Design Guidelines for Developing Truck Inspection Stations

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ABSTRACT

Many jurisdictions are experiencing rapid growth in truck traffic volumes and truck loads. This tendency has caused considerable increases in the accumulated damage in the pavement and bridge networks. The highway agencies are striving to protect their investment in their infrastructure, while simultaneously promoting the economic viability of truck transportation. Substantial protection can be derived from a multi-faceted weight enforcement program, a key component of which is a system of Truck Inspection Stations. For many agencies, the actual or potential capital investment in the truck inspection station system is relatively large. All agencies desire to optimize their capital investments, thus creating the necessity for a rational methodology for the planning and development of Truck Inspection Stations. This paper presents guidelines for designing a Truck Inspection Station (TIS) and planning a system of truck inspection stations for an entire jurisdiction.

The site selection process and a procedure to identify the required functions of a TIS are explained. Depending on an agency's or a site's unique requirements, the functions of a specific TIS may include weighing, measuring vehicle dimensions, safety inspection and verifying operating authority. The paper describes how data regarding truck traffic volumes and distribution classifications are collected and analyzed. The guidelines detail how the results are used as input to determining the components of a TIS, its layout, necessary equipment, facilities and operational procedures.

Weigh-in-Motion (WIM) technology, widely used as a data collection system, can be a major element in a TIS system. WIM improves the time-effectiveness and handling capacity of truck inspection stations in sorting heavy trucks prior to weighing and inspection. Thus, only trucks suspected of being overloaded are stopped for static weighing. Finally, the economic feasibility of the TIS system and individual stations is illustrated. The various cost components are compared with the benefits derived from the reduced infrastructure damage.

1. INTRODUCTION

The trucking industry operates in a highly competitive environment. As the industry endeavors to increase productivity and lower costs, a natural tendency is to operate vehicles of increasing size and weight. Authorities are continually seeking ways to promote the viability of the industry by altering heavy truck weights and dimensions regulations. Positive consequences of the current global trend towards deregulation of the trucking industry are increased trade with heavy trucks and the appearance of alternative varieties of rig and axle configurations.

The other side of the issue must be considered as well. The impact of the resulting growth in truck traffic volumes, number of axle loadings and greater axle weights has been accelerated along with the deterioration of the pavements and bridge structures. To protect the highway infrastructure from decaying rapidly, the highway agencies are implementing more comprehensive and effective weight enforcement programs. A well designed system of Truck Inspection Stations greatly enhances a weight control program.

Some agencies may already have some Truck Inspection Stations in place; others may be considering the development of a network of Truck Inspection Stations. For either situation this paper aids the agency in planning and developing both the individual TIS and the overall system.

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1.1 INFRASTRUCTURE UTILIZATION COSTS

The benefits gained from increasing the allowable weights and dimensions of heavy trucks should always be viewed in conjunction with the incurred additional cost of pavement and bridge damage in the highway network. In jurisdictions with substantial truck traffic volumes, the deterioration of the pavement and bridge structures is affected directly by the level of the enforcement program and its acceptance by the trucking industry.

The trucking industry will offer a greater degree of acceptance of realistic weight, dimension and safety regulations if the regulations are set in cooperation with the industry. Dramatic changes in regulations may have a negative impact on a trucking firm's viability, especially regarding the use of existing vehicles. Due to their design, some existing vehicles may not comply with new regulations. But they cannot be suddenly and arbitrarily forbidden to operate, especially when the older trucks constitute a major proportion of the trucking industry as is the situation in many developing regions of the world. Therefore, to avoid inflicting harm to an economy whose commercial and trade activity depends on older vehicles that may violate new regulations, grandfathering of those vehicles should be considered. The time frame and rules governing the grandfathering must be unmistakably specified and widely distributed.

Properly devised regulations and fair enforcement practices ensure that all trucking firms operate under the same conditions. If some firms are allowed to operate outside the regulations, then the ones abiding by the rules are not given equal opportunity to compete, resulting in unfair competition. Therefore, the truck inspection station serves a symbolic purpose as well - it is a highly visible indicator of the agency's commitment to weight enforcement.

Dramatic increases in maintenance costs have been observed in jurisdictions without effective enforcement programs. The following example of an economic analysis serves to put into perspective the significance of investing in a comprehensive weight enforcement system. Bear in mind that each jurisdiction will have its own particular values for input to the calculations.

For example, in 1980 Louisiana's highway agency quantified the cost of primary highway use by a heavy truck to be $(US) 0.25 per tonne-km (1). In terms of highway use and deterioration, the annual cost of a 36 400-kg truck travelling 1 000 km every day on the state's Interstate system is 3.3 million dollars. If the agency's weight enforcement system permits just one truck that is 10 T overweight to travel on the pavements for 1000 km every day, that total annual cost increases by nearly one million dollars. The U.S. tonnage and truck survey statistics (1) reveal that, based on a national overall average of the trucks weighed by all means, one percent are overweight violators. In one specific case, Louisiana recorded 10 000 violations in 4.675 million trucks weighed in 1979. Many jurisdictions have much higher traffic volumes and therefore could expect much greater pavement and bridge damage costs.

The actual costs depend on each agency's particular situation and accounting procedures. The example illustrates how the pavement and bridge network damage costs increase dramatically as the number of overweight trucks, tonnage, and distances travelled goes up. The economic analysis emphasizes the importance of a comprehensive and efficient TIS system. The potential savings to the agency more than compensate for the cost of a good system of truck inspection stations.

2. SITE SELECTION

After the development of the TIS system is approved, the first objective is to devise a general site selection plan covering all of the agency's jurisdiction, including an inventory of any existing Truck Inspection Stations. The master plan should be devoted to a long-term period of 15 to 20 years or more; this master plan will coordinate the staged introduction of new truck inspection stations over the chosen time period. The master plan prescribes a periodic update of the truck volumes and changing conditions. The site selection process for the TIS network should satisfy the most efficient utilization of the available resources. The overall goal is to provide the maximum possible coverage of the jurisdiction's trucking operations within the budgetary constraints.

The following steps outline the procedure for selecting sites for the TIS system:

Step 1: Initiating a study to determine the heavy truck volumes, the origin-destination characteristics of the heavy truck traffic movements, segments of the network's routes that are major truck corridors, and strategic links in the agency's highway and bridge network. Truck flow diagrams are then prepared. A map of the jurisdiction is drafted to graphically present the above information and indicating the locations of existing and proposed truck inspection stations.

Step 2: Preparing a thorough feasibility study of implementing the agency-wide system of Truck Inspection Stations and strongly emphasizing the possible negative consequences of not implementing the development of the system.

Step 3: Determining the requirements for developing truck inspection stations at specific sites where the need is identified by the master plan.

Further inputs to the site selection in a particular location include the highway characteristics, type of industry and development present, heavy truck volumes and patterns, proximity of other facilities, bypass potential, availability of land, utility connections, and concerns of local interests.

Some TIS sites may be indicated by defining the strategic links identified in the original agency-wide traffic study. Strategic links are near intermodal transfer facilities, developed areas, central industrial locations, and interjurisdictional borders for checking operating authority. Using natural obstacles to delineate advantageous interception points enhances the effectiveness of the TIS system.

The spatial relationship of the sites must satisfy the goal of the truck inspection system to reduce the probability of weighing the same truck more than once during a single trip. The origin destination movements provide the input for determining the strategic locations.

The TIS master plan aims to reduce or eliminate alternative routes, to minimize their availability for bypassing the truck inspection station. A properly-designed system does not allow a significant number of overweight vehicles free travel while unfairly stopping legal trucks. Specific sites are chosen in a manner that reflects this commitment to fairness.

Regardless of the characteristics of any particular site, there must be sufficient land available for immediate development of the TIS and, if possible, space for future expansion of the station. The actual size of the particular TIS depends on its geometric design and unique requirements in handling the design truck volumes and the assigned functions.

3. TIS FUNCTIONS

The functions of the truck inspection station must be identified prior to designing the station layout, determining equipment requirements and devising the operational procedures. The prescribed functions may include weight enforcement, safety inspection, verification of operating authority of the vehicle, and other functions selected to meet the agency's and a site's unique requirements.

3.1 WEIGHING

Weighing the individual axles, axle groups and the vehicle is the main function of the truck inspection station. In most instances, evaluating a truck's compliance with the weight regulations requires the measurement of the spacings between individual axles and axle groups. The majority of jurisdictions dictate that static weights or slow roll-over weights are to be compared with regulatory weights for enforcement purposes. 'Slow roll-over' refers to weighing a multi-axle truck driving over a single-axle short-platform scale at a maximum speed of 5 kph.

3.2 OPERATING AUTHORITY

The operating authority of the vehicle may also be verified at some truck inspection stations, especially where interjurisdictional commerce is concerned. Concurrently, the registration of the vehicle would be confirmed, and the eligibility and authority of the driver to operate the vehicle would be checked. A central record of repeat offenders should be accessible to TIS personnel.

3.3 OTHER FUNCTIONS

Other functions of the station may include determining compliance of the truck's contents with that stated on the accompanying documents and with respect to other regulations (hazardous materials, contraband), and conformance of the vehicle, its load, tire condition and the operator with applicable safety regulations.

After all the functions to be performed at the specific TIS have been identified, the designer proceeds to the next step - evaluating the heavy truck traffic volumes at the site.

4. EVALUATION OF TRUCK VOLUMES AT A PROPOSED TIS SITE

The next step is examine the traffic characteristics at the particular site. Portable classifiers are used to collect data for the present traffic volumes and characteristics. Then, the following steps should be taken:

i) Calculate the directional peak hourly volume of heavy trucks and develop a table showing the distribution of the relative populations of trucks of various classifications for the existing situation.

ii) Analyze the present conditions and develop an estimated projection of the peak hourly truck volume by direction and the vehicle classification distribution for a fifteen to twenty year design period.

If new weight and dimension regulations are implemented simultaneously with the development of the TIS, then the shift in weight distribution patterns for heavy trucks must be considered during the analysis of projected distributions and design volumes (2).

A preliminary short-term weight study could be performed at the proposed site. The weight study evaluates the numbers, weights and configurations of truck axles. A thorough traffic study is necessary to determine the requirements of the TIS and to design it to suit the situation at a particular site.

5. DESIGNING AND PLANNING THE TRUCK INSPECTION STATION

The design of a particular TIS must satisfy both the agency's enforcement requirements and the financial restraints imposed by the agency's budget. The layout of the TIS should accommodate the weight, dimension and safety regulations of the jurisdiction. If the weight regulations are partially based on the bridge formula, then the TIS scale configuration must reflect that influence. The weight regulations may also depend on the accurate measurement of axle spacings, therefore, the facility must be capable of making those measurements.

The main variables involved in the design of a Truck Inspection Station's layout are the functions assigned to and the heavy truck volumes incurred at the TIS site. The capacity of the TIS must include those trucks that fail their initial weighing and inspection, and must be reweighed or reinspected.

5.1 CONFIGURATION OF THE CONVENTIONAL SCALE

The main function at most Truck Inspection Stations is weighing. The characteristics of and method of operating the weighing scales affect the ability of the TIS to handle the truck volumes incurred at the site. Therefore, designing the permanent platform weighing scale(s) for the TIS must include a number of considerations. The configuration, method of operating and motion dampening characteristics of the scales are the primary influences in the weighing time. The scales' configuration and dimensions are based on the classification distribution derived from the traffic study.

The scale configuration must be capable of handling the peak hourly design volume at an optimal level of service. In order to achieve the required truck-handling capacity, a very high percentage (approaching 100%) of the truck volume shall be weighed with one stop. Weighing all the axle groups of a truck simultaneously with only stop provides a high throughput of truck volumes. The critical scale configuration is determined from the analysis of the truck fleet mix. Therefore, the TIS designer must have accurate projections of the expected truck volumes so that the weigh scales will not be under- nor over-designed for the truck volumes that are incurred at a site.

For simplicity's sake, assume that the estimated time to perform a single weighing operation is forty (40) seconds for the first stop, regardless of the number of axles that can be weighed simultaneously, and thirty (30) seconds for each additional stop or axle group. Thus, the maximum peak volume handled by a single weighing lane is about 90 trucks per hour if all trucks are weighed with one stop.

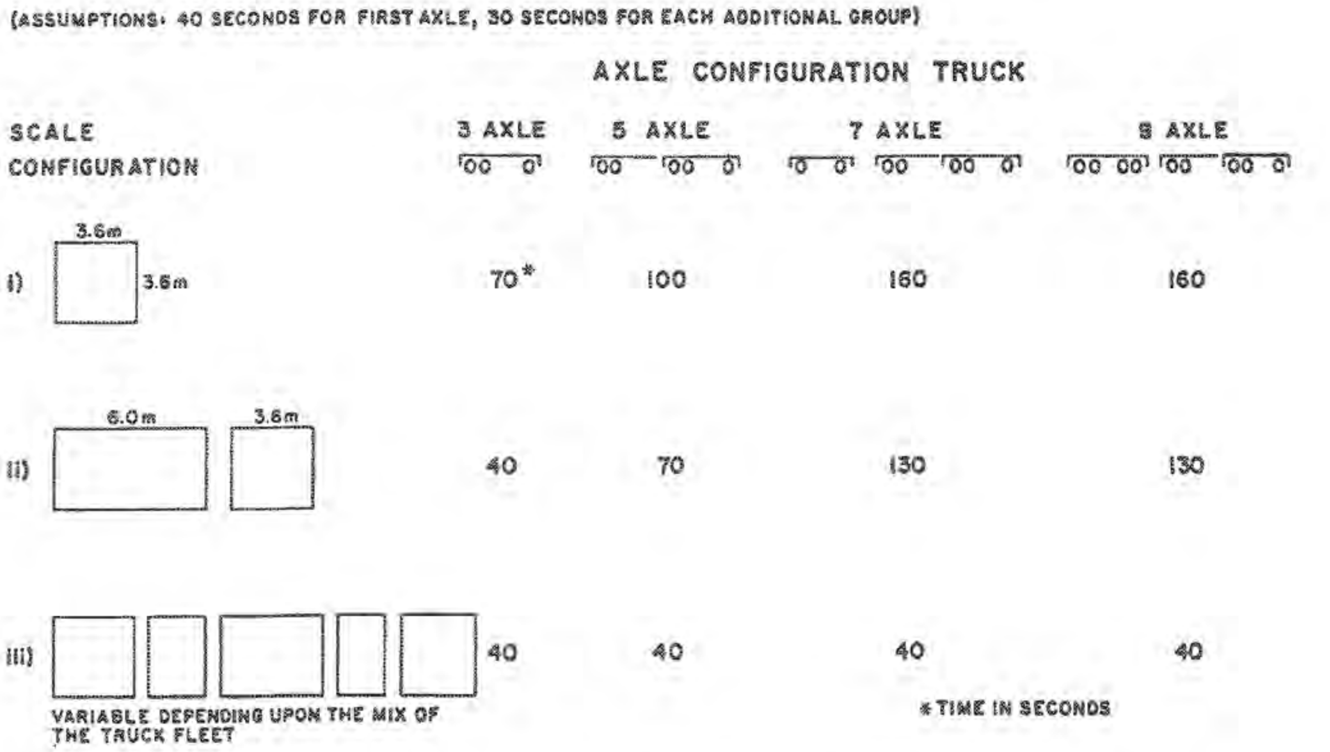
The weighing scales can be classified in a variety of categories, ranging from a single, short platform-scale three meters long, to multi-platform series of scales up to 24 meters long. Figure 1 illustrates some of the possible configurations of the static platform scales and the time required to weigh some representative trucks.

The effect of the scales' configuration on the station's truck capacity to handle truck volumes is shown in the following example. The total heavy truck volume at a particular site is 1000 trucks per day per direction. At any given time, thirty percent are empty. The peak design hourly volume is 100 heavy trucks, and 80 of those are triple-axle straight heavy trucks. The remainder of the mix are multi-unit semi-trailer trucks with more than three axles or axle groups. A single platform scale 3 m long will weigh an axle or closely-spaced axle-group in forty (40) seconds and thirty seconds for each succeeding axle on the same vehicle, including trailers. Therefore, up to fifty-five of the triple axle-group trucks can be weighed in an hour. But this is not satisfactory because, using a short platform scale that weighs one axle-group at a time, processing a nine-axle tractor-trailer combination will take two minutes. And twenty percent of the trucks have more than two axle-groups. Of those, 15 are expected to be loaded. If they average 4 axle groups apiece, the total truck volume handling of the short platform scale is reduced to about 30 trucks per hour. Of course, the calculations must be adjusted for specific situations.

5.2 WEIGH-IN-MOTION SORTER SCALES

A major consideration for improving the traffic handling capability of a TIS is to incorporate Weigh-In-Motion (WIM) scales as sorters. Their function is to sort the trucks according to the measured weights, and direct the vehicles to the appropriate lane. When the truck volumes will exceed the maximum volume-handling capacity of the platform scales, utilization of WIM sorter scales prior to the static scales reduces the number of trucks to be weighed by the static scale by up to 80%. The sorter scales may also allow for a reduction in the size of the static scale required. Actually, WIM sorter scales are a major component of many Truck Inspection Stations.

The accuracy of the WIM equipment depends on their particular characteristics, the speed of the vehicle, the roughness of the approach pavement, and the vehicle dynamics. Typical accuracies expected of WIM scales at different speeds are shown in Table 1. This variability in load measurements, no matter how small, precludes the use of WIM scales for enforcement purposes. However, functioning as sorters, WIMs can greatly enhance



Effect of weigh scale configuration on the total time required to weigh different types of trucks

FIGURE 1

the traffic handling capacity of a TIS equipped with the conventional static scale.

After choosing a specific scale, the agency can directly control only the roughness of the approach pavement. Acceptable results with a high degree of confidence can be achieved by specifying that the maximum approach roughness is 3 mm under a 3 meter-long straightedge. This degree of roughness should prevail for 100 meters prior to the WIM scale and for 20 meters downstream.

The highway turnout lane speed is a function of the optimum speed at which the sorter scale operates, with slower speeds providing more beneficial results. A fifteen (15) to sixty (60) kilometre per hour speed range is satisfactory.

The headway between arriving trucks must be considered when attempting to optimize the efficiency of the sorter scale. This is achieved by designing the TIS entrance such that trucks flow continually and evenly across the sorter scale. Queuing of waiting trucks before the sorter scale and back onto the highway-exit ramp cannot occur. Therefore, queuing can occur only ahead of the permanent weighing platform.

The queuing that can be expected to occur ahead of the conventional platform weigh scale is a function of the average service rate for truck inspection. Assuming that truck arrivals follow approximately a Poisson's distribution, the average amount of time that a truck spends in the queue and the associated delay time can be readily determined. Delay can be minimized by prescribing the maximum allowable time that any one truck should be in the queue, and designing the TIS layout such that the queue length will not exceed the theoretical maximum. The length of a queue is also governed by the level of tolerance of overweight vehicles (for example, any axle load or gross vehicle weight which is 105% of the legal regulations is permitted to proceed). The level of tolerance is set automatically preferably, or adjusted manually.

Table 1 — Typical accuracies expected of weigh-in-motion scales

Weight measured	Speed (Kph)	Mean (%)	One standard deviation (%)
Single Axle	20	0.5	3
	60	1.0	5
Tandem Axles	20	0.5	2
	60	1.0	4
Gross Vehicle	20	0.5	1.5
	60	1.0	3

The WIM microprocessor analyzes the measured weights and axle spacings, and determines if the truck is overloaded. The truck is directed by means of overhead or roadside signals to either the static scales or the bypass lane. The distance between the sorter scale and the overhead signalization should be sufficient to permit the signal processing and instruction display by the WIM micro-processor. The computer cannot begin processing the data until 1 second elapses after the last axle of a truck has passed over. A truck 35 meters long, travelling 16.7 m/s (60 kph), would require a distance of at least 70 meters between the WIM scale and the signal board in order to give the driver enough time to safely respond to the displayed instructions. Note that Alberta Transportation is evaluating a 35-meter truck combination expected to be in use in the near future (3).

WIM scales in the travelled lanes of the highway and operated primarily as data acquisition systems can be used as sorters if they are located a short distance ahead of the TIS which has conventional static scales only. Only a slight modification of the WIM scale software and roadside signalization allows the WIM to perform both functions. Vehicle weights measured in this manner, under smooth approach conditions at highway speeds (100 kph), are within 5% of the actual weight (4). If WIMs cannot be placed in all travelled lanes, then signing is used to direct truck drivers to move over to the lane with the WIM.

5.3 AUTOMATED DATA-ACQUISITION AND PROCESSING

To provide improved service, detection of vehicle characteristics should be automated. Sensors for detecting overweight vehicles are readily available and possess a high degree of accuracy. Double inductive loops (acting as axle sensors) installed flush with the pavement surface accurately measure axle spacings, both between axle groups and individual axles.

Automatic detection of vehicle width is more difficult to obtain; in Canada, this is due to the influence of snow and extreme climatic conditions. Automated truck height determinations lack accuracy.

The TIS official compares the actual measured weights, spacings and dimensions with the allowable, taking into account the particular specifications for each vehicle. The system should directly compare actual and allowable axle spacings and other measurements, and the information displayed on video monitors.

The regulations should be presented in a form that makes comparisons easy and quick to do, similar to that shown in Figure 2. In addition, the TIS operator is notified by a sound buzzer, flashing panel light, or visual pointer that an infraction has been discovered, and its position on the vehicle indicated.

Communication between the station personnel and the vehicle operators is a crucial factor in the truck handling capacity of the station. The signing must be designed to aid the flow of traffic by reducing potential misunderstandings, offering clearly visible and simple, easy-to-follow instructions. Internationally accepted and recognizable symbols should be used instead of words, especially where problems may be encountered due to language diversity and high rates of illiteracy. Verbal communication of instructions is enhanced with outdoor speakers.

Induction loops are installed at critical locations in the bypass and weigh/inspection lanes to determine if trucks are indeed following the instructions given to the drivers. The loop-monitoring system shall be capable of automatically determining if incorrect movements are occurring, and notifying the TIS operator of such movements, possibly by means of an audible alarm or video screen display. The TIS operator should then be able to respond by remotely controlling the movement of the truck and redirecting the driver with new instructions. Provision for overriding all or some of the above automatic controls and permitting manual operation is advised.

If printed records and fines are to be issued at the TIS, then good quality, automatic printers should be provided, instead of requiring the TIS personnel to hand-write the orders, a much slower process.

The data acquisition and monitoring system should be capable of determining and recording the numbers of trucks passing through, and calculating percentages of trucks that violate the regulations. The information on violators and all trucks going through the TIS shall be stored in a database. The data (records, orders and fines) should be printed by the computer on request, and recoverable on a time-scale basis, so that, for example, the operator could retrieve the information for a particular shift at the end of that shift.

5.4 WEIGH HOUSE

A building (Weigh House) is needed for housing sensitive monitoring equipment and facilities for personnel and visitors. The Weigh House may accommodate the administrative functions of the station, such as providing informational services, issuing special permits, checking the operating authority and levying fines on regulatory infractions. The internal arrangement of the building depends on the number of employees and visiting truck drivers to be accommodated, service facilities provided for the drivers and personnel, and the functions to be performed inside. The station may also need a detention area for temporary detainment of violators.

The degree of visibility towards the trucks on the scales and of those bypassing the weighing should be enhanced, possibly by larger viewing areas, elevating the observer position to permit viewing of truck drivers, or the introduction of remote video monitoring. The camera may be mounted for clear viewing of multiple lanes and the far side of

TRUCK CONFIGURATION	**o . . . . oo . . . . oo**					**GVW**
ACTUAL SPACINGS (m)		4.11	1.32	6.53	1.41	
ALLOWABLE LOAD (kg)	5 500	15 900			15 900	37 300
ACTUAL LOAD (kg)	5 160	* 16 540 *			15 470	37 170

* overloaded *

Sample display of weight and dimension data as shown on the weigh house CRT monitor

Figure 2

vehicles, leaving the station operator inside where more functions may be handled by one person.

Ease of access for people walking between the station's administrative building and the parking and storage areas must be considered. The addition of pedestrian signalization, elevated walkways, or underground tunnels may be warranted when safety and increasing delay times are a problem.

5.5 VEHICLE STORAGE

Storage is provided between the sorter scale and the platform weigh scales to allow room for temporarily stopped trucks, because queuing is expected to develop in front of the scales. Another storage area is required past the conventional platform scales for stopped vehicles when thorough inspection and checking is required. This storage area is referred to as the 'racetrack'. The size and configuration of the racetrack should be designed to accommodate the numbers and types of vehicles expected. The design of the approaches, exits and storage areas of the racetrack should consider also future developments in heavy truck configurations and technology. A critical factor is the turning characteristics of larger, multi-unit vehicles.

The movements of trucks leaving the weighing/inspection area must be strictly controlled and carefully planned. The vehicles should be able to proceed to the racetrack or the exit with minimal interference from other traffic or lanes, in the case of multi-lane or multi-stage inspection stations. The approach to the racetrack must be clearly indicated and visible to truck drivers. The racetrack itself must be configured to handle a number of different truck configurations. The parking and storage area of the racetrack must provide for further inspection and load adjustments, including unloading of goods. Special storage areas may have to be provided where the interception of hazardous materials or illegal goods is expected. Additional area for future expansion should be designated in the original land use plan.

The vehicles returning to the weigh/inspection lanes from the racetrack will have to merge with the newly arrived trucks if no provision is made for separated lanes. Correct design of these movements is a crucial element in maintaining the capacity and efficiency of the station.

6. TIS CONFIGURATIONS FOR VARIOUS TRUCK TRAFFIC VOLUMES

As suggested earlier, the TIS configuration is largely dependent on the truck traffic volumes to be handled at the particular site. The following discussion elaborates on the possible TIS configurations and on their potential traffic handling characteristics, beginning with a TIS designed to handle the most crucial truck volume, in the range of 2000/day.

6.1 CONCEPTUAL LAYOUT OF A TYPICAL TIS

In this case, the typical situation is a divided, multi-lane highway incurring heavy truck traffic volumes in the range of 2000 trucks per day per direction. The TIS consists of two identical setups, on each side of a multi-lane, divided highway. The TIS layout should incorporate the following aspects.

Initially, only a single weigh/inspection lane may be required to accommodate the truck volumes that are instructed to stop. The configuration of the scales will vary for different agencies and locations, but should consist of at least two platforms of 6 m and 3.6 m in length; the 3.6 m platform is forward of the longer platform. Figure 1 presents a conceptualized diagram of scale configurations needed to handle different truck configurations.

A WIM scale in the approach lane sorts the incoming trucks, directing them to either the weigh/inspection lane or the bypass lane. Signing at the start of the turnoff ramp instructs drivers to maintain the necessary headway (in most instances, 30 meters) between vehicles.

A bypass lane permits vehicles that do not have to be weighed to pass by the station's observation booth, allowing the TIS personnel to make a cursory visual inspection of the vehicle. The bypass lane should be closest to the highway and the lane's speed limit shall be chosen to permit a proper visual inspection and aid the station's capacity. The weigh/inspection lane is next from the highway, then the Weigh House. The storage/parking area is furthest away from highway traffic, as in Figure 3. With this configuration, drivers and station personnel have a safe and easy access between the weigh house and the station's other areas.

6.2 LOW TRAFFIC VOLUMES ON A TWO-LANE UNDIVIDED HIGHWAY

At the low end of the traffic volume ranges, of approximately 300 heavy trucks per day travelling in one direction on a double-lane undivided highway, no capacity problems should occur with the simplest truck inspection layout. A typical TIS layout for a low-volume site consists of a Weigh House, a single weigh/inspection lane and minimal storage space for trucks. Provision for future expansion, such as for a bypass lane and/or racetrack, must be made in the initial design.

Commercial heavy trucks are requested to report according to the information given on a roadside information sign. The signing indicates what type of vehicle reports, and when the TIS is open. Normally, only about two-thirds of the commercial trucks might have to be weighed; the remainder could bypass the weighing if they are empty or lightly loaded. Each agency will determine its own particular requirements and design the TIS accordingly.

6.3 LOW TRAFFIC VOLUMES ON A FOUR-LANE DIVIDED HIGHWAY

A four-lane divided highway with low volumes of heavy trucks requires an alternative TIS layout. The TIS should be located in the median between the pairs of lanes. Having a single station in the median requires left exits off the highway, which reduces the highway's traffic capacity and level of safety. Complicated operational directions and control would be required at the station, regardless of whether one weigh/-inspection lane or more are included. Finally, there is limited space for construction and no room for future expansion.

6.4 MEDIUM TRAFFIC VOLUMES AT THE TIS SITE

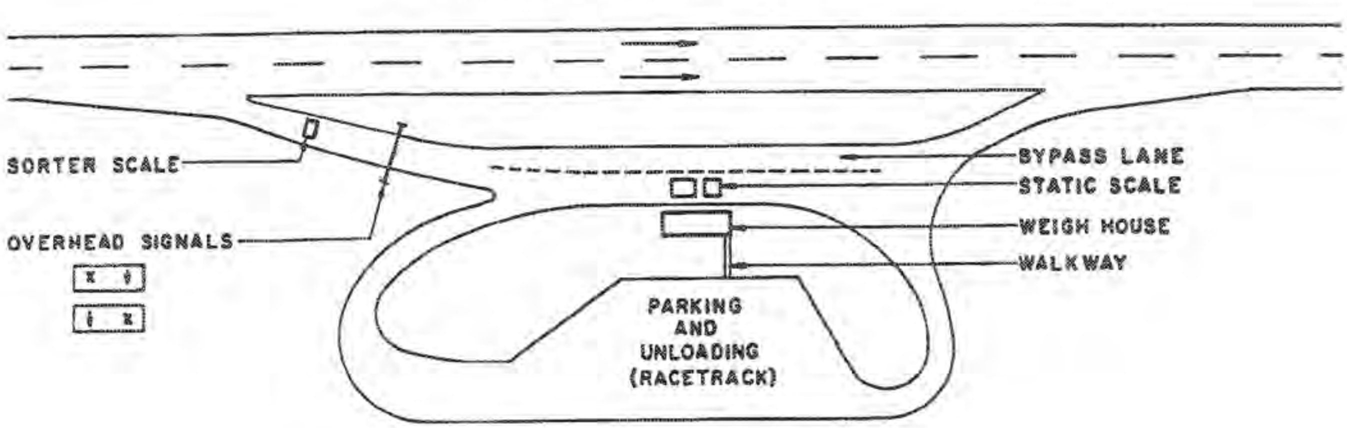
For sites which have medium truck volumes of 400 to 800 trucks per day per direction and on four-lane, divided highways, the conceptual layout can be slightly changed. Alterations could include having only a single weigh house on one side operating both sides of the TIS; an underground passage under the highway would lead from one side to the Weigh House.

A WIM scale will most likely be needed to sort the trucks prior to weighing. Using WIM scales installed in the travelled lanes of the highway as sorter scales, in addition to the data collecting function, is not satisfactory because of the much greater accuracy of the WIM scale at lower speeds.

6.5 A TIS FOR VERY HIGH VOLUMES ON MULTI-LANE HIGHWAYS

If the truck traffic volumes are higher than the maximum volumes that can be handled by a single platform-scale lane (which is approximately 90 trucks per hour per direction), then extra features

FOUR LANE - DIVIDED HIGHWAY



Typical truck inspection station layout (for peak hourly volumes of trucks by direction maximum daily volume of < 3,000 trucks)

FIGURE 3

to be considered are additional parallel weigh/inspection lanes and a series of scales positioned to weigh multiple axle vehicles with one stop.

The maximum sorter scale volume-handling capacity is a function of the headway between vehicles, but is nominally 200 trucks per hour per directions. When this volume is exceeded, the TIS layout could include additional WIM sorters. A less preferred option is to use WIMs installed in the travelled lanes of the highway for data acquisition to identify potentially overweight trucks that have to stop.

At TIS sites expecting to incur heavy (2000 trucks per day per direction) and very heavy (greater than 3000 trucks/day/direction) volumes, the sorter scales are found only in the off-highway exit lanes. Here, the lower vehicle speeds enhance the accuracy of the measurement of the weights and axle spacings, thereby providing positive separation and signal control.

The critical peak hourly volume is about three hundred (300) trucks per hour, which requires an uniform arrival rate of 1 truck every 12 seconds. The allowable headway between vehicles is a function of the speed permitted over the sorter scale (usually 30 meters at speeds of 15 to 40 km/hr).

6.6 HIERARCHY OF TIS LAYOUTS

The hierarch of layouts for Truck Inspection Stations is related to heavy truck traffic volumes, truck characteristics and complexity of the highway. Table 2 encapsulates the information discussed in the above sections, and presents it in the form of a matrix describing the relationship between truck traffic volumes and the required components of the corresponding TIS layout.

7. OPERATING STRATEGIES

Agencies should devise operating strategies uniquely suited to the function of Truck Inspection Stations in their jurisdiction. The following sections offer suggested guidelines for setting operating strategies.

7.1 TIMES OF OPERATION

Ideally, the TIS should be operated continuously, 24 hours a day, year round. Ten to twelve officers should be assigned to each TIS that operates around the clock. This permits a minimum staff of 3 and maximum of 4 per shift, depending on holidays, retraining courses, sickness and special reasons.

Table 2 — Hierarchy of truck inspection stations – truck traffic volumes versus complexity of TIS

	Average daily truck volumes by direction			
TIS component item	**Low (300)**	**Medium (600)**	**High (2000)**	**Very high (3000+)**
Static Weigh Scales				
Single Platform	Yes	No	No	No
Multiple Platform	Opt.	Yes	Yes	Yes
Multiple Lanes	No	No	Opt.	Opt.
WIM Sorter Scales				
Single Lane	Opt.	Opt.	Yes	Yes
Multiple Lanes	No	No	Opt.	Opt.
Bypass Lane	Opt.	Yes	Yes	Yes
Racetrack	Opt.	Opt.	Yes	Yes
Automation of Processes	Opt.	Opt.	Full	Full

Yes – Inclusive of item is strongly recommended.
Opt. – Inclusion of item is recommended, but optional.
No – Inclusion of item is not necessary.

However, if continuous operation is not feasible, then random opening times should be implemented. The random opening times cannot have a discernable pattern; truck drivers will soon recognize the pattern and adjust their driving schedule to coincide with closing times. Where the TIS is not open continuously then a WIM scale installed in the travelled lanes of the highway could be used to collect data for determining the relationship between commercial vehicle characteristics and the operating schedule of the station.

7.2 HANDLING QUEUING UNDER PEAK CONDITIONS

In high volume locations, weighing/inspecting only every second (or nth) truck helps prevent the development of queuing and related safety problems. However, a definite selection sequence is quickly determined and manipulated by drivers who will position themselves in large convoys so as to avoid inspection. Randomized selection of trucks for inspection does not lend itself to such a manipulation and therefore is more effective.

Another alternative for handling temporary peaking in the truck volumes is increasing the level of tolerance of the allowable weight limit (say, from 100% to 105% of the legal limit). The sorting system can be altered to temporarily allow some possibly overweight vehicles to bypass rigorous inspection. Information of this procedure would be kept confidential, because truck drivers might take advantage of the flexibility provision by travelling in convoys of overweight vehicles.

When unforeseen excessive volumes arise, the enforcement personnel can be given the option of allowing empty or lighter trucks to bypass the sorter scale, on their honour. These vehicles may be instructed to slow down and routed past an observation booth close enough to allow visual inspection by enforcement officials. In some instances up to thirty (30) percent of the trucks are empty.

7.3 HANDLING VEHICLE INSPECTION

The degree of examination to which the commodities, documentation, vehicles and operators are subjected affects the time required to complete the inspection cycle for each vehicle. This cycle time determines the processing capacity of the TIS. The procedure for processing trucks that are overweight or possess other improprieties must be devised to minimize delay times and should be clearly defined beforehand.

Of course, as the truck inspection layout and system becomes more complex, the time required to weigh trucks with greater numbers of axle groups decreases. But the enforcement procedures and directional movements become more difficult to follow and the cost of construction and operations increases.

8. ECONOMIC CONSIDERATIONS

Based on the agency's regulations and guidelines, the economic feasibility of the TIS should be evaluated. The economic analysis involves four cost/benefit components - initial construction, operation/maintenance cost, benefit from reduced truck delay, and benefits gained from protecting the highway and bridge infrastructure. If the agency possesses a comprehensive management information system, and is accessible to the designer, then the economic viability is evaluated easily.

8.1 CONSTRUCTION COSTS

Cost components may include land acquisition and development, construction materials for geotechnical and pavement items, permanent scale foundation and installation, building the Weigh House and associated features, racetrack-parking-storage areas, telecommunications, signing and signalization, acquiring and programming a WIM sorter/data collection system, and storage facilities for accommodating the dumping of overweight, illegal and hazardous goods. The feasibility of purchasing additional land, for expansion, at the outset of the development or later in the station's life must be evaluated in the preliminary design study. Actual monetary costs of the above items depend on the particular situation found in each jurisdiction.

8.2 OPERATING COSTS

A significant part of the truck inspection station's budget will have to be spent on operating expenses, mainly personnel salaries. The number of personnel required per TIS depends on the functions and operating strategy of the TIS. Alternative time-of-operation schedules should be developed, and accurate estimates of the monetary value of each option prepared.

For example, assuming that a normal working week consists of five, 7.5 hour-long days, a typical working year consists of 1800 hours (37.5 hrs/wk*24 working weeks/year = 1800 hrs/yr).

The cost of supplying one fully trained station operator, including benefits, wages and holidays, would be approximately $80 000 per year. Assuming the normal operation of a TIS having two persons per shift requires 3 employees per year, the total annual cost is about $240 000.

The preferred alternative is a twenty-four hours a day, year round operation, which will therefore be in operation 8760 hours per year (365 days/year*24 hrs/day = 8760 hrs/yr). The ideal staffing requirement for this option is 10 to 12 employees per TIS, resulting in a total annual personnel cost of almost 1 million dollars. The authorities responsible for implementing the development of the TIS and systems must justify the additional expenses.

Maintenance of the TIS installation will further increase the operating cost component, whether it is performed by the TIS personnel or others.

8.3 BENEFITS FROM REDUCED TRUCK DELAY

Calculating the truck delay costs requires the availability of a large amount of information regarding the finances of truck movements and the commodities hauled. Typically, the delay cost to a trucking unit is assigned a value of $150/hour, which accounts for the driver's time, fuel burnt during idling, lost revenues due to late deliveries, overhead and miscellaneous expenses.

If each truck movement involves just one unnecessary delay of one minute duration, the accumulated yearly expense amounts to approximately $1,000 per year. It is easy to visualize the cost implications of stopping millions of truck movements for extended periods of time every year. The benefits of operating an efficient TIS network are seen as reduced costs derived from stopping trucks for inspections only when it is considered absolutely necessary. Proper selection of the weighing equipment and their configuration must ensure that the interruption of trucking movements should be kept to a minimum. Ideally, the TIS planner should balance the incremental costs of providing faster truck processing with the benefits resulting from reduced delay.

8.4 BENEFITS FROM REDUCED INFRASTRUCTURE COSTS

As pointed out earlier, highway usage costs are quite substantial mainly due to the continuous need for maintenance caused by heavy loads on the pavement and bridge structures. Highway utilization was reported as $0.25 per ton*km, (1). It was shown earlier that this value suggests that 10 overweight tonnes travelling 1,000 km a day cause an additional cost of highway usage amounting to $910,000 per year.

To examine the effect of lack of load enforcement in the utilization costs of a highway network let us examine the actual extent of load regulation violations. As shown by statistical data from the U.S., (1), 1% of all truck movements are overweight to an average of one tonne per vehicle. Considering an average size jurisdiction, the expected number of truck movements is roughly 10 million. This suggests that lack of proper enforcement would allow 10,000 additional tonnes per year on the highway network. In monetary terms this amounts to a staggering $900,000,000 per year! This actual cost would manifest itself in the form of reduced pavement life and the need for early resurfacing. Such situations are not uncommon. Arkansas, for example, determined that a highway originally designed for an Average Daily Traffic (ADT) volume of 450 trucks and permissible gross truck weight of 33,240 kg would require an overlay in 16.4 years. However, an increase in the legal gross vehicle weight limit to 36,300 kg resulted in an overlay being needed after only 10.6 years, (1).

When the cost component associated with highway utilization is thoroughly examined, little doubts are left about the financial feasibility of a TIS network.

9. SUMMARY AND CONCLUSIONS

Design Guidelines to Developing Truck Inspection Stations has introduced the concept of applying a rational approach to the monitoring of heavy truck traffic and enforcement of a jurisdiction's vehicle safety, weight, and dimensions regulations. The emphasis on the optimization of the economic benefits with respect to the required functions of the TIS reflects the growing pressures on agencies to maintain an expanding highway and bridge network with depreciating resources. Providing a seemingly expensive TIS actually pays for itself many times over during its design life, from reduced maintenance and rehabilitation costs, and prolonged pavement and bridge lives, to the benefit of the agency. From the viewpoint of the trucking industries, a well-developed and comprehensive TIS system induces fair competition among firms and helps to reduce the direct costs associated with weight, dimension and safety regulations, and the indirect costs that may be levied against all trucking concerns for the increased structural damage caused by truck operators not adhering to the regulations.

The guidelines presented in this paper require modification for adaptation to a specific location and for individual agencies.

ACKNOWLEDGEMENT

Special thanks to A.T. Papagianakis, Dept. of Civil Eng., University of Waterloo, Ont. for his critical review and help in the final preparation of this paper.

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SESSION 8
VEHICLE STABILITY 2

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