A PROPOSAL OF AN INTERNATIONAL VEHICLE DESIGNATION STRUCTURE FOR CARGO COMBINATION VEHICLES

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Abstract
Heavy vehicle nomenclature is, in many countries, based on foreign classification schemes that frequently lead to dubious interpretations about the relevant technical characteristics that affect road design and operation. The continuous search for more productive transport vehicles in the heavy goods and general cargo transport market, permitted the advent and continuous growth of a fleet of quite innovative configurations of CCVs-Cargo Combination Vehicles. These vehicles, frequently with two or more towed units, several types of connections between units and different axle arrangements, impact traffic safety, as well as bridge and pavement loading characteristics on the road network. A literature review on classification schemes proposed by other authors and adopted by leading world government agencies and technical organizations, is presented. The paper presents the conceptual base and the proposed designation structure illustrated with some examples.

Keywords: Heavy vehicles, Cargo combination vehicle, Classification, Denomination, Taxonomy.

Résumé
La nomenclature des véhicules lourds, dans beaucoup de pays, est basée sur des schémas de classification étrangers qui mènent souvent à des interprétations douteuses des caractéristiques techniques qui conditionnent la conception et l'exploitation de la route. La recherche continue de véhicules plus productifs de transport de marchandises, et le marché du transport de fret, ont permis l'apparition et la croissance continue d'une flotte de véhicules de configurations tout à fait innovantes de CVM (combinaisons de véhicules de marchandises). Ces véhicules, souvent à deux remorques ou plus, plusieurs types de liaisons entre les modules et des configurations d'essieux diverses, impactent de manière différenciée la sécurité routière, et les caractéristiques de charges des ponts et des routes. Une étude bibliographique est présentée avec des schémas de classification proposés par d'autres auteurs et adoptés par des organismes gouvernementaux de stature mondiale et des organismes techniques. L'article présente la base conceptuelle et la structure proposée illustrée par quelques exemples.

Mots-clés : Véhicules lourds, combinaisons de véhicules de cargaison, classification, dénomination, taxonomie.

1. Introduction

There are various classification systems, within the regulation structures of the economic leading countries, whose directives serve as a reference to the technicians of other countries, with a weaker technical structure.

In Brazil, for instance, ECE standards are widely used by the members of ANFAVEA the tractor units, bus chassis and car manufacturers association. Road designers and constructors use the AASHTO standards, (AASHTO, 1994) adopted “in totum” in the Geometric Design Manual of DNIT – Departamento Nacional de Infraestrutura Terrestre (DNER, 1999).

Australia and Canada have developed their own classification systems, (AUSTROADS 2000), probably motivated by the fact that, in these countries, with relatively large unpopulated areas, transport of low value agricultural and mining products had to be hauled economically over great distances. Market pressure to transport longer and heavier containers in Australia is pushing research and practical trials in the direction of 4 axle tandems, lifting axles, steering axles and even a supplemental dolly to spread axle loads of the tractor unit (Di Cristoforo, 2004). The same is true for Asian countries, as pointed out in the United Nations ESCAP working paper WP/07/02 (UNESCAP, 2007).

Some years ago, Ramsay et al. (2000), Australian researchers, made an important contribution proposing a more general classification, suitable for countries with an expressive number of LCV – Long Combination Vehicle operations. As they pointed out, most of the European countries have more restrictive size and weight standards, in a way that vehicle nomenclature used in Europe is unlikely to be directly relatable to vehicles in other countries.

In South America, for instance, many national regulations, as well as the MERCOSUL regulations, assume that the maximum GCM - Gross Combination Mass is the sum of the maximum legal axle or axle group masses, which leads to the fact that GCM can be, significantly, increased through spaced axle arrangements. Therefore, it is understandable that road authorities and concessionaires of road operations want to make a distinction in terms of road user taxes and tolls between configurations of CCVs – Cargo Combination Vehicles with spaced axle arrangements.

It is also interesting to note that some countries, like Canada, with the aim of promoting more stable combinations, permit higher GCMs for combinations that are connected with type B couplings, inducing the use of this configuration as opposed to A type couplings, (Canada, 2005).

In terms of vehicle licensing, there is also a point in specifying the footprint of CCVs, as Liftable axle arrangements, are permitted in many countries and often lead to considerable changes in stability and control aspects as the combinations travel full, partially loaded, or empty. Even 6x2 tractors may lift the towed axle in the rear axle group in Brazil.

The purpose of this paper is to build upon the proposal made by Ramsay et al. (2000) in a complementary approach that looks promising in terms of having a general international vehicle designation system. If it really reaches this goal is to be evaluated by the international heavy vehicle transport community.

2. Literature Revue

2.1 Europe

Given the quite restrictive size and weight regulations in the western European countries, the code in use was initially put in force in 1970 and is today consolidated in the EEC 70/156 Directive, last revised in 2001 (EEC 70/156, 2001). It is a code developed with the vehicle manufacturers perspective. The code N - motor vehicles with at least four wheels, designed for the transport of goods, subdivided into categories N_1, N_2 and N_3 as a function of GVM, for tractor units; and the code O - trailers (including semi-trailers) subdivided into categories O_1, O_2, O_3 and O_4 as a function of GVM of the trailer; does not propose a designation structure that is suitable to evaluate vehicle road interaction for CCVs in a broader sense, since it does not include information on axle numbers, axle configurations or coupling mechanisms between units.

Combination vehicles are limited to two units by the GCM limit of 40t, or 44t for combinations hauling containers. The European road design circle has promoted basically three combinations: 3 axle truck plus 2 axle full trailer, 2 axle tractor plus 3 axle semi-trailer and the 3 axle truck plus 2 or three central axles trailer hooked to a point close to the rear axle or axle group. The Scandinavian countries operate heavier, 60t GCM truck plus 4 axle full trailer, combinations for many years and the Dutch also made some experiments with the impact of longer and heavier trucks reported in Hoogevelt and Huibers (1998).

2.2 United States of America

There are three different types of classifications, two related to road design and operation and one related to the vehicle manufacturers perspective.

The Federal Highway Administration divides vehicles in 13 classes (FHWA, 2003): motorcycles, passenger cars, buses, two-axle six tire unit trucks, three axle single unit trucks, four or more axle unit trucks, four or fewer axle single-trailer trucks, five axle single-trailer trucks, six or more axle single-trailer trucks, five or fewer axle multi-trailer trucks, six axle multi-trailer trucks, seven or more axle trailer trucks. A complementary scheme was developed by AASHTO (1994) which proposes 15 classes having the wheelbase as the main distinction in the case of heavy or long combination vehicles: passenger car (P), single unit truck (SU), single unit bus (BUS), articulated bus (A-BUS), semi-trailer intermediate (WB-12), semi-trailer combination large (WB-15), semi-trailer full trailer combination (WB-18), interstate semi-trailer (WB-19), interstate semi-trailer (WB-20), triple semi-trailer (WB-29), turnpike double semi-trailer (WB35), motor home (MH), passenger car with travel trailer (P/T), passenger car with boat and trailer (P/B), motor home and boat trailer (MH/B), AASHTO (1994).

The third is the Society of Automotive Engineers – SAE classification system, adopted by the vehicle manufacturers, that is described in Fitch (1994). This is a more detailed classification structure of the designation type, presenting a more detailed identification of the vehicle or vehicle combination in terms of number of units, types of connections and numbers of axles or axle groups in each unit. A truck or a tractor is represented by its number of axles. The connection is represented by an –S when the towed unit is a semi-trailer and by – when the towed unit is a full trailer. The towed unit is represented by the total number of axles, regardless if they are tandems or independent axles.

2.3 Canada

The Transport Association of Canada has its own "Uniform Vehicle Classification System" which is described in Billing (1994), and known as the "Canada Scheme A". This classification scheme comprises 22 classes of vehicles and, similar to the FHWA classification system is used in the context of road design, construction and operation. Provinces have their own standards and probably the most liberal is the Province of Ontario, where a large number of configurations with spaced axles, four axle groups and retractable axles are permitted (Ontario, 1995).

2.4 Australia

From the literature review it seems that Australian researchers and government authorities have made the largest efforts in the last decade to reach consensus on a more general classification system (AUSTROADS, 2000). This is possibly because it is also the country where, geographic and economic conditions led to long road combination vehicles, the so called roadtrains, back in the nineteen fifties and sixties, when most western world countries were running with unit trucks, also known as rigid or straight trucks.

There are two classification systems described in Ramsay et al. (2000): one which is more roadway oriented, similar to the FHWA and TAC system, dividing road vehicles into 12 classes (AUSTROADS, 1994 and Ramsay, 2000), and the other, formerly adopted by the National Association of State Road Authorities (NAASRA) which later became AUSTROADS, which is a designation structure, detailing couplings and axle numbers in each unit. AUSTROADS (2000) is a proposition to substitute the NAASRA denomination structure, but no reference was found to indicate if this proposal has been adopted or not by AUSTROADS in the last decade.

3. The Conceptual Base

A unit automotive vehicle, which propels a combination of vehicles, has two axle groups: the front axle group, with one or two steering axles, and the rear axle group, with one, two, or even three axles, as can be observed on some heavy tractor units in Australia. The rear axle group has one or more axles driven by the engine resulting in a large possibility of denominations in the form of 4x2, 6x2, 6x4, 8x2, 8x6, etc. The characteristics of the drive axle groups are important, in terms of certifying a higher GCM combination for a road network in hilly or mountainous regions, where traction limits may affect safety.

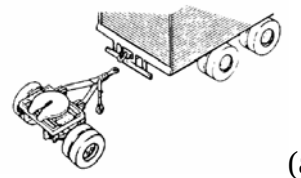
The towed units are of three types: a full trailer, that has a front axle group and a rear axle group, the front group with a chassis, a self steering device and a tow bar that connects it to the leading unit; a semi-trailer, that has only a rear axle group and is connected to the leading unit through a king pin-fifth wheel connection; and a central axles trailer, that has a central axle group and has its chassis connected to the leading unit by a rigid tow bar.

3.1 Coupling alternatives

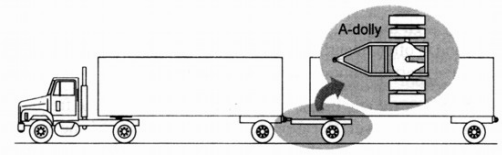
The connections, or couplings between units, can be divided into four classes.
The A type connection, figure 1, with a single draw bar connected to a vertical pin. In many cases the fifth wheel–king pin coupling is substituted by a turntable fixed to the trailer, constituting what is normally called a full trailer. From the stability point of view both are very similar but, if the fifth wheel-king pin coupling is used, the convergent bars should be rigid, as shown on figure 1b, to prevent the dolly from pitching forward during braking. A

type connections only transmit translational forces between the coupled vehicle units, including towing, lateral and vertical forces. Roll moments are not transmitted through A type connections.

The B type connections, figure 2, became a standard in Australia and Canada during the nineteen eighties, because of their improved stability and control characteristics over A type connections. B type connections transmit translational forces as well as roll moments.

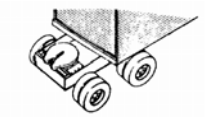


(a)



(b)

Figure 1 – A type coupling



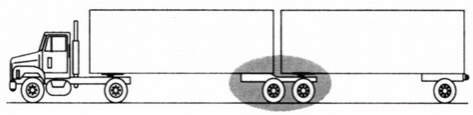
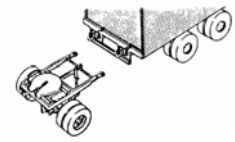


Figure 2 – B type coupling

C type connections, figure 3, where developed during the RTAC–Road Transport Association of Canada study and several alternative configurations of innovative dollies where investigated at UMTRI in the eighties (UMTRI, 1986) including steering axles. This type of connection did not become very popular due to its weight and tire wear increase. Nonetheless, they are still in use in Canada and the USA. C type connections transmit translational forces as well as a part of the roll moments.



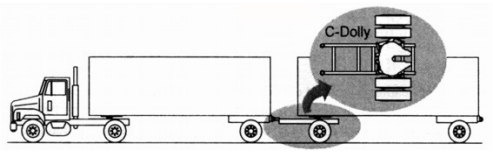
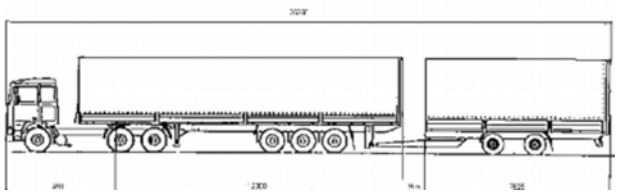


Figure 3 – C type coupling

In Europe, where the European circle limit, of the 5,3m internal and 12,5 external radii, imposes a severe limit on longer cargo combination vehicles, an innovative form to increase transport capacity of the truck plus trailer combinations, within the size and weight restrictions, was the central axles trailer proposed by the Dutch industry in the eighties. The basic configuration is shown on figure 4. To improve stability and permit close coupling because of the overall length limit, the tow bar is connected to a point close to the rear axle of the truck. This solution, with a very long bar running very close to the road surface, is limited to a very high standard road network because of its limitations in terms of negotiating vertical curves. The Dutch industry even developed very smart bar extending devices, actuated in the curves, to gain another row of pallets within the rear trailer.

It is proposed that this special coupling be named a D type coupling.

a



b (Hoogvelt and Huibers 1998)

Figure 4 – Central axles trailer with D type coupling

3.2 Axle configurations

The second point of interest is axle arrangements. In countries where spaced axles do not bring any economic advantage to operators, they simply are not used, because of their negative aspects in terms of tire and pavement wear. In places where there is an economic advantage to the operators, like in Brazil, Argentina, Uruguay and in the Province of Ontario in Canada, for instance, spaced axle arrangements on trailers are quite common.

Taking the Brazilian example, a 1S3 tractor semi-trailer with a tridem has a legal GCM of 41.5t, whereas the 1S3 with a spaced axle arrangement (more than 2.4m between axle centers) on the trailer, has a GCM of 45t, a 4,5t gain just through axle spacing. In terms of ESALS, the first has an approximate total value of 5 and the second an approximate total value of 10, a result that leads to similar conclusions of the increased pavement wear potential as drawn by Salama H. and K. Chatti (2006) through a mechanistic-empirical rutting model. The problems of accelerated pavement wear with spaced axle arrangements also motivated the Ontario Government to study alternative policies to change the operating scenario (Billing, 2006).

A second aspect of axle arrangements that should not be neglected in terms of CCV certification and impact on pavement wear, is the allowance for lifting axles. As pointed out by Billing et al. (1991), such axles were, and still are in use in a number of US states and in some provinces in Canada. There is little or no restriction for lifting axles in South America. Most arrangements permit raising and lowering from the cab. In the case of spaced axles the driver usually raises axles to make turns and lowers them after the turn to reduce tire wear. He also can change the air pressure on the lifting mechanism to reduce axle loads when driving empty or partially loaded, as well as lift axles on toll plazas with axle counting devices, where lifted axles are not charged. In the case of 6x2 tractor units it is common that the driver lifts the rear towed axle on wet pavement and steep grades to improve traction.

Therefore, a truck and CCV denomination system that accounts for a more detailed axle configuration description may be of interest for vehicle certification authorities as well as road operators.

3.3 Tire configurations

As pointed out in the COST 334 study (COST 334, 2000), dual tires and wide single tires may have different impacts on pavements, particularly on thin pavement structures, which, in general, constitute a large portion of the paved road network in the poorer regions of the world. In the recent past, particularly in the European market, one observes also the advent of

smaller wheel diameters on towed units to gain capacity in the cargo compartment. It is shown in COST 334 that this technology may also have an adverse impact on pavement wear.

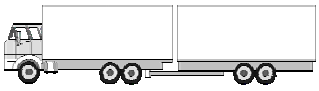
Therefore, a denomination system should also be able to convey information on the tire arrangements used in each of the axles of a truck or CCV, if traffic authorities want to make a distinction in terms of road user charges that are consistent with the potential impact on pavement wear.

4. Proposed Denomination Structure

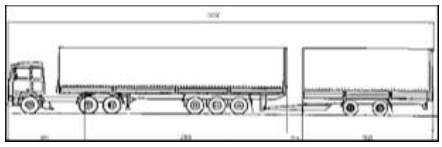
The basic reasoning is that any cargo vehicle can be either a unit truck with a loading bridge or a combination vehicle, with a tractor units and one or more towed units. In the second case the tractor unit (could be more than one) can be of two types: a unit truck with its own loading bridge, or a tractor, also known as prime mover, without a loading bridge. It is proposed that a unit truck receives the designation UXY, where U holds for unit truck, X represents the footprint of the front axle group and Y the footprint of the rear axle group. For tractors, or prime movers, the idea of just XY specifying the front and rear axle group, as proposed by Ramsay et al. (2000), is maintained.

To a tractor unit different towed units can be connected. In the case of a unit truck the connections are usually of type A, or type D (European central axle trailer), but nothing impedes the idea of connecting a semi-trailer through a B type coupling. In the case of a tractor, or prime mover, the usual connecting mechanism is a B type coupling, which historically became an S because the towed unit is a semi-trailer. As proposed by Ramsay et al. (2000) it seems adequate to maintain the S, instead of the B, to represent a kingpin – fifth wheel connection type. So, a towed unit is described by its connector type plus Z axles.

Example: the unit truck plus a central axles trailer on figure 5a would have the designation U12D2 and the semi trailer plus a central axles trailer shown on figure 5b would have the designation 12S3D2.



a U12D2

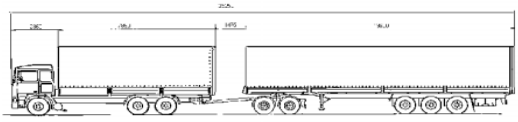


b 12S3D2 (Hoogvelt and Huibers 1998)

Figure 5 – CCVs with D type connectors

If one has A couplings the alternatives are, for example: a tractor semi-trailer towing a 5 axle full trailer with a designation 12S3A2S3, figure 6a, or a unit truck towing the same 5 axle full trailer with a designation U12A2S3, figure 6b.

a 12S3A2S3



b U12A2S3 (Hoogvelt and Huibers 1998)

Figure 6 – CCVs with A type connectors

Up to this point the only changes to the Ramsay et al. (2000) proposal are the substitution of the connector sign – for the letter A and the addition of the D type connector.
For the B type connector or C type connector the Ramsay et al. (2000) proposal is incorporated. The 9 axle tractor semi-trailer configuration of figure 7a, known as a B train or B double, would be a 12S3S3 and the 3 axle tractor with a 2 axle semi-trailer towing a 4 axle full trailer of figure 7b would be a 12S2C2S2,.

As long as standard configurations are used this denomination structure is sufficient, but if spaced axle arrangements are permitted, with a payload increase, as is the case in the South American Market (MERCOSUL, 1998) for the 5 axle tractor semi-trailer shown on figure 8, some information to indicate the difference in GCM should be included in the denomination structure.

a 12S3S3 b 12S2C2S2

Figure 7 – CCVs with B and C type connectors

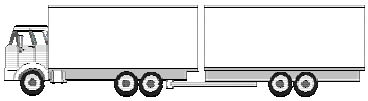
a 11S3 – GCM=41.5t b 11S3 – GCM=43.0t c 11S3 – GCM=46.0t

Figure 8 – Differences in GCM for spaced axle 2S3 configurations in the MERCOSUL

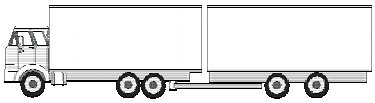
The proposed complement to the Ramsay et al. (2000) proposal is to add subscripts and superscripts to the axle numbers that convey axle configuration information on the subscripts and tire information on the superscripts, if needed. On the tractor units it is possible to convey information on which axles are driven. In the case of a 6x2 unit truck, the denomination structure will require three numbers $U11_d1$ to permit a complete description of the truck. In some countries 6x2 tractor units may be equipped with standard single tires on the trailing axle. In this case the denomination would be $U11_d1^s$. A U12 would always be understood as a 6x4 with dual tires on the rear axles. In the special case of an 8x6 tractor unit one would have, for example, a $U1_d12_d$, which indicates that the first steering axle is driven, the second is a steering trailing axle and the two rear axles are driven.

On figure 9a it is assumed that the CCV has a configuration as depicted on figure 4a, and that the central axles on the trailer are tandem axles (spaced less than a minimum value – 2.4m in South America – with an axle load sharing mechanism) with a standard dual tire configuration. On figure 4a the tractor unit is a 6x2 with a single tire arrangement on the trailing axle. The proposed denomination would be $U11_d1^sD2$. In the second case if one assumes that the trailing axle of the truck is a standard wide single tire axle and the trailer is equipped with small radii dual tires, the denomination would be $U11_d1^wD2_i^r$.

The Canadian (Ontario) 9 axle tractor semi-trailer of figure 10 would receive the denomination $12S1_i41_i$ instead of simply a 12S6.



a $U11_d1^sD2$



b $U11_d1D2_i^r$

Figure 9 – Denominations for the European central axles CCV

Figure 10 – Canadian 9 axle tractor semi-trailer

To take lifting and steering axles or axle groups, like the Australian track axle (Di Cristoforo, 2006), into account, the subscripts may also be used. It just adds complexity because, in some instances, two or three subscripts for the same axle may be required to explain the correct footprint. If, for example, on the Canadian rig, the first axle of the trailer is Liftable and the last is steerable, then the denomination would be $12S1_{il}41_{is}$.

The suggested subscripts are as follows:
d-driving axle; i-independent axle; l-lifting axle; s-steering axle

The suggested superscripts are as follows:
s-single standard diameter tire; w-wide single standard diameter tire; r-small radius tire

5. Conclusions

A relatively precise and consistent designation system of unit trucks and of the vast variety of CCVs that transport cargo around the world, that may improve understanding among transport operators, tractor units and trailer manufacturers, road designers, constructors and operators, and regulatory and enforcement agents, seems to be possible.

It is hoped that discussion and review of this proposal within the International Forum for Road Transport Technology community, may ultimately lead to a system that reaches the goal of a uniform, worldwide accepted, form to describe heavy cargo vehicles.

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