

Preserving Highway Infrastructure Using Weigh-In-Motion (WIM)

November 1998

Dr. A.T. Bergan^a, Norm Lindgren^b, Dr. Curtis Berthelot^c, Bob Woytowich^d

^a Professor Emeritus, College of Engineering, University of Saskatchewan

^b Utah Department of Transportation Motor Carrier Division (Retired 1998)

^c College of Engineering, University of Saskatchewan

^d Director, CVO Market Development, International Road Dynamics Inc.

EXECUTIVE SUMMARY

A nation's transportation infrastructure is its lifeline, contributing to its economic prosperity and social well being. The importance of a healthy, safe and efficient transportation infrastructure cannot be overstressed, and steps must be taken to ensure that a nation's highway system remains intact and useable. Comprehensive weight enforcement programs are critical to the preservation of roads. Random inspections and traditional static weighing are no longer sufficient to combat the deterioration of our roads, accommodate the truck volumes, or to level the playing field for carriers. While many technologies exist to promote cooperation between the industry, state and enforcement agencies, such as electronic preclearance, *only weighing addresses the issue of road preservation*. At a time when transportation officials are looking for ways to preserve the roads amidst limited funds, the need for weight control and efficient management is increasingly important. Weigh-In-Motion (WIM) is a proven solution, both, as a tool for weight enforcement and data collection.

In weight enforcement, WIM acts as a preweighing and prescreening tool, to complement static weighing activities at weigh stations. Increasingly, static weigh scales cannot accommodate the volumes of trucks through weigh stations. WIM retrofits to existing weigh stations and makes them more efficient, without costly renovations or new construction. The WIM system weighs all trucks, and directs only those potentially overweight or out of compliance vehicles for further inspection. All other trucks are allowed to continue traveling, with minimal interruption to their operations. WIM encourages clean safety records and compliance with regulations by targeting potential violators for further inspection. WIM systems help to level the playing field between illegally operating carriers and carriers who operate in compliance with the law. More importantly, WIM systems help to minimize the likelihood of illegally overloaded trucks traveling on the nation's highways, which contribute to the acceleration of road deterioration.

In data collection, WIM systems located on the mainline, continuously collect valuable data on truck weights, speeds, time of travel, axle configurations, and volumes. This provides the most unbiased data since most illegally operating carriers avoid weigh stations, or travel when weigh stations are closed, thereby, artificially skewing the figures to indicate a lower frequency of overweights. WIM systems record all traffic information, even when weigh stations are closed. WIM data can be used to accurately predict future traffic volumes for planning of new construction, management of maintenance activities, to identify if overloading problems exist, and to evaluate the performance of pavements.

The economic benefits of WIM far outweigh the costs involved with its implementation and operation. Truckers and enforcement personnel experience greater efficiencies through targeted inspections, the highway infrastructure benefits from fewer illegal overloads, transportation planners have access to valuable data with which to plan maintenance and construction activities, and the taxpayer's enjoy the benefits of lower costs for freight and for roads. WIM systems have been invaluable in the past, continue to be beneficial in the present, and are an increasingly important tool for the future, with both short and long term benefits for the industry, state and public.

1. INTRODUCTION

A nation's transportation infrastructure is its lifeline. An efficient and safe road network allows goods to reach the markets quickly, thus, stimulating economic activity and ensuring trade competitiveness. More efficient travel allows motorists greater ease of travel, less frustration, increased mobility and more time to spend at other activities. A healthy transportation infrastructure is vital for any nation's economic and social well being.

In the United States, over 46,000 miles of interstate combined with a network of almost 4 million miles of other roads makes up the nation's lifeline.¹ Each year, nearly five trillion dollars worth of goods is transported via the nation's lifeline via commercial trucks.² Unfortunately, commercial truck traffic also contributes greatly to the cost of deteriorating highways across the nation. The increased costs of maintenance with the diminished highway funds available have meant that many roads are now in or rapidly approaching a critical condition. Industry experts estimate that there is currently a \$300+ billion shortfall to repair roads and bridges to an acceptable standard.³ Granted, past studies have indicated that the trucking industry and public could gain substantial economic benefits through increased truck sizes and heavier loads⁴, but this means that roads and bridges will deteriorate faster. Who is going to pay for the increased costs of maintenance and construction? Will the public or the industry tolerate potholes, bumps, ruts and unsafe roads that have been brought to that state because of limited highway funding? Will the public and industry tolerate frequent delays and detours due to constant reconstruction and maintenance? At some point, unless the economic benefits to the industry are transferred to the state highway officials for maintenance and repairs, the ability to haul heavier loads on the roads will mean unsafe and failing roads.

State highway officials are faced with the dilemma of preventing the acceleration of highway deterioration, with limited funds available for maintenance. Already, a quarter of the annual highway budget, \$27.5 billion, is allocated towards maintenance of the nation's roads⁵. So, while the weight regulations in place tend to limit the economic efficiency of commercial operations, they also help to preserve the road and the taxpayer's investment. Amidst the modern challenges of highway management, a progressive approach is necessary to address the interrelated needs of the public, industry and government.

For many years, states have been looking at developing a system that can be beneficial to the trucking industry, the taxpayers and the states, while helping to protect the infrastructure – Weigh-In-Motion (WIM) technology provides benefits to all parties involved. While many activities go a long way in achieving cooperation between commercial carriers, the general public and the regulatory bodies, a successful highway management program is not complete until combined with weight enforcement activities to preserve the highways. An integral part of highway management activities must include the weighing of vehicles to protect existing infrastructure and the collection of traffic data to plan for future investments in infrastructure. Given the current truck volumes and need for efficient weighing, WIM is the most efficient and cost effective method of enforcing weights while minimizing unnecessary stops for carriers.

Ultimately, WIM systems serve two very important functions:

1. Enforcement of illegally overloaded trucks to prevent premature deterioration of the infrastructure
2. Data collection for planning and management purposes

2. WEIGHT ENFORCEMENT – THE HISTORY

Effectively monitoring and controlling truck weights is critical to preserve the life of a road and to minimize pavement costs. In a 1995 study, it was found that pavement cost is more dependent on the level of enforcement than weight limit.⁶ Thus, strict enforcement can result in minimized pavement costs. An increase in loading means a fourth power exponential increase in the acceleration of road wear. In other words, if a pavement is subjected to 10% overloading, it can mean an acceleration of road wear by over 45%.⁷ Increased loads mean shorter pavement life and more frequent maintenance and rehabilitative work.

As early as 1918, highway officials concluded that heavy trucks were critical to the design of highways.⁸ Today, it is well known and accepted that heavy trucks cause the majority of damage to highways. Truck weight regulations are firmly in place to protect pavements and bridges from the effects of heavy loads, to ensure the safety of all motorists and to maintain manageable traffic operations. The first laws regulating truck weights were passed in 1913, and by 1933, all states had a truck weight limit of some kind.⁹ Ultimately, the regulations are intended to balance the economic benefits of commercial vehicle operations with the various costs resulting from large trucks, including road wear, increasing maintenance costs, new construction costs, risk to public safety, and additional design requirements for the infrastructure.

While weight regulations have been in place since near the beginning of the century, states have only just recently fully realized the importance of extensive weight enforcement operations to ensure compliance with the law. During the 1977-1978 congressional hearings on the impact of overloads on the Highway Trust Fund, it was reported that the Interstate system was wearing out 50 percent faster than it could be replaced due to a number of factors, one of which was overloaded trucks. Strict weight enforcement was deemed essential to preserve the roads, and the Surface Transportation Assistance Act of 1978 followed, which allowed penalties to be imposed on states which did not comply with weight enforcement programs.¹⁰

Five years later, the Office of the Inspector General reported that state weight law enforcement programs were inadequate deterrents to overweight trucking and recommended that WIM systems be implemented nation wide to measure the effectiveness of state weight law enforcement programs.¹¹ Much of the data collected at permanent weigh stations does not reflect the true magnitude or frequency of illegally overweight trucks because illegal carriers tend to avoid weigh stations when they are open. WIM systems collect data continuously, even when stations are closed, thereby providing unbiased data. Using WIM data from 1984 to 1986, the FHWA estimated that about 25 per cent of all combinations were overweight, 10 to 20 percent of which were operating illegally.¹² Given today's volume of over 5.1 million trucks¹³, that means that over 500,000 to 1,000,000 trucks would be operating illegally.

The Transportation Research Board states, "enforcement is a critical element of any plan for controlling vehicle weights. Without effective enforcement, including the certainty of penalties and sanctions sufficient to deter violation, weight limit laws become meaningless."¹⁴ Minimal fines and the low probability of being caught, provides a considerable economic incentive for trucks to operate illegally. In 1987, six states had minimum first-offense fines of \$100 or less for operating 20,000 lb. over the gross weight limit of 80,000 lb.¹⁵

In a 1985 study, the FHWA identified several shortcomings of the process by which truck weight violation were adjudicated, and found that the judicial system did not understand or appreciate the severe social costs associated with overloading violations.¹⁶ Illegally overloading trucks cost taxpayers \$160 to \$670 million per year for pavement costs at the national level.¹⁷ Meanwhile, the illegally operating carriers reap the benefits of overloading the taxpayer's highways by gaining an unfair advantage over their honest competition, by making more profits, and by avoiding the responsibility of paying for the damage they cause. Honest carriers, and the associations representing truckers strongly support strong enforcement of truck weight laws to eliminate the unfair advantage that illegally operating carriers have.

3. WIM – COMPLEMENT TO STATIC WEIGHING

Traditionally, weigh stations with static scales have been used to weigh the majority of commercial carriers on the road. Where truck volumes are low, static scales are a reasonable means to weigh trucks. However, in many instances, the existing weigh stations cannot accommodate the existing or projected truck volumes. There are currently over 5.1 million trucks on the nation's highways, with the number increasing 6-7% yearly. Weighing each one just once would require 10 million minutes, or 17 years, given the average two minute delay at a weigh station for most trucks. Based on the industry standard cost of one dollar per minute of delay at a weigh station, this equates to 10 million dollars for weighing each truck in the nation just once. Considering that a normal 8 hour day of travel for each trucker could easily involve at least 3 stops at weigh stations, means that over the course of a year, weigh station stops could cost over 10 billion dollars for the nation's trucking industry.

WIM scales automatically weigh trucks traveling at highway speeds and presort the trucks based on weights. Those trucks which are suspected of being overweight are directed to the static scales, while all other trucks are allowed to bypass. Between 1984 and 1987, the number of trucks weighed with WIM scales increased from 5.8 million to 13.4 million.¹⁸ Assuming that 80% of carriers were compliant with weight regulations, and, thus, were allowed to bypass the static scales, translates into an approximate savings of \$9.3 to \$21.4 million dollars. How many trucks are subjected to unnecessary delays at weigh stations without WIM capabilities? What are these unnecessary delays costing honest carriers, the industry and the public?

In the course of a year, the number of delays to truckers translates into an enormous cost to truckers, industry and the public. Obviously, there is a need to minimize unnecessary delays for truckers while also fulfilling enforcement objectives. Since the majority of carriers are legally loaded and comply with safety regulations, it is in the public's best interests to target potential violators for further inspection and static weighing.

In traditional weigh station operations, all trucks are required to report to the weigh station for visual inspection and/or static weighing. At busier weigh stations and during peak travel times, it is normal for trucks to fill the weigh station ramps such that the stations must close temporarily until the queues diminish. The temporary closure of the weigh stations is often necessary to prevent traffic backups onto the highway, and to eliminate the safety hazard of having immobile trucks adjacent to vehicles traveling in excess of 55 miles per hour. However, while weigh stations close, some trucks are able to bypass the weighing process, even though they may be overweight without a permit.

Weigh in Motion (WIM) technology is an efficient and cost effective weight prescreening device to complement static weighing, minimizing unnecessary stops and delays for truckers. Implementing a WIM system means that trucks can be automatically weighed and sorted at highway speeds on the mainline or ramp, with little or no interruption to truckers. Only those suspected of overweight violations are required to report to the static scale, allowing focused enforcement on potential violators.

4. WIM AND WEIGHT ENFORCEMENT

WIM systems can be used to preweigh and presort vehicles on the highway or ramp when weigh stations are in operation. When WIM systems are installed on the mainline, *all* trucks are weighed, both legal and illegal. The WIM system sorts all vehicles based on weight, and, where applicable, credentials. Based on preclearance criteria determined by the state, the WIM system directs only vehicles suspected of non-compliance to report for further inspection. Those suspected of overweight or oversize violations are directed to report to the static scale lane, while all others are allowed to bypass with minimal interruption. The reduction of trucks required to report to weigh stations has additional benefits in: safety, from fewer truck exits to and merges from the weigh station; operating costs, from less wear and tear on the static scales; more focused and thorough inspections, from lower traffic volumes reporting to the weigh station; and, fewer overloads from greater enforcement visibility and effectiveness.

WIM becomes a valuable enforcement tool for targeting potential violators, allowing legal operators to benefit tremendously from fewer interruptions to their operations. With WIM, it is possible to eliminate the unnecessary checks and associated time delays for most of the 5 million trucks on the highways. Since the majority of carriers operate within the law, this translates into tremendous savings for the trucking industry and clients. WIM effectively levels the playing field between good carriers and those which attempt to operate outside of the law to gain a price advantage. The majority of the 442,000 trucking companies operating in the United States¹⁹ discourage illegal operations which creates unfair business competition, shortens the life of the roads, degrades the quality of travel, and increases their costs of operation and maintenance. WIM helps to free up enforcement resources to concentrate on unsafe and non-compliant carriers and trucks. Only those suspected of overweights or violations, will be subjected to further inspection, allowing the other carriers to keep on trucking.

The use of WIM scales as a weight enforcement tool was first introduced in Alberta, Canada in 1982 and has been increasing steadily since. In the United States, another WIM sorting system was installed in Oregon in 1984. By 1998, over 35 states in the United States and 4 provinces in Canada had installed WIM technology as a weight enforcement tool. In effect, WIM systems help to level the playing field for all carriers, eliminating the unfair advantage that illegally loaded carriers have. More focused enforcement means fewer delays to the trucking industry which translates directly to savings in operational costs, less deterioration to roads and more efficient enforcement operations.

5. CURRENT PROGRAMS USING WIM

WIM systems integrated with electronically based automatic vehicle identification (AVI) technology enables the combination of sorting and preclearing trucks based on weights, credentials, licensing, proper registration and other requirements such as safety records. This information can be transmitted and shared electronically through regional, state, national and, even, international networks. Many initiatives have already been taken to streamline the administration of commercial vehicle operations and transportation management. The combination of WIM with AVI is compatible with the Commercial Vehicle Information Systems and Networks (CVISN) Program, a nationwide cooperative effort to integrate and link weight, safety and credential information from all state databases. Integrating WIM with other technologies is an economical and effective strategy for preserving roads, while allowing for information exchange, efficient administration, electronic preclearance, and providing incentives to good carriers.

WIM technology has enabled the development of many other exciting projects and programs, including Oregon's Green Light Project (a statewide automation of truck inspection stations based on weight and credentials), Advantage CVO (a region wide electronic preclearance system based on weight and credentials), and MAPS (a Northwest region wide program for Multi-Jurisdictional Automated Preclearance Systems based on weight and credentials) and HELP PrePass (electronic preclearance based on credentials and safety records). There are also some new initiatives using WIM and AVI at border crossing applications. With WIM, AVI and other ITS technologies, the future of transportation management is challenging existing boundaries of what is possible.

6. WIM AND DATA COLLECTION

Having access to reliable traffic loading data helps highway departments to correctly plan maintenance activities and rehabilitative measures to ensure the prolonged integrity of a road. When maintenance activities are mistimed due to inaccurate traffic loading estimates due to lack of reliable information, or overloading, it can mean the degradation of a road. WIM systems provide the state enforcement agencies with valuable traffic information data, which is owned by the state and can be used by the state for management, evaluation and planning purposes.

WIM systems can be used to collect valuable traffic data at all times, even when regular truck weigh stations are not operating. This is especially important because the number of overweight trucks drops sharply when weigh stations are known to be in operation. Some states, such as California,²⁰ have found that immediately after modifying their regular enforcement hours, there is a higher incidence of overweight violations. Other states, such as Texas, vary their enforcement schedules to avoid predictability in their hours of operation.²¹ Drivers of overweight trucks frequently find out when weigh stations are open so that they can postpone travel until the stations close, or select an alternate route. At weigh stations where WIM is installed, overweight trucks cannot avoid detection, thus, the tendency to travel when the weigh stations are closed is recorded by the WIM equipment. Numerous weigh stations equipped with WIM technology, have witnessed the number of overweight trucks increase when the Ports are closed. At the East Boise Port of Entry in Idaho, which has been using WIM since 1996, the data consistently showed an increase in the number of overweights when the Port was closed. The increase was sufficient enough for Idaho Department of Transportation to implement an additional shift, where at least one side was open at night, every day of the week. The selection of which side to open was random. The WIM data indicated that whichever side was closed continued to consistently experience a higher number of overweights.²²

The data collected by WIM systems have proven to be invaluable for planning and enforcement purposes. Several states, such as California and New Jersey implemented state wide WIM data collection systems to collect traffic data, such as volume, speed, classification, weights, configurations, etc. for the purposes of predicting traffic patterns and loading requirements in order to design their pavements accordingly. For other states and agencies, use of WIM data has helped better plan maintenance activities and future upgrades based on loading patterns. Without WIM systems in place, it is nearly impossible to predict the nature, frequency or even cost of overloading. The Seaway International Bridge Corporation (SIBC), responsible for the management of the Seaway International Bridge between New York state and the province of Ontario implemented WIM systems in 1996. Based on the data collected, SIBC has identified a weight overload problem and is now able to address the situation based on known data.²³ Other states, such as Idaho, have used their WIM systems to identify overloading problems when the weigh station was closed. Consequently, they were able to justify additional enforcement hours during the night, based on the WIM data.

WIM data can also be used to evaluate the performance of pavements. Part of the Strategic Highways Research Program (SHRP) involved experimenting with various formulae for road construction. Implementing WIM systems to collect data helps transportation analysts to determine the performance of the pavement mixtures. For instance, when a road is built, it may be designed for specific loading, environmental and life cycle parameters. In order to evaluate whether the design was adequate, it is necessary to know what the actual loading conditions were. For example, two pavement designs may have a similar life cycle, but one may have been subjected to much harsher loading conditions. Knowing these loading conditions provides a better comparison between the actual performance of the pavements. Does one road last longer because of superior performance or because of less than expected loading? WIM data provides accurate and unbiased loading data necessary for analysis.

7. ECONOMIC JUSTIFICATION

WIM systems provide economic benefits in many respects. WIM systems provide invaluable traffic data for better planning and management of maintenance and new construction activities. Accurate loading data provides highway officials with the opportunity to adjust their maintenance and rehabilitation schedules based on actual levels of deterioration. For example, rehabilitative maintenance may be performed two years earlier than scheduled or more frequently if the traffic volumes exceed the design volumes. This ensures that rehabilitative maintenance is timed correctly, rather than after the structural integrity of the road has already been breached. Since maintaining a good road is five times less expensive than rehabilitating a poor one,²⁴ it is important to prevent roads from deteriorating. Furthermore, since rehabilitating a bad road is much less expensive than new construction, it is very important to avoid reconstruction and new construction wherever possible. A recent study done on I-66 in Kentucky estimated new construction costs for conventional interstate highways at between \$11 million per mile to \$19.3 million per mile.²⁵

WIM systems also allow transportation officials to plan new construction based on actual pavement loadings. Using WIM data, much of the guesswork involved with estimating traffic conditions is eliminated, allowing for more suitable designs. Thus, pavement designs are not under designed, nor over designed, both of which are costly situations to remedy.

From an enforcement perspective, the use of WIM serves to target illegally overloaded trucks for inspection to prevent premature deterioration of the roads. This provides economic benefits to the public, the state and the industry. Use of WIM at a weigh station enables current highway and enforcement facilities to accommodate increases in truck volumes, without expensive new construction. For example, the Woodburn Port of Entry in the state of Oregon was built in the mid-1980s. At that time, truck volumes were approximately 2,000 per day. Two static scales were put into operation to accommodate these volumes. Now, the truck volumes exceed 5,000 trucks per day, and are increasing by 8% each year. Rather than expanding the weigh station facility, the Oregon Department of Transportation implemented two lanes of WIM equipment which preweighs the 5,000 trucks. This solution has helped to protect the existing weigh station facility from unnecessary wear, allowed the enforcement officials to spend their time on potential violators.

The positive economic benefits of WIM far outweigh the costs. WIM systems help to protect hundreds of miles of roads at less than 1% of total maintenance costs for those hundreds of miles of road. The cost for operating and installing a deluxe Weigh-In-Motion (WIM) system is under \$75,000 per year over a ten year period. In comparison, the cost to maintain five hundred miles of four lane interstate is \$8 to 10 million per year. WIM costs less than 1% of total maintenance costs! This insubstantial investment will have a tremendous impact on reducing maintenance costs and preserving hundreds of miles of interstate from premature wear.

With the recent passing of TEA-21, and the continued focus on road preservation, more highway funds will be available for implementation of cost effective technologies such as WIM. Fewer stops at weigh stations for compliant carriers means less delay to their operations. Being able to target illegally overloaded trucks helps to free up enforcement resources and make enforcement operations much more efficient, allowing more thorough inspections of potential violators. For the taxpayers, more efficient enforcement operations, more efficient carriers and less damage to the infrastructure means fewer tax dollars or tax dollars which can be spent in other important areas. The cost of maintenance and new construction of roads is an enormous burden for taxpayers, one which can be minimized with WIM as a data collection and enforcement tool.

8. SUMMARY

Weight enforcement activities are a critical component of any successful highway management program. Without weighing, the infrastructure cannot be preserved or managed effectively. Without sufficient deterrents for overloading, such as likelihood of getting caught and stiff penalties, weight restriction laws become meaningless. In recent years, the use of WIM technology as an enforcement and management tool has been increasing steadily. The role of WIM in road preservation has two main applications: weight enforcement to minimize the deterioration of roads, and data collection for management and planning purposes.

WIM technology weighs trucks dynamically and prevents the overloading of highways by targeting overweight vehicles. This helps to protect the public's investment in the transportation infrastructure by controlling and managing the deterioration of roads. Targeting overweight vehicles also makes vehicles safer by preventing rollovers, unbalanced loads, and various hazards associated with heavy loads. WIM technology provides valuable information regarding vehicle configurations, weights, speeds, volumes, peak travel times, and a multitude of other information. This information can then be used by various state agencies for statistical analysis of road usage, road wear, truck overloading, and vehicle configurations both for the planning of new roadways and for the management of existing roadways. The data can be used to establish guidelines for building new highways and plan maintenance activities. WIM is the only feasible solution to pre-weighing trucks efficiently, given the tremendous volumes of truck traffic on interstate highways and over static scales. WIM also provides the most reliable and unbiased information on truck weights and volumes for planning and management purposes.

WIM systems are a tool for the future. The states have an opportunity to extend the life of a very costly road system by investing in technology that can weigh the loads to protect the roads. Implementing WIM will save taxpayers money. Implementing WIM will also mean lower maintenance costs for the state and the motorists. WIM will make roads more efficient and safe by facilitating smooth traffic flows and limiting disruptive and dangerous truck exits and merges from weigh stations. WIM will make traffic backups at weigh stations a thing of the past and minimize the unnecessary and costly stops at weigh stations for legal carriers. WIM systems will enable current highway management operations to accommodate the increasing traffic volumes without having to build more weigh stations.

As roads become more congested and as pressure mounts to deliver safe, efficient and reliable transportation systems, it is increasingly important to look at the technologies available to achieve these objectives. Investing in WIM systems produces a positive economic impact through fewer delays, fewer accidents, fewer emissions, fewer overweights and reduced road deterioration.

REFERENCES

1. **1996 Highway Statistics, Public Road Length – 1996: Miles by Functional System**, FHWA, Office of Highway Information Management, 1996.
2. **Truck Movements in America: Shipments From, To, Within, and Through States**, TranStats, BTS/97-TS/1, Bureau of Transportation Statistics, 1997.
3. **U.S. Freight: Economy in Motion**, Report No. FHWA-PL-98-034, p.61, Federal Highway Administration, 1998.
4. **Special Report 225: Truck Weight Limits: Issues and Options**. p. 52, Transportation Research Board, National Research Council, Washington, D.C.,1990.
5. Thomas Cooper, **Highway Financing**, Public Roads, March/April 1998, Vol. 61, No. 4., Federal Highway Administration, 1998.
6. Edward S. K. Fekpe, Alan M. Clayton, and Ralph C. G. Haas, **Evaluating Pavement Impacts of Truck Weight Limits and Enforcement Levels**, Transportation Research Record, No. 1508, Pavement Design, Management and Performance, Transportation Research Board, National Research Council, National Academy Press, Washington, D.C., 1995.
7. **WIM Scale Calibration: A Vital Activity for LTPP Sites**, Publication No. FHWA-RD-98-104, Federal Highway Administration, McLean, 1998.
8. **Special Report 225: Truck Weight Limits: Issues and Options**. p. 34, Transportation Research Board, National Research Council, Washington, D.C.,1990.
9. **Special Report 225: Truck Weight Limits: Issues and Options**. p. 1, Transportation Research Board, National Research Council, Washington, D.C.,1990.
10. **Special Report 225: Truck Weight Limits: Issues and Options**. p. 42-43, Transportation Research Board, National Research Council, Washington, D.C.,1990.
11. **Special Report 225: Truck Weight Limits: Issues and Options**. p. 136, Transportation Research Board, National Research Council, Washington, D.C.,1990.
12. **Special Report 225: Truck Weight Limits: Issues and Options**. p. 141, Transportation Research Board, National Research Council, Washington, D.C.,1990.
13. **U.S. Freight: Economy in Motion**, Report No. FHWA-PL-98-034, Federal Highway Administration, 1998.
14. **Special Report 225: Truck Weight Limits: Issues and Options**. p. 135, Transportation Research Board, National Research Council, Washington, D.C.,1990.
15. **Special Report 225: Truck Weight Limits: Issues and Options**. p. 140, Transportation Research Board, National Research Council, Washington, D.C.,1990.
16. **Special Report 225: Truck Weight Limits: Issues and Options**. p. 137-138, Transportation Research Board, National Research Council, Washington, D.C.,1990.
17. **Special Report 225: Truck Weight Limits: Issues and Options**. p. 141, Transportation Research Board, National Research Council, Washington, D.C.,1990.
18. **Special Report 225: Truck Weight Limits: Issues and Options**. p. 136, Transportation Research Board, National Research Council, Washington, D.C.,1990.
19. **Trucking Facts & Industry Issues**, American Trucking Association, www.trucking.org/trucking_facts/trucking_facts.html, 1998.
20. Rich Quinley, Division of Traffic Operations, Caltrans, 1998.
21. Carol T. Rawson, Traffic Engineering Section, Texas Department of Transportation, 1998.
22. Craig LaChance, East Boise Port of Entry, Idaho Transportation Department, 1998.
23. Rick Saaltink, Seaway International Bridge Corporation, 1998.
24. Gary Naeyaert, Office of Communications, Michigan Department of Transportation, 1998.
25. Mohammed Taki, Transportation Planning, Kentucky Department of Transportation, 1998.