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THE ROLE OF LESS COMMON TRUCK CONFIGURATIONS

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ABSTRACT

Analysis of freight movement, safety impacts and infrastructure effects of potential transport policies tend to focus on the more common vehicle configurations. This approach assumes that the most common truck configurations exhibit and adequately represent the average situation which can be applied to the entire traffic spectrum. It however ignores the outlying effects due to the less common truck configurations which may have some important effects on the variables under consideration. The less common truck configurations have some important roles to play in freight transportation. These configurations evolve to satisfy certain specific needs. This paper examines some characteristics of a selected sample of the less common truck configurations. These configurations are compared with a common baseline truck in terms of efficiency, productivity, infrastructure impacts, stability and control properties. The analysis is based on the hypothesis that truck configurations found in a given jurisdiction are determined by the governing size and weight regulations and the freight characteristics.

INTRODUCTION

It is often hypothesized that the physical characteristics of heavy vehicles are determined primarily by the size and weight (TS&W) regulations. Other major factors that have been identified to contribute immensely to vehicle configurations include technology in the vehicle manufacturing industry and the nature of freight. Equipment are designed to optimize the size and weight requirements without compromising safety related dynamic performance attributes. The analysis presented in this paper is based on the hypothesis that truck configurations found on the highways is a primary function of the TS&W regulations and the nature of freight generating activities. The extension of the initial hypothesis to include freight characteristics is an outcome of observations that carriers and shippers strive to optimize operations by selecting configurations that can maximize the size or weight or both limitations in the jurisdictions and highway systems on which they operate. Manufacturers also respond to motor carriers' demand by configuring trucks within the constraints of the size and weight regulations. The result is two generation of trucks, those configured for the transporting a wide range of freight and those configured to transport specific commodities only or those that can operate only in specific jurisdictions. The latter is the focus of this paper. The term less common is used in the context to include configurations that are configured to satisfy the TS&W regulatory requirements of certain jurisdictions and are generally restricted to operate in those jurisdictions and/or on certain highway systems only. This definition excludes specialized vehicles e.g., snow blowing equipment and long combination vehicles (LCV).

REGULATORY FRAMEWORK

Regulatory factors that generate the less common configurations include the U.S. Federal Bridge Formula (BFB), the grandfathering laws and the regulatory philosophy. There are inter-jurisdictional and regional differences in the governing TS&W regulations. The legislative frameworks of these governing regulations include the Intermodal Surface Transportation Efficiency Act (ISTEA) freeze, state Truck Size and Weight (TS&W) provisions, Federal TS&W provisions, Western Association of State Highway and Transportation Officials (WASHTO) and the Federal Bridge Formula B. The Federal Bridge Formula B is an integral part of the TS&W regulations for most states of the US. The formula is used to regulate the maximum weights that vehicles can operate on the highways. This is designed to limit the weights on groups of axles in order to reduce the risk of damage to highway bridges. The allowable gross vehicle weights (GVW) are determined as a function of the number of axles and the distance between those axles.

The examples of less common truck configurations examined in this paper can be found in the states of Washington, Idaho and Montana mainly. An example from Michigan is also included, that is the tractor semitrailer configuration will multiple single axles on the trailer (**Figure 1**). The regulations in the states of Washington, Idaho and Montana are similar in terms of the provisions of the BFB and operations on the Interstate System (IS) and National Network highway system (NN). The specified maximum GVW limits in these states are: 47,850 kgs in Washington and Idaho; and 59,400 kgs in Montana. Permits are generally required to operate at GVW greater than 36,300 kgs on the IS highways. These permits are obtained across the counter for a fee. Once the permit is obtained, the carrier must at any time be able to demonstrate that the vehicle is in compliance with the axle weight limits and BFB to on-road enforcement personnel. The overall vehicle length is not regulated in Washington but the box length is limited to 20.73 m. In Idaho, the maximum overall vehicle length is limited to 32.0 m and the box length limited to 28.96 m for operations on the IS and NN. Montana's length restriction is similar to Washington except that the maximum box length is 28.34 m. The regulations in Michigan are quite different from those in the Northwestern states. A higher maximum GVW in Michigan is 63,950 kgs. The permitted maximum axle weights are determined as a function of spacing between the axles. The overall vehicle length is not regulated but the semitrailer length is limited to 17.4 m and trailer lengths for double trailer configurations to 8.7 m.

EXAMPLES OF LESS COMMON CONFIGURATIONS

Figure 1 shows sketches of the sample of less common configurations examined in this paper. These trucks are used primarily for transporting a variety of weight-out freight for both domestic and international trade. Examples of freight include, agriculture produce, wood chips, logs, imported semi-finished manufactured products like machinery, primary export produce such as hay and beef. Products for international trade are transported in containers. The truck trailer combination with adjustable long drawbar is designed to increase the allowable GVW, depending on the number of axles in order to satisfy the BFB provisions. These are used for commodities such as, gravel, fuel and grain. They are normally used for short haul operations. This configuration is a classical example of trucks configured purposely to maximize the requirements of the U.S. Federal BFB. Variations in this configuration are the number of axles on the truck and/or trailer and the use of liftable axles on the truck.

The use of liftable axles on the semitrailers is common in some states of the US and Provinces of Canada. The single tire auxiliary liftable drive axle with airbag suspension is however not very common. The purpose of introducing the auxiliary liftable axle is to distribute the weight better on the pavement so as to minimize the potential damage. Figure 1 shows three examples of trucks equipped with this type of axle: (i) the 8-axle tractor semitrailer (4-S4) wood chip truck; (ii) 4-S4 container; (iii) and the 6-axle tractor pole trailer logging truck. The wood chip truck is an example of configurations that take advantage of the provisions of the TS&W regulations to optimize the transportation of specific types of freight. This truck has a unique body type designed to have a low center of gravity so as to ensure adequate stability. This configuration is also used for hauling fuel hog. The container hauling truck plays an important role in international trade in the transportation of weight-out freight such as semi-processed resource products for export and imported finished consumer products. Container movement is of economic importance in international trade.

Logging trucks, also illustrated in Figure 1, are also designed to optimize operations by assuming different configurations depending on whether it is loaded or unloaded. This truck can be folded when empty and operates as a straight truck and as tractor semitrailer combination when loaded (Figure 1). Logging trucks present an interesting example of the importance of the uncommon trucks. The logging industry routinely transports high payloads on public highways and on private logging roads that are often narrow and with substandard horizontal curves. To operate effectively on these roads, special types of articulated vehicles have been developed in various parts of Canada and the U.S. These types of trucks consist of standard highway tractors and one or more articulated units, and have certain unique design features which are virtually unknown on conventional articulated heavy vehicles designed for highway use. The major differences between these logging trucks and the more conventional commercial articulated vehicle are:

(1) The number of the articulation points is equal to the number of vehicle elements, while in the case of the conventional vehicles of n articulated units the number of the articulation points is n-1.

(2) Due to the increased number of articulation points, one of the articulated vehicle units (usually the pole trailer) must has a "sidding reach" (i.e., an extendable (telescoping) length).

These examples do not exhaust the possible list of truck configurations that can be classified as less common. These examples are used to explore certain physical and operating characteristics relative to the more common configurations.

ANALYTICAL FRAMEWORK

In policy decisions making, certain analyses are required to provide the technical basis for policy initiatives. Such analyses include infrastructure impacts, safety, environmental, productivity of freight and balance of modal competition. It is recognized that there are a large number of different truck configurations operating on the highway system each configured to satisfy a specific regulatory requirement and for a specific set of uses. It is practically impossible to base the policy decisions on the responses or impacts on every existing configuration or those expected to be induced as a result of a regulatory policy. More often, decisions are based on the potential impacts of the more common configurations. This is the usual and logical approach given that any policy revisions will most likely affect the more common configurations. This approach however ignores the potential impacts on the less common or the outlying configurations. The implicit assumption is that, any impacts exhibited by the common or presumably representative configurations should account sufficiently for all possible configurations in the spectrum.

The outlying or less common truck configurations may be of interest in understanding their importance in carriers and shippers decision making process regarding freight equipment selection, modal competition and inter-jurisdictional freight movement. The analyses presented in this paper address two questions: (i) should these configurations be considered in TS&W policy impact analyses? (ii) are the common configurations truly representative of the performance characteristics of the wide range of trucks likely to operate under a given set of TS&W regulations?

The following sections discuss the potential impacts of the study trucks relative to a baseline truck in terms of safety related dynamic performance measures, operating efficiency measured by the equivalent single axle load (ESAL) per payload, and highway geometry improvements. Only brief discussions of the evaluation methodologies are presented for the sake of completeness. Detailed discussions on these can be found elsewhere. The axle weights and spacings used in the analysis are derived from knowledge of the existing trucks and the prevailing maximum limits in the jurisdictions in which they operate.

DYNAMIC PERFORMANCE MEASURES

Analysis of safety related dynamic performance properties of trucks is an integral part of the analytical approach in the development of TS&W regulations as well as vehicle design. These assessments are critically important to ensure that vehicles are manufactured to possess desirable performance properties that satisfy safety requirements. Certain dynamic performance measures appear more important than others in terms of their casual relationship to accidents. Fekpe et al. (1997) found that three performance measures namely, Load Transfer Ratio (LTR), Static Rollover Threshold (SRT) and Rearward Amplification (RWA) are critical in assessing the dynamic performance properties of heavy trucks. Some analyses have linked these measures to risks of certain classes of accidents (Ervin, 1986). The analysis presented in this paper focuses on these three measures. Results of other measures, high and low speed offtracking are also determined as shown in Table 1.

Table 1. Dynamic Performance Measures

Configuration	GVW (kgs)	LTR	RWA	SRT	HOF (m)	LOF (m)
3-S2 baseline	36,300	0.39	1.11	0.46	-0.305	5.9
6-axle truck trailer	43,000	0.46	1.51	0.38	-0.68	8.4
4-S4 container	47,300	0.46	1.22	0.38	-0.39	5.8
4-S4 woodchip	47,850	0.46	1.17	0.37	-0.38	6.3
3-S1111van	47,850	0.44	1.30	0.41	-0.53	5.0
4-P2 Pole logger	43,600	0.42	1.76	0.45	-0.4	4.8

LTR- Load transfer ratio *RWA - Rearward amplification*
SRT - Static rollover threshold *FD - Friction demand*
HOF - high speed offtracking *LOF - Low speed offtracking*

The 5-axle tractor semitrailer with 53-foot trailer was used as the baseline truck for comparison. This truck is the most common truck configuration in the U.S. and Canada and normally used as the basis of comparative analysis. Percent departures of the dynamic performance measures from the corresponding values of the baseline truck are shown in **Figure 2**. It is observed that the configurations studied generally perform better than the baseline truck in SRT and worse than the baseline truck in RWA and LTR. The percent deviations are in the range of 7-18 percent for LTR, 3-20 percent for SRT and 10-58 percent for RWA. The 4-S4 combinations (woodchip and container body types) exhibit the least deviations overall (less than 20 percent). The truck trailer and multi-axle semitrailer configuration (3-S1111) however, show wide deviations from the baseline truck values. An analysis of the dynamic performance of different logging truck configurations (El-Gindy et al., 1994, and Tong, et al. 1995) showed that most of these uncommon heavy trucks perform within the performance limits of the common commercial trucks.

Earlier studies (Fekpe et al. 1997) found that GVW is a critical parameter affecting dynamic performance. Dynamic performance deteriorates rapidly with increasing GVW for any given configuration. These trucks were analyzed at GVW that are between 12 and 32 percent respectively higher that the baseline truck (**Figure 3**). It can be deduced that when operated at similar GVW as the baseline truck, some less common configurations are likely to perform better in all three critical measures. Configurations with tridem drive axles generally have better dynamic performance properties than those with tandem drive axles.

HIGHWAY GEOMETRY

In terms of highway geometry, offtracking and swept path width are the key truck characteristics that affect the ability of existing roadway system to accommodate larger trucks. The low speed offtracking (LOF) is measured as part of the dynamic performance evaluation (Table 1). This measure has implications for safety, highway geometry improvement and traffic operations. The dimensional and operating characteristics of some trucks could require certain highway geometry improvements to accommodate them adequately to ensure their safe operation. For example, the use of longer and heavier combination vehicles could lead to significant productivity gains for certain portions of the trucking industry. However, the current roadway system, may not be adequate to fully support any or all of the proposed new truck configurations.

Highway geometric elements that may be require improvements includes horizontal curves on mainline roadways, curb return radii and right-turn roadways for at-grade intersections, horizontal curves on freeway on- and off-ramps. Highway geometry impact evaluation does not consider high-speed offtracking, because it was found to be less critical than low-speed offtracking (Fekpe et al., 1998). The low speed offtracking of the trucks are compared with the baseline truck to provide an indication of the need for highway geometry improvements.

Figure 2 compares the LOF of the study trucks with the baseline truck. It is interesting to note that, the LOF values for the two 4-S4 configurations are quite different. The LOF of the wood chip truck is about 7 percent higher than the baseline truck while the container truck compares very well (< 2 percent below) with the baseline value (Table 1). The GVW of these two 4-S4 combinations are 47,300 kgs and 47,850 kgs respectively. These are about 32 percent higher than the baseline truck GVW of 36,300 kgs. The logging truck offtracks the least among the trucks examined. The GVW of this truck is 43,500 kgs, that is, about 20 percent more than the baseline truck. The truck trailer combination offtracks the most, about 42 percent more than the baseline truck. These results show that the GVW is not a major determining factor of LOF. The results indicate that some less common truck configurations require more road space to operate safely without encroaching on adjacent lanes or curbs. Highway improvement costs to accommodate some less common trucks will be higher than required for the baseline truck.

OPERATIONAL EFFICIENCY

The relative pavement damaging potential of trucks are conventionally and conveniently evaluated in terms of equivalent pavement loading. Truck productivity, from the highway agency's viewpoint, can be derived from the payload and the relative pavement damage potential. Fekpe (1995) defined efficiency in terms of safety related dynamic performance measures, highway infrastructure damage and productivity. Given adequate stability and control properties, the operational efficiency is the ratio between the potential highway pavement measured by the equivalent standard axle to the average payload. This study highlighted the importance and the possible role of considering truck productivity in regulating the sizes, weights, and operating conditions for heavy vehicles. This concept of efficiency is used to compare the relative efficiencies with the baseline truck.

The operational efficiencies of these trucks are also compared to the baseline truck in Figure 3. The operational efficiencies of the truck trailer combination and the 4-S4 container truck compare very favorably (< 1 percent above) with the baseline truck. The 4-S4 woodchip truck on the other hand, shows significantly higher (38 percent) operational efficiency compared to the baseline truck. The operational efficiency of the pole trailer logging truck compares very well with the baseline truck. The configuration with multiple single axles on the semitrailer (3-S1111), is the least efficient of all trucks investigated (66 percent less than baseline truck). This truck has much higher pavement damaging potential than the expected payload benefit. The results suggest that wide ranges of operational efficiencies could be expected.

DISCUSSION

Based on the results presented in the previous sections, an attempt is made to address the questions posed earlier. The analysis is too limited to provide sufficient data for any general statements on the subject to be made. The discussions presented in this section are intended to serve as indications rather than firm conclusions. The results show that the characteristics of baseline truck lie somewhere in the range exhibited by the less common trucks investigated.

(i) should these configurations be considered in TS&W policy impact analyses?
The less common configurations examined possess properties that are worse or better than the average or representative baseline value in a number of respects. The range of variation suggests that the baseline truck may not account for the possible full range of operational characteristics for all possible truck configurations in the traffic stream. The results suggest that in order to capture a wider range of operational characteristics, it may necessary to consider samples of the less common configurations in policy impact analyses. While it may not be practicable to identify and analyze all possible configurations, or provide for the specific needs of the full range of possible configurations, it may be important to have an idea of the variation about the mean depicted by the selected baseline truck(s). Examples of less common configurations to consider may include samples from trucks with tridem drive axles; those with auxiliary airbag single tired drive axles; trucks with adjustable tongues; semitrailers with unconventional axle spacings; and trucks with rear lift axles. Their inclusion will provide the opportunity to better assess the full range of potential impacts and cost implications.

(ii) are the common configurations truly representative of the performance characteristics of the wide range of trucks likely to operate under a given set of TS&W regulations?

The results seem to suggest that the common configuration approach in impact assessment does not provide a true representation of the range of performance properties and requirements. Given that some of the less common trucks have better operating efficiencies their inclusion in the analysis might help promote regulations and policies that optimize vehicle design, truck operations, highway infrastructure usage and maintenance. Using the mean or median value as the basis of freight transport policy decisions ignores the outlying effects and may not necessarily provide for the needs of a large majority of configurations that are likely to make up the fleet.

As discussed earlier the less common truck configurations have an important role to play in freight transportation. The common configurations are used to transport a wide range of freight and sometimes less efficiently. The less common truck configurations emerge in response to specific needs in freight movement while taking full advantage of the provisions of the governing regulations controlling their sizes and weights. The importance of these less common configurations can also be discussed in terms of the specific circumstances in which they are employed and the regulatory controls that permit their usage. In general, carriers attempt to optimize operations by selecting equipment that maximize allowable weights and dimensions. The truck configuration and body types selected are dependent on the commodity type. Ultimately, the less common trucks tend to be optimally utilized in freight movement.

CONCLUDING REMARKS

This paper presents a preliminary analysis that investigates certain performance characteristics of less common truck configurations relative to the more common trucks. The results suggest that the consideration of the common trucks only in potential policy impact assessment is limiting. The range of variation of impacts can be more adequately assessed by considering samples of the less common truck configurations in the analyses. These less common configurations emerge to optimize the provisions of regulations governing the physical and operating characteristics of trucks and in response to the needs of specific freight. These trucks have important roles to play in freight movement in both short and long haul operations.

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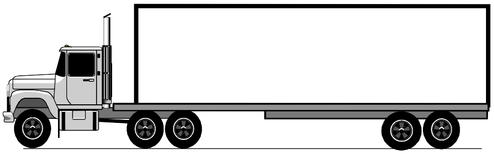
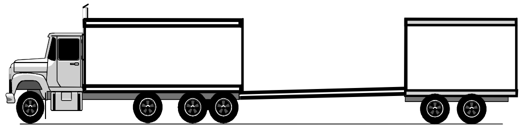
GVW = 36,300 kgs.



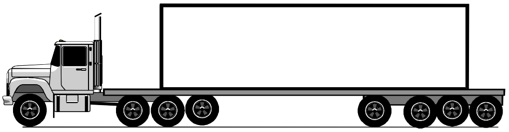
5-axle Tractor Semitrailer (3-S2)- "Van"
Baseline truck

GVW = 43,000 kgs.



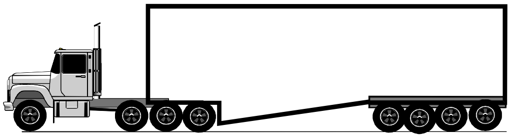
6-axle Truck Ttrailer (BFB)
"Gravel"

GVW = 47,300 kgs.



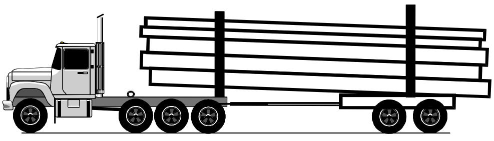
8-axle Tractor Semitrailer (4-S4)
"Container"

GVW = 47,850 kgs.



8-axle Tractor Semitrailer (4-S4)
"Wood chips"

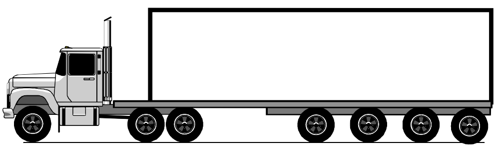
GVW = 43,600 kgs.



6-axle Tractor Semitrailer (4-S3)
"Logging (loaded)"

6-axle Tractor Semitrailer (4-S3)
"Logging (unloaded)"

GVW = 47,850 kgs.



7-axle Tractor Semitrailer (3-S1111)
"Van"

Figure 1. Less Common Truck Configurations Investigated

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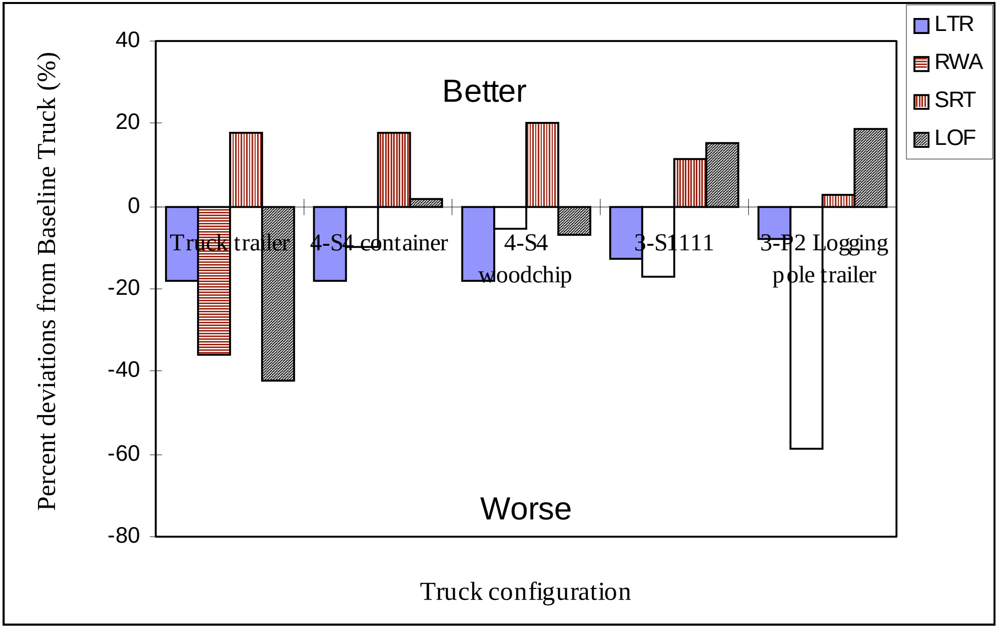

Figure 2. Comparison of Dynamic Performance Measures

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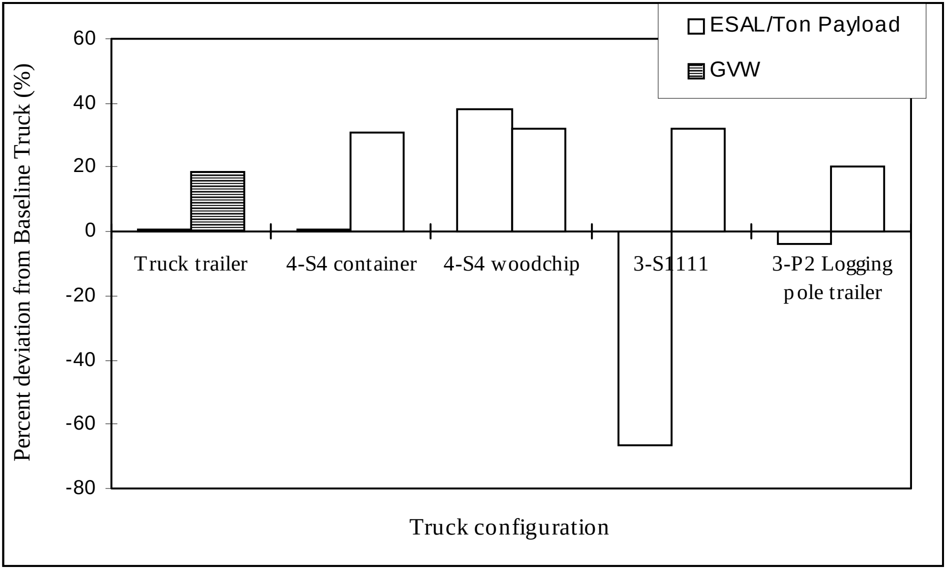

Figure 3. Comparison of Operational Efficiency and GVW

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