Comparison of the Fuel Consumption Performance of Rear and Front Wheel Drive Vehicles via Road Test

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Abstract

This paper presented an on-site investigation of a fuel consumption comparison between a Front Wheel Drive (FWD) and Rear Wheel Drive (RWD) vehicle. Those were the two most common drive types used in the commercial vehicle. The study focuses on the fuel consumption rate by comparing the average distance achieved by one liter of fuel using the same type of engine. The road test was varied from the normal highway, uphill, downhill, and normal city roads to give more insight into the fuel consumption characteristics of each variation. The results showed that each road type gives significantly different characteristics to fuel consumption and comparing FWD and RWD regarding fuel consumption gives interesting results for further vehicle transmission developments.

Keywords: *Fuel Consumption, Front wheel drive, Rear Wheel Drive, Road Test, Vehicle.*

1. Introduction

The development of automotive technology is rapidly advancing, encouraging humans to continue creating innovations. The use of cars is increasing every year because the public highly seeks them. According to data from the Gaikindo, the Association of Indonesia Automotive Industry, monthly car sales continue to increase [1]. For example, at the end of last November 2022, total sales increased by 4.2% from the previous year, from 87,437 units to 91,086 units. It has led to increasing advancements in every car available in the market.

The drivetrain system in a car is one of the most important components as it functions as the power transfer from the engine to the wheels. It consists of several components: the clutch, transmission, drive shaft or propeller shaft, rear axle, and wheels. Based on this drivetrain type, cars are divided into four categories: front-wheel drive (FWD), rear-wheel drive (RWD), all-wheel drive (AWD), and four-wheel drive (4WD). Each drivetrain system has its advantages and disadvantages. Due to the significant impact of this component, research needs to be conducted to determine the factors that can influence the types of drivetrain systems in cars.

Extensive research has been conducted on car drivetrains by several researchers, one of which is mentioned by Eckert et al. [2]. The research aimed to minimize fuel consumption by optimizing the drivetrain via multi-objective optimization. Similarly, Nguyen et al. optimized the drive train system to improve a car's dynamic and energy balancing[3]. Researchers also investigated many ways to make improvements regarding the wheel drive system. Marino and Scalzi proposed a semiactive control system for the rear-wheel drive vehicle [4], closely similar to the work of Cyril and Manikandan recently [5].

Meanwhile, the energy optimization through the wheel drive system was also getting more interest since the research was extended by Guo et al. by designing a novel front and rear vehicle platoon control [6]. Road and traffic tests that affected wheel drive performance were also interesting topics conducted by researchers, such as [7] and Shigematsu [8], where sloppy sandy terrain surface was used as the test track. The result gave useful information, whereas the terrain surface significantly impacts the driving performance. Recently, the improvement idea of wheel drive and drive train have been extensively applied for other applications such as farm tractors [9], [10] and aeronautics [11].

This paper extended the study from the above previous works of the wheel drive systems by proposing a comparison study of fuel consumption performance between FWD and RWD vehicles with various on-site road test conditions that have never been done before. The relation of FWD and RWD to fuel consumption and various road test conditions were the most actual phenomena experienced by the driver daily, yet no comprehensive studies were available. Furthermore, this study could provide useful insight for further drive train design improvements.

2. Method

The research method was briefly presented in the research flowchart in Figure 1 below. It started by reviewing all literature on drive trains and wheel drive systems, followed by specimen preparation. In this case, two same-type Engines were used for two different wheel drive systems: one FWD and one RWD. The technical specification was shown in the next sections. Then, it was followed by an on-site performance test and analysis of the comparison results.

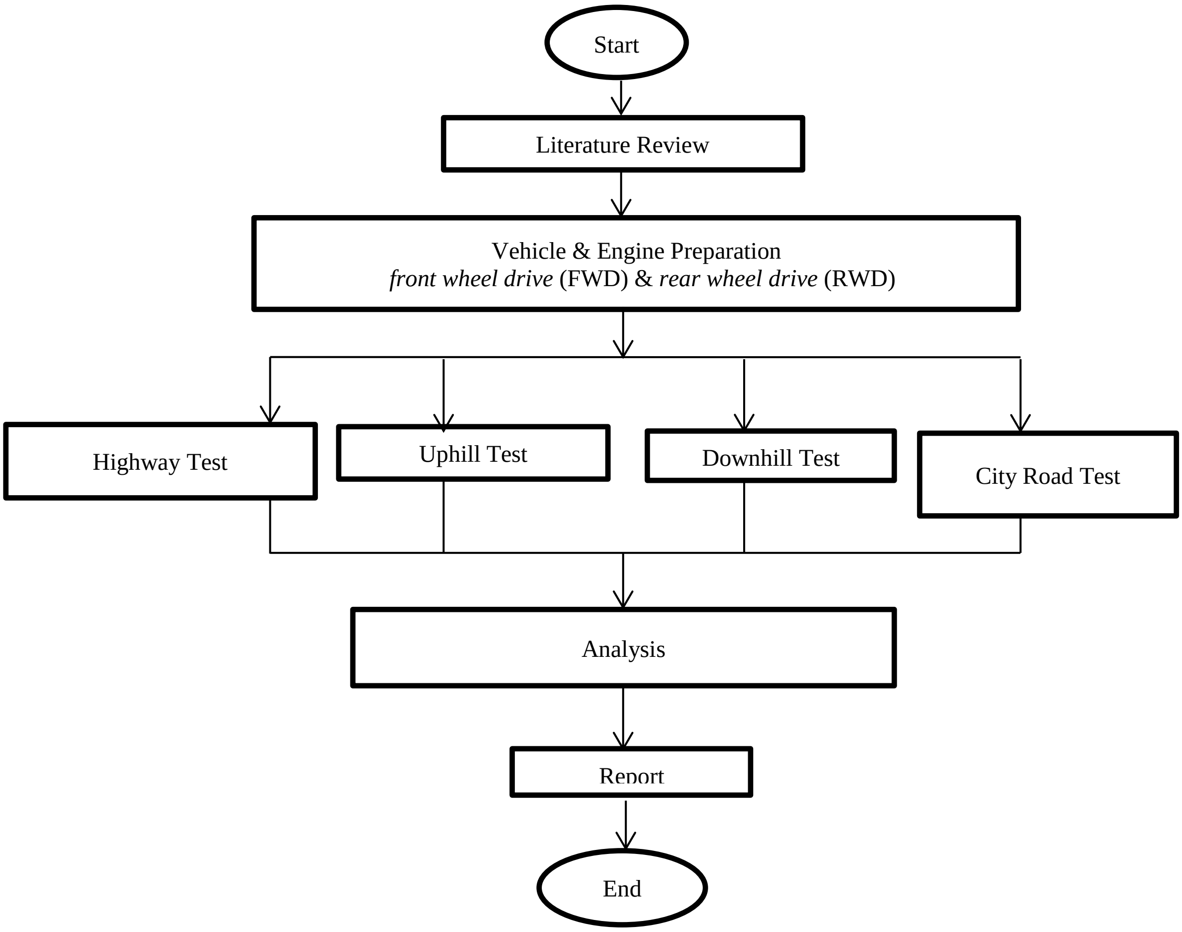

Figure 1. Research Flowchart

Table 1 showed the engine used for the road test measurements. It was a commercial engine commonly used for Toyota Avanza and Rush nowadays. The cylinder capacity and other necessary information were shown as well.

Table 1. Engine Specification for On-site Measurement

Type	Drive Train	Cylinder Capacity	Cylinder Number	Valve Number
2NR-VE DOHC Dual VVTi	FWD	1496 cc	4	16
2NR-VE DOHC Dual VVTi	RWD	1496 cc	4	16

Meanwhile, the variation of the road test condition was shown in Table 2 below. Four different road conditions were used, i.e. highway, uphill, downhill, and ordinary city road. These roads were the most common road conditions in the world. So, conducting the road test under those conditions was useful, so that the results were wider and more comprehensive.

Table 2. Road Condition for On-site Measurement

Drive Train Type	Fuel	Road Condition
FWD	*Pertamax*	Highway
		Uphill
		Downhill
		City Road
RWD	*Pertamax*	Highway
		Uphill
		Downhill
		City Road

The fuel consumption rate, *C*, in our case, is determined by the ratio between the average distance achieved *S*, and the total fuel consumption along that distance, *F*, given by

$$C = \frac{S}{F} \quad (1)$$

Hence, our fuel consumption rate unit was a kilometre per liter (km/l). This unit was also a common comparison value in the commercial vehicle fuel consumption performance. Even more, some of the latest types of cars have this unit in the dashboard display.

Next, the four road test conditions were outlined in the explanation below. Google Maps was also used to show the tracks and route more clearly, as seen in Figures 2 to 5:

1. **Highway Road Test:** Figure 2 showed the distance of Toll Gate Tambak Sumur 2 to Toll Gate Sidoarjo; the total distance was 21,2 km.

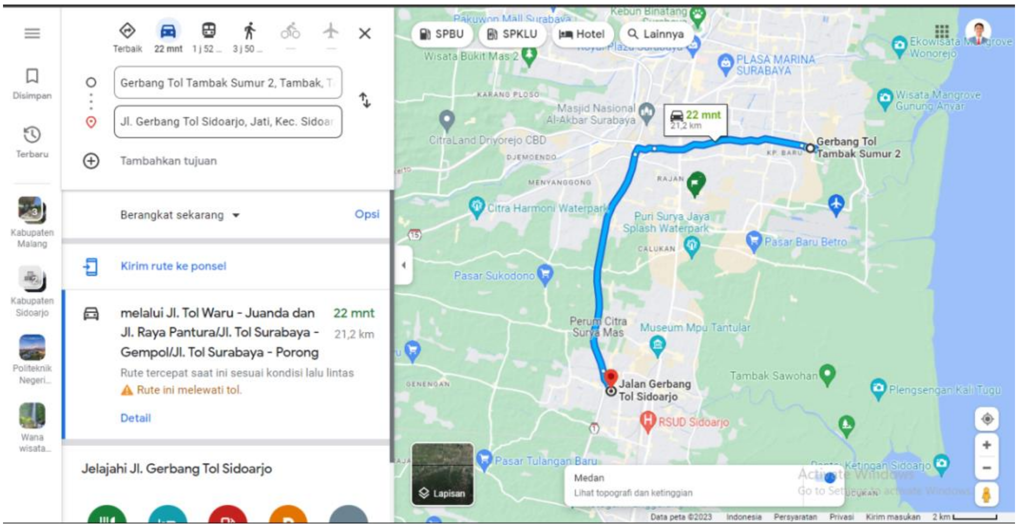

Figure 2. Highway test route and track.

2. **Uphill Road Test:** Figure 3 showed the distance from SPBU Pertamina 54-65127 Jl. Perusahaan raya No.24 Malang to Wana Wisata Coban Talun and total distance was 22,9 km.

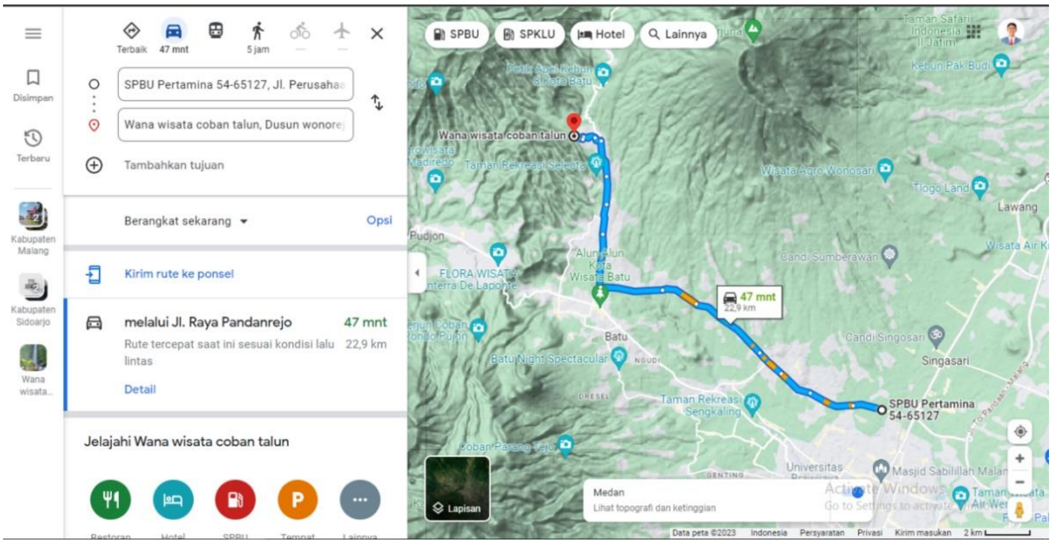

Figure 3. Uphill test route and track.

3. **Downhill road test:** Figure 4 showed the distance from Wana Wisata Coban Talun to SPBU Pertamina 54-65127 Jl. Perusahaan raya No.24 Malang, with total distance of 22,9 km.

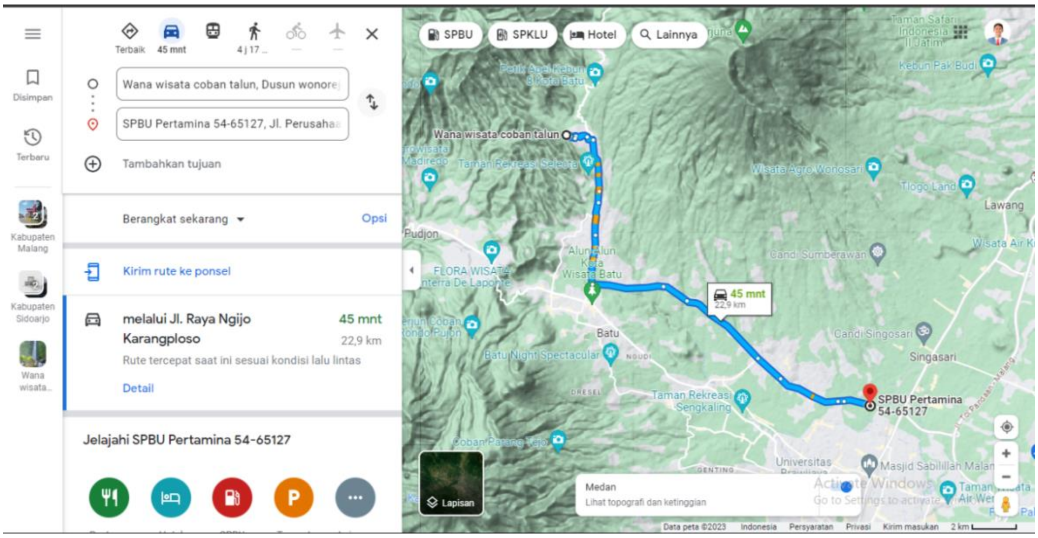

Figure 4. Downhill test route and track.

4. **City Road Test:** Figure 5 showed the distance from Toll Gate Singosari to Politeknik Negeri Malang, to Toll Gate Singosari, with a total distance of 18,2 km.

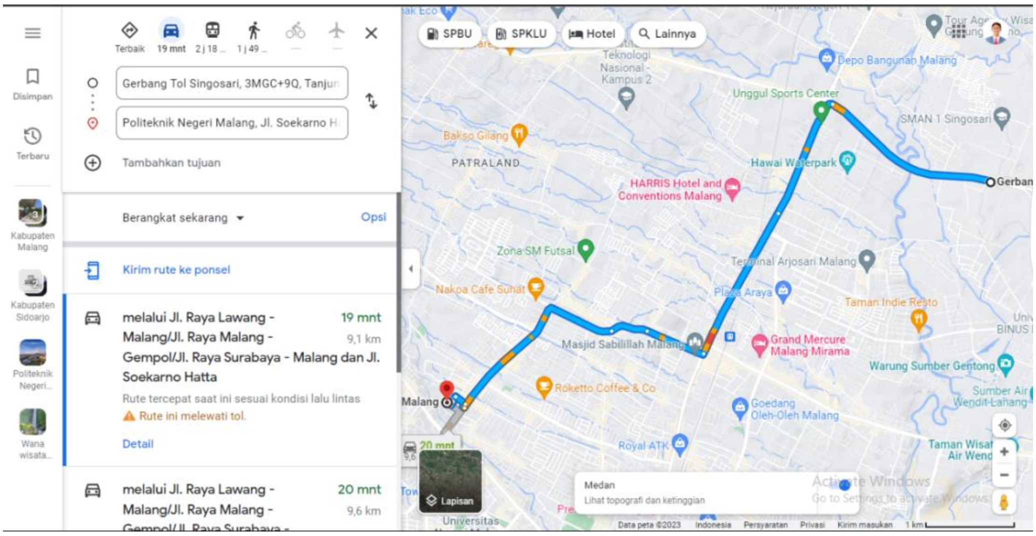

Figure 5. City road test route and track.

3. Results and Discussion

The road test results for FWD and RWD vehicles were summarized in Tables 3 and 4 below, with the additional captured data from the Multi-Information Display (MID) on the dashboard as seen in Figures 6:

Table 3. FWD Road Test Result

Drive	Road	*S*	*C*
FWD	Highway	21,2 km	16,9 km/l
	Uphill	22,9 km	7,4 km/l
	Downhill	22,9 km	20,0 km/l
	City Road	18,2 km	9,8 km/l

Figure 6. Example of MID display result of Highway Test.

The MID was captured during the test to give an example of the observation process. It could be a good way to ease the observation process during the test. The MID results are tabulated in Table 3 and Table 4 for the rest of the discussions.

Table 4. RWD Road Test Result

Drive	Road	*S*	*C*
(RWD)	Highway	21,2 km	18,9 km/l
	Uphill	22,9 km	8,6 km/l
	Downhill	22,9 km	27,1 km/l
	City Road	18,2 km	11,8 km/l

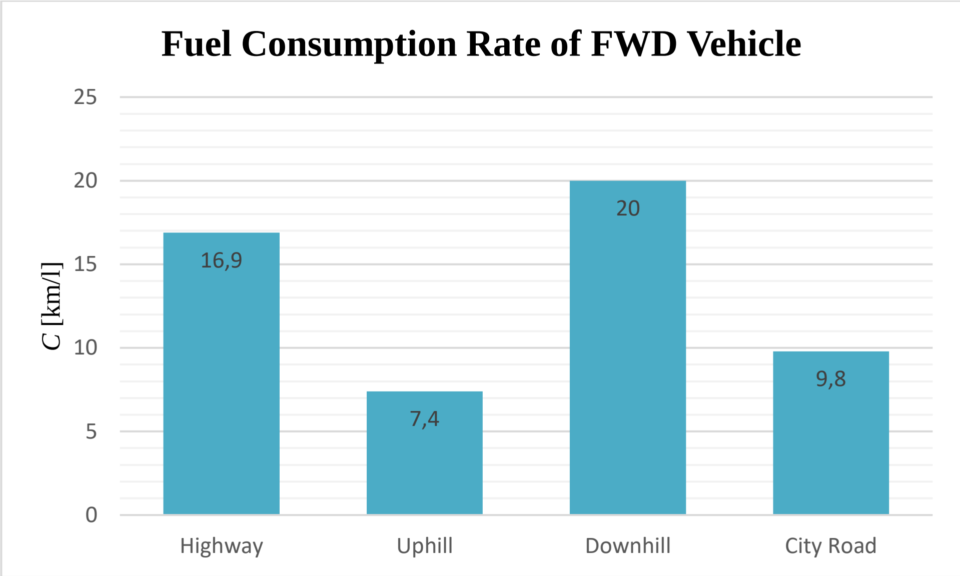

Figure 7. The fuel consumption rate of FWD.

Figure 7 showed that FWD cars had different fuel consumption rates in each type of road test. The most fuel-efficient consumption was on downhill roads, with a rate of 20 kilometers per liter, meaning that one liter of fuel can cover a distance of 20 kilometers. On the other hand, the highest fuel consumption was on uphill roads, with a rate of 7.4 kilometers per liter, meaning that one liter of fuel could only cover a distance of 7.4 kilometers. It was linear with the result from Yu et al. [12], which investigated heavy-duty commercial vehicles under different test conditions. During downhill, the amount of throttle was significantly less than during uphill needing much torque energy from the engine.

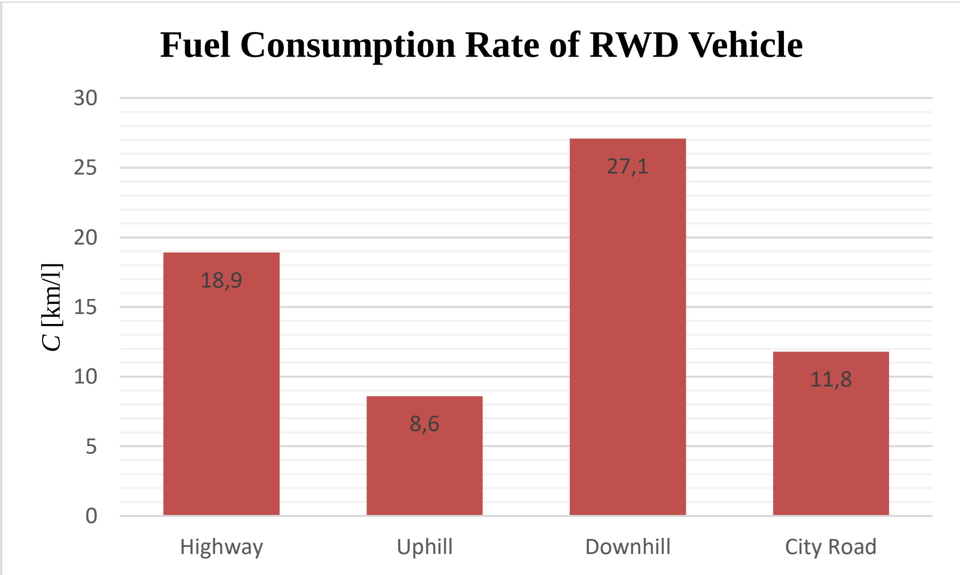

Figure 8. The fuel consumption rate of RWD.

Figure 8 shows that RWD cars have different fuel consumption rates in each type of road test. The most fuel-efficient consumption is on downhill roads, with a rate of 27.1 kilometers per liter, meaning that one liter of fuel can cover a distance of 27.1 kilometers. On the other hand, the highest fuel consumption is on uphill roads, with a rate of 8.6 kilometers per liter, meaning that one liter of fuel can only cover a distance of 8.6 kilometers. Again, this result also agreed with the result from Yu et al. [12] with the same uphill-downhill phenomena. It was more clear that a comparison between the two drivetrains is discussed further below.

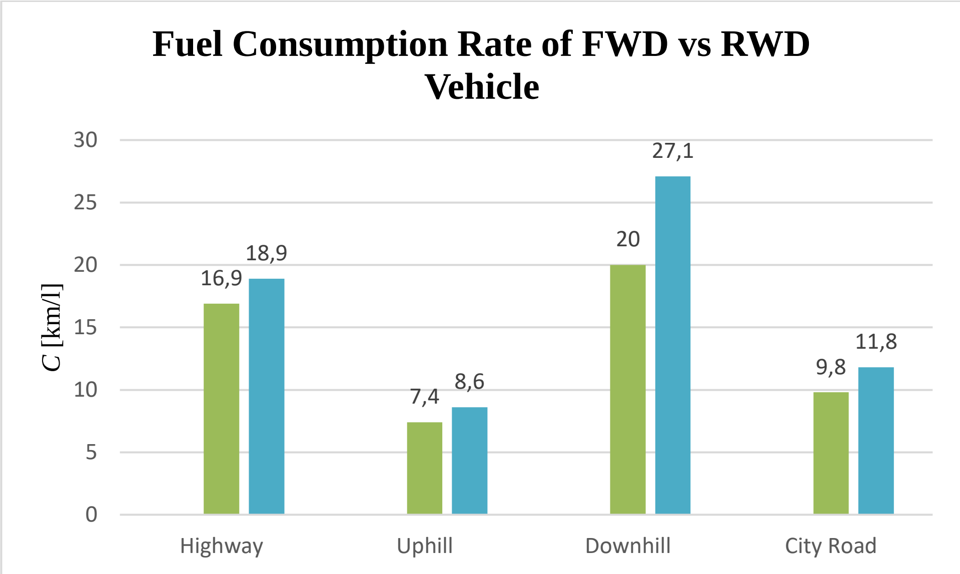

Figure 9. Fuel consumption rate comparison of FWD (green) vs. RWD (blue)

Figure 9 showed the difference in fuel consumption between FWD and RWD cars in each road test. On a highway (toll road), FWD cars had a fuel consumption of 16.9 kilometers per liter, while RWD cars had a fuel consumption of 18.9 kilometers per liter. It means that in the tests conducted, the RWD car could travel 2 kilometers with 1 liter of fuel.

In the uphill test, FWD cars had a fuel consumption of 7.4 kilometers per liter, while RWD cars had a fuel consumption of 8.6 kilometers per liter. This means that in the tests conducted, the RWD car could travel an additional 1.2 kilometers with 1 liter of fuel. In the downhill test, FWD cars had a fuel consumption of 20 kilometers per liter, while RWD cars had a fuel consumption of 27.1 kilometers per liter. This means that in the tests conducted, the RWD car could travel an additional 7.1 kilometers with 1 liter of fuel. In the normal city road test, FWD cars had a fuel consumption of 9.8 kilometers per liter, while RWD cars had a fuel consumption of 11.8 kilometers per liter. It means that in the tests conducted, the RWD car could travel 2 kilometers with 1 liter of fuel.

Based on the observations, it was found that the distribution of weight between the wheelbase of a car affects the engine workload. The longer the wheelbase obtained, the heavier the engine workload. FWD cars had a wheelbase of 2,750 mm, while RWD cars had a wheelbase of 2,685 mm. It caused FWD cars to have a heavier engine workload, resulting in higher fuel consumption. To explain the statement, the center concept of gravity could be used as in [13], which found similar phenomena. The gravity center of the FWD vehicle was placed slightly forward due to the engine locations. It made the engine workload bigger than the RWD vehicle. The RWD vehicle, meanwhile, had an additional component, namely the propeller shaft and distributor gear, to transmit the energy from the engine to the rear wheel. It eventually shifted the RWD vehicle's centre of gravity slightly backwards, making the load relatively more evenly distributed. In turn, the engine workload, as well as fuel consumption, was lesser.

4. Conclusions

The main conclusion of the study might be summarized as follows:

1. The fuel consumption of FWD and RWD vehicles has been studied independently, showing that every road test condition provided different characteristics to one another.
2. The results provided useful information for further design and drivetrain engineering for making improvements.
3. The comparison result showed the advantages of using RWD caused by the wheel base difference. However, it could be more explored for future works involving the dynamic analysis of each drive train type.

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