THE INFLUENCES OF VEHICLE WEIGHT AND DIMENSION (VWD) REGULATIONS ON TRUCK FLEET CHARACTERISTICS : LESSONS FROM CANADA

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ABSTRACT

There are various factors influencing the dimension, weight, and configuration characteristics oflarge trucks operating on highway network. One of the most important factors is vehicle weight and dimension (VWD) regulation governing those trucks. In Canada, the governing VWD regulations have had a marked effects on truck fleet characteristics. In examining the VWD regulatory system and its influences on truck fleet characteristics, certain patterns emerge which will be potentially applied to trucking situation in Thailand. This paper is prepared to present : the Cauadian VWD regulations; the effects of VWD regulations on truck fleet selection, truck fleet mix, and gross vehicle weight (GVW); VWD regulatory enforcement consideration; limitation of transferability; and conclusion.

บทคัดย่อ

มีปัจจัยหลายอย่างที่มีอิทธิพลต่อขนาด น้ำหนัก และรูปร่างลักษณะของรถบรรทุกขนาดใหญ่ซึ่งวิ่งอยู่บนทางหลวงทั่วไปปัจจัยที่สำคัญที่สุดปัจจัยหนึ่งคือ กฎหมายข้อจำกัดเกี่ยวกับขนาดและน้ำหนักบรรทุกซึ่งควบคุมรถบรรทุกเหล่านั้นอยู่ ผลจากการศึกษาในประเทศแคนาดา พบว่า กฎหมายข้อจำกัดเหล่านี้มีอิทธิพลอย่างยิ่งต่อลักษณะของรถบรรทุก ดังนั้น การศึกษาระบบโครงสร้างของกฎหมายข้อจำกัดดังกล่าวรวมทั้งศึกษาอิทธิพลของกฎหมายข้อจำกัดนี้ต่อลักษณะของรถบรรทุก จะทำให้เราทราบถึงรูปแบบความสัมพันธ์ที่เกิดขึ้นระหว่างกฎหมายข้อจำกัดนี้กับลักษณะของรถบรรทุก ซึ่งอาจประยุกต์ใช้กับสภาพรถบรรทุกในประเทศไทยได้ บทความนี้จะบรรยายถึงหัวข้อต่าง ๆ เกี่ยวกับ : กฎหมายข้อจำกัดเกี่ยวกับขนาดและน้ำหนักบรรทุกของรถบรรทุกในประเทศแคนาดา; อิทธิพลของกฎหมายข้อจำกัดดังกล่าวต่อการเลือกใช้ประเภทของรถบรรทุก, ต่อสัดส่วนของจำนวนรถบรรทุกประเภทต่าง ๆ ที่วิ่งอยู่บนทางหลวง, และต่อน้ำหนักของรถบรรทุกป อิทธิพลของมาตรการการควบคุมให้เป็นไปตามกฎหมายข้อจำกัดเกี่ยวกับขนาดและน้ำหนักบรรทุก; ข้อจำกัดในการถ่ายทอดความรู้ที่ได้มาสู่ประเทศไทย; และบทสรุป

INTRODUCTIGN

There a·e various factors influencing the dimension, shape, weight, and configuration characteristics of large trucks operating on highway system. One of the most important factors is vehicle weight and dimension (VWD) regulations governing those trucks. The relationship between VWD regulations and truck fleet charateristics is important to the highway and bridge engineers and planners. This is because the VWD regulations and their relaxations are critical factors in both design and maintenance of highway system

for example, dimensions and configurations are of direct importance to many geometric design; axle weight and tire pressure affect pavement design; and gross vehicle weight (GVW) and its distribution are of particular importance to bridge structures. In Canada, the VWD regulations governing trucking industry have had a marked effects on truck fleet and operating characteristics. In examining the VWD regulatory system and its influences on truck fleet characteristics, certain patterns emerge. The purpose of this paper is to review recent Canadian literature and publications concerning these matters to extract the areas of relevance which will be possibly applied to the trucking situation in Thailand.

CANADIAN VWD REGULATIONS

VWD regulations are the governmental tool to prevent highway infrastructure such as highway geometry, pavements, and bridges from rapid deterioration due to the operation of too heavy and too large truck configurations. In addition, the effects of truck operational performances (i.e. offtracking, braking, passing manoeuvres, etc.), traffic considerations (i.e. highway traffic capacity and level of service, etc.), historical accident records, environmental impacts (i.e. vibration, noise, air pollution, etc.) and public concerns (i.e. small cars vs. big trucks, etc.) also have some influences on VWD regulatory setting. VWD regulationsgenerally restrict on the maximum size (height, width, and length) and maximum weight (tire weight, axle weight, and gross vehicle weight (GVW)) of different types of trucks. However, in some cases, the bigger and heavier trucks were allowed to operate under special permits.

The Canadian VWD regulations are composed of six principal elements [1]. These elements are :

- vehicle height
- vehicle width
- vehicle length (for trucks and tractors, trailers, semitrailers, and combinations)
- tire weight
- axle weights (for single-front-steering, other-front steering, single, tandem, triple axles
- gross vehicle weights (GVW)

In addition to these principal elements, there are a number of other VWD regulatory elements such as axle spread, axle spacing, kingpin-to-rear of unit, behind cab-to-rear of unit, etc., interacting and complicating those principal elements [1]. These VWD regulatory elements are differently established and administered among the different provinces. This, coupled with the complicated juris dictional structure (e.g., municipal, territorial, provincial, and federal governments) leads to a complex and nonuniform VWD regulatory structure. The complexity and non-uniformity of the VWD regulations strongly affect truck fleet characteristics andtheir operations. For example, most of truck configurations operated under multiple VWD regulations in differently restrictive regions must conform to the least common regulatory denominators, or must reduce their carried load or change their configurations prior to passing through the higher restrictive region.

Over time, the Canadian VWD regulations have been relaxed in the direction of providing the utilization of bigger and heavier trucks. For examole, on primary highways in the Prairies, the single-axle weight, tandem-axle weight, and maximum GVW limits were increased from 8.2, 14.5 and 33.6 tonnes to 9.1, 16.0 and 56.0 tonnes, respectively,

according to the Prairie Highway Strengthening Program (H.S.P.) in 1974. This VWD regulatory relaxations could stimulate (5-axle) tractor-semitrailer units to operate on primary highways at GVWs of 36.4 tonnes (assumming 4.5 tonnes steering single axles) and also allowed double trailer (A-train) units to effectively operate on primary highways at GVWs of 50.0 tonnes [2]. Further for primary highways, the maximum GVW limit was increased to 53.6 tonnes in Alberta and Saskatchewan and to 56.5 tonnes in Manitoba, and for secondary highways, the maximum GVW limit was raised from 33.6 to48.8 tonnes in the prairie provinces according to their VWD regulatory changes in 1981/82. This change allowed double trailer combinations operated on primary highways to register at the GVW limits equal to the summation of axle weight limits of all axle sets in those combinations and permitted double trailer units to effectively operate on secondary highways [2]. For dimension limit changes, in 1979, the combination length limit was increased from 20.0 m. to 21.5 m. to facilitate the utilizations of double trailer combinations encouraged by the GVW regulatory change in 1974. In 1980, this limit was raised againto 23.0 m. to facilitate the use of long-wheel base tractors in double trailer unit[3]. However, the height limit of 4.15 m. and width limit of 2.60 m. are remaining constant.

The main reason of introducing these VWD regulatory relaxations was to improve economy and uniformity in trucking operations because the utilization of bigger and heavier trucks operated under the more uniform VWD regulations among several regions would lead to the higher efficiency and productivity of truck transportation. Table 1 summarizes the allowable limits on height, width, length, tire weight, axle weight, and GVW for various truck types in different provinces as of January, 1988 [1]. It should be noted that a lot of other details concerning VWD regulations was not included in this table.

THE RELATIONSHIP BETWEEN VWD REGULATIONS AND TRUCK FLEET CHARACTERISTICS

The following topics will present the effects of VWD regulations on truck fleet selections, truck fleet mix, and GVW. It should be noted that these effects are based on pre-RTAC VWD regulations (before February12, 1988).

The Effects of VWD Regulations on Truck Fleet Selection

The truck operators face three basic options in response to the changes in VWD regulations. The first option is to continue using their existing truck configurations. In this situation, the truck operators can get the benefits from the VWD regulatory changes by directly increasing GVW limits up to the levels equal to the summation of the present axle-weight limits of all axle sets in those trucks and/or by increasing axle weight limits (and therefore GVW limits). The second option is to modify the existing truck configurations to be more productive ones (e.g., adding more axle, changing axle position/spreads, adding a trailer). The third option is to adopt the new truck configurations to replace the existing ones (e.g., purchasing 7-axle double trailer (A- or B-train) units to replace a 5-axle (3-S2) tractor semitrailer combinations). The typical features of tractor semitrailer, A- and B-train double trailer units are illustrated in Figure 1.

Table 1 Canadian weight and dimension regulations

	ALLOWABLE DIMENSIONS (metres)								
	height	width	length						
			truck or tractor	full trailer	semi trailer	combinations			
						tractor -semi	truck + trailer	A-train	B-train
Nfld	4.15	2.6	12.5	14.65	14.65	20.0	20.0	"	21.0
NS	4.15	2.6	12.5	14.65	14.65	21.0	21.0	"	21.0
PEI	4.5	2.6	12.2	none	none	20.0	"	"	"
NB	4.12	2.6	12.5	14.65	14.65	21.0	21.0	"	21.0
Que	4.15	2.6	12.5	14.65	15.5	23.0	23.0	23.0	23.0
Ont	4.15	2.6	12.5	12.5	14.65	23.0	23.0	23.0	23.0
Man	4.15	2.6	12.5	12.5	none	20.0	21.5	23.0	23.0
Sask	4.15	2.6	12.5	12.5	14.6	20.0	23.0	23.0	23.0
Alta	4.15	2.6	12.5	12.5	none	20.0	23.0	23.0	23.0
BC	4.15	2.6	12.5	12.5	14.65	20.0	23.0	23.0	23.0
Yukon	4.2	2.6	12.5	13.5	13.5	22.5	22.0	"	"
NWT	4.2	3.05	12.5	12.5	none	21.5	21.5	24.4	24.4

	ALLOWABLE LOADS (kg, except tire loads) (3)							
	tires kg/mm	single axle		tandem axle	triple and/or triaxle	maximum gvw			
		front steer	non-front			truck	truck + trailer	tractor semi	train (2)
Nfld	10	9,000	9,000	18,000	27,000	34,000	52,500	48,500	52,500
PEI	10.7	9,000	9,000	18,000	27,000	26,082	"	53,296	"
NS	rating	9,000	9,000	18,000	27,000	34,000	50,000	48,500	50,000
NB	10.7	9,000	9,000	18,000	27,600	34,000	56,500	48,500	56,500
Que	rating	8,500	10,000	20,000	30,000	37,500	57,500	57,500	57,500
Ont	11	9,000	10,000	19,100	30,000	47,500	63,500	63,500	63,500
Man	9	8,190	9,100	16,000	16,000	32,000	56,190	40,190	56,500
Sask	9	5,500	9,100	16,000	16,000	27,000	53,500	37,500	53,500
Alta	9	7,300	9,100	16,800	16,800	30,400	53,500	40,900	53,500
BC	11	9,100	9,100	17,000	26,100	34,000	60,100	52,200	63,500
Yukon	11	9,000	10,000	19,100	28,600	47,500	63,500	63,500	"
NWT	8	6,500	8,128	16,256	16,256	29,256	54,500	39,012	54,500

(Source : Nix, 1987, PP. 14)

The corresponding outcome from VWD regulatory changes is also significantly affected by the operating situations ("weight-out" or "cube-out" operation). "Weight-out" operation is that the truck weights reach their GVW limits, prior totheir space completely filled. Therefore,"Weight-out" operation involves the handling of "high-density" commodities, and the trucks need more weight rather than space. In contrast, "cube-out" operation is that the truck space is fully filled prior to truck weights reach their GVW limits. This operation involves the haulage of "low-density" commodities andthe trucks needspace rather than weight. It should be noted that any truck operated under "weight-out" situation is

primarily sensitive to the changes of axle weight limits and/or GVW limits, but the trucks operated under "cube-out" situation are primarily sensitive to the changes of size limits.

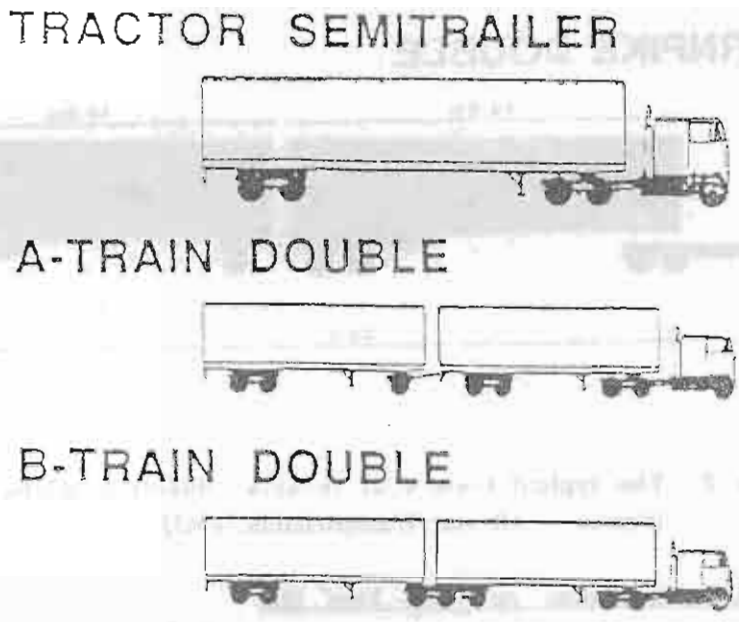

Figure 1. The typical features of tractor semitrailer, A-, and B-train double trailer combinations (Source : RTAC, 1986, PP. 5 and 56)

The truck operators using their own trucks under a single VWD rgulatory regime will take the highest advantage from the governing VWD regulations based on "weight-out" or "cube-out" operating situations. For example, for "weight-out" situation, the operators will employ the truck configurations providing the greatest GVW handling capability, but for"cube-out" situation, the operators will adopt the one which provides the greatest cubic capacity (in practice, usually the longest trailer configuration). However, whenever those trucks are subject to multiple VWD regulatory regimes, the operators have three basic options in response to this circumstance : (i) to employ truck configurations matching the least common regulatory denominators; (ii) to employ the truck configurations which can be modified to operate under several VWD regulatory regimes by means of placing many adjustable devices on those configurations such as sliding fifth wheels, moveable kingpins, liftable axles, sliding axles, etc.; or (iii) to employ the existing configurations, but the operators will have to reduce their carried load (to be less than truckload (LTL) operation) or change their configurations (i.e., turnpike double combination as illustrated in Figure 2 will drop the second trailer off at the border prior to passing through the more restrictive region [1]. Each of these responses will reduce truck transportation efficiency and increase truck operating costs.

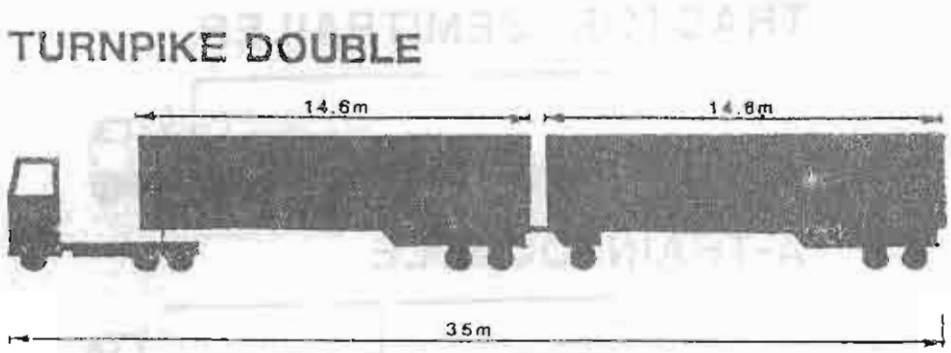

Figure 2 The typical feature of turnpike double combination (Source : Alberta Transportation, 1985)

The Effects of VWD Regulations on Truck Fleet Mix

The utilization of existing truck configurations to carry more payload due to the direct increases of the current GVW limits up to the level equal to the summation of axle weight limits of all axles sets in that configuration (while keeping those axle weight limits constant) or the direct increases of axle weight limits (and therefore GVW limits) will potentially have quicker response than the utilization of a new and more productive configuration. The evidence for this was that, in response to the Western Canadian Provinces Highway Strengthening Program (HSP) in 1974 and in 1981-82, standard (5-axle) tractor-semitrailer combinations in Manitoba rapidly registered at higher GVW limits according to the direct increases of axle weight limits (and therefore the GVW limit), while the double-trailer combinations progressively resistered at higher GVW limit [6]. This is because the operators can directly obtain the benefits from the VWD regulary changes by using their existing configurations to operate at greater GVW levels without any concerns of the capital investment to purchase a new configuration, remaining useful life of the existing configurations, the quantity of commodity to be transported, or any operational problems.

Although the existing truck configurations will respond to the direct increases of GVW limits and/or of axle weight limits (and therefore GVW limits) in a quicker manner as mentioned above, the absolute GVW increases are, however, small when comparing to the GVW increases due to utilization of new bigger/heavier configurations and further increases in axle weight limits and/or GVW limits will be restricted by highway pavement and bridge strength. This regard, coupled with competitive and economic pressures, will force truck operators to employ the bigger/heavier truck configurations. As a result of the Prairie VWD regulatory changes in 1974 and in 1981-82, in Manitoba, double trailer proportions in the truck fleet mix are gradually increasing over time, while the proportions of straight trucks and single drive axle tractors and vehicle combinations employing single drive axle tractors are declining [7]. This is because the maximum GVW limits can be achieved only by using double trailer combinations, while straight

trucks and any other truck configurations towed by single drive axle tractors cannot even come close to that GVW limit. This trend can also be observed from Figure 3 derived from data collected at Manitoba Department of highways truck weight and dimension survey sites [3]. It should be noted that A-train combinations are dominant in double-trailer configurations rather than B-train units because A-train units can carry freight at higher permisible GVW level than B-train units (maximum GVW limits of 56.5 vs 53.5 tonnes).

The increases in individual vehicle length and/or combination length limits will potentially encourage truck operators who presently operate their truck configurations under "cube-out" situations to employ the bigger truck configurations. In Canada, there are two apparent examples illustrating the response of such VWD regulatory changes : (i) the use of a longer semitrailer (48 ft vs 45 ft) in a tractor-semitrailer (3-S2) unit; and (ii) the use of a long wheel-base tractor carrying a drome box in a tractor-semitrailer unit.

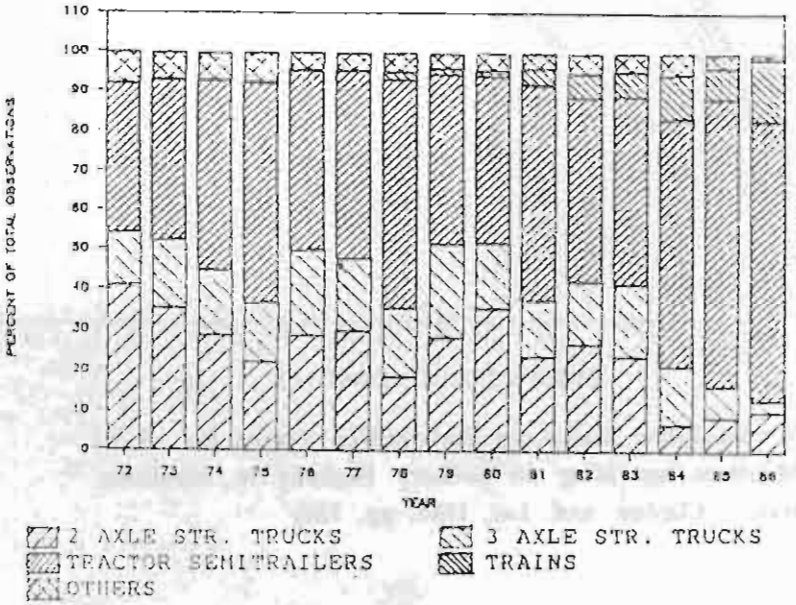

Figure 3 The breakdown of Manitoba truck fleet mix (Source : Plett, 1989, pp. 6-5)

The Effects of VWD Regulations on Gross Vehicle Weight (GVW)

For a particular vehicle configuration type, the heavier trucks implying "weight-out" operations will be primarily sensitive to the GVW and/or axle-weight limit changes. In contrast, the lighter ones implying "cube-out" or "less-than-truck load" (LTL) operation will be insensitive to those changes. For 5-axle (3-S2) tractor-semitrailer units in Manitoba, as the units operated at GVW's lower than the median GVW value had little change in their GVWs, but the units operated at higher GVW's than themedian GVW value showed a trend of significant and progressive increases in their GVWs over time in response to the Prairie Highway Strengthening Program (HSP) in 1974 [7]. Figure 4 illustrates the alterations of the upper half of the GVW cumulative frequency distribution curves (1974-1984) for 3-S2 tractor-semitrailer combinations in response to VWD regulatory changes. According to the Prairie HSP in 1974, the 3-S2 units hauling freight at GVW's above the median GVW value (approximately 31,700 kg) prior to 1974 were employed to haul freight at greater GVW levels provided by the greater maximum GVW limit. Consequently, the GVW cumulative frequency distribution curves of 3-S2 units operating at

the GVW greater than the median GVW value shifted to the right approaching to the new GVW limit. However, the 3-S2 units operating at GVWs lower than the median GVW value had little change. This was because they operated under "cube-out" or "less-than truck load" (LTL) situations which were less affected by GVW limit changes.

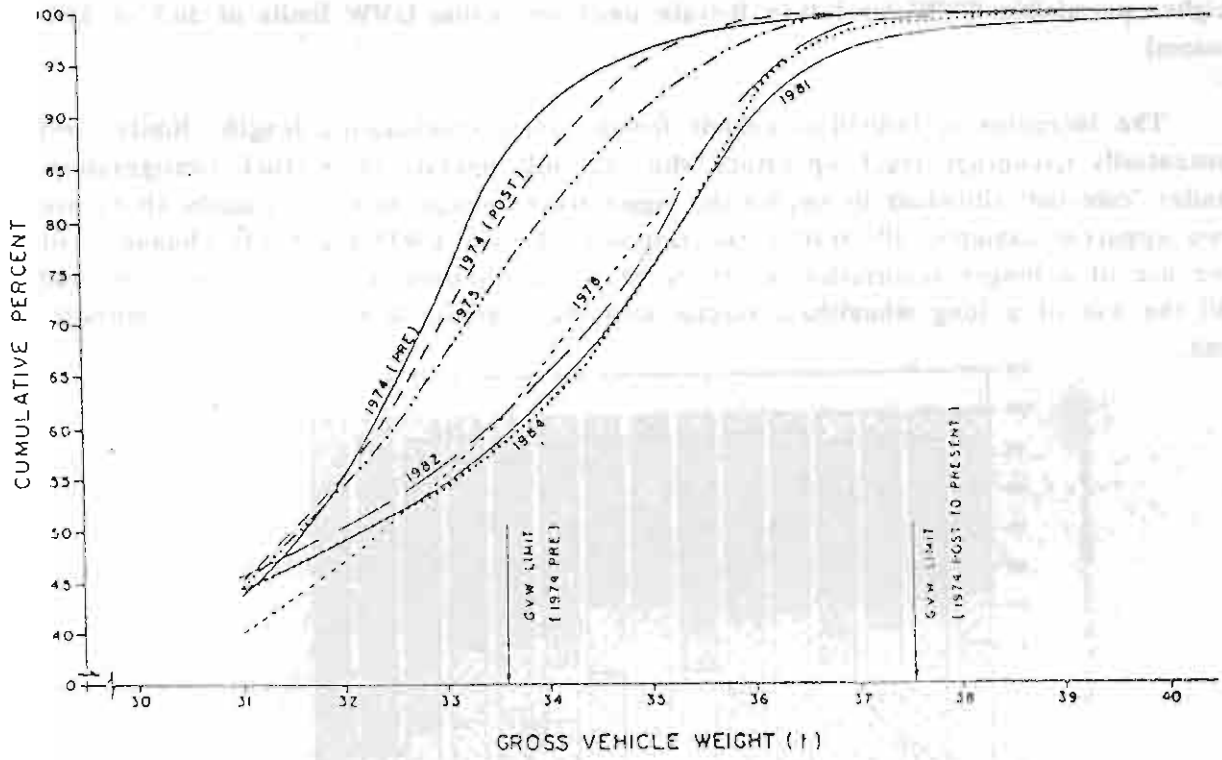

Figure 4 GVW cumulative frequency distribution curves for 3-S2 combinations operating on primary Highway in Manitoba (Source : Clayton and Lai, 1986, pp. 756)

Clayton and Lai [7] found that in Manitoba, 7-axle A-train (3-S2-2) and B-train (3-S2-S2) combinations have been employed to carry freights under "weight-out" situation in which most of these combinations having their GVWs heavily skewed to the high GVW levels approaching to their GVW limits. Consequently, these truck combinations will be very sensitive to the GVW limit changes. In addition, they also found that in Manitoba, 6-axle (3-S1-2) double trailer combinations have been operated at "cube-out" situation in which all of these units were operated at GVW levels significantly lower than their permissile GVW limits. This iplies that the extra weight carrying capacity provided by their allowable GVW limit is not necessary to them. Therefore, this truck type will be insensitive to the GVW limit change.

VWD REGULATORY ENFORCEMENT CONSIDERATION

In addition to the changes of VWD regulatory limits, the VWD regulatory enforcement also affects truck fleet characteristics. Paxson and Glickert [8] pointed out that ".. Enforcement programs are a critical parts of effort to control overweight trucks. Unlessthese programs are effective, truck weight limits are meaningless..." The in appropriate enforcement programs will lead to the more overweight and/or overdimension truck operation. For example, many long wheel-base tractors pulling 48-ft semitrailer combinations

have been used in the Atlantic region, although these combinations exceeded the overall length limit (21 metres) and tracter-semitrailer (3-S2) units are operated at GVW's greater than 37,500 kg (say 42,000 kg) on primary highway networks in Manitoba. For the first example, the expected legal tractor-semitrailer units should be short wheel base tractors with 48-ft semitrailers or long wheel base tractorswith 45-ft semitrailers combinations, and for the second example, the expected legal combinations should be double trailer combinations such as 7 axle A-train (3-S2-2) units [9]. These examples shows that under the same VWD regulatory environment, the different degree ofVWD regulatory enforcement will result in different truck fleet characteristics. It is recommended that the effective enforcement program will be the one which makes truckers realize that the expected cost of fines and penalties, coupled with the possibility of being caught, must be greater than the incentive to overload and/or overdimension [8].

LIMITATIONS OF TRANSFERABILITY

The major purpose of this paper is try to present the general findings of the explicit influences of VWD regulations upon some truck fleet characteristics in Canada. This will give the basic idea of how trucking industry will respond to the changes of governing VWD regulations which will be, to some extent, applicable to trucking operation in Thailand. However, the alterations of truck fleet characterists as a result of the VWD regulatory relaxations in Thailand may be uniquely different from what had happened in Canada. This is because there are a number of other factors affecting those relationship. They are as follows :

- truck fleet characteristics and compositions in Thailand and Canada are very different. For example, under typical VWD regulations, the heaviest and largest truck combination (generally used to haul bulk commodities under "weight-out" situation) in Canada is 7-axle double trailer (A-train) (3-S2-2) unit with maximum GVW of 56.5 tonnes and maximum length of 23.0 m., but the one in Thailand is 3-axle straight truck plus 2-axle full trailer (3-2) unit with maximum GVW of 39.2 tonnes and maximum length of 18.0 m. Further, the dominant truck category employed to carry freights between provinces in Canada is the standard tractor semitrailer (3-S2) unit, but in Thailand is 3-axle (10-wheel) straight truck (3).

- VWD regulatory structures and settings between Thailand and Canada are also very different. While, in Thailand, the only one VWD regulation set is authorized for the whole country, but, in Canada, each province established and administered its own VWD regulation which leads to a complex and non-uniform VWD regulatory structure. Further, several principal VWD regulatory elements governing in Thailand and in Canada are different [10]. In addition, there are a number of other VWD regulatory considerations such as road class, seasonality, liftable axle, axle spread, axle spacing, etc. restricted in Canada, but not in Thailand [1].

- VWD regulatory enforcement practice in Thailand and Canada is quite different. Fine and penalty structures, number and locations ofpermanent and temporary weighting scales being operated, tolerance, seasonality restrictions (spring weight reduction vs winter weight premium), weight-in-motion operations, etc. between these two countries have been differently set up and enforced. This will lead to the difference in overweight and/or overdimension situation in truck flows between these two countries. For example, Ruenkrairergsa [11]) reported that based on the spot axle load surveys carried out at

specific locations to detect the overweight situations of trucks hauling certain bulk commodities in Thailand in 1986, 36 percent of 157 weighed trucks illegally exceeded their permissible GVW limits. However, for the weighed trucks surveyed from 1975 to 1985 in Manitoba, Canada, only 10 percent of36150 weighed trucks illegally exceeded their alllowable GVW limits [12].

- The geometric and structural characteristics of highway pavements, road networks, and bridges are slightly different. These result from the divergence in geometric and structural design method and criteria for these infrastructures between both countries.

In addition to these four factors, the differences of the types and characteristicsof goods to be transported, budget constrain, competitive situation in trucking industry, etc. also have some influences on the differences of the VWD regulation-truck fleet characteristic relationship between these two countries.

CONCLUSION

It is clear that the VWD regulations strongly influence truck fleet characteristics, in terms of truck fleet selection, truck fleet mix, and GVW. The major changes in truck fleet mix and GVW of truck configurations mainly result from the VWD regulatory changes. The VWD regulatory enforcement also affects truck fleet characteristics. However, the relationship between VWD regulations and truck fleet characteristics is very complicated and not fully understood yet. In addition, a number of non VWD regulatory elements such as freight, route, vehicle operational, terminal and end-point characteristics, etc. also have some impacts on those truck fleet characteristics [9]. This paper is prepared to illustrate the obvious impacts of the VWD regulations upon truck fleet characteristics in Canada which would be potentially applied to trucking situation in Thailand. However, it does not mean that what had happened in one place (Canada) will similarly occur in another place (Thailand). This is because there are several differences between these two countries as mentioned above. Consequently, only the basic knowledge is confidently transferable and meaningful.

REFERENCES

[1] Nix, F.P., 1987, "VEHICLE WEIGHT & DIMENSION REGULATIONS CANADA'S TRUCKING INDUSTRY : FINAL REPORT", Transportation Development Center Transport Canada, April 1987.

[2] Clayton A.M. and Nix, F.P., 1986, "EFFECT OF WEIGHT AND DIMENSION REGULATIONS : EVIDENCE FROM CANADA", TRR 1061, Transportation Research Board, 1986.

[3] Plett, R., 1989, "WEIGHT AND DIMENSION CHARACTERISTICS OF LARGE TRUCK COMBINATIONS AS A FUNCTION OF REGULATORY LIMITS : MANITOBA HIGHWAYS", M.Sc. Thesis, Department of Civil Engineering, University of Manitoba,Winnipeg, Manitoba, Canada, 1989.

[4] Road and Transportation Association of Canada (RTAC), 1986, "VEHICLE WEIGHT S AND DIMENSIONS STUDY : TECHNICAL STEERING COMMITTEE REPORT", November, 1986.

[5] Alberta Transportation, 1985 , "A TRAFFIC OPERATION AND PERFORMANCE EVALUATION OF OVERLENGTH TRUCK COMBINATIONS", Transportation Safety Branch, December, 1985.

[6] Clayton A.M., Spark, G.A., and Mak, R., 1983, "TRUCK INDUSTRY TECHNOLOGICAL RESPONSE TO THE WESTERN CANADA HIGHWAY STRENGTHENING PROGRAM", Road and Transportation Association of Canada Annual Conference, Edmonton, Saskatchewan, Canada.

[7] Clayton, A.M. and Lai, M., 1986, " CHARACTERISTICS OF LARGE TRUCK TRAILER COMBINATIONS OPERATING ON MANITOBA'S PRIMARY HIGHWAY : 1974-1984 ", Canadian Journal for Civil Engineering, 1986.

[8] Paxson, P.S. and Glickert, J.P., 1982, "VALUE OF OVERWEIGHTING TO INTERCITY TRUCKERS", TRR 889, Transportation Research Board. 1982.

[9] Klungboonkrong, P., 1989, "TRUCK TRANSPORTATION OPERATING EFFICIENCY AND PERFORMANCE CONSIDERATIONS OF IMPORT TO HIGHWAY DEVELOP-DEVELOPMENT IN NORTHEAST THAILAND: LESSONS FROM CANADA AND OTHER COUNTRIES", M.Eng. Project Report, Department of Civil Engineering, University of Manitoba, Canada, January 1989.

[10] Klungboonkrong, P., 1990, "RELAXING VEHICLE WEIGHT AND DIMENSION REGULATIONS GOVERNING TRUCK OPERATION IN THAILAND", KKU Engineering Journal, the 17th Year, Vol.1-2, (January-February), Faculty of Engineering, Khon Kaen University, Thailand, 1990.

[11] Ruenkrairergsa T. 1990, "PROBLEM OF TRUCK OVERLOADING IN THAILAND," Report No. 123, Material and Research Division, Department of Highways, October 1990.

[12] Clayton, A.M. and Girling, R., 1989, "ASPECTS OF OVERWEIGHT TRUCKING IN MANITOBA", Proceeding of the 24th Annual Meeting of the Canadian Transportation Research Forum, Halifax, N.S., pp. 57-67, 1989.