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The Analysis of Freight Transport in Indonesia: Trailer and Semi-Trailer

Anton Budiharjo [a,b,*], Puspita Buana STJ [a], Pratikso [b], Rachmat Mudiyono [b], Reza Yoga Anindita [a]

[a] *Politeknik Keselamatan Transportasi Jalan, Tegal, Indonesia*
[b] *Civil Engineering Doctoral Program, Universitas Islam Sultan Agung, Semarang, Indonesia*
*Corresponding author: *anton@pktj.ac.id*

Abstract—**Freight transportation is crucial in supporting economic growth in Indonesia. The movement of freight has increased over the years, in line with economic expansion and technological advancements. The growing trend of online shopping through e-commerce has significantly boosted the logistics and delivery services sector, particularly in freight transportation. The transportation of goods using road transport remains the most dominant mode in Indonesia's logistics system. Logistics transportation via highways accounts for 80-90% of total freight movement, while the remaining percentage relies on other transportation modes. Semi-trailer trucks and trailer vehicles are widely used in the national logistics industry. However, these vehicles present significant challenges, such as traffic accidents and road damage, primarily due to insufficient government oversight. Large trucks play a crucial role in logistics by transporting goods more efficiently. However, their size often creates operational challenges on highways. This study aims to assess the load capacity and axle configuration compliance with existing regulations. The research employs both vehicle load capacity calculations based on regulations and field surveys. The findings reveal that many semi-trailer trucks and trailer vehicles operating on public roads violate load capacity regulations and engine power requirements. This is primarily due to the absence of technical regulations governing these vehicles. Vehicle manufacturers only produce and sell single-unit trucks, while owners custom-build semi-trailers. This practice results in mismatches between engine power and load capacity. The study recommends that the government promptly establish regulations for semi-trailer trucks and trailer vehicles to ensure road safety.**

Keywords—**Freight transportation; load capacity; PWR; regulation.**

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I. INTRODUCTION

Indonesia, with over 17,000 islands, is the largest archipelago in the world [1], [2][, 3]. Despite being an archipelago, its national logistics system is predominantly reliant on road-based transportation [4], [5]. This preference is understandable given that road transport infrastructure in Indonesia is more developed and cost-effective compared to other modes of transportation [6], [7]. Road transport is estimated to account for approximately 90% of freight transportation [8]. The dominance of road transport is evident from the significant growth in the transport and warehousing sector in early 2022, which contrasts with the decline in sea freight volumes [9]. Economic development in any country heavily depends on sufficient and efficient transportation services, without which positive outcomes cannot be achieved [10]. The growth of the logistics business has been increasing in this digital era due to the presence of online markets (e-commerce) [11], [12].

Road-based freight transportation essentially utilizes truck fleets [13], [14], including the largest types such as semi-trailer trucks and trailer trucks. These trucks are used to transport large quantities of goods, making them cost-effective since they can provide door-to-door service without additional costs [15], [16].

The dimensions of semi-trailer trucks and trailer vehicles can reach a maximum length of 18,000 cm and a width of 2,500 cm, with up to six axles, making them the longest and largest vehicles permitted to operate on public roads [17]. However, these vehicles move slowly on the road, often causing traffic congestion and accidents [18], [19], [20]. As stated in the final report [21], a traffic accident occurred on the Cikopo – Palimanan (Cipali) Toll Road involving a semi-trailer truck and a trailer truck, resulting in the death of 10 people. According to the investigation report by the National Transportation Safety Committee (KNKT), one of the causes of the accident was the way the tractor head was attached, pulling a 40-foot semi-trailer. Another accident, a single-vehicle accident (Fig.1), occurred in Bekasi (West Java) involving a flatbed trailer transporting 14,200 pre-cast concrete rods, resulting in 11 fatalities [22].

Fig. 1 Vehicle Accident in Bekasi

Regulations concerning semi-trailer and trailer vehicles are not yet well-established in Indonesia, resulting in minimal and weak oversight of their operations on public roads. There has been limited research on this type of vehicle in Indonesia. On the development of freight distribution models using the breadth-first search algorithm, it was found that load capacity must be adjusted to the production volume of each zone [23]. Another study by [24] examined liability in accidents caused by over-dimensional and overloading (ODOL) of freight vehicles in Indonesia, concluding that drivers cannot be solely held responsible for ODOL-related accidents. Research on freight vehicles, particularly semi-trailers and trailer vehicles, is also scarce internationally, with some studies focusing on the impact of truck weight on road pavement quality [25], [26]

This study addresses semi-trailers and trailers explicitly from a regulatory and technical operational perspective. The objective is to assess the technical compliance of these vehicles with existing regulations and provide technical recommendations to enhance road safety in Indonesia.

II. Materials and Method

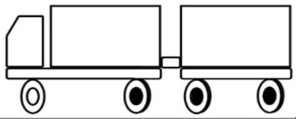
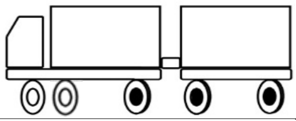
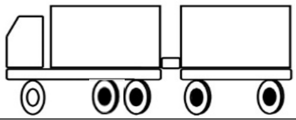
A. Materials

According to regulations [27], a semi-trailer/ articulated truck is a vehicle in which a tractor head is coupled with a trailer. The trailer is a carriage used to transport goods, with its entire load concentrated on the trailer itself, designed to be pulled by the tractor head. A semi-trailer truck consists of a tractor head and a trailer, as illustrated in Fig. 2. According to Indonesian government regulations [28], there is only one type of semi-trailer truck, which has a configuration of up to four axles.

A distinctive feature of articulated trucks is the presence of two cargo containers at the rear. The first cargo container is directly connected to the front of the truck, while the second cargo container is positioned behind it and equipped with its wheels. This system enables the truck to carry a greater load than conventional trucks. The large capacity makes it efficient for transporting heavy loads in a single trip, thereby reducing the number of journeys required to deliver goods [29].

Fig. 2 Semi-trailer Truck

TABLE I
THE CONFIGURATION OF SEMI-TRAILER TRUCK

Side view	Axle Configuration
	1.2 + 22
	1.1.2 + 22
	1.22 + 22

According to Table I, the axle configuration for semi-trailer trucks as per the regulations is as follows:

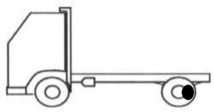
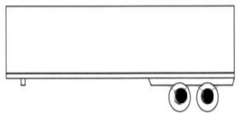
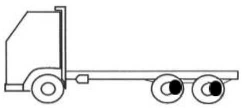
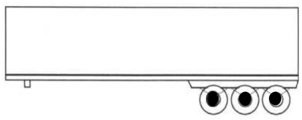
1.  Single axle single tire (steering axle)
2  Single axle dual tire
\+ Coupled with an additional trailer

A trailer truck is a vehicle designed to carry goods [30] and is intended to be pulled by a tractor head, with part of its load borne by the tractor head [31]. The tractor head has a fifth wheel placed between the two axles on the chassis, which serves as the coupling device with the trailer (Fig.3).

Fig. 3 Trailer Truck

Table II outlines the various types of semi-trailer trucks permitted to operate in Indonesia according to regulations.

TABLE II
THE CONFIGURATION OF TRAILER TRUCK

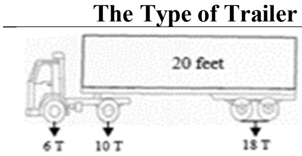
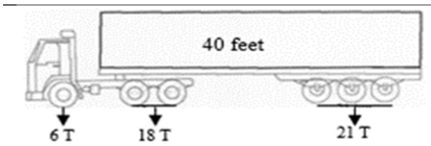
Tractor head	Trailer Attachment
	20 Feet
 1. 2	 2 2
	40-45 Feet
 1. 2 2	 2 2 2

The axle configurations permitted for trailer vehicles for a 20-foot container are 1.2 - 22, while for a 40-foot container, they are 1.22 – 222. The hyphen (-) indicates that the vehicle is either assembled or coupled. The permissible axle weights for trailer vehicles according to [27] are as follows:

- Single axle with single tire: 6000 kg/ 6 tons.
- Single axle with dual tire 10.000 kg/ 10 tons
- Tandem axle with dual tire: 18.000 kg/ 18 tons
- Triple axle with dual tire: 21.000 kg/ 21 tons, or a tandem axle with dual tire using air bag suspension: 20.000 kg

According to Table III, the gross permitted weight for a trailer vehicle carrying a 20-foot container is a Gross Combination Permit Weight (GCPW) of 34 tons, while for a vehicle carrying a 40-foot container, the GCPW is 45 tons.

TABLE III
THE TYPE OF TRAILER TRUCK

The Type of Trailer Truck	**GCPW**
	34 Tons
	45 Tons

It is anticipated that each vehicle should be capable of carrying loads by its own carrying capacity. This has implications for traffic safety and road transport. Essential considerations in calculating the carrying capacity for trailer and combination vehicles are as follows [27]:

1) Gross Vehicle Weight or GVW: Means the total weight of a vehicle or combination of vehicles, including its load, transmitted to the road by its axles.

2) Gross Combination Weight (GCW): it refers to the maximum weight of a motor vehicle combined with its load, as permitted by the manufacturer's design specifications. GCW is calculated based on engine power, braking capacity, tire capability, axle strength, and gradient ability.

3) Gross Combination Permit Weight (GCPW): it is the maximum weight of a motor vehicle combined with its load, consistent with the road class being used.

4) Maximum Axle Load (MAL/MST): it represents the total pressure exerted by the wheels on a single axle against the road surface. MAL is adjusted according to the road class in Indonesia.

In Indonesia, roads are classified into several categories [32]:

1) Class I: Arterial and collector roads used by motor vehicles with a maximum width of 2,500 mm, length of 18,000 mm, height of 4,200 mm, and MST of 10 tons.

2) Class II: Arterial, collector, local, and environmental roads used by motor vehicles with a maximum width of 2,500 mm, length of 12,000 mm, height of 4,200 mm, and MST of 8 tons.

3) Class III: Arterial, collector, local, and environmental roads used by motor vehicles with a maximum width of 2,100 mm, length of 9,000 mm, height of 3,500 mm, and MST of 8 tons.

4) Special Class: Arterial roads used by motor vehicles with a width exceeding 2,500 mm, length exceeding 18,000 mm, height exceeding 4,200 mm, and MST exceeding 10 tons.

B. Method

To calculate the distribution of weight on the front and rear axles of a truck, formula (1) is used. The principles for calculating weight distribution are the same for this configuration as for distributing payload on a truck tractor with one or more trailers. The calculation results obtained using formulas (1) and (2) were compared with field data collected through weighing.

$$Wr = \frac{W \times CGf}{WB} \quad (1)$$

$$Wf = W - Wr \quad (2)$$

Where:
WB : Wheelbase
W : Total Weight being distributed (e.g., Weight of body)
Wf : Weight on front axle
Wr : Weight on rear axle
CGf : Distance from Center of Gravity to front axle

Engines power trailer and semi-trailer vehicles. Engine power is a parameter used to determine the performance of a vehicle [33]. Power represents the amount of work performed by the engine over a specific period, with different vehicles having varying engine power [34]. There are various units of vehicle power, including:

1) Horsepower (HP): Used to compare the performance of steam engines and horse-drawn capabilities. Horsepower is also used to measure the power output of pistons, turbines, electric motors, and engines in genera [35], l. One horsepower is equivalent to 745.7 watts. One kilowatt (KW) is equivalent to 1.34 horsepower.

2) Pferdestärke (PS): A term derived from German, meaning "horse strength," and is also known as "Paardenkracht" (PK) in Dutch. The value of PS is always higher compared to HP and KW, with PS = PK as shown in Table IV. PS and PK are commonly used units of vehicle power in Europe, while KW and HP are more frequently used in countries such as the United States and the United Kingdom.

TABLE IV
POWER WEIGHT RATIO CONVERSION

Unit	PS	HP	Kw
PS	1	0,98632	0,7355
HP	1.01387	1	0,7457
Kw	1,35962	1,34102	1

According to regulations in Indonesia [27], trailer and semi-trailer vehicles must have a minimum engine power of 5.5 kilowatts for every 1,000 kg of the allowable gross combination weight (GCW). Specifically:

- Motor vehicles towing a trailer or combination with a Gross Combination Weight (GCW) of up to 750 kg must meet this requirement.
- Motor vehicles towing a trailer or combination with a GCW greater than 750 kg but not exceeding 3,500 kg must comply.
- Motor vehicles towing a trailer or combination with a GCW greater than 3,500 kg but not exceeding 10,000 kg are subject to this requirement.
- Motor vehicles towing a trailer or combination with a GCW exceeding 10,000 kg must also adhere to this regulation.

The research is conducted on toll roads in Central Java. The method for determining the sample size, given an unknown population size, uses the Lemeshow method. The Lemeshow formula is as follows:

$$n = \frac{Z^2 P(1-P)}{d^2} \quad (3)$$

Where:
n = Sample size
P = Maximum estimation (50% = 0,5)
Z = Z-score for a 95% confidence level = 1,96
d = Sampling error (5%=0,05)

Thus, the minimum number of samples required for this study is 96. The researcher rounded up this number to 100 samples. These 100 samples will be divided into two categories, with 50 samples for articulated vehicles and 50 samples for combination vehicles.

III. RESULTS AND DISCUSSION

Based on the survey results and data analysis, it was found that there is a discrepancy in the types of towing vehicles. The articulated vehicles that comply with regulations have an axle configuration of 1.2+22, which accounts for 75% of the total sample. However, there are articulated vehicles with axle configurations of 1.1.2+22 and 1.22+22 that do not meet the regulatory standards, although their number does not exceed 50% of the total sample, as shown in Fig. 4.

From the 50 validated periodic inspection records of articulated vehicles, it was observed that some load capacities measured by the testers exceeded the maximum load capacity limits established by the regulations. This discrepancy arises because the testers used the MST (Maximum Axle Load) for Class 1 roads, which is 10 tons, as the basis for calculating the design strength of the axles.

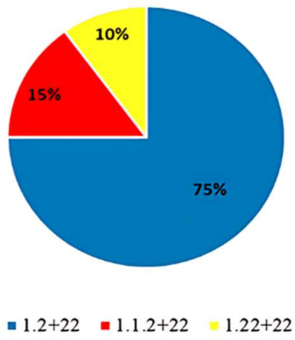


Fig. 4 Axle configuration of Semi-Trailer Truck

According to the regulations, a single axle with single tires has a maximum weight of 6,000 kg, while a single axle with dual tires has a maximum weight of 10,000 kg. Therefore, an articulated truck with an axle configuration of 1.2+22 has a Gross Combination Permit Weight (GCPW) of 31,000 kg. In contrast, a vehicle with an axle configuration of 1.1.2+22 has a GCPW of 37,000 kg, and a vehicle with an axle configuration of 1.22+22 has a GCPW of 38,000 kg. It is evident that an articulated truck with an axle configuration of 1.22+22 has the highest carrying capacity. However, this calculation differs from field measurements; the GCPW values obtained from the survey are based on periodic inspection data conducted by officials.

TABLE V
SURVEY RESULTS OF SEMI-TRAILER POWER WEIGHT

Type	GVW truck (kg)	GPW truck (kg)	GVW trailer (kg)	GPW trailer (kg)	GCW (kg)	GCPW (kg)
1.2+22	16.000	15.000	20.000	16.000	36.000	31.000
1.1.2+22	22.000	21.000	20.000	16.000	42.000	37.000
1.22+22	26.000	22.000	20.000	16.000	46.000	38.000

Table V shows the GCPW values listed in the periodic inspection documents. There is a discrepancy between the calculated values according to regulations and those reported in the papers. For example, for an articulated vehicle with an axle configuration of 1.2+22, the regulatory Gross Combination Weight (GCPW) is 36,000 kg; however, the survey revealed a value of 31,000 kg, representing a difference of 5,000 kg, or 14%. This discrepancy is also observed in other articulated vehicle configurations.

TABLE VI
CALCULATION OF SEMI-TRAILER POWER WEIGHT RATIO

Type	Engine Power (Ps)	GCW_{actual} (kg)	GCW_{max} (kg)
1.2+22	240	36.000	32.095
1.1.2+22	260	42.000	34.769
1.22+22	280	46.000	37.444

The results of the power-to-weight ratio (PWR) calculations for articulated trucks also revealed a discrepancy between engine power and GCW, as shown in Table VI For example, with an axle configuration of 1.2+22 and an engine power of 240 PS (176.52 kW), the calculated maximum GCW is 32,095 kg. However, the actual GCW for the vehicle is 36,000 kg. This imbalance between engine power and the load being towed affects vehicle performance, as the engine power is insufficient to pull the required weight. This misalignment in PWR can cause the vehicle to operate very slowly and struggle to climb inclines. Such discrepancies may contribute to significant speed gaps between articulated vehicles and other vehicles on the toll road, potentially leading to accidents [36].

The field survey results in Table VII show that only 6% of articulated vehicles were within the standard load limits, while the rest were overloaded. Trucks with a 1.2+22 configuration were all found to be overloaded, with excess loads reaching up to 49% in this category. This type of truck contributes to road damage due to the transportation of excessive loads [37].

TABLE VII
THE RESULTS OF THE LOAD SEMI-TRAILER SURVEY

No.	Type	GVW Truck (Kg)	GVW Trailer (Kg)	GCW (Kg)	GPW Truck (Kg)	GPW Tailer (Kg)	GCPW (Kg)	Loaded Truck (Kg)	Loaded Trailer (Kg)	Total loaded (Kg)	Remarks
1	1.2+22	16000	20000	36000	15000	14000	29000	21760	19765	41525	Overloaded
2	1.2+22	16000	20000	36000	14800	16000	30800	17550	23000	40550	Overloaded
3	1.2+22	16000	20000	36000	14500	16000	30500	14350	16550	30900	Overloaded
4	1.2+22	16000	20000	36000	15780	16000	31780	16450	19540	35990	Overloaded
5	1.2+22	15000	20000	35000	15000	16000	31000	15440	17420	32860	Overloaded
6	1.2+22	16000	20000	36000	14610	14800	29410	18540	18650	37190	Overloaded
7	1.2+22	15000	20000	35000	13000	14000	27000	16000	19540	35540	Overloaded
8	1.2+22	14000	20000	34000	15000	16000	31000	15320	21020	36340	Overloaded
9	1.2+22	15000	20000	35000	15000	16000	31000	18760	19350	38110	Overloaded
10	1.2+22	16000	20000	36000	15000	14850	29850	19500	17540	37040	Overloaded
11	1.2+22	14500	20000	34500	11540	15500	27040	16460	15230	31690	Overloaded
12	1.2+22	15680	20000	35680	15000	14000	29000	15305	18790	34095	Overloaded
13	1.2+22	15000	20000	35000	12650	16000	28650	19760	16520	36280	Overloaded
14	1.2+22	15000	20000	35000	15000	13950	28950	17540	15500	33040	Overloaded
15	1.2+22	15000	20000	35000	15000	14850	29850	19357	19560	38917	Overloaded
16	1.1.2+22	22000	20000	42000	16000	16000	32000	19560	21000	40560	Overloaded
17	1.1.2+22	22000	20000	42000	15680	15500	31180	17400	18700	36100	Overloaded
18	1.1.2+22	22000	20000	42000	14870	14850	29720	18450	21000	39450	Overloaded
19	1.1.2+22	22000	20000	42000	16000	16000	32000	19700	23500	43200	Overloaded
20	1.1.2+22	22000	20000	42000	15900	16000	31900	20500	18500	39000	Overloaded
21	1.1.2+22	22000	20000	42000	14890	14850	29740	24500	19700	44200	Overloaded
22	1.1.2+22	22000	20000	42000	16000	16000	32000	22800	21500	44300	Overloaded
23	1.1.2+22	22000	20000	42000	16000	16000	32000	21700	16500	38200	Overloaded
24	1.1.2+22	22000	20000	42000	16000	15500	31500	19000	17500	36500	Overloaded
25	1.1.2+22	22000	20000	42000	16000	15500	31500	17600	16800	34400	Overloaded
26	1.1.2+22	22000	20000	42000	16000	16000	32000	19000	20000	39000	Overloaded
27	1.1.2+22	22000	20000	42000	15800	16000	31800	23000	17500	40500	Overloaded
28	1.1.2+22	22000	20000	42000	15900	16000	31900	21680	18700	40380	Overloaded
29	1.1.2+22	22000	20000	42000	16000	15500	31500	23000	22450	45450	Overloaded
30	1.1.2+22	22000	20000	42000	15480	15500	30980	17600	19750	37350	Overloaded
31	1.1.2+22	22000	20000	42000	16000	16000	32000	15600	21000	36600	Overloaded
32	1.22+22	26000	20000	46000	22000	15500	37500	27500	15600	43100	Overloaded
33	1.22+22	26000	20000	46000	21500	16000	37500	30750	17800	48550	Overloaded
34	1.22+22	26000	20000	46000	19800	15500	35300	19600	14500	34100	Standard
35	1.22+22	26000	20000	46000	22000	16000	38000	23700	19800	43500	Overloaded
36	1.22+22	26000	20000	46000	21500	16000	37500	22500	20670	43170	Overloaded
37	1.22+22	26000	20000	46000	21800	15500	37300	28000	15690	43690	Overloaded
38	1.22+22	26000	20000	46000	22000	16000	38000	21750	18500	40250	Overloaded
39	1.22+22	26000	20000	46000	20500	16000	36500	24600	23000	47600	Overloaded
40	1.22+22	26000	20000	46000	19500	16000	35500	23500	16500	40000	Overloaded
41	1.22+22	26000	20000	46000	22000	15500	37500	27600	17800	45400	Overloaded
42	1.22+22	26000	20000	46000	21600	16000	37600	20500	15600	36100	Standard
43	1.22+22	26000	20000	46000	21500	16000	37500	24700	19800	44500	Overloaded
44	1.22+22	26000	20000	46000	22500	15500	38000	21500	16450	37950	Standard
45	1.22+22	26000	20000	46000	20000	16000	36000	28500	19800	48300	Overloaded
46	1.22+22	26000	20000	46000	19600	16000	35600	24500	20700	45200	Overloaded
47	1.22+22	26000	20000	46000	22000	16000	38000	27600	16500	44100	Overloaded
48	1.22+22	26000	20000	46000	19700	15500	35200	24500	18700	43200	Overloaded
49	1.22+22	26000	20000	46000	21700	16000	37700	25450	21000	46450	Overloaded
50	1.22+22	26000	20000	46000	22000	16000	38000	21550	15480	37030	Overloaded

Table VIII shows that all types of articulated vehicles, including configurations 1.2 + 22, 1.1.2 + 22, and 1.22 + 22, have engine power that does not align with the total combination weight (GCW). Actual engine power refers to the engine power specified for the vehicle, while Analysis Engine Power represents the power that should be by the total vehicle weight (GCW).

TABLE VIII
COMPARISON OF SEMI-TRAILER POWER WEIGHT RATIO

Type	GCW (Kg)	Engine Power (KW)		Information
		Actual	Analysis	
1.2 + 22	36.000	191,23	198	(-) 34.000 kg
1.1.2 + 22	42.000	201,53	231	(-) 36.000 kg
1.22 + 22	46.000	205,94	253	(-) 37.000 kg

The largest discrepancy between actual engine power and the analytical results is observed in the 1.22 + 22 configuration, with a difference of 47.06 kW. This vehicle should have an engine power of 253 kW, but the actual power is only 205.94 kW, equivalent to 280 PS. The gap between actual engine power and the analytical results is illustrated in Fig. 5.

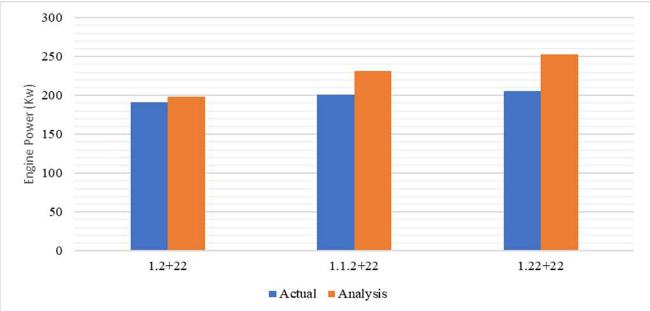


Fig. 5 Chart of engine power actual and analysis on Semi-Trailer

The survey results for trailer trucks revealed that 60% of vehicles with axle configurations 1.2-22 (40 ft), 1.2-222 (40 ft), 1.22-22 (40 ft), and 1.2-11 (Car Carrier/CC) do not comply with the applicable regulations. These vehicles are required to have a maximum length of 18 meters. The survey findings are illustrated in Fig. 6.

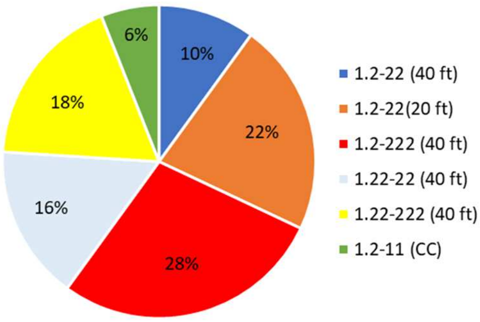


Fig. 6 Axle configuration of Trailer Truck

Similar to a trailer truck, a semi-trailer truck also exhibits discrepancies between GCW and GCPW, where the GCPW should be lower than the GCW. However, survey results from field inspections, as shown in Table VIII, reveal that some vehicles have a GCPW greater than the GCW. This is observed in vehicles with axle configurations 1.2-22 (40 ft) and 1.2-11 Car Carrier (Fig. 7). Trailer trucks are a crucial element in the logistics industry, playing a significant role in the transportation of various types of goods in large quantities. However, in practice, many of these trucks transport excessive loads [38].

Fig. 7 Car Carrier 1.2 – 11 (Car Carrier)

GCPW (Gross Combination Permit Weight) is the maximum total weight allowed to travel according to the road class regulations established in Indonesia. GCPW is calculated and determined by vehicle inspectors. GCW (Gross Combination Weight) represents the vehicle's design strength as specified by the manufacturer. Regulations in Indonesia categorize roads into different classes—Class I, II, III, and Special. Each road class is defined based on vehicle dimensions and the load carried by the heaviest axle.

TABLE IX
SURVEY RESULTS OF TRAILER POWER WEIGHT

Type	GVW head (kg)	GPW head (kg)	GVW trailer (kg)	GPW trailer (kg)	GCW (kg)	GCPW (kg)
1.2-22 (40ft)	16.000	14.600	20.000	18.000	36.000	32.600
1.2-22 (20 ft)	16.000	14.600	20.000	18.000	36.000	32.600
1.2-222 (40 ft)	16.000	14.600	30.000	21.000	46.000	35.600
1.22-22 (40 ft)	26.000	22.500	20.000	18.000	46.000	40.500
1.22-222 (40 ft)	26.000	22.500	30.000	21.000	56.000	43.500
1.2-11 (CC)	16.000	15.500	12.000	10.500	28.000	26.000

Table IX shows that all types of combination vehicles exhibit discrepancies between engine power and the total combination weight (GCW), except for the 1.2-11 (CC) type. Table X shows that the highest discrepancy between actual engine power and analytical results is observed in the 1.22-222 (40F) type, where the GCW is 56,000 kg with an engine power of 209 kW. Analysis indicates that for this GCW, the engine should have a power of 308 kW or approximately 419 PS.

As with articulated vehicles, insufficient engine power relative to the total load (GCW) results in very slow vehicle movement, causing traffic congestion behind the vehicle. Additionally, vehicles often struggle to climb inclines with certain gradients. This issue is particularly prevalent on Indonesian roads, where single-vehicle accidents frequently occur due to the inability of certain combination vehicles to manage inclines [39].

TABLE X
COMPARISON OF POWER ENGINE ACTUAL AND TRAILER TRUCK ANALYSIS

Type	GCW (Kg)	Power Engine (KW)		Information
		Actual	Analysis	
1.2-22 (40 F)	36.000	191,23	198	(-) 34.000 kg
1.2-22 (20 F)	36.000	191,23	198	(-) 34.000 kg
1.2-222 (40 F)	46.000	191,23	253	(-) 34.000 kg
1.22-22 (40 F)	46.000	209	253	(-) 38.000 kg
1.22-222 (40 F)	56.000	209	308	(-) 38.000 kg
1.2-11 (CC)	28.000	191,23	154	Normal

Figure 8 illustrates a significant difference across various axle configurations of combination vehicles, with only the 1.2-11 (CC) type having engine power that aligns with the requirements. The actual engine power of this vehicle is greater than the analytical results, allowing it to handle its maximum load (GCW) adequately. Table XI shows Survey data indicate that this type of vehicle experiences overloading up to 53%, except for the 1.2-11 category.

Trailers and semi-trailers are essential components of Indonesia's transport system, as they possess a greater carrying capacity than other types of cargo vehicles. However, from a regulatory perspective, the government has not established specifications for vehicles that can be configured as articulated or combination vehicles. Analysis results indicate that all articulated vehicles experience overload on the heaviest axle and have engine power that is not proportional to the load weight.

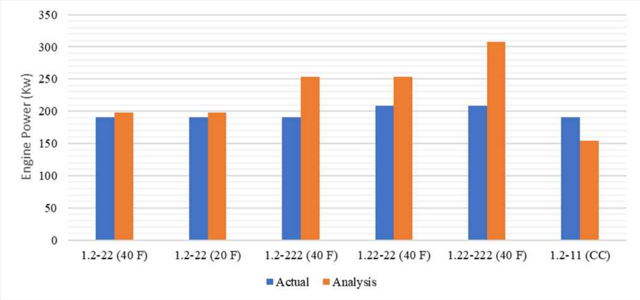


Fig. 8 Chart of Power Engine Actual and Analysis on Trailer Truck

This issue arises because there are no regulations governing these aspects, allowing vehicles to operate freely on the roads. The Original Equipment Manufacturers (OEMs) also do not design vehicles to be articulated; they only sell single vehicles, which are then modified into articulated configurations by the vehicle owners. Articulated components are ordered by the owner from vehicle body manufacturers. As a result, the engine power does not match the total load, as OEMs only design the vehicles as single units. In contrast to articulated vehicles, combination vehicles are more diverse in type. Indonesian government regulations only address articulated vehicles transporting containers through regulation

TABLE XI
THE RESULTS OF THE LOAD TRAILER SURVEY

No.	Type	GVW Head (Kg)	GVW Trailer (Kg)	GCW (Kg)	GPW Head (Kg)	GPW Tailer (Kg)	GCPW (Kg)	Loaded Combination (Kg)	Remarks
1	1.2-22 (20')	16000	20000	36000	14600	18000	32600	37500	Overloaded
2	1.2-22 (20')	16000	20000	36000	14600	18000	32600	30550	Standard
3	1.2-22 (20')	16000	20000	36000	14600	18000	32600	29250	Standard
4	1.2-22 (20')	16000	20000	36000	14600	18000	32600	35680	Overloaded
5	1.2-22 (20')	16000	20000	36000	14600	18000	32600	34200	Overloaded
6	1.2-22 (40')	16000	20000	36000	14600	18000	32600	49780	Overloaded
7	1.2-22 (40')	16000	20000	36000	14600	18000	32600	47600	Overloaded
8	1.2-22 (40')	16000	20000	36000	14600	18000	32600	45340	Overloaded
9	1.2-22 (40')	16000	20000	36000	14600	18000	32600	48000	Overloaded
10	1.2-22 (40')	16000	20000	36000	14600	18000	32600	47800	Overloaded
11	1.2-222 (40')	16000	30000	46000	14600	21000	35600	47650	Overloaded
12	1.2-222 (40')	16000	30000	46000	14600	21000	35600	48600	Overloaded
13	1.2-222 (40')	16000	30000	46000	14600	21000	35600	45700	Overloaded
14	1.2-222 (40')	16000	30000	46000	14600	21000	35600	43200	Overloaded
15	1.2-222 (40')	16000	30000	46000	14600	21000	35600	47800	Overloaded
16	1.2-222 (40')	16000	30000	46000	14600	21000	35600	46500	Overloaded
17	1.2-222 (40')	16000	30000	46000	14600	21000	35600	48000	Overloaded
18	1.2-222 (40')	16000	30000	46000	14600	21000	35600	45800	Overloaded
19	1.2-222 (40')	16000	30000	46000	14600	21000	35600	48080	Overloaded
20	1.2-222 (40')	16000	30000	46000	14600	21000	35600	45800	Overloaded
21	1.22-22 (40')	26000	20000	46000	22500	18000	40500	47800	Overloaded
22	1.22-22 (40')	26000	20000	46000	22500	18000	40500	45800	Overloaded
23	1.22-22 (40')	26000	20000	46000	22500	18000	40500	47700	Overloaded
24	1.22-22 (40')	26000	20000	46000	22500	18000	40500	45800	Overloaded
25	1.22-22 (40')	26000	20000	46000	22500	18000	40500	45800	Overloaded
26	1.22-22 (40')	26000	20000	46000	22500	18000	40500	46750	Overloaded
27	1.22-22 (40')	26000	20000	46000	22500	18000	40500	49900	Overloaded
28	1.22-22 (40')	26000	20000	46000	22500	18000	40500	52350	Overloaded
29	1.22-22 (40')	26000	20000	46000	22500	18000	40500	46790	Overloaded
30	1.22-22 (40')	26000	20000	46000	22500	18000	40500	45600	Overloaded
31	1.22-222(40')	26000	30000	56000	22500	21000	43500	56790	Overloaded
32	1.22-222(40')	26000	30000	56000	22500	21000	43500	65470	Overloaded
33	1.22-222(40')	26000	30000	56000	22500	21000	43500	47890	Overloaded
34	1.22-222(40')	26000	30000	56000	22500	21000	43500	57500	Overloaded
35	1.22-222(40')	26000	30000	56000	22500	21000	43500	57340	Overloaded
36	1.22-222(40')	26000	30000	56000	22500	21000	43500	61000	Overloaded
37	1.22-222(40')	26000	30000	56000	22500	21000	43500	48900	Overloaded
38	1.22-222(40')	26000	30000	56000	22500	21000	43500	53450	Overloaded
39	1.22-222(40')	26000	30000	56000	22500	21000	43500	58700	Overloaded
40	1.22-222(40')	26000	30000	56000	22500	21000	43500	55400	Overloaded
41	1.2-11 (CC)	16000	12000	28000	15500	10500	26000	25000	Standard
42	1.2-11 (CC)	16000	12000	28000	15500	10500	26000	24500	Standard
43	1.2-11 (CC)	16000	12000	28000	15500	10500	26000	25600	Standard
44	1.2-11 (CC)	16000	12000	28000	15500	10500	26000	26000	Standard
45	1.2-11 (CC)	16000	12000	28000	15500	10500	26000	25780	Standard
46	1.2-11 (CC)	16000	12000	28000	15500	10500	26000	25450	Standard
47	1.2-11 (CC)	16000	12000	28000	15500	10500	26000	22500	Standard
48	1.2-11 (CC)	16000	12000	28000	15500	10500	26000	22750	Standard
49	1.2-11 (CC)	16000	12000	28000	15500	10500	26000	25700	Standard
50	1.2-11 (CC)	16000	12000	28000	15500	10500	26000	25450	Standard

In practice, combination vehicles are used for various purposes beyond container transport, including the transport of fuel, steel coils, cement, heavy equipment, and more. Therefore, regulations need to be updated and refined to accommodate all types of combination vehicles operating on the roads (Fig. 9).

Experiences from other countries demonstrate that trailers and semi-trailers are regulated by specific guidelines concerning their dimensions, load capacity, and engine power[40], [41]. Research by [42], [43], [44] indicates that such vehicles contribute to road damage due to their substantial load capacity. However, there is a lack of references regarding the comparison between engine power and load capacity. This research is critical, considering that the supervision of this type of vehicle is still weak, especially in Indonesia. Many of these vehicles operate on highways, and in Indonesia, they are exempted from entering weigh stations. This situation persists and necessitates immediate and concrete action from the government to address it by formulating and implementing regulations specifically governing these types of vehicles.

Fig. 9 Many Types of Trailer Trucks in Indonesia

In addition, articulated and combination vehicles in Indonesia suffer from weak oversight due to minimal regulations. The government conducts road monitoring for these vehicles through weighbridges; however, regulations exclude certain types of vehicles from this oversight, such as those transporting containers, fuel, hazardous materials, and heavy equipment. As a result, articulated and combination vehicles often evade scrutiny, leading to numerous violations by vehicle owners, including those related to the maximum axle load, transportation procedures, and power-to-weight ratio (PWR).

These violations contribute to several problems, including road and bridge damage, single-vehicle accidents resulting from inadequate climbing ability, and accidents caused by speed differentials on highways. The Indonesian National Transportation Safety Committee (KNKT) has reported that accidents on highways are partly caused by significant speed differences between large vehicles (articulated and combination vehicles) and lighter vehicles [45]. KNKT has also highlighted that one cause of accidents involving combination trucks is their inability to climb inclines due to a mismatch between the vehicle load and engine power [22]. Similar issues have been reported in Poland [46]. The discussion underscores the urgent need for regulations governing articulated and combination vehicles in Indonesia to ensure road safety and efficient transportation.

Based on the findings of this study, several technical recommendations are proposed to improve the safety of trailer and semi-trailer operations:

1) Establishment of Minimum PWR Standards for Different Axle Configurations: The study indicates that insufficient PWR leads to reduced acceleration capability and higher safety risks. It is recommended that transport authorities establish and enforce minimum PWR thresholds based on axle configuration and payload weight to ensure adequate vehicle performance in various road conditions.

2) Adaptive Load Management to Optimize PWR: Given that excessive payloads significantly reduce the effective PWR, it is advised that fleet operators implement load distribution strategies that maintain an optimal balance between engine power and weight. This may include enforcing maximum payload limits per truck category and promoting the use of load equalization systems.

3) Regulatory Review of Gross Vehicle Weight (GVW) Limits about PWR: Current weight regulations often do not account for the impact of PWR on vehicle maneuverability and safety. It is recommended that policymakers revise GVW limits based on PWR considerations, ensuring that heavily loaded trucks maintain sufficient power reserves to meet acceleration, climbing, and braking performance requirements.

4) Mandatory Vehicle Performance Testing for Compliance: The study suggests that real-world performance testing of trailer and semi-trailer trucks is essential to verify compliance with PWR-based safety standards. It is recommended that authorities implement periodic vehicle assessments, including loaded acceleration tests, hill-climbing capability checks, and brake efficiency evaluations under full payload conditions.

5) Infrastructure Adaptation for Heavy and Low-PWR Trucks: Road infrastructure plays a critical role in mitigating the risks associated with low-PWR vehicles. It is advised that highway planners consider dedicated climbing lanes for heavy trucks, improved signage for steep gradients, and extended deceleration lanes to accommodate trucks with longer stopping distances.

6) Integration of Telematics for Real-Time PWR Monitoring: The research suggests that real-time PWR monitoring through telematics and onboard diagnostics can help fleet operators optimize vehicle performance and detect potential safety risks. It is recommended that trucking companies adopt GPS-integrated fleet management systems capable of analyzing power output, load conditions, and road gradients to prevent operational inefficiencies and safety hazards.

By implementing these recommendations, transport authorities, fleet operators, and policymakers can improve road safety, enhance truck performance, and optimize freight transport efficiency. Future studies should focus on real-world validation of these recommendations, particularly in diverse geographical and traffic conditions.

IV. CONCLUSION

The research findings reveal that articulated vehicles are not sold by Original Equipment Manufacturers (OEMs); OEMs only sell single vehicles, while owners create articulated configurations through body manufacturers. This situation arises due to the lack of regulations governing technical specifications for articulated vehicles in Indonesia. Conversely, combination vehicles in the field are highly diverse in type and configuration, yet Indonesian regulations only address combination vehicles transporting containers.

Both articulated and combination vehicles are found to violate load capacity and engine power requirements. On-site oversight is also inadequate; weighbridges do not monitor these vehicles due to regulatory exemptions. Consequently, articulated and combination vehicles operate without government oversight, leading to numerous accidents caused by the lack of enforcement. This situation is critically urgent, as thousands of articulated and combination vehicles operate daily without supervision, posing significant risks to road safety. This study recommends that the government promptly establish technical regulations for articulated and combination vehicles to ensure traffic safety and effective road transportation in Indonesia.

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