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Abstract – *Road accidents involving heavy commercial passenger vehicle (HCPV) in Malaysia have always been in the spotlight and various efforts have been taken with much attention given on operational issues. At present, the weight and dimensions of HCPV in Malaysia generally regulated under prescriptive standards regulations which do not provide clear safety outcomes and often limits the flexibility about how to achieve it. This paper provides an overview of opportunities and challenges of implementing Performance Based Standards (PBS) regulation for HCPV vehicle in Malaysia based on the Australian PBS regulation implementation for heavy vehicle. It was found that Tail Swing, Braking Efficiency and Maximum Stable Inclination Angle under the existing regulation have or partly met the PBS approach. The opportunities for implementing PBS regulation were explained in terms of the possibility adopting PBS approaches in the existing regulation and second, the institutional readiness to develop and implement it. However, challenges were expected, for example increase in cost of vehicle's assessment. Implementing PBS regulation for HCPV in Malaysia will provide various benefits such as increase productivity, efficiency and most importantly safety.*

Keywords: High capacity passenger vehicle, prescriptive standard regulations, performance based standards regulation, opportunities, challenges

1.0 INTRODUCTION

Heavy commercial passenger vehicle (HCPV) or specifically bus accidents in Malaysia have always in the spotlight and various efforts has been taken by the government especially on operational issues such as introducing the Safety Health and Environment Code of Practice

(SHE COP) for transportation sector (Osman et al., 2009) and relentless enforcement activities. In 2016, the number of fatalities was recorded at all time high where 7,152 road users died on the road and 29 were taking the bus (Road Safety Department Malaysia, 2017). The fatalities involving HCPV are the lowest compared to other road users. Unfortunately, it may not enough to convince the public on its safety and reliability.

In light of improving HCPV safety, this paper presented the opportunities and challenges of adopting PBS approaches to regulate heavy vehicles with focus into HCPV. In regards weight and dimensions, the existing Malaysian HCPV regulations on its construction were generally prescriptively defined. Implementing PBS regulation for HCPV in Malaysia was expected to improve safety, productivity and also lifting the limitations under the prescriptive standards regulation. Table 1 compares the general concept, advantages and disadvantages of prescriptive standard and PBS regulation for heavy vehicle (read including HCPV):

Table 1: Concept, advantages and disadvantages of prescriptive and PBS regulation

(Coglianese et al., 2002; Leary & Burvill, 2005; Calvert, 2004; Edgar et al., 2002)

Prescriptive Standards Regulation	Item	PBS Regulation
Simple set of reference for vehicles to be complied without direct or clear relationship of the on-road performance.	Concept	Vehicles are set to comply a sets of performance, but not restricting how to achieve the objectives.
• Usually direct and easily understood. • Less complex measures for enforcement purposes.	Advantages	• Offer relaxation of prescriptive sets of regulation i.e. overall length of heavy vehicles. • May provide a clearer prediction of impacts on safety and infrastructure i.e. suggest excessive vehicles feasibility to operate on the prescribed roads.
• Not flexible towards changes and development in heavy vehicle technology. • Inadequate to predict impacts on safety and infrastructure. • Less responsibility to the regulated entities (operators) in achieving the safety outcomes. • Perception of the existing regulation is sufficient due to actual outcomes possibly unknown or unexamined.	Disadvantages	• Incurred cost for performance evaluation. • Longer time needed for vehicle approval processes. • The regulations references might not be well understood, lead to poor implementation. • Changes in the regulation may be too frequent due to rapid advancement of technology.

Despite the disadvantages list of PBS approach, question to ask is why implementing PBS for heavy vehicle. The reasons to implement PBS regulation for heavy vehicle could be ranging from various perspectives. Attending the road logistics industry player demand to increase the heavy vehicle loading capacity has been the most cited reason to implement PBS regulation for example by (Knight et al., 2008; Sleath et al., 2006; Cristoforo et al., 2004). Such demand also exists in Malaysia when the Ministry of Transport suggested to increasing the current load limit of lorries after being demanded by the operators (Ahmad, 2016).

Implementing PBS regulation for heavy vehicle does not benefit the operators alone. For example in Australia, the implementation of PBS regulations for heavy vehicles was found to be positively contributed in various aspects such as increased productivity, allowing innovation in vehicle design and operation, improved road safety, traffic operations and asset management, national centric regulation for heavy vehicles, consistent performance assessment procedures, better matching between vehicle's capability and the road system and a uniform system in permitting local and specific-use vehicles (Edgar et al., 2002).

2.0 METHODOLOGY

This paper applied comparative content analysis strategy to identify the possible opportunities of implementing PBS regulation for HCPV in Malaysia. Gap analysis was conducted to analyze the present state of HCPV regulation in Malaysia where the current performance set of Australian PBS regulation for heavy vehicle is the intended future state of regulation for HCPV in Malaysia. The opportunities discussed in this paper defined how to bridge the gap as the last stage of gap analysis.

It was found that five countries have successfully implemented PBS regulation for heavy vehicle which are New Zealand, Australia, Canada, South Africa and Sweden. The implementation in those countries however takes a different approach influenced by factors such as regulatory approach, local road networks design, purposes etc. Nevertheless, Australia has the most comprehensive PBS regulation for heavy vehicle which took more than a decade to be developed (Nordengen, 2014).

3.0 THE AUSTRALIAN PBS

The Australian PBS regulations have been referred and discussed by different authors that wish to adopt PBS approaches in the existing regulation for heavy vehicle (Nordengen, 2014). The approach taken by Australia to develop the regulation was broadly agreed to be comprehensive due to the processes and details involved in developing the performance instruments. The Australian PBS scheme for heavy vehicle aimed to improve the regulations that controlling heavy vehicles safety and infrastructure impacts towards sustainable transport systems. Besides, the PBS regulations was expected to boost innovation and application of new technologies, while providing seamless national operations by relaxing the normally rigid transport regulations under prescriptively defined regulation (Woodrooffe, 2012).

3.1 Background

During the initial stage, there were more than 100 potential performance measures for heavy vehicles covering all relevant areas and after refinement processes, only 25 potential regulatory performance measures reviewed by stakeholder that cover safety and infrastructure related issues (Edgar et al., 2002). Each performance measure was provided with the definition which includes the performance level and measuring methods. Then, the developed regulatory performance standards (up to a disposable level) were tested among the existing Australian heavy vehicle fleet using computer modelling (Edgar et al., 2002).

The Australian PBS regulation for heavy vehicle was guided by five basic principles as basis of the policy framework. These principles were developed through stakeholder consultation and agreed by the Australian Transport Council (ATC) (Edgar et al., 2002). Table 2 shows the five principles and its brief remarks.

Table 2: The principles that guided the development of the Australian PBS regulation (Edgar et al., 2002)

Principle	Brief Remarks
1	PBS will be implemented as an alternative to the existing prescriptive regulations which is a national based system of regulating heavy vehicle safety and infrastructure impacts.
2	The road and traffic conditions must be complemented by the performance standards.
3	To ensure PBS compliancy will be on nationally consistent and practical methods that lies on the principal of that vehicle-related features achieved the performance standards and identifying simple operating conditions.
4	Each party involved in the transport course are responsible for elements in their control to ensure performance standards are achieved and maintained.
5	The proposed PBS operations will be gone through an approval process and the PBS system will apply to two (2) types of access (general and limited routes/regions).

The PBS regulation for heavy vehicle in Australia was carefully developed through six phases to ensure a smooth and transparent implementation. According to Nordengen (2014) and Woodrooffe (2012), the six phases are:

i. <u>Phase A: Performance Measures and Standards</u>
Recognizing the suitable performance measures and standards and at the same time assessing the existing heavy vehicle fleet performance.

ii. <u>Phase B: Regulatory and Compliance Processes</u>
Establishing a regulatory system that allow PBS to operate seamlessly as an alternative (national) to existing prescriptive regulations that also considering the compliance and enforcement arrangements.

iii. <u>Phase C: Guidelines</u>
Preparing guidelines, detailing the procedures and processes for the uniform application of PBS.

iv. <u>Phase D: Legislation</u>
Developing the legislative arrangements for PBS to operate as an alternative to prescriptive regulations.

v. <u>Phase E: Case Studies</u>
Compiling previously conducted works and demonstrating the practical application of PBS to nationally agreed priorities.

vi. <u>Phase F: Implementation</u>
Putting in place the necessary legislative and administrative systems to allow PBS to operate nationally and providing the training and information to support these changes.

Besides, the road and highway network in Australia has been categorized into four (4) types (Level 1 to 4) as a mean to identify the vehicle performance requirement as well as to ensure the existing road network will be optimized based on the types of heavy vehicles that can be operated on various parts of the network. Therefore. where appropriate, different performance levels are specified for each of the four levels (Nordengen, 2014); (Leary & Burvill, 2005).

3.2 The Safety Performance Measures

The current set of performance standards regarding safety under the PBS regulation for heavy vehicle in Australia consist of 16 performance measures (Karlsson et al., 2015). The performance standards are divided into four categories according to different road access. The 16 performance standards and its performance level are as Table 3:

Table 3: The Australian safety performance standards for heavy vehicle (NTC, 2008; Karlsson et al., 2015; Nordengen, 2014)

Performance Category	Performance Standards	Performance Level Per Road Class			
		Level 1 (Unrestricted Access)	Level 2 (Significant Freight Route)	Level 3 (Major Freight Route)	Level 4 (Remote Area Access)
Longitudinal Performance (Low Speed)	Startability (% Slope)	≥15%	≥12%	≥10%	≥5%
	Gradeability (A: Maintain Motion) (% Slope)	≥20%	≥15%	≥12%	≥8%
	Gradeability (B: Maintain Speed on 1% Grade)	≥80km/h	≥70km/h	≥70km/h	≥60km/h
	Acceleration Capability	≤20.0s	≤23.0s	≤26.0s	≤29.0s
Longitudinal Performance (High Speed)	Overtaking Provision	Have been moved to the *Network Classification Guidelines*			
	Tracking Ability on a Straight Path	≤2.9m	≤3.0m	≤3.1m	≤3.3m
	Ride Quality (Driver Comfort)	Yet to be defined			
Directional Performance (Low Speed)	Low Speed Swept Path Width	≤7.4m	≤8.7m	≤10.6m	≤13.7m
	Frontal Swing: Rigid Trucks, Truck Tractors and Buses	Trucks and truck tractors: ≤0.7m; Buses: ≤1.5m			
	Tail Swing	≤0.3m	≤0.35m	≤0.35m	≤0.5m
	Steer Tyre Friction Demand	≤80% of the max. available tyre/road friction limit			

Performance Category	Performance Standards	Performance Level Per Road Class			
		Level 1 (Unrestricted Access)	Level 2 (Significant Freight Route)	Level 3 (Major Freight Route)	Level 4 (Remote Area Access)
Directional Performance (High Speed)	Static Rollover Threshold	≥0.35g (≥0.40g for road tankers and buses)			
	Rearward Amplification	≤5.7 SRT of rearmost unit or roll-coupled set of units			
	High Speed Transient Off Tracking	≤0.6m	≤0.8m	≤10. m	≤12.0m
	Yaw Damping Coefficient	≥0.15m			
	Handling Quality (Oversteer/Understeer)	Yet to be defined			
	Directional Stability Under Braking (Deceleration from 60km/h of Speed)	0.4g braking for rigid trucks and buses			

The Overtaking Provision performance standard is a key component of classifying the heavy vehicle freight network and has been moved to the Network Classification Guidelines. This allows the standard to be applied to the PBS network while maintaining the intent of the standard, at the same time improving the assessment process of individual applications. However, NTC (2008) have provided the maximum vehicle length for different road classes to assist in the application of the Network Classification Guidelines.

Meanwhile, the Ride Quality and Handling Quality performance standards level has yet to be defined in the assessment rules due the fact that the three main components (a performance measure, a test procedure from which to obtain the performance measure and a performance level, or levels, to be satisfied) are not able to be defined to an acceptable level of robustness at that time based on current research (NTC, 2008). The latest publication by Nordengen (2014) for example have excluded Overtaking Provision, Ride Quality and Handling Quality performance standards in his attempt to develop and evaluate a PBS approach for regulating the use of heavy vehicle in South Africa. Besides, other author such as Karlsson et al. (2015) also have not further discussed on the three performance measures except for Handling Quality.

4.0 HCPV REGULATION IN MALAYSIA

This paper only reviews the safety performance standards that are applicable to HCPV. In that context, HCPV in Malaysia currently regulated under the Road Transport Rules (Construction and Use) 1959 and the United Nations Regulation (UNR). The regulations were governed through the Vehicle Type Approval (VTA) procedure as compliance controls before new vehicles to be allowed on the road by the Road Transport Department (RTD), Ministry of Transport Malaysia. Besides, relationship between the vehicle design and the road geometric design is also an important subject and will be discussed. The vehicle and road design conformity will ensure a safe interaction of vehicles and the road.

4.1 The Road Transport Rules (Construction and Use) 1959

The Road Transport Rules (Construction and Use) 1959 is generally a prescriptive standards regulation. The examples of related existing regulation regarding the weight and dimensions of bus vehicle construction in Malaysia are in Table 4.

Table 4: Related rules for public transport vehicle construction under the Road Transport Rules (Construction and Use) 1959 (RTD, 2014)

Reference	Rules	Remarks
10	Overall length of trailer and motor vehicle	(1)(a) West Malaysia – motor vehicle and hinged motor vehicle not more than 9.14m. With special approval, not more than 12.19m. (1)(b) Sabah & Sarawak – motor vehicle and hinged motor vehicle not more than 7.32m. With special approval, not more than 10.06m. (2) West Malaysia – Trailer (not include pulling bar) not more than 6.71m. Sabah and Sarawak – Trailer (not include pulling bar) not more than 4.57m.
11	Overall width of motor vehicle	(1) Not more than 2.28m. With special approval, not more than 2.44m. (2) Any parts of the vehicle except navigation mirrors not more than 6 inches from the outer part of rear tire.
29	Overhang	Not more than 50% of the wheelbase. In condition of vehicle length not more than 6.09m and 60 CWTS, if the overhang is not more than 56%, the overhang must be measured.
36	Overall height of motor vehicle	Single decker vehicle must be not more than 3.2m and double decker vehicle must be not more than 4.57m.
37	Weight of public transport vehicle	(3) Vehicle more than four tires – Not more than 12 ton.

4.2 The United Nations Regulation

Meanwhile, the regulation references in the UNR are both prescriptive and performance based. Malaysia is a member of United Nations Economic Commission for Europe (UNECE) World Forum for Harmonization of Vehicle Regulations or known as WP29 since 4 April 2006 and was obliged to implement the UNR in its current regulations.

Therefore, the government has included the UNR as part of the minimum requirements need to be met by heavy vehicle manufacturers under the VTA. To date, the RTD have gazetted 100 UNR from a total 136 UNR and looking forward to implement it by 2017. HCPV was categorized as M2 and M3 with a total of 52 UNR applicable under the VTA. Figure 1 shows the UNR applicable for HCPV.

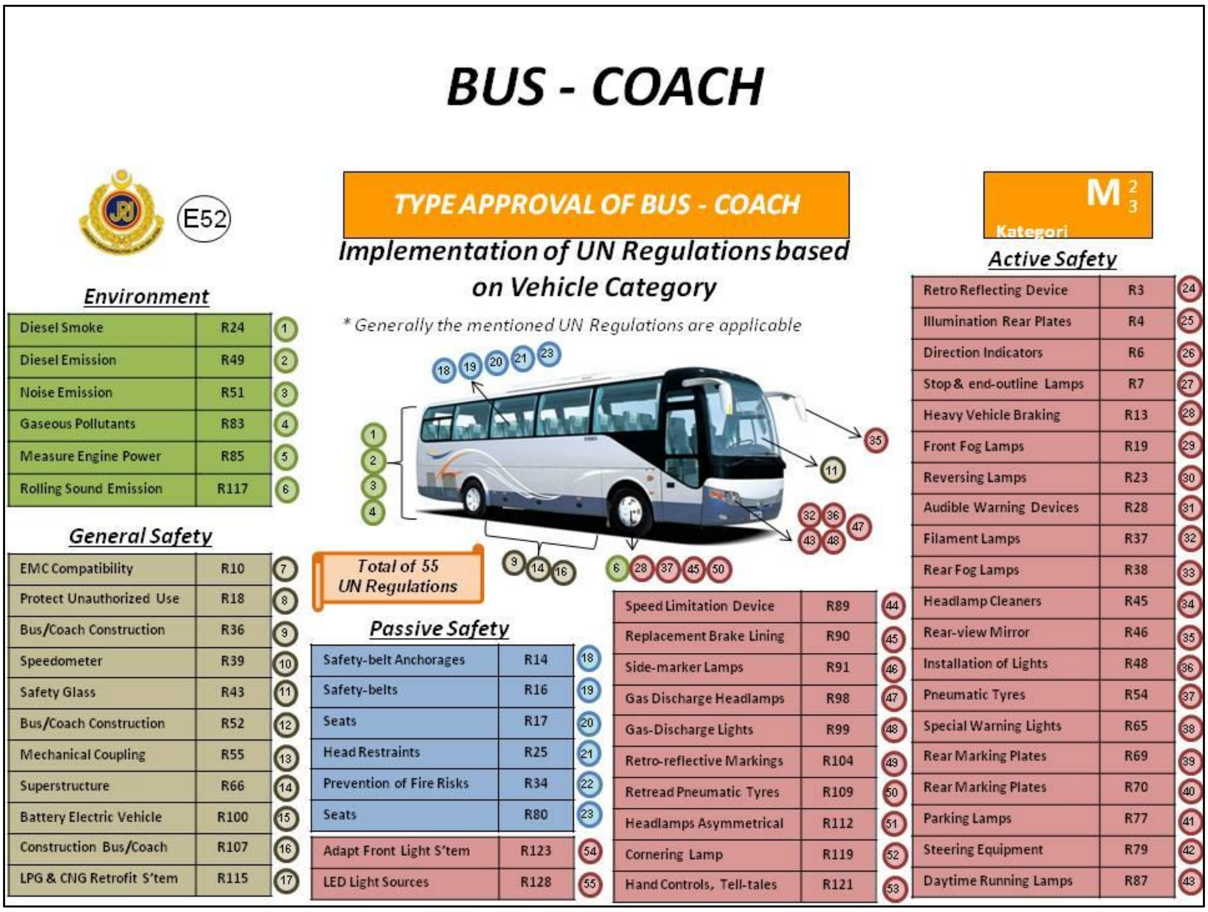

Figure 1: The United Nations regulations for HCPV in Malaysia

Comparing between the safety performance standards of PBS regulation in Australia and the existing regulations for HCPV in Malaysia, there were three performance standards (or partly) has already in force in Malaysia as below:

i. Maneuverability (Tail Swing);
ii. Static Rollover Threshold ('Maximum Stable Inclination Angle' in the VTA); and
iii. Directional Stability under Braking ('Braking Efficiency' in the VTA).

4.3 *Arahan Teknik Jalan 8/86*

The *Arahan Teknik Jalan 8/86*-A Guide on Geometric Design of Roads 1996 (after this will be referred to as ATJ 8/86) under the Public Works Department, Ministry of Works Malaysia stated that the dimensions and minimum turning radius of design vehicles must be not less than all vehicles in its class for the purposes of geometric design of roads. Therefore, in term of the geometric design of roads, HCPV supposed could be operated safely if its turning radius is less than the design vehicle. The ATJ 8/86 only provides three types of design vehicle which are known as P for 'passenger vehicle', SU for 'Single Unit Truck or Bus' and WB-50 for 'Semi-Trailer Combination'.

The length of SU design vehicle is only 9.1m with a turning radius of 12.8m. Meanwhile, the WB-50 design vehicle length is 16.7m with a turning radius of 13.7m (see Figure 2). Both design vehicles produced 8.7m of turning radius (SU) and 6.0m for WB-50. Even though the off-tracking path of WB-50 is different from a single unit (rigid) design vehicle, WB-50 was commonly used as the design vehicle in Malaysia under the principal of designing roads for future traffic congestion.

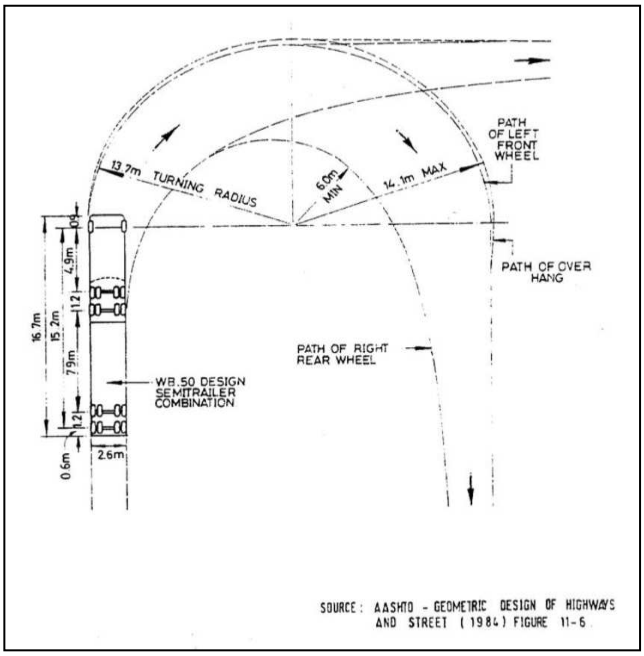

Figure 2: The WB-50 design vehicle dimensions and its off-tracking path (ATJ 8/86, 1996)

Therefore, the WB-50 design vehicle in the ATJ 8/86 may suggest the opportunity to allow HCPV of more than 12-metre length to be operated safely on Malaysian roads based on the swept path area. Plus, advancement in heavy vehicle's technology nowadays such as steerable rear axle will improve vehicle manoeuvrability performance. It may be biased to claim HCPV that exceeds 12-metre length could safely operate on Malaysian roads. However, it has been a common practice where route assessment to be conducted before such vehicles being allowed on certain part of the desired routes.

5.0 THE OPPORTUNITIES

The opportunities presented in this paper were in the perspective of first, the possibility of adopting PBS approaches to the existing regulation and second, the institutional readiness to develop and implement PBS regulation.

5.1 Manoeuvrability

Under the Directional Performance (Low Speed), the performance standard includes Low Speed Swept Path, Frontal Swing, Tail Swing and Steer Tyre Friction Demand. These performance standards are referring to the manoeuvrability. The existing UNR adopted in Malaysia refers the manoeuvrability performance under Regulation 36: Bus/Coach Construction.

The UNR 36 however, only briefly defined Frontal Swing performance measure and specifically for Tail Swing. The main intention of this standard are to manage safety risk caused by participating vehicle in the scheme when making a low speed, tight turn by limiting the road space required by the vehicle. The performance measure and level for Tail Swing in the UNR 36 for rigid vehicles, when negotiate with the prescribed 12.5m radius 90˚ low speed turns, the Tail Swing must not exceed 0.8m (Figure 3). While for articulated vehicle, when negotiate with the prescribed 12.5m radius 180˚ low speed turn, the Tail Swing must not exceed 1.2m.

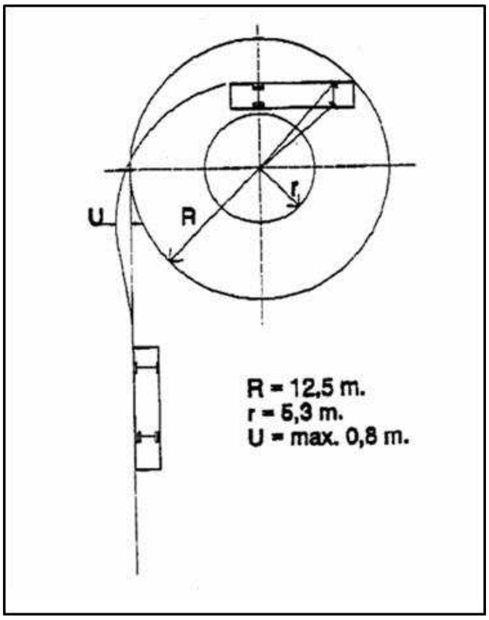

Figure 3: Tail swing illustration in the UNR 36 (ECE R36, 2008)

Two performance standards (Low Speed Swept Path and Steer Tyre Friction Demand) not match any existing reference in the regulations. However, the Road Transport Rules (Construction and Use) 1959 has regulated public transport vehicle to not exceeding a maximum 21.33m of turning circle. Hence, adopting Tail Swing performance standard will lift the limitation of vehicle overall length rule by which, may allow more productive HCPV to be used such as articulated buses (25m) or single rigid long bus (15m).

5.2 Static Rollover Threshold

The Static Rollover Threshold performance standard was grouped under the Directional Performance (High Speed) Category. The performance measure was defined in the NTC (2008) as the steady-state level of lateral acceleration that a vehicle can sustain during turning without rolling over.

Two testing methods available to measure this performance standard which is first, the assessed vehicle must be driven on a circular path and gradually increasing speed until a vehicle unit (or a roll-coupled unit) rolls over. The measured lateral acceleration at the point of rollover is the steady-state rollover threshold. Second, the vehicle is placed on a tilt table and gradually titled until it rolls which in accordance to the recommended practice of SAE J2180 by the Society of Automotive Engineers (SAE).

Currently, it was understood that the second testing method is being applied in Malaysia and the maximum tilting angle under the Road Transport Rules (Construction and Use) 1959 is 28 degrees.

5.3 Directional Stability Under Braking

The Directional Stability Under Braking performance standard was defined in the NTC (2008) as the ability to maintain stability under braking. The performance measures are explained as below:

i. A vehicle must not exhibit any wheel lock, and must remain in a straight lane of width equal to that specified in the standard 'Tracking Ability on a Straight Path' for the corresponding level of operation, when it is braked at a deceleration rate of 0.45g from an initial speed of 60km/h on a high friction pavement in both unladen and laden states.
ii. A vehicle must meet the stopping distance performance levels in the relevant versions of Australian Design Rules 35 and 38 (as applicable); and
iii. Auxiliary brakes (if fitted) must not apply automatically if the computed friction utilization at any wheel can exceed 0.1 when the vehicle is braked from a road speed corresponding to three quarters (3/4) governed engine speed (unless the motive vehicle has an acceptable Anti-lock Braking System).

The VTA currently only required applicants to state the front and rear brakes efficiency for service brake and parking brake. However, it was noted that UNR 13: Heavy Vehicle Braking is currently applied. Karlsson et al. (2015) in their report also considering the UNR performance level for heavy vehicle braking. The performance measures under the UNR 13 are braking deceleration/stopping distance, braking efficiency, braking stability on straight path, braking stability on a split friction and parking ability on a grade.

5.4 Discussion

The existing regulations for HCPV may already specify certain aspects of PBS. Therefore, the opportunities of implementing PBS regulation for HCPV in Malaysia are based on the phases explained below:

i. Aligning the existing three regulations (Tail Swing, Maximum Stable Inclination Angle and Braking Efficiency) to match the requirement needed as per safety performance standards of Australian PBS regulation.
ii. Considering the adoption of other safety performance standards of Australian PBS regulation and suitable for local context.
iii. Also, expanding the PBS regulation into other area such as environment and infrastructure safety towards a conclusive, sound and people centric heavy vehicle regulation.

Such approach of adopting the Australian PBS regulation for heavy vehicle into the existing regulation was explained and exampled by Nordengen (2014) in South Africa. Besides, the details information on each performance standard (definition, purpose, test method and procedure etc.) in the NTC (2008) was easily accessible for reference.

In terms of institutional readiness, the Malaysian Institute of Road Safety Research (MIROS) will have an important role to play during the initial stage of the PBS regulation development. MIROS as the ASEAN Road Safety Centre (ARSC) may lead the initiative with the supports from relevant agencies such as the Land Public Transport Commission, the RTD, the Public Works Department and perhaps a government to government (G2G) collaboration.

6.0 THE CHALLENGES

Based on author's knowledge, PBS approaches for heavy vehicle never been discussed previously to lift the limitations of prescriptively defined regulation in Malaysia. The challenges highlighted in this paper were the expected general challenges based on the Australian experiences that relatively also applicable to Malaysian situation. The expected challenges are:

i. Unavailability of a complete and proper testing facility (runway and equipment). The vehicles that wish to participate in the scheme shall be needed to undergo a set of assessment either a full scale physical testing or numerical modelling. It would be meaningless to implement PBS regulation if the vehicle performance could not be properly measures which provide the assurance of a safe interaction of vehicles and the road (Calvert, 2004);

ii. Ensuring a wide access to PBS at cost as low as possible (Calvert, 2004). Implementing PBS regulation will demand more testing procedures for vehicles thus, increase in cost to bear the testing which triggers a rejection of application. This constantly needs to be equitable by the need for a high level of confidence in the outcomes achieved. Besides, more testing procedures will also be time consuming;

iii. To setting up the performance threshold would require various extensive data such as road classification data, performance level of existing vehicles etc. Studies will also need to be carry out to prove various benefits of PBS regulation implementation in different aspects (Nordengen, 2014); and

iv. Negotiation with the industry players on the impact (pro and contra) to the existing fleet or local industry ecosystem are also an utmost priority if the government decided to move from prescriptive standards regulation. Industry take up on the initiative will be one of important factor to determine the success of the initiative.

7.0 CONCLUSIONS

The PBS concept for heavy vehicle was first introduced into South Africa after received an exposure through a series of symposium on the subject (Nordengen, 2014). Thus, this paper was believed to provide an important exposure to the government on PBS concept for heavy vehicle in Malaysia. The sum benefits attributed to PBS approach were in line with the focus area in the 11th Malaysia Plan 2016-2020 of unleashing growth of logistics and enhancing trade facilitation.

As of HCPV, lifting the limitation of prescriptive regulation will enhance the productivity and efficiency which supports the goal of increasing the public transport modal share. However, implementing PBS regulation for heavy vehicle or HCPV in Malaysia will need further research to study the impact and challenges that suit to local context such as industry and infrastructure readiness, existing heavy vehicles population, drivers' license etc.

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