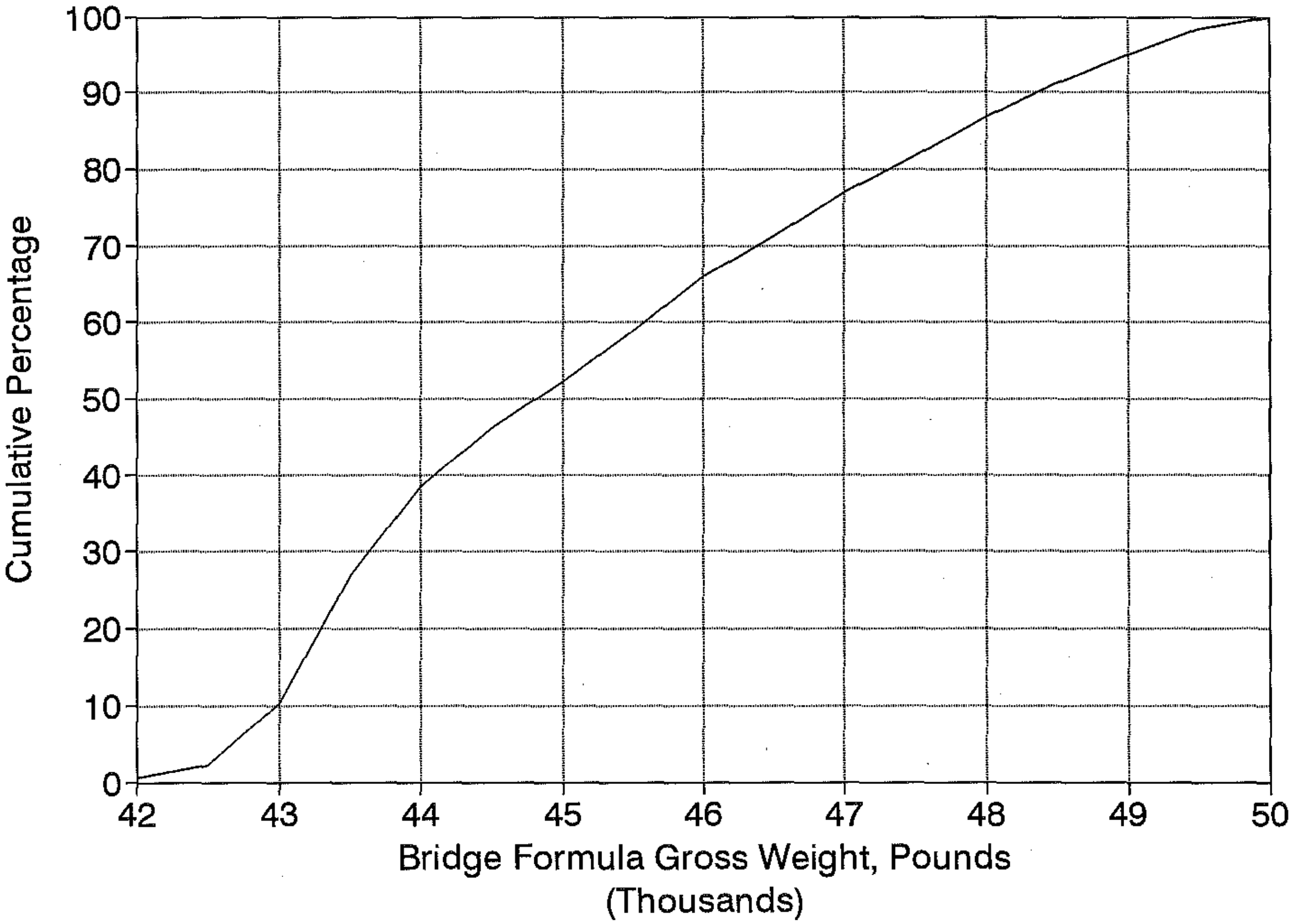



VT 11, Rural Principal Arterials
Cumulative Percentage
0
10
20
30
40
50
60
70
80
90
100
30
40
50
60
70
80
90
100
Wheelbase, Feet

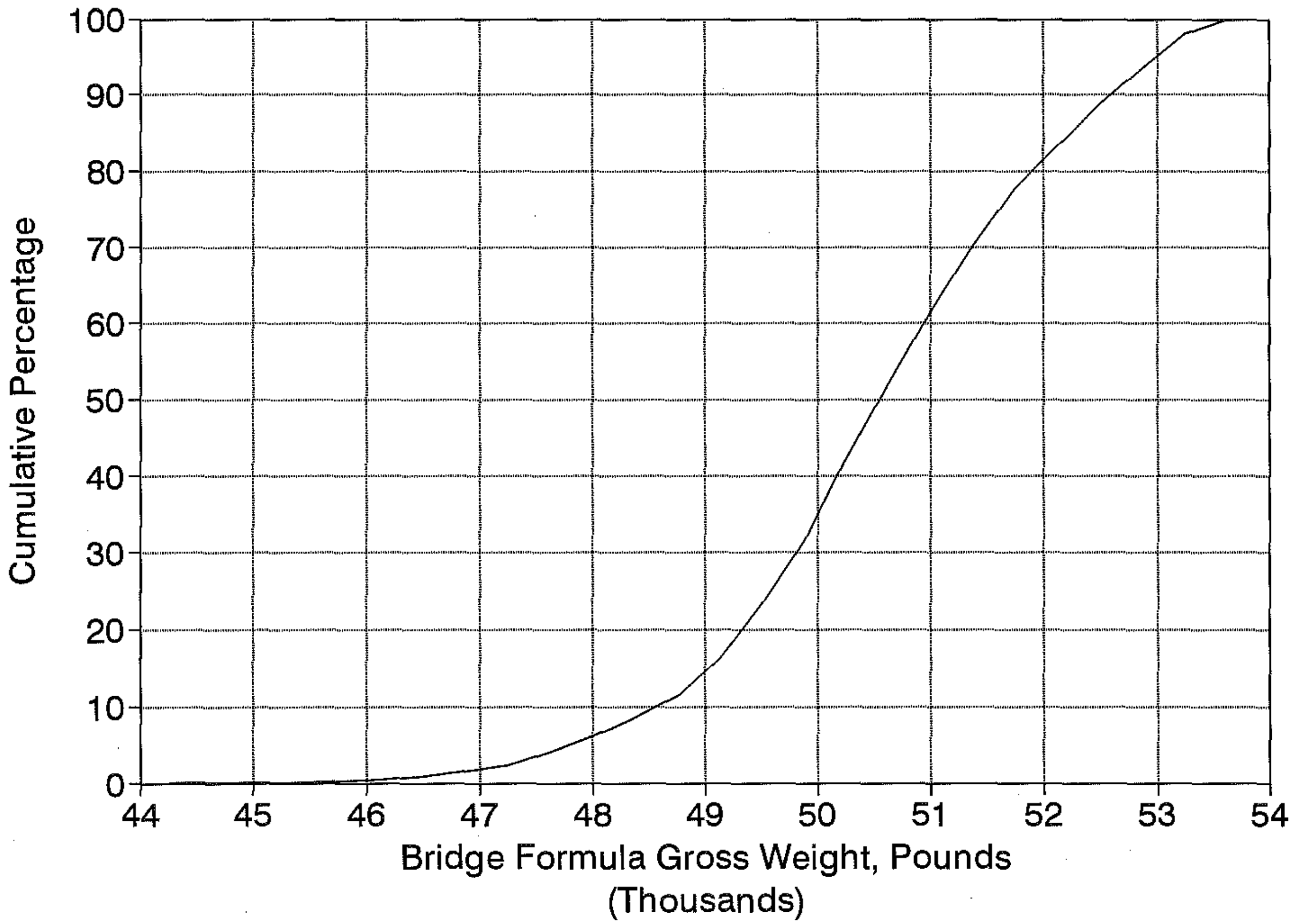
VT 12, Rural Principal Arterials



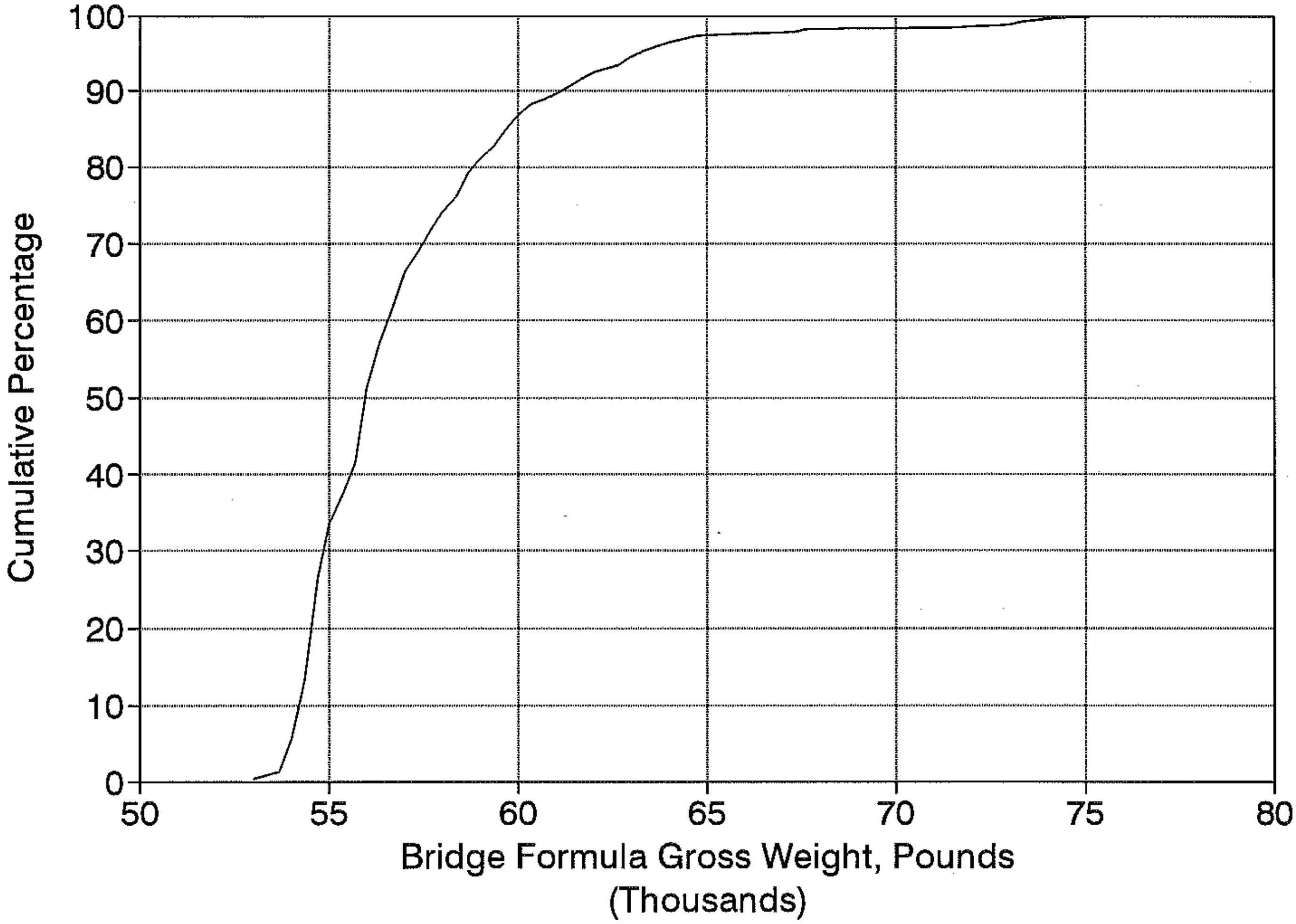
VT 5, Rural Principal Arterials



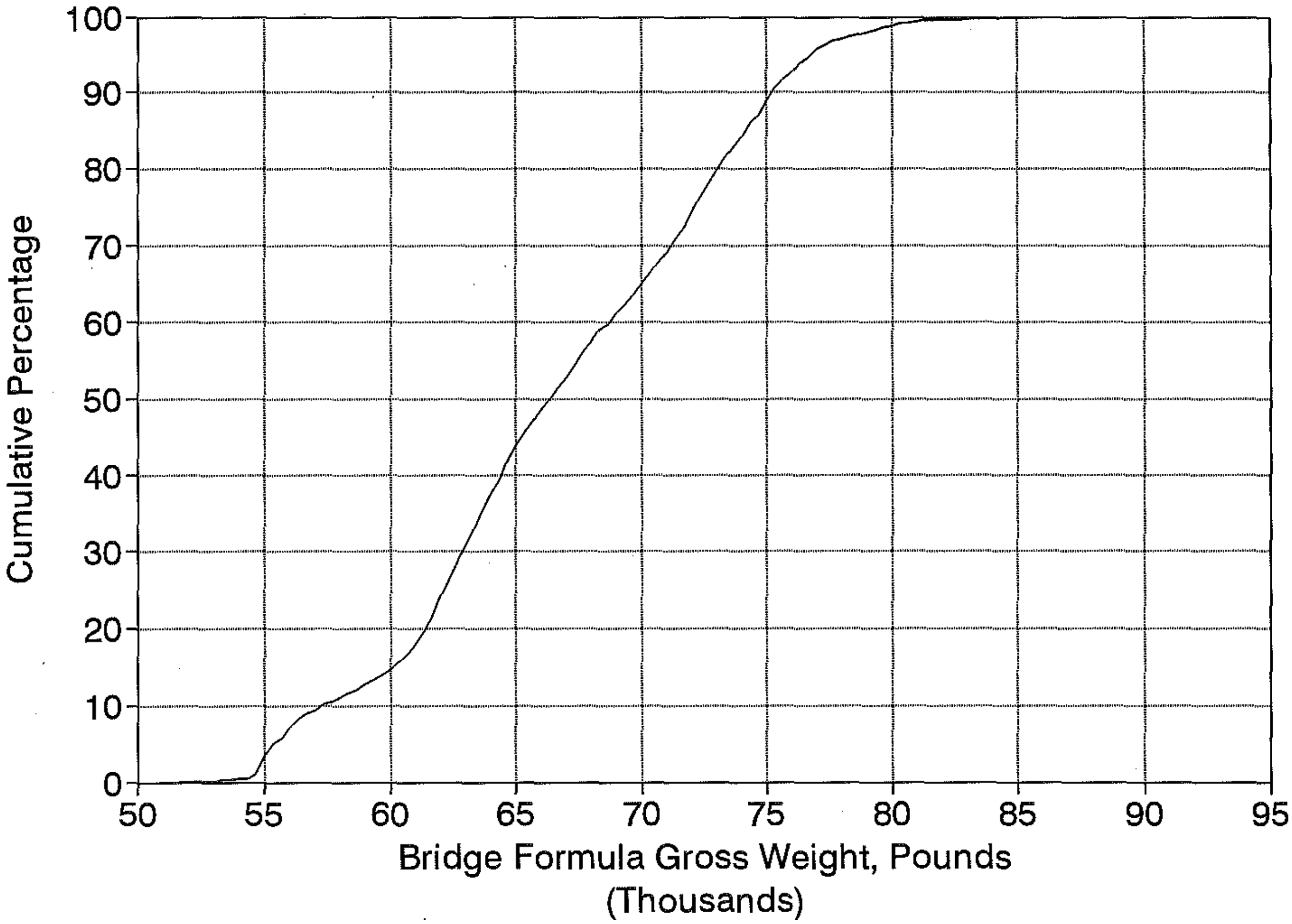
VT 6, Rural Principal Arterials



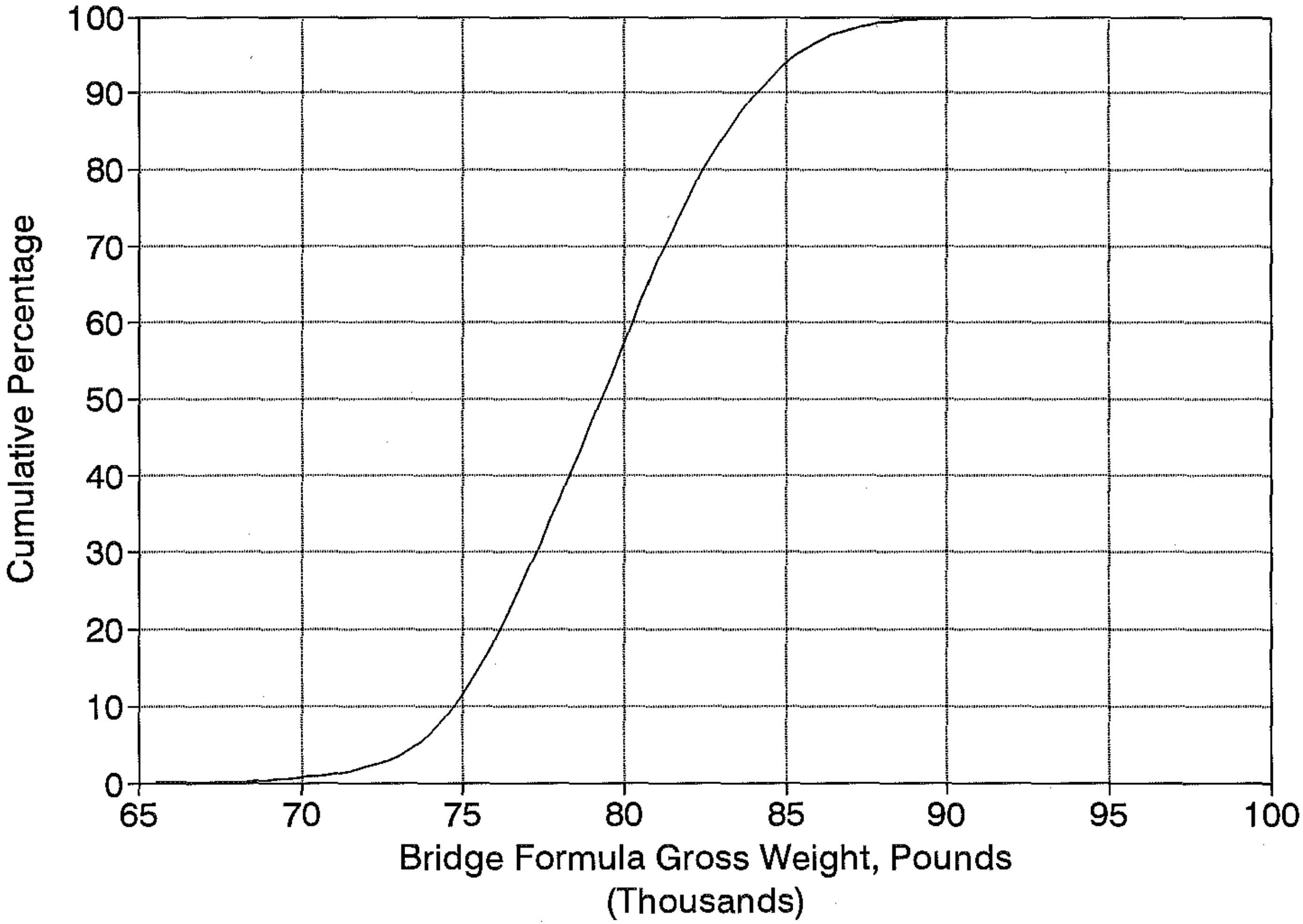
VT 7, Rural Principal Arterials

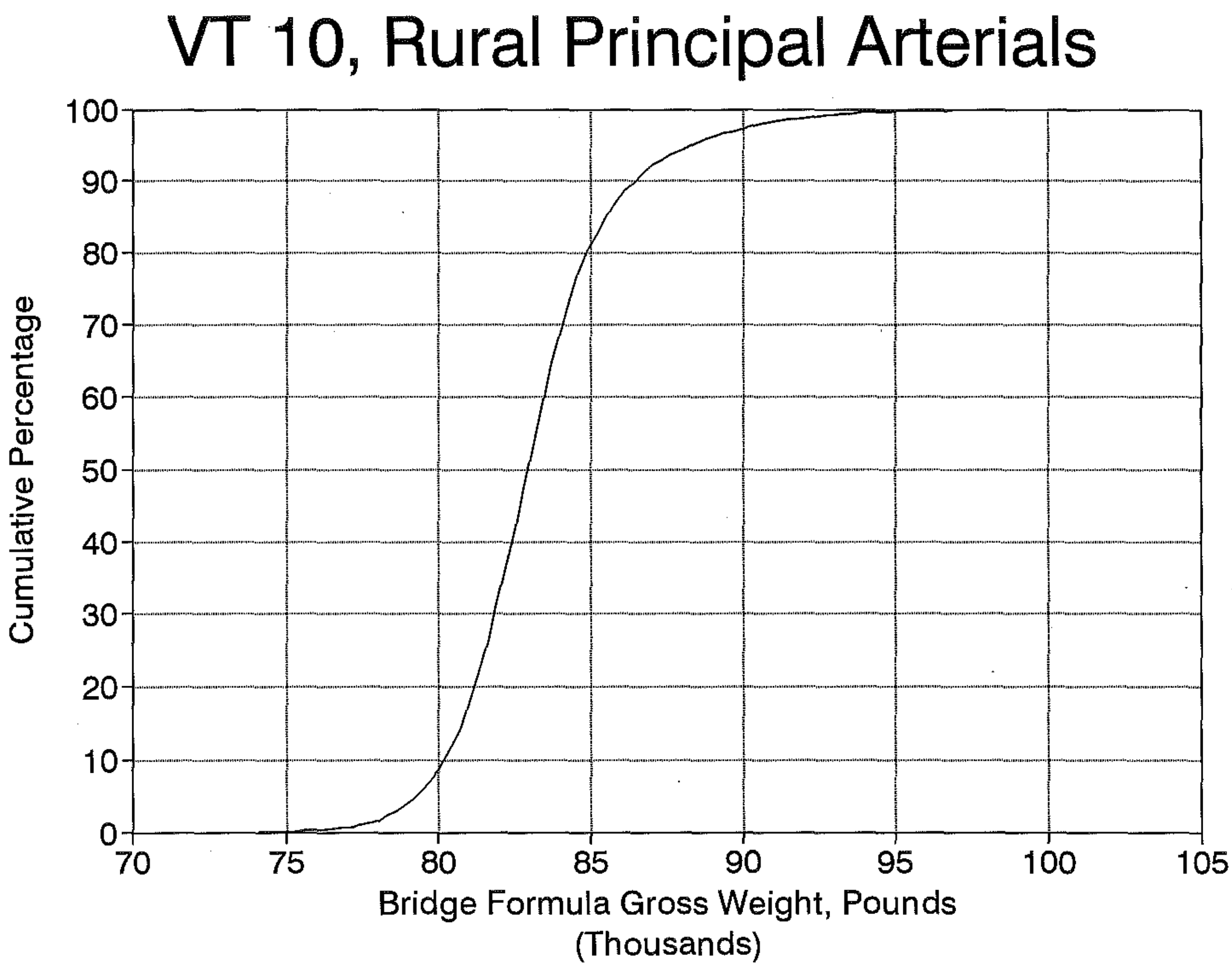


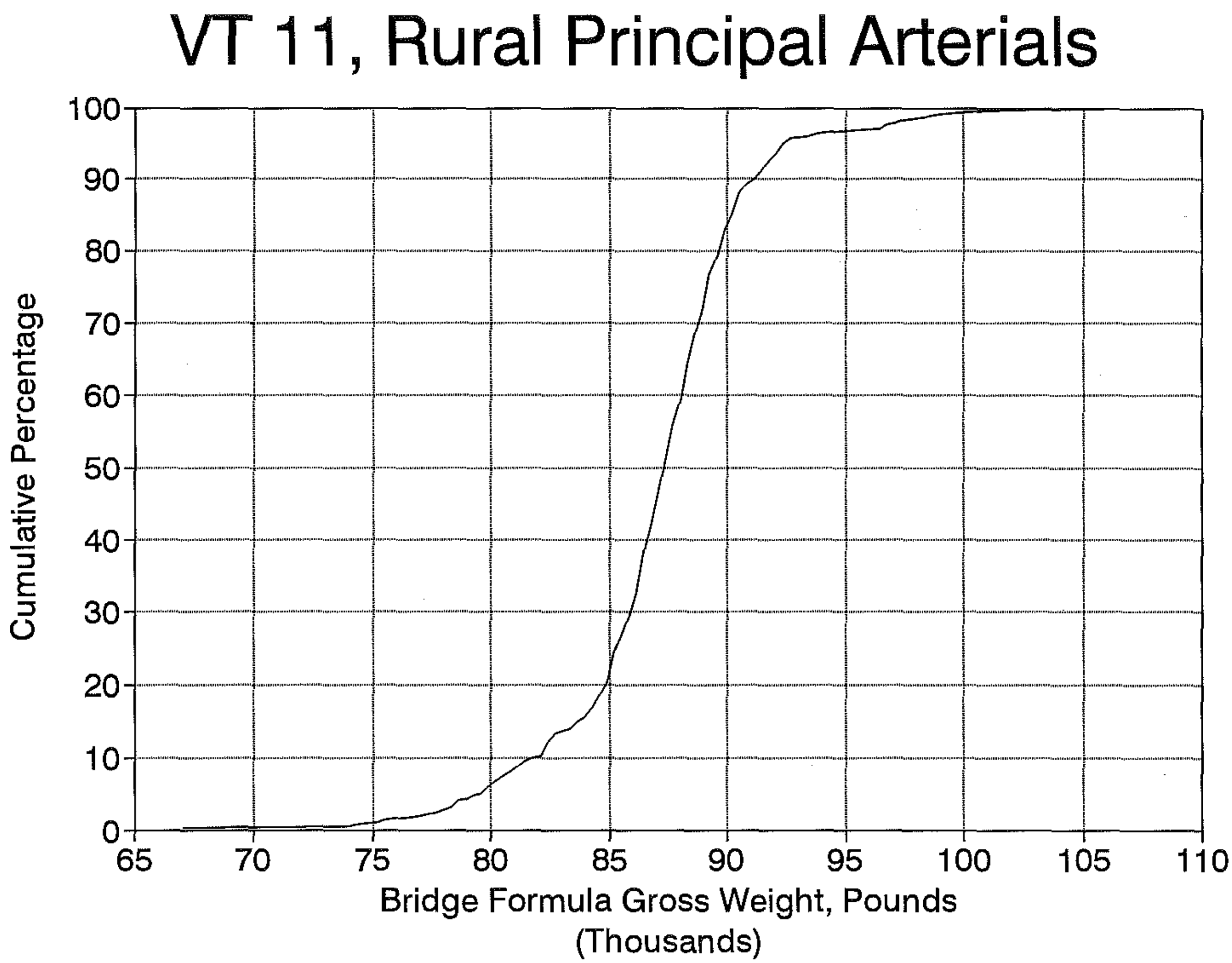
VT 8, Rural Principal Arterials

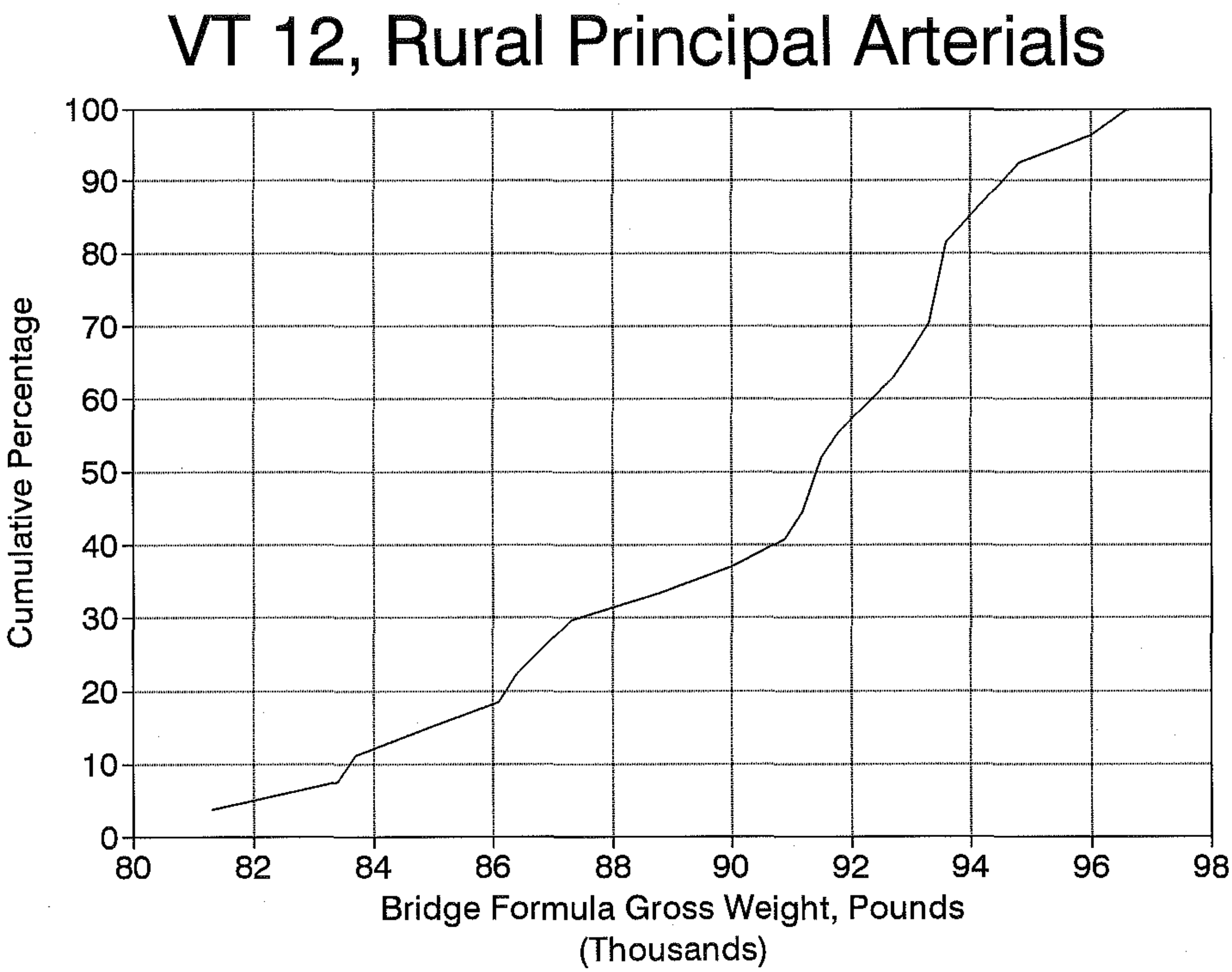


VT 9, Rural Principal Arterials




VT 10, Rural Principal Arterials
Cumulative Percentage
0
10
20
30
40
50
60
70
80
90
100
70
75
80
85
90
95
100
105
Bridge Formula Gross Weight, Pounds
(Thousands)


VT 11, Rural Principal Arterials
Cumulative Percentage
0
10
20
30
40
50
60
70
80
90
100
65
70
75
80
85
90
95
100
105
110
Bridge Formula Gross Weight, Pounds
(Thousands)



VT 12, Rural Principal Arterials
100
90
80
70
60
50
40
30
20
10
0
Cumulative Percentage
80
82
84
86
88
90
92
94
96
98
Bridge Formula Gross Weight, Pounds
(Thousands)

Appendix F

Proposed Outline of Training Course for Large Truck Operators

COURSE OUTLINE

1. Introduction
    a. Truck Accident Statistics
    b. High-Accident Locations
    c. Characteristics of Truck Accidents

2. Traffic Signs and Signals
    a. Meaning of Signs
    b. Application of Signs and Signals
    c. Stopping Distances for Signs and Signals

3. Large Truck Characteristics
    a. Stability
    b. Acceleration
    c. Braking
    d. Maneuverability
    e. Turning Radius

4. Motor Vehicle Regulation
    a. Federal Motor Vehicle Safety Standards
    b. State Regulations
    c. Enforcement Practices

5. Truck Maintenance/Mechanical Issues
    a. Brakes
    b. Tires
    c. Suspension Systems
    d. Axles
    e. Fifth Wheels

6. Driver Licensing

7. Defensive Driving

8. Safety/Liability Concerns
    a. Accident Potential
    b. Types of Accidents
    c. Safety Inspections

9. Coal Truck Accidents - Case Studies

Appendix G

Summary of Selected Personal Interviews

SUMMARY OF SELECTED PERSONAL INTERVIEWS

FLORIDA

Presently, Florida allows axle weight limits of 22,000, 44,000, and 66,000 pounds for single, tandem, and tridem axles; respectively. However, the gross weight limit remains at 80,000 pounds, even though the axle limits are higher than most states. The law to permit these axle limits was passed in the 1950's and was continued through a grandfather clause when the 1982 STAA requirements were put into place. Permits for gross loads in excess of the 80,000-pound limit require the operator to submit the axle-weight limit, the axle spacing, and the manufacturer's tire limits for pressure and load before a permit is issued. Special attention is given to tire load limits as part of the enforcement process in Florida. Beginning April 1, 1994, enforcement officers would check the tire load limits to determine if they are in conformance with the axle weights being carried by a specific vehicle. Reliance is placed on CFR Part 393.75 for requirements to enforce the weight rating on truck tires.

Based on information obtained from the Florida Department of Transportation, it does not appear that Florida has identified any safety problems associated with the increased axle limits.

MICHIGAN

Axle weight limits in Michigan are 20,000, 34,000, 39,000 pounds for single, tandem, and tridem axles; respectively. Gross weight limits are 149,000 pounds for Interstates, and 164,000 for other roads in Michigan. These limits have been in place for a long period of time and a grandfather exemption was granted to permit the limits after enactment of the 1982 STAA. With fairly restrictive axle weight limits, the only means to haul significantly greater loads is to add axles to the truck configuration. There is a limit of 11 axles for a gross weight of 164,000 pounds.

An analysis of accident records for trucks operating in Michigan was completed in 1990. The objective was to determine if there were safety problems associated with various configurations of trucks. The results indicated that bobtail units have significantly higher accident rates than combination units with either single or double trailers. In any case, it was found that there was a serious degradation of safety when the various configurations of trucks operated on lower classes of roadway. The crash rate on the lowest class of road was five to seven times higher than those on limited access highways. Another finding of interest was that very few of the truckers on Michigan roads had any driver training (the study was completed prior to data being available on the Commercial Driver License).

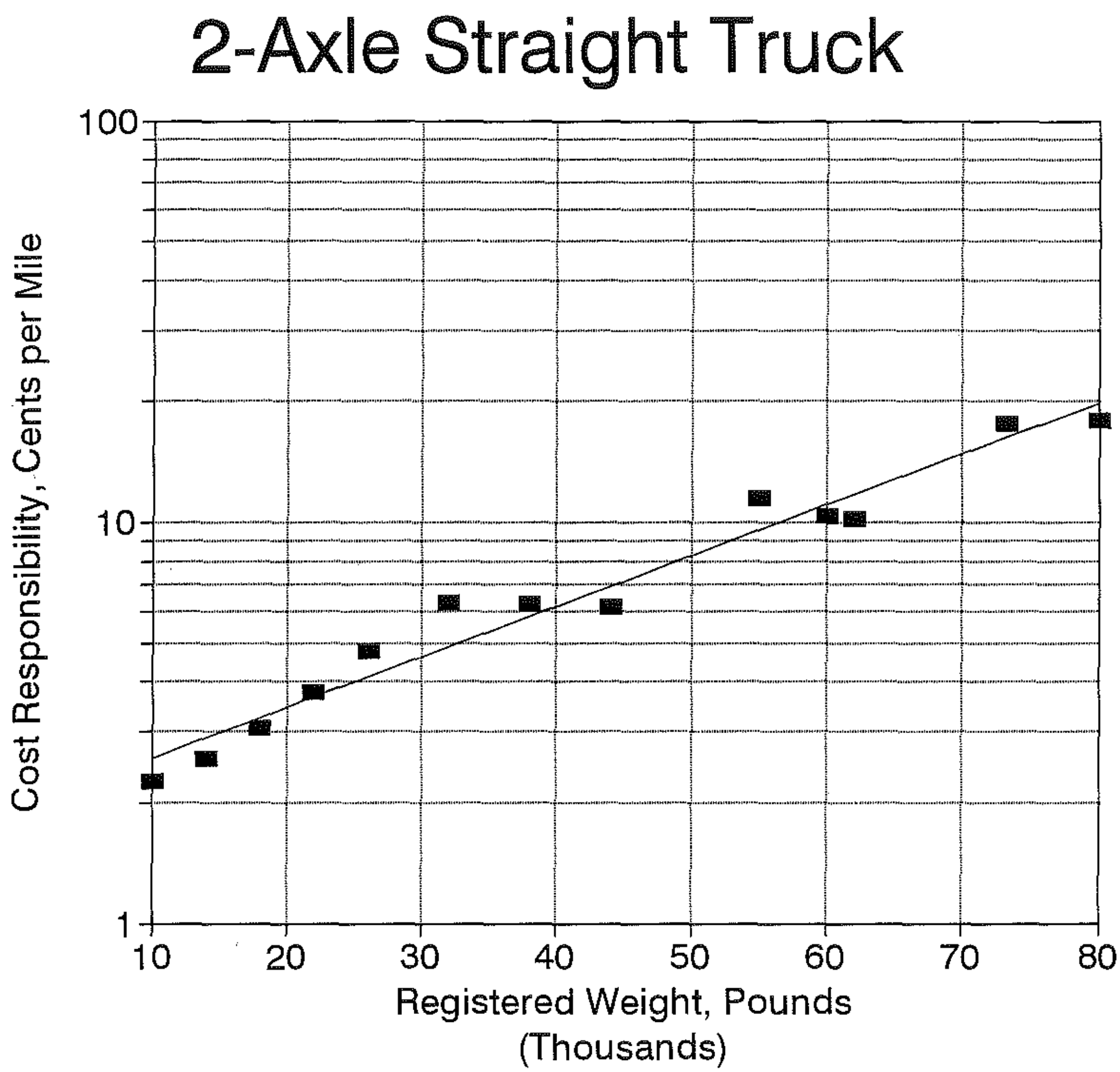
ONTARIO

The province of Ontario allows axle limits of 20,000, 42,100, and 63,000 pounds for single, tandem, and tridem axles; respectively. The maximum gross weight limit is 140,000 pounds. Ontario has a special office set up to monitor and administer the allowable weight limits relative to the configuration of the truck. Truck companies and manufacturers are expected to provide truck configuration and axle weights to the regulatory office to allow a determination to be made whether a unit is allowed to be licensed to operate in Ontario.

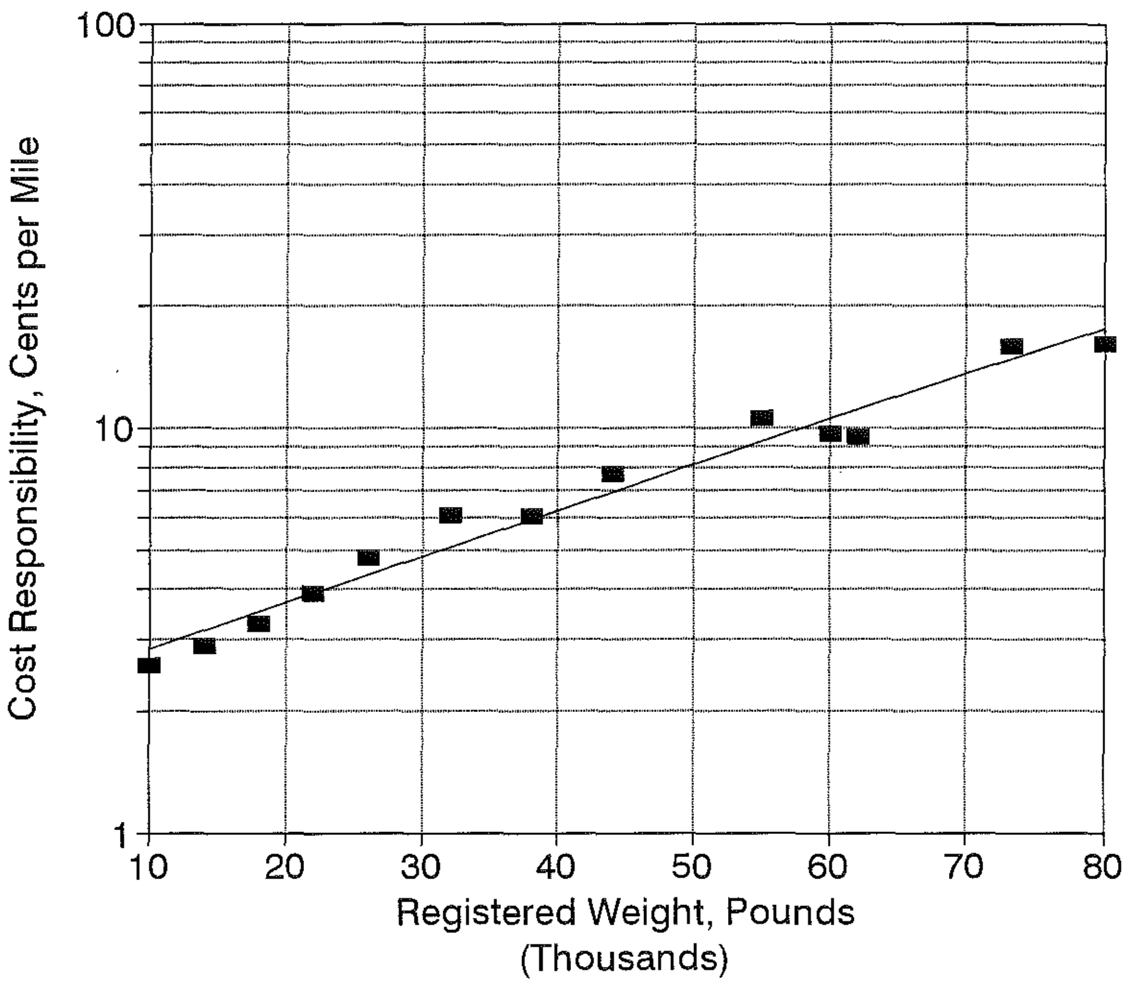
Information was not available which suggested problems associated with the safety of operating trucks with axle and gross weights as permitted in Ontario.

Appendix H

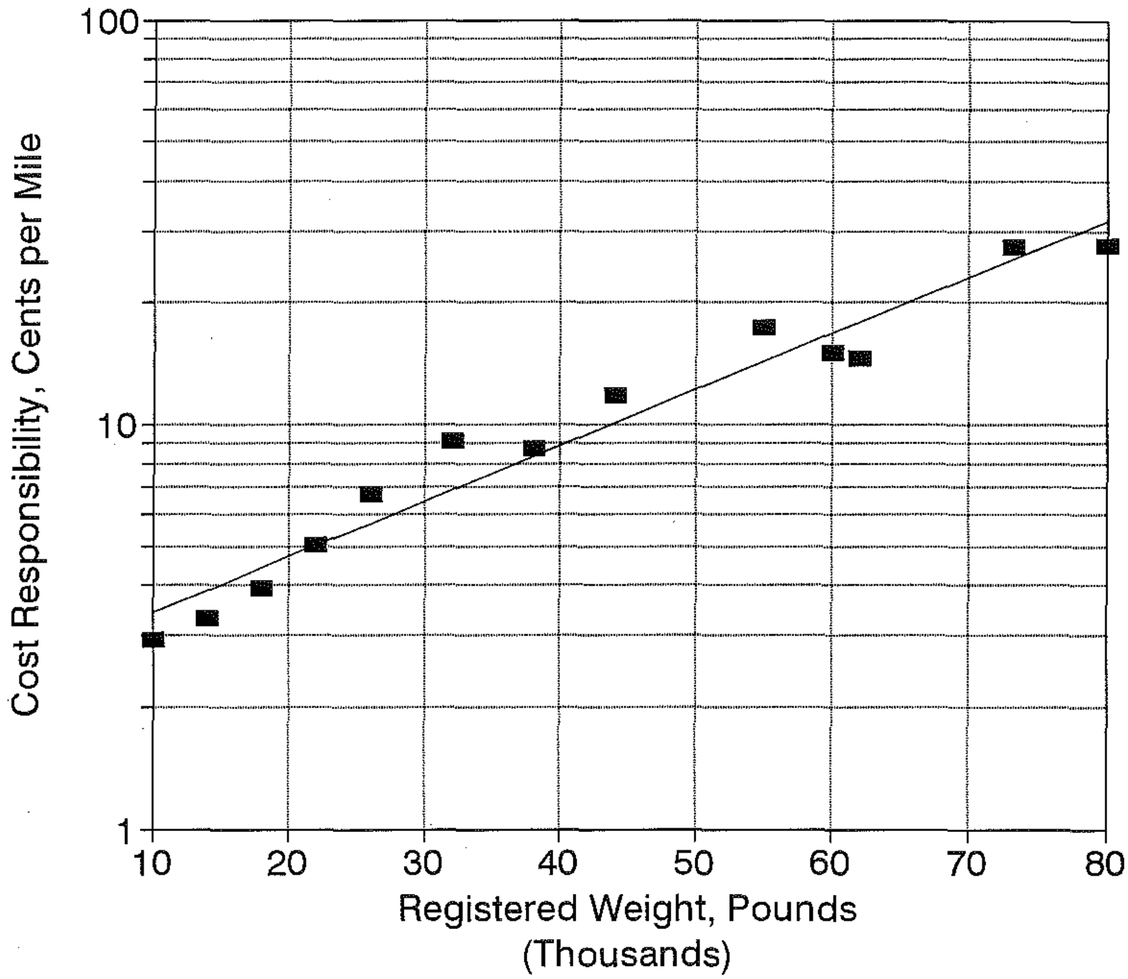
Cost Responsibility of Kentucky Trucks


2-Axle Straight Truck
100
10
1
Cost Responsibility, Cents per Mile
10
20
30
40
50
60
70
80
Registered Weight, Pounds
(Thousands)

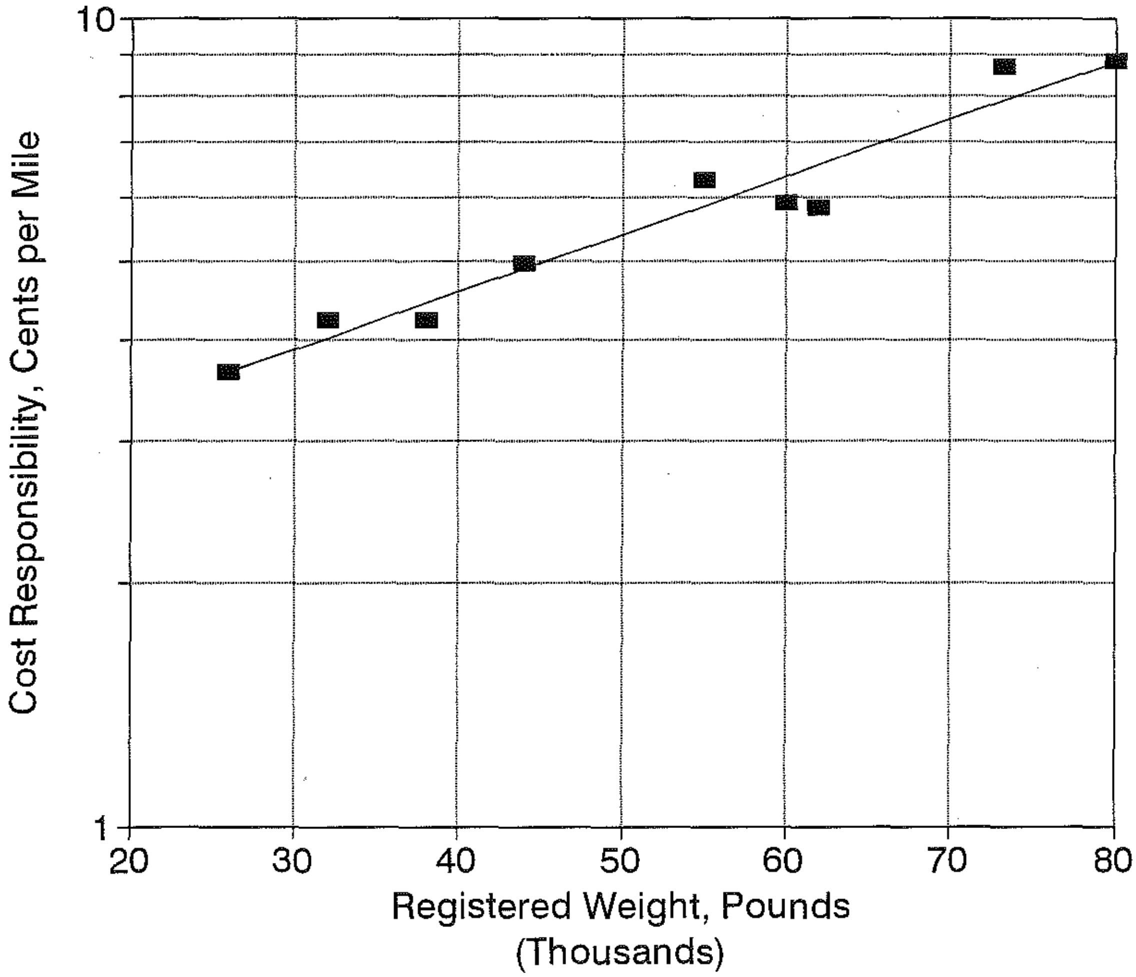
3-Axle Straight Truck



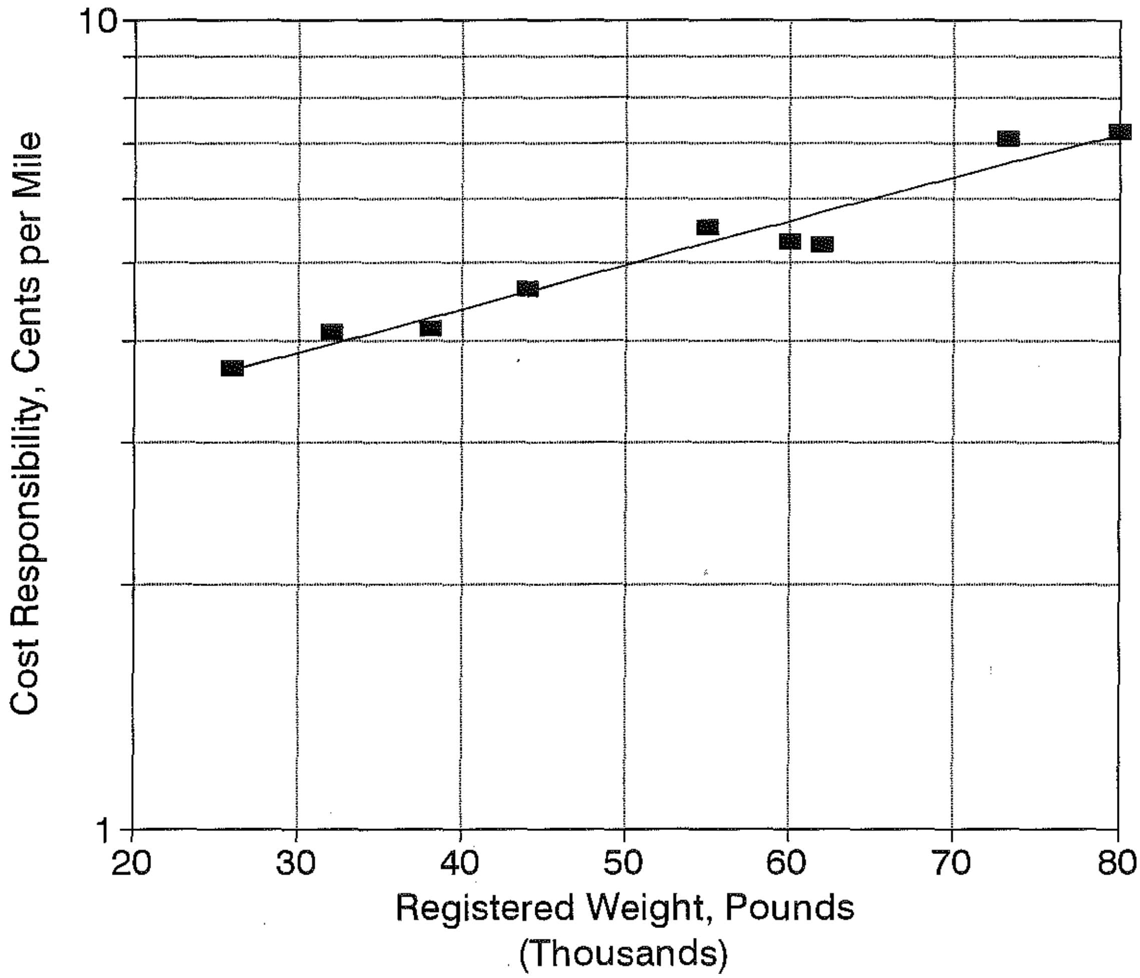
4-Axle Straight Truck



4-Axle Tractor-Semitrailer



5-Axle Tractor-Semitrailer



6-Axle Tractor-Semitrailer