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Simulating the Effects on Lap time from Changing Variables

Introduction To Automotive Engineering ACHA4035

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1 Base Vehicle

1.1 Overview

We have been provided a base prototype vehicle that we have been tasked with altering certain variables to test the changes in performance across numerous tracks, varying in different styles of driving. Some tracks are more reliant on maintain higher speeds through both low and mid speed corners, whereas there are some tracks that a vehicle could gain as advantage for focusing on higher straight-line speed but might need to sacrifice speed in corners to achieve this.

1.2 Baseline Performance

Utilising the Optimum Lap software and running a simulation of the prototype vehicle across all 6 tracks to get a baseline time and performance of the vehicle without any alterations. This allows a control time for each track to compare the effect of any changes that I make will have on the vehicle. It Also provides the ability to then provide value to the changed variables for the cost to visualise where the largest and smallest gains are and in which variables. The Below figure shows the baseline times that are targeted to be beaten.

The targeted variables to be altered to attempt to achieve a faster lap time have been limited to, the mass of the vehicle,

Selected Results	
[100.14]	Baseline Assignment Prototype, Round 1 Silverstone Circuit
[83.49]	Baseline Assignment Prototype, Round 2 Monaco
[121.41]	Baseline Assignment Prototype, Round 3 Spa-Francorchamps
[88.77]	Baseline Assignment Prototype, Round 4 Portugal
[200.57]	Baseline Assignment Prototype, Round 6 Le Mans
[91.91]	Baseline Assignment Prototype, Round 5 Catalunya

Figure 1 – Baseline Lap Times of Prototype Vehicle

ranging from the baseline mass of 975Kg to the minimum of 915Kg. The aerodynamic factors of both drag and downforce coefficient to which the baselines are 0.51 and 1.6 respectively. The Stock Tyres start at a base radius of 1.8 for both lateral and longitudinal radii and are able to be increased to an maximum of 1.85 for both. Then the last two variables to change between tracks are the power scaling factor of the Engine, baseline being 100% and able to increase to 120%, and the drive efficiency, base of 90%, alterable to a maximum of 95%. The gear ratios per gear are also eligible to be altered however, once the gear ratios have been decided they must be consistent across all 6 tracks.

2 Simulations and Tests

2.1 Gear Ratios

As a general understanding of gears, increasing the ratio of a gear would shorten it, therefore increasing the effect on acceleration, however it would then lead to a lower top speed being achieved in that select gear. This is why the baseline gears of the prototype as show in figure 2 start at 3.1 and end at 1.2. Testing varying setups of gear ratios, both increasing the initial ratios to increase the acceleration of the vehicle and equally lowering the latter gear ratios to provide longer a longer gear with the desired effect of achieving higher max speeds.

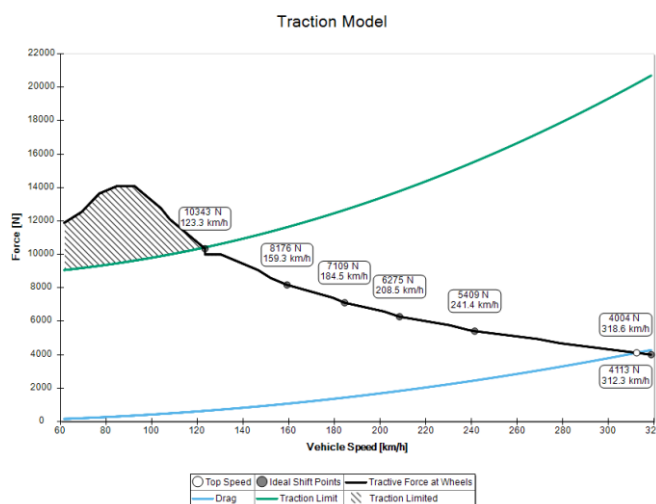


Figure 2.2 – Traction Model of Baseline Prototype Vehicle

	Gear Ratios	Shift Points (rpm)
► Gear 1	3.1000	8000
Gear 2	2.2000	7331
Gear 3	1.8000	6947
Gear 4	1.6000	6979
Gear 5	1.4000	7071
Gear 6	1.2000	8000

Figure 2.1 – Baseline Gear Ratios

The traction model of the baseline vehicle as show in figure 2.2 shows that even with the first gear being shorter to allow for greater acceleration. The driving force of the vehicle is greater than that of the

traction limit leading to a loss of performance due to the tyres spinning. However, changing the initial gear ratio has little effect due to the shift point being at the point of which the traction limit surpasses the driving force then outputted by the vehicle. The graph also shows that in the final gear at max RPM the vehicle is already at mac speed due to the drag surpassing the driving force outputted. Therefore, increasing the gear ratio of the final gear in isolation here would not have a visible effect unless we then alter other variables. In the Article (Ikkei KOBAYASHI, 2022) they delve into the effects of changing the gear ratios. The focus is over a shorter distance of 400m to try and optimise the acceleration of the vehicle. Their findings show that a very long gear will massively increase the ‘lap’ time and drastically decrease in time as the gear ratio gets shorter but then will begin to increase again like a bell curve.

2.2 Initial Tests

Initial Tests consisted of doing batch simulations of the variables, such as the mass to gauge the difference at each step of the runs to see how big a time gain can be obtained and gauge where the best value against gain is. Figure 2.3 shows that with each

incremental step of reducing the mass, there appears to be a consistent decrease in lap time with a time of 94.33s at the baseline weight of the 975Kg, compared to a time of 93.05s at a vehicle mass of 915Kg. Therefore, there is a total potential gain of roughly

1.3s. However, a time gain of 1.3s

for a total cost of 60 credits, near half of the budget is not as significant as the gains made by altering other variables. Going down the list of variables, running tests for each in isolation to get results for every variable to look at side by side and judge which are more valuable at what cost per track. Using Silverstone as a control circuit, it is interesting to see that changing some variables don't have a significant gain in time over the entire circuit. One variable of note was the tyre friction values. The baseline values of 1.8 for both lateral and longitudinal friction the time was 100.14s, however even at the maximum values of 1.85 for each respective variable, there is only a total gain of 0.56s. Taking in account that the budget hit for the maximum is the same for both the friction and the vehicle mass, the comparison of the mass having double gain than friction leads to the budget favouring the mass. Through the testing of the power scale, a factor that is evident in the graphs is as power scale increases, the driving force is then increased leading to the traction limit remaining under the transaction limit for longer, leading to losses in acceleration and would lead to potentially lower exit speeds out of corners as if the apex speed is lower than that if the transaction limit there won't be as much drive out of the corner. However, the payoff is the ability to reach higher speeds on the straights once the vehicle can get the power down.

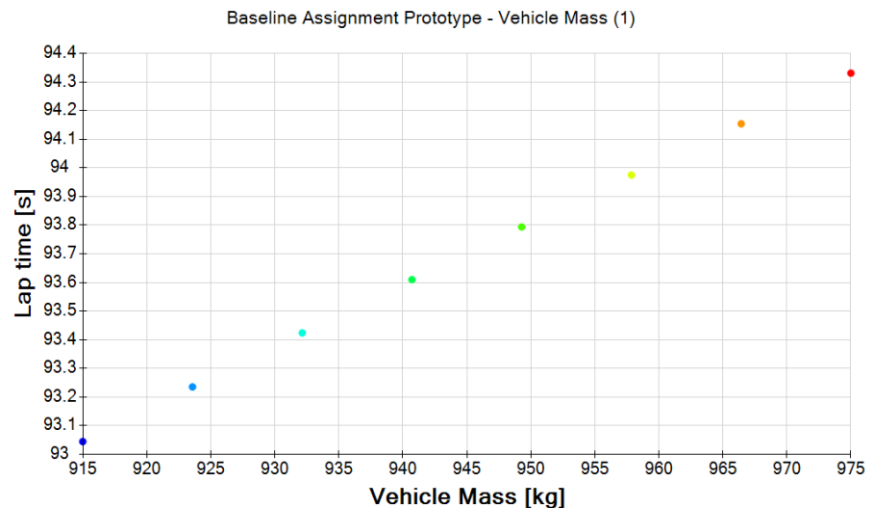


Figure 2.3 – Simulations of Mass Changes in Isolation

3 Setup Decisions

Accumulating all the data from the preliminary tests. Tests began on using variables in conjunction with one another. There was a lot of trial-and-error to discover how variables react when changed with another instead of purely in isolation. In the instance where the power scale was changed in conjunction with the vehicles mass. There was a compounding effect of the vehicle maintaining a higher driving force than what the traction limit would allow for a longer period. However, testing of the power scaling in conjunction with increasing the friction seemed to more harmonious effect as the friction negated the impact of the increased driving force in first gear, whilst still allowing the power scale to accelerate the car to the higher speed on the straights. Another positive correlation seemed to be increasing the power factor as well as the aero package, as it led to increasing apex speeds due to the capacity to maintain driving force through the corner. This again in conjunction with the tyre friction values allowed for a further compounding result in achieving better corner speeds. In the article (Racecar Engineering, 2022) the focus on the unconventional and different aero package that was introduced by Mercedes F1 team back in 2022 shows that how a car displaces the air around it and uses it to its advantage can have massive impact on the performance of the car. Knowing this and across multiple categories of racing on varying levels, there is always a major focus on the aerodynamics of the vehicle, hence during the simulations there was a major focus on finding the best aero package as a basis to build the setup upon.

4 Conclusion and Finalised Setups

After experimenting with the gear ratios and attempting to find a middle ground that is applicable on every track due to the limitations of being restricted to the same gear ratios across all 6 tracks. The initial gear ratios fulfilled what was needed and caused no major implications on any track therefore was kept for the final build. Across testing, the initial tests were on the aero package, which seemed to me synonymous across all tracks that Map D, which was the highest aero package setting but was in the mid-range of budget had the greatest impact on lap times, thus used as the initial foundation to build upon. The power factor, used in conjunction with the aero package already decided, was then implemented. Using the max power factor of 120% used, a significant time was saved on every map. Paired with increasing the tyre friction from the 1.8 of base to 1.825 for the longitudinal and 1.85 for the lateral friction, times continued to decrease across all tracks. As the budget wanes, increasing the drive efficiency to 92% had the largest impact with the remaining balance, achieving the fastest lap times across the board. The lap times for all 6 tracks are shown in figure 4.1.

2025 Championship	Circuit	Lap Time Achieved (s)
Round 1	Silverstone Circuit	93.36
Round 2	Monaco	79.83
Round 3	Spa Francorchamps	113.5
Round 4	Portugal	84.22
Round 5	Catalunya	86.52
Round 6	Le Mans	188.24

Figure 3.1 – Final Lap times for all 6 Rounds

The set up finalised on Silverstone, was the bases then used on all other tracks. It appeared to be through numerous tests of all variables to remain the fastest across all tracks. The assumption being that altering the gear ratios from the decided set would cease this and further alterations would be required.

5 References

Ikkei KOBAYASHI, K. O. (2022). Investigation of Gear Ratios for Hybrid System in Small Race Car Using Lap Time Simulation. *9th IFAC Symposium on Mechatronic Systems MECHATRONICS*, 442-447.

Racecar Engineering. (2022). Formula 1 2022. *Formula 1 2022*, 22.

5.1 Figures

Figure 4 – Baseline Lap Times of Prototype Vehicle

-Optimum Lap

Figure 2.1 – Baseline Gear Ratios

-Optimum Lap

Figure 5.2 – Traction Model of Baseline Prototype Vehicle

-Optimum Lap

Figure 2.3 – Simulations of Mass Changes in Isolation

-Optimum Lap

Figure 6.1 – Final Lap times for all 6 Rounds

-Optimum Lap