# Implementation of Malaysian National Axle Load Policies through Weight Restriction Orders 1989, 2003 & 2017

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**Abstract.** Axle Load Study in 1987 had led to the formulation of Weight Restriction Order (WRO) 1989 for truck legal axle weights based on Short Term Axle Load (STAL) policy, which considers HA loads with no checking done on HB load. Medium Term Axle Load (MTAL) policy was later implemented in 2003 by the introduction of WRO 2003. MTAL are loadings derived from HA load or 45 units HB loading guided along the centreline. A new assessment load model to evaluate existing bridge carrying capacity is proposed in the new axle load study conducted in 2016. The findings were accordingly gazetted in 2017 with the issuance of WRO 2017. Oblivious of these studies, many Malaysian engineers today are not informed of the rationales or basis of the practices, especially those related to bridge assessment. The purpose of this paper is to revisit these studies and discuss pertinent decisions made with regard to the national axle load policies. Based on the comparison between the previous and new assessment procedure, bridges that were rated as capable of safely carrying the load equivalent to MTAL are capable of safely carrying the vehicles that are in compliance with WRO 2017.

## 1. Introduction

Axle Load Study in 1985 – 1987 (Study '87) among others aims at increasing the legal commercial vehicle dimensions and weight limits in Motor Vehicle Regulations to be compatible with the vehicles available in the world market [1]. Motor Vehicle Regulations of Malaysia prior to Study '87 were deemed outdated as compared to other regulations worldwide and there was doubt in the existing bridge capacity to carry the load from vehicles available in the world market.

In Study '87, a new bridge loading standard known as Long Term Axle Load (LTAL) and a Special Vehicle (SV) model were proposed. This was subsequently published as a bridge design standard by JKR [2, 3]. As for the new Motor Vehicle Regulations, the increase in the axle and gross vehicle weight limits should comply with the bridge loading standards. However, to immediately permit vehicles equivalent to LTAL loading as the basis for the new Motor Vehicle Regulations would require many existing bridges to be strengthened or replaced [1, 4]. Therefore, a more practical step-by-step approach towards the long-term regulations, which involves the introduction of Short Term Axle Load (STAL) and Medium Term Axle Load (MTAL) policy, was proposed.

Transportation companies have been complaining the inconveniences caused by the different axle load limits along Federal Roads due to the enactment of WRO 2003. Therefore, a new Axle Load Study was conducted in 2016 (Study '16) to formulate a coordinated programme for the road transport sector in relation to the proposed plan to increase the commercial vehicular configurations and legal weight limits. The study also resulted in the formulation of a new procedure for the assessment of existing bridges. The vehicle weight limits in WRO were also accordingly revised following the recommendation given in the Study '16 through the issuance of WRO 2017.

**2. Weight Restriction Order (WRO)**
In Malaysia, all vehicle design and construction are required to comply with WRO, which consists of:

Schedule 1 – Outline the allowable axle loads, in relation to the axle configuration of vehicles and list of Federal Roads given in Schedule 2. Vehicles that comply with the axle configuration and axle load limits in this schedule are regarded as normal vehicle

Schedule 2 – Categorizes Federal Roads into several lists, i.e. List I, List II, List III, etc. Maximum load limits stated in Schedule 1 are different for each lists

Schedule 3 – List of gazette number for WRO

Schedule 4 – Provides the information on abnormal vehicles that are allowed to travel on Federal Roads stated in Schedule 5. These vehicles are not allowed to travel uncontrollably and shall be guided by pilot vehicles

Schedule 5 – Provides the information on Federal Roads permitted for abnormal vehicles

The enactment of WRO will ensure that the load effects from the worst combination of vehicles allowed to travel on the bridge are within the expected bridge capacity.

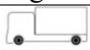
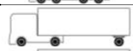
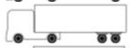
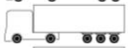
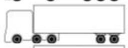
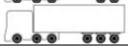
**3. The Study '87**

*3.1. General*
The Study '87 on bridges involves inspection of 966 bridges in Peninsular Malaysia and studies of bridge design practices in Malaysia [1]. It was reported that approximately 72 % of these bridges were incapable of safely carrying the worst likely combination of the vehicles available in the world market. From Study '87, three axle load policies termed as STAL, MTAL and LTAL were proposed. LTAL policy requires all new bridges to be designed to LTAL and SV loading [1, 2]. Whereas, existing bridges were to be controlled through two interim axle load policies termed as STAL and MTAL [1].

STAL policy was to be implemented immediately while at the same time, bridge upgrading works were to be carried out. MTAL policy was to be introduced once the bridge stocks are capable of safely carrying the load equivalent to MTAL. STAL and MTAL correspond to WRO 1989 and WRO 2003, respectively. As such, STAL and MTAL were the assessment loading standards for measuring the load carrying capacity of existing bridges that simulate the traffic loading regulated by their respective WRO [4].

*3.1.1. STAL Policy.* STAL policy was implemented through the issuance of WRO 1989 [4, 5]. In this policy, it was expected that majority of the existing bridges in Malaysia were capable of safely carrying the load equivalent to STAL. Generally, bridges located within the Federal Roads specified in List VI of Second Schedule in WRO 1989 have the capacity of at least for STAL. Table 1 summarizes the proposed load limits in Study '87 and gazetted load limits for roads specified in List VI of Second Schedule in WRO 1989. Accordingly, 74 bridges rated as substandard to the STAL in Study '87 were recommended to be replaced [1].

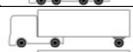
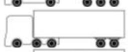
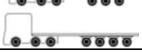
**Table 1.** Vehicle weight limits for Federal Roads in List VI of Second Schedule, WRO 1989 [4, 5]

| Type of vehicle | Number of axle | Axle configuration | Load limit (tonne) | |
|---|---|---|---|---|
| | | | Study '87 | WRO 1989 |
| Rigid | 2 axle |  | 17.5 | 14 – 16 |
| | 3 axle |  | 21 | 18 – 21 |
| | 4 axle |  | 28 | 20 – 25 |
| Articulated | 3 axle |  | 27 | 22 – 26 |
| | 4 axle |  | 32 | 22 – 32 |
| | 5 axle |  | 36 | 22 – 36 |
| | 5 axle |  | 36 | 22 – 34 |
| | 6 axle |  | 39 | 30 – 38 |

*3.1.2. MTAL Policy.* MTAL policy was implemented through the issuance of WRO 2003 [4, 6] when majority of the bridges in Malaysia were deemed to be capable of safely carrying the load equivalent to MTAL. The enactment of WRO 2003 increased the legal load limits to be equivalent to MTAL for selected Federal Roads in Peninsular Malaysia, which were listed in List I of the Second Schedule in WRO 2003. Federal Roads with bridges that were inadequate for MTAL but have the capacity of at least for STAL were categorized in List II of the Second Schedule in WRO 2003.

Since Sabah, Sarawak, and Labuan were not included in Study '87, the axle weight limits for Federal Roads in these states were restricted to List II of the Second Schedule. Table 2 summarizes the proposed load limits in Study '87 and gazetted load limits for roads specified in List I of Second Schedule in WRO 2003. Additionally, load limit and vehicle arrangement for 7 axle articulated vehicle were introduced in WRO 2003, which was not proposed in Study '87.

**Table 2.** Vehicle weight limits for Federal Roads in List I of Second Schedule, WRO 2003 [4, 6]

| Type of vehicle | Number of axle | Axle configuration | Load limit (tonne) | |
|---|---|---|---|---|
| | | | Study '87 | WRO 2003 |
| Rigid | 2 axle |  | 19 | 16 – 18 |
| | 3 axle |  | 26 | 20 – 26 |
| | 4 axle |  | 33 | 25 – 33 |
| Articulated | 3 axle |  | 30 | 26 – 30 |
| | 4 axle |  | 38 | 27 – 37 |
| | 5 axle |  | 40 | 39 |
| | 5 axle |  | 40 | 28 – 40 |
| | 6 axle |  | 44 | 34 – 44 |
| | 7 axle |  | – | 53 |

While vehicular loads were controlled by Road Transport Department (JPJ) vide WRO, existing bridges had to be assessed of their load carrying capacity. The load carrying capacities for majority of the bridges in Malaysia are expected to be of least STAL and MTAL whilst STAL policy and MTAL policy, respectively, were in effect [1].

*3.2. Bridge Assessment*

*3.2.1. The Procedures.* Bridge Replacement Policy in JKR Terms of Reference (TOR) for Bridge Assessment Procedure [7] imply that the decision to replace, widen or strengthen a bridge can only be executed if any one of the following criteria was not satisfied:-

i. The condition of the existing bridge based on visual inspection
ii. The hydraulic capacity of an existing bridge based on site investigation and discharge capacity
iii. the existing bridge capacity based on theoretical calculation

The theoretical strength evaluation was to be in accordance with the procedure proposed in a study by JKR in 1995 [8]. Evaluation Load Rating, $ELR$, which represents the ratio of the available live load capacity of a member to the effect of reference live load can be obtained using Equation 1 [7, 8].

$$ELR = \frac{R^* - D^*}{L^*} \quad (1)$$

where:
$R^*$ = factored resistance
$D^*$ = factored dead load effect
$L^*$ = factored reference live load effect

The TOR specifies that the reference live load shall be of LTAL [7]. Hence, $ELR_{LTAL}$ represents the ratio of the available live load capacity to the effect of LTAL as shown in Equation 2. Based on Equation 2, it is logical to infer that if a bridge has $ELR_{LTAL}$ of less than 1, it is theoretically not capable of safely carrying the load equivalent to LTAL.

$$ELR_{LTAL} = \frac{R^* - D^*}{L^*_{LTAL}} \quad (2)$$

The implementation of STAL policy through WRO 1989 requires most of the bridges in Malaysia to be capable of safely carrying the load equivalent to STAL [1, 9]. This means that $ELR_{STAL}$ of the existing bridges need to be more than or equal to 1. However, as per the TOR, the rating was calculated based on the effect of LTAL and it was considered that a bridge with $ELR_{LTAL}$ of 0.8 or higher is capable of safely carrying at least the load equivalent to STAL, i.e. the worst possible combination of vehicles allowed in WRO 1989.

MTAL policy was later implemented through WRO 2003, which increases the limits on legal axle load and gross vehicle weight. This requires most of the bridges in Malaysia to be capable of safely carrying the load equivalent to MTAL [1, 9]. The relationship between $ELR_{MTAL}$ and $ELR_{LTAL}$ is represented by a $\beta$ ratio, which varies with the loaded length as shown Figure 1. Therefore, if a bridge has $ELR_{LTAL}$ of at least $\beta$, the bridge is deemed capable of safely carrying at least the load equivalent to MTAL, i.e. the worst possible combination of vehicles allowed in WRO 2003. The procedure in developing the $\beta$ ratio is explained in a paper published in 2013 [9].

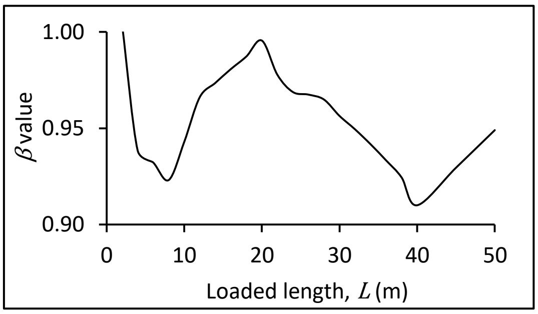



**Figure 1.** $\beta$ ratio of $ELR_{MTAL}/ELR_{LTAL}$ [9]

*3.2.2. Assessment Load.* STAL, MTAL and LTAL each consists of a uniformly distributed load, $\omega$ and knife edge load, $KEL$ which represents the effects of all normal vehicles that are permitted by the WRO to travel uncontrolled on the road. The $KEL$ was to be taken as 100 kN per lane [3, 4] whereas Figure 2 shows the curve for load, $\omega$ according to STAL, MTAL and LTAL along with the curves for load, $\omega$ in BS 153 and BD 21/84 for comparison.

The derivation of load, $\omega$ for STAL was governed by the strength of the nation's bridges built before 1972 that were designed to BS 153 or its equivalent with no checking done on HB load [4]. As shown in Figure 2, the load curve for STAL was technically a BS 153 load curve that has been modified at loaded length of 4 – 9 m.

Composite line of bending moment effect from HA load of BS 153 and equivalent HB load was used to derive the vehicle dimension and weight limits. Then, the shear force effect from these vehicles were determined to derive equivalent UDL, which was then proposed to be used as the load, $\omega$ in the MTAL [4] shown in Figure 2.

The derivation of load, $\omega$ for LTAL was based on the loading curve in BD 21/84 where modification has been made to suit a fixed notional lane width of 2.5 m. The equation to derive the loading curve given in BD 21/84 was multiplied by the lane width factor, $F_w$ for 2.5 m lane width to obtain the equation for load, $\omega$ in LTAL [2, 3].

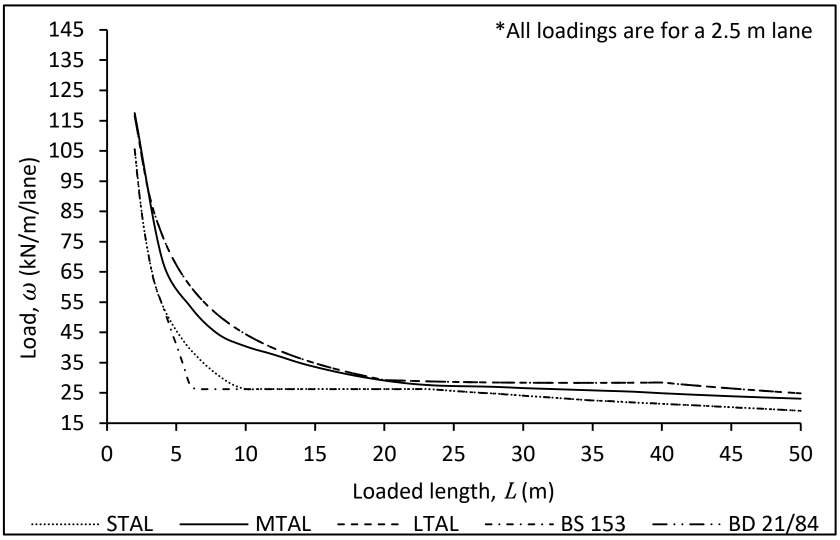



**Figure 2.** Load, $\omega$ according to STAL [4], MTAL [4], LTAL [3], BS 153 [10] and BD 21/84 [11]

The notional lane width for STAL, MTAL and LTAL was to be fixed at 2.5 m as opposed to the varying notional lane width usually used in other standards [4]. This was to avoid from the reduction in the total live load with the increase of carriageway width. The anomaly in total load due to varying notional lane width is illustrated in Figure 3.

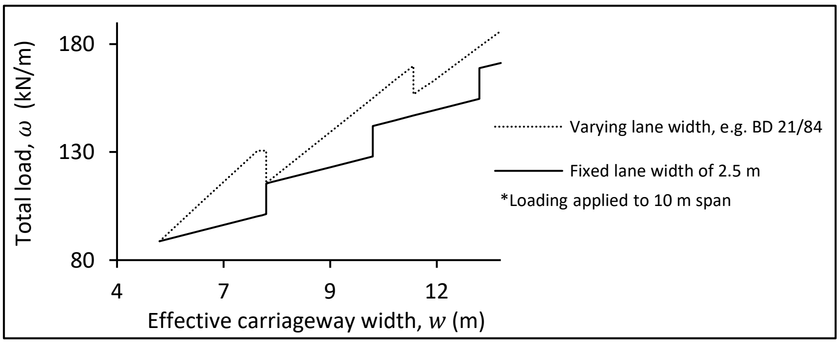


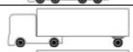
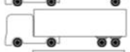
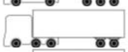

**Figure 3.** Total load, $\omega$ for varying carriageway width [4, 11]

## 4. The Study '16

*4.1. General*

From Study '16, a new assessment load was developed for the assessment of existing bridges. One of the reasons was the previous assessment load that was developed based on the Study '87, might have unnecessary safe-sided assumptions [12]. The Study '16 involves the review of weight-in-motion (WIM) data and the limits given in WRO 2003. WIM data was used as it can provide a more realistic representation of the types, distributions and overloading situations of vehicles in Malaysia. The weight limits given in WRO 2003 also had been proposed to be revised accordingly [13]. The proposed weight limits were then applied in WRO 2017. Table 3 summarizes the proposed load limits in Study '16 and gazetted load limits for roads specified in List I of Second Schedule in WRO 2017.

**Table 3.** Vehicle weight limits for Federal Roads in List I of Second Schedule, WRO 2017 [13, 14]

| Type of vehicle | Number of axle | Axle configuration | Load limit (tonne) | |
|---|---|---|---|---|
| | | | Study '16 | WRO 2017 |
| Rigid | 2 axle |  | 19 | 16 – 19 |
| | 3 axle |  | 27 | 20 – 27 |
| | 4 axle |  | – | 25 – 33 |
| Articulated | 3 axle |  | 31 | 26 – 31 |
| | 4 axle |  | 39 | 27 – 39 |
| | 5 axle |  | 41.5 | 40 |
| | 5 axle |  | 45 | 28 – 45 |
| | 6 axle |  | 50 | 34 – 50 |
| | 7 axle |  | – | 53 |

*4.2. Bridge Assessment*

*4.2.1. The Procedure.* In Study '16, the new assessment procedure for evaluating a bridge capacity is given in Technical Note No. 15 (TN15) [15]. Essentially, the strength of a bridge is indicated by a $C$ rating that can be obtained using Equation 3 [15], which represents the ratio of the maximum theoretical live load capacity of a member to the assessment live load. If a bridge has $C$ value of less than 1, then it should be classed as 'Immediate Risk' and treated as the highest priority for remedial management.

$$C = \frac{\omega_R^* - \omega_D}{\omega_L^*} \tag{3}$$

where:
$\omega_R^*$ = factored resistance in terms of load intensity
$\omega_D$ = unfactored dead load intensity
$\omega_L^*$ = factored reference live load intensity

*4.2.2. Assessment Load.* The new assessment load to be used in evaluating the load carrying capacity of a bridge was given in Technical Note No. 1 (TN1) [12] of the Study '16. The notional lane width to be used in bridge assessment generally follows Eurocode [12, 16] as shown in Table 4. It is reasonable to infer that the notional lane width is always equal to 3 m except for the carriageway width between 5.4 – 6 m. The load model was derived for two types of routes, namely Federal Route and Port & Cement Route. However, it was proposed that the load model for Federal Route to be used for the assessment of all bridges [12]. The formula for the load, $\omega$ and $KEL$ in the new assessment load is summarized in Table 5.

**Table 4.** Notional lane width for assessment in Study '16 [12]

| Carriageway width, $w$ (m) | Number of lanes | Lane width, $w_l$ (m) | Remaining width (m) |
|---|---|---|---|
| $w < 5.4$ | $n = 1$ | 3 | $w - 3$ |
| $5.4 \leq w < 6$ | $n = 2$ | 2.7 to 3 | 0 m |
| $6 \leq w$ | $n = \text{Integer}\left(\frac{w}{3}\right)$ | 3 | $w - 3n$ |

**Table 5.** New assessment load in Study '16 [12]

| Routes | $\omega$ (kN/m/lane) | $KEL$ (kN) |
|---|---|---|
| Federal Routes | $40\left(\frac{1}{L}\right)^{0.2}$ | 180 |
| Port and Cement Routes | $42\left(\frac{1}{L}\right)^{0.2}$ | 190 |

Study '16 also recommended the use of equivalent uniformly distributed load, $EUDL$ for comparison of different load models, i.e. STAL, MTAL and LTAL to the new assessment load. $EUDL$ for an assessment load model can be calculated using Equation 4.

$$EUDL = \omega + \frac{2*KEL}{L} \tag{4}$$

## 5. Comparisons of the Procedures and Load Models

The difference between the previous and new procedure is summarized in Table 6. $C$ is essentially similar to the old rating, $ELR$. The equation used to obtain the rating in both procedures indicates that the judgement is to be made based on the ratio of available live load capacity to the reference live load. However, the available live load capacity in previous procedure was obtained by subtracting the factored resistance with factored dead load, whereas in the new assessment procedure, it is to be subtracted with unfactored dead load. This means that there was no safety factor applied on the dead load in calculating $C$, thus giving a higher value of available live load capacity, and therefore, a higher $C$ rating.

**Table 6.** Difference between the previous and new procedure in bridge assessment [4, 7, 15]

| Procedures | Study '87 / Previous procedure | Study '16 / New procedure |
|---|---|---|
| Rating | $ELR = \frac{R^{*} - D^{*}}{L^{*}}$ (Refer 3.2.1) | $C = \frac{\omega_R^{*} - \omega_D}{\omega_L^{*}}$ (Refer 4.2.1) |
| Notional lane width | Fixed at 2.5 m | 3 m except at 5.4 – 6 m carriageway width where notional lane is between 2.7 – 3 m |
| ω and $KEL$ | $EUDL$s as per Study '16 recommendations are as shown in Figure 4 | |
| Application of load | Full $\omega$ and $KEL$ applied on two notional lanes and 0.6 times $\omega$ and $KEL$ to all other notional lanes. Remaining areas not covered with notional lane to be applied with minimum load of 5 kN/m². Refer Figure 5 and Figure 6 | |

Figure 4 shows the $EUDL$ for STAL, MTAL, LTAL and the new assessment load in a single notional lane. The new assessment load is generally equivalent to MTAL with minor difference. However, the notional lane of 2.5 m in MTAL and 3 m in the new assessment load meant that the load intensity per area in MTAL is actually greater than the new assessment load.

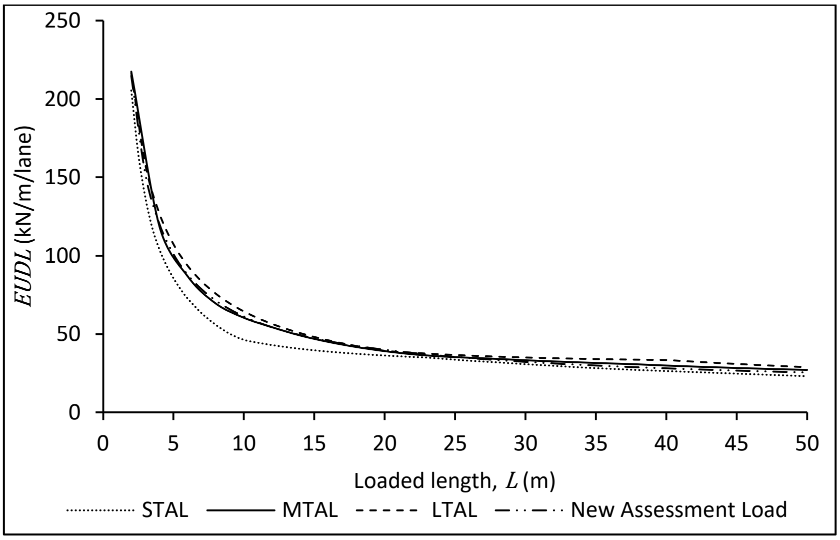



**Figure 4:** $EUDL$ on a single notional lane [4, 15]

The applications of load, based on the previous and new procedure are as shown in Figure 5 and Figure 6, respectively. Using the load arrangement shown in these figures, the total load acting on the bridge was calculated and shown in Figure 7. Figure 7 shows that the total load from previous load model, i.e. MTAL and LTAL, is greater than the new load model; signifying a higher reference live load used in previous procedure. This could be attributed to the safe-sided assumptions as stated in Study '16 [12].

Therefore, if a bridge has been previously assessed to the previous procedure and rated as capable of safely carrying the load equivalent to MTAL or LTAL, then it is capable of safely carrying the vehicles that are in compliance with WRO 2017. This is due to the fact that the limits in WRO 2017 was derived from the new load model.

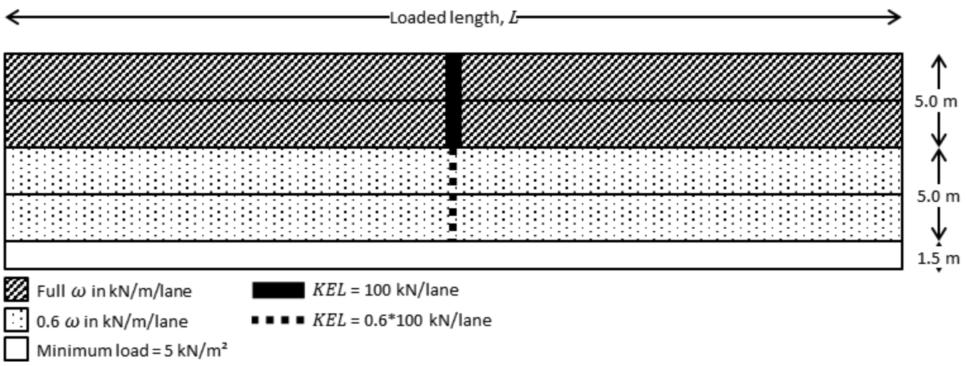



**Figure 5.** Load distribution plan on a bridge with 11.5 m carriageway (Study '87) [4]

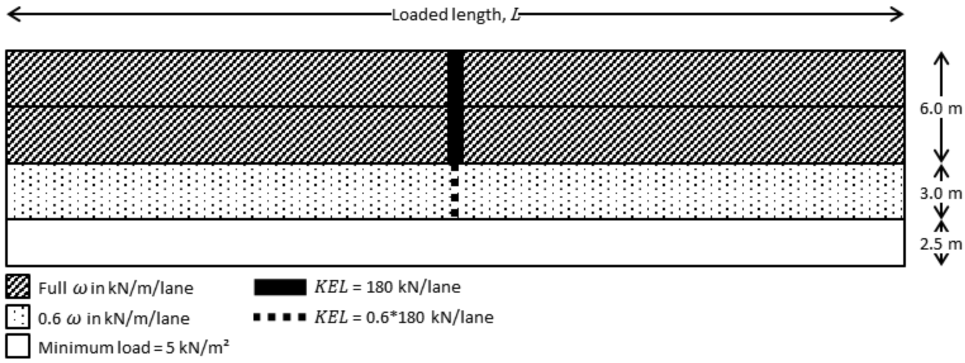



**Figure 6.** Load distribution plan on a bridge with 11.5 m carriageway (Study '16) [15]

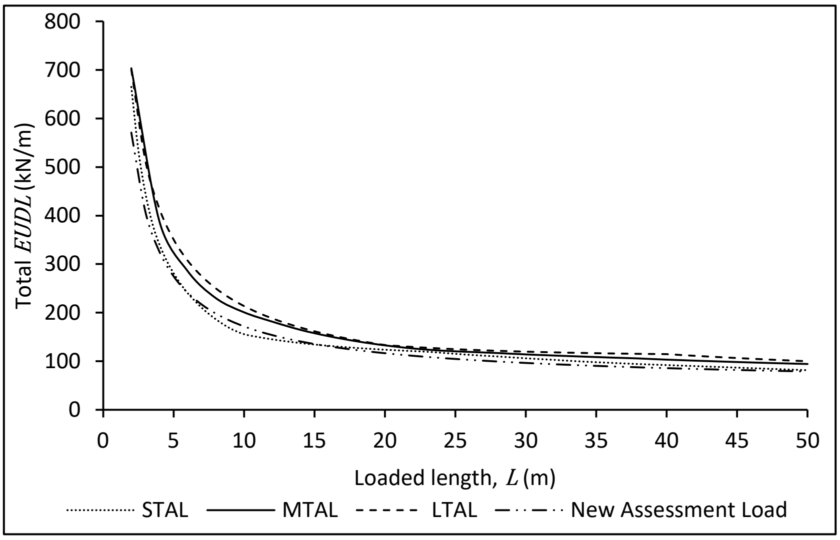



**Figure 7.** Total $EUDL$ on the bridge [4, 15]

## 6. Conclusions

This paper gives general idea on how the STAL, MTAL and LTAL policies originated from, and its relation to the WRO. STAL policy and MTAL policy are load policies made to ensure that the vehicles permitted in its corresponding WROs are within the safe carrying capacity of the existing bridges. LTAL policy is the futuristic policy that specifies new bridges to be designed to LTAL loading. JKR has adopted LTAL loading in the design of new bridges until around 1997. Study '16 has come up with a new procedure for bridge assessment and a higher load limit has been allowed in WRO 2017 as a result from the study. Based on the comparison between the previous and new assessment procedure, bridges that were rated as capable of safely carrying the load equivalent to MTAL or LTAL will also be capable of safely carrying the vehicles that are in compliance with WRO 2017.

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