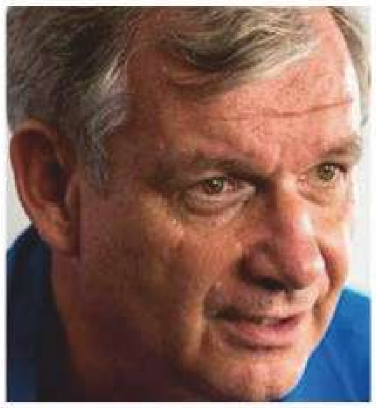

The coast is clear

Why analysing the data when a race driver is neither on the throttle nor the brakes is an excellent way of honing outright performance

By **CLAUDE ROUELLE**

In the last few articles we have covered how to analyse the aspects of the braking part of a corner by looking at braking aggression, brake application point, and braking stability.

However, braking is only one small fraction of what can be analysed in a corner. Corner apex and exit speed can prove to be just as important, as it will define how much quicker a driver is through the corner and along the next straight.

To determine how well a driver can accelerate out of a corner we can analyse how much time they are spending with no throttle or braking input through a given turn. The time, or the percentage of the lap time spent neither on brake or on throttle, known as coast factor, can in turn be used to determine how well a driver is performing relative to their competitors, and thus how a different driving style can be used to help them beat the competition.

For most corners, one of the fastest ways to take them is to minimise the time with no throttle or brake input. **Table 1** shows the equations that can be used in MoTeC i2 Pro to calculate coast factor. The coast factor can be calculated as a Boolean function, meaning that when there is only a residual braking or throttle signal, the function will return a value of 1. The residual value of coasting should be determined when calibrating the throttle position sensor and the brake pressure sensor. We will integrate the time that the car is in the state of no inputs for each corner of the course to generate the coast KPI (key performance indicator) in a corner. We can additionally track the total time coasting each lap by adding the corner times together.

NASCAR

NASCAR Truck in action at Pocono Raceway. Evaluating how long a driver coasts throughout a lap is a useful performance indicator

For this analysis we will compare two NASCAR Truck drivers on their qualifying lap at the Pocono Raceway tri-oval. Given that the two drivers were driving for peak performance, the variation in coast factor can be correlated to the lap time each driver achieved. This can in turn provide feedback to the driver on how to approach the track. The coast factor can also be used in combination with other KPIs to help provide information that can be utilised to determine set-up changes to make to a vehicle to minimise the coast factor magnitude.

We will start by looking at the coast factor on a map to gauge where and how much the driver is coasting. Each loop shown is a different driver's best lap. Red on the plot denotes where the drivers were coasting, while the plot is green when they were not. In the example shown in **Figure 1**, we can see that the black driver (denoted by the red surfaces on the inner loop) was coasting a significantly larger amount in the first and third corners when compared to the red driver. However, without additional knowledge of the driving style and

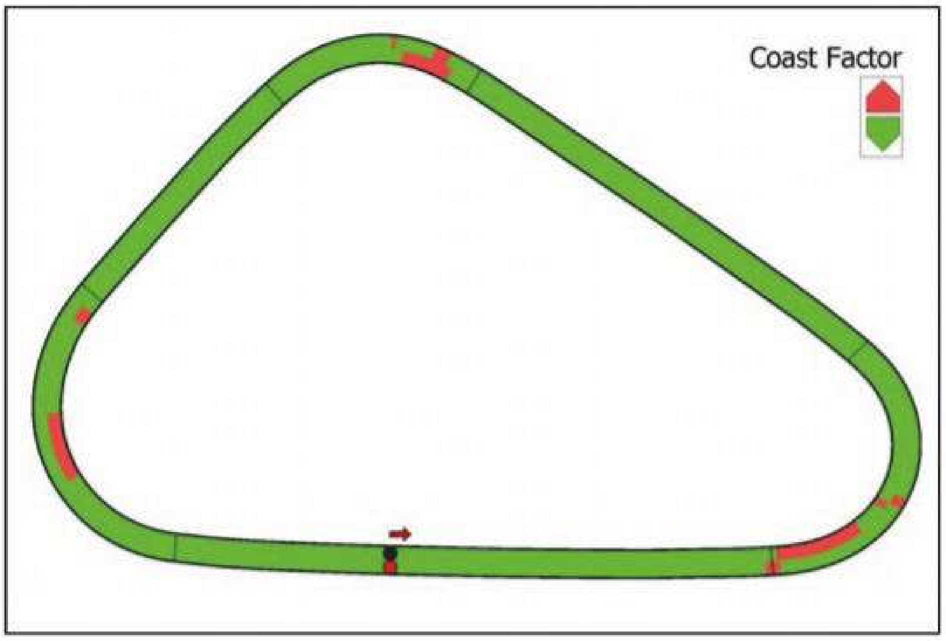

Figure 1: Coast factors for two NASCAR Truck drivers on their qualifying laps at Pocono

Table 1: Motec i2 coast factor math channels

Name	Equation
Coast factor	choose('Throttle' [%]<0.5 and 'Brake' [%]<0.5, 1, 0)
Coast factor corner KPI	integrate('Coast Factor','Corr Speed' [km/h]>0,range_change("Outings:Laps:Track Sections:Default:Straights"))
Coast factor lap KPI	integrate('Coast Factor','Corr Speed' [km/h]>0,range_change("Outings:Laps"))

For most corners, one of the fastest ways for a driver to take them is to minimise the time with no throttle or brake input

without lap time comparison, we cannot yet come to a conclusion over which driver was slower.

To make a more informed conclusion, we can look at the minimum speed of the drivers using a second track plot. The minimum speed is defined as the lowest speed that the vehicle reaches during a corner. This can have a significant effect on which driver is quicker, especially on a track with a high concentration of straights, which is the case at Pocono Raceway.

In **Figure 2** a higher concentration of red denotes a higher speed while a higher concentration of blue correlates to a lower speed. The inner loop with the black dot refers to the black driver, while the outer loop with the red dot refers to the red driver. In this plot, we can see that the black driver reduced speed much more significantly than the red driver in turn three, which in turn led to a lower end speed on the longest straight of the track. This gap becomes clearer in a speed trace and lap time variance comparison, which is shown in **Figure 3**.

When the variance increases it means that the red driver is increasing the gap to the black driver, and a negative slope means that the black driver is gaining on the red driver. Looking at the speed trace, we see that the biggest gains made by the red driver came as a result of a better performance in the third turn, as seen on the speed map. This can be seen in the combination of the gap at the start of the lap from 0m to 600m and at the end of the lap from 3600m to 4000m. This shows that while coasting through Turn 1 did not make a significant difference between the two drivers, in the third turn coasting made a significant difference in driver performance. Based on the comparison of the two data traces of the laps, the driver with the black trace now has the knowledge to help gain ground during the race and be more competitive. Alternatively, the black driver's team can also use the information learned from the session to modify the set-up of the vehicle to better suit the driver's style.

The analysis of performance can be extended to the full session as well. By looking at the percentage of time that each driver was spending coasting we can have a

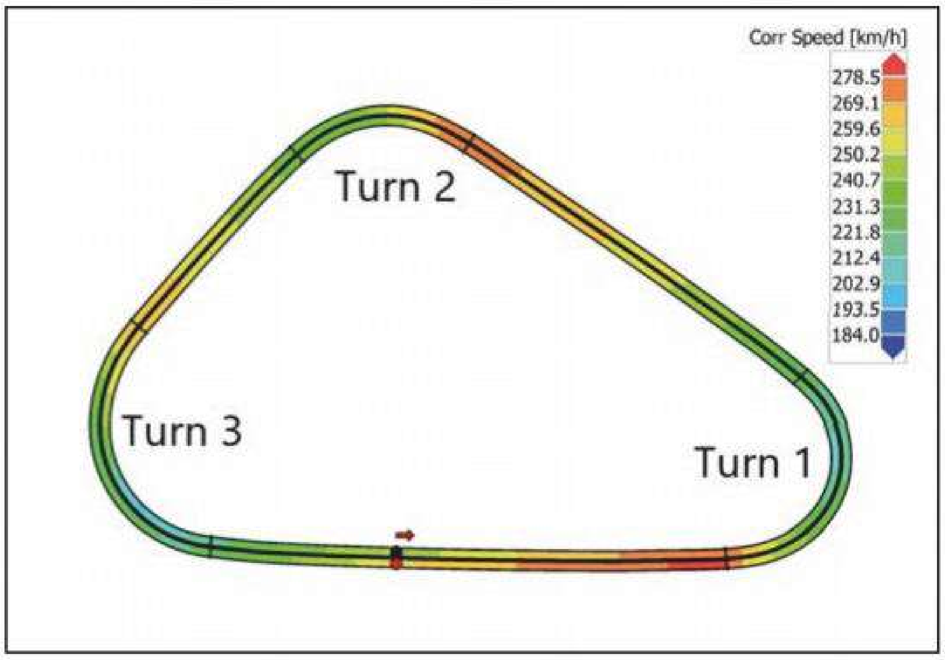

Figure 2: Track map showing the speed of the black and red drivers on their best lap

It is also important to consider the outside context when predicting the driver performance

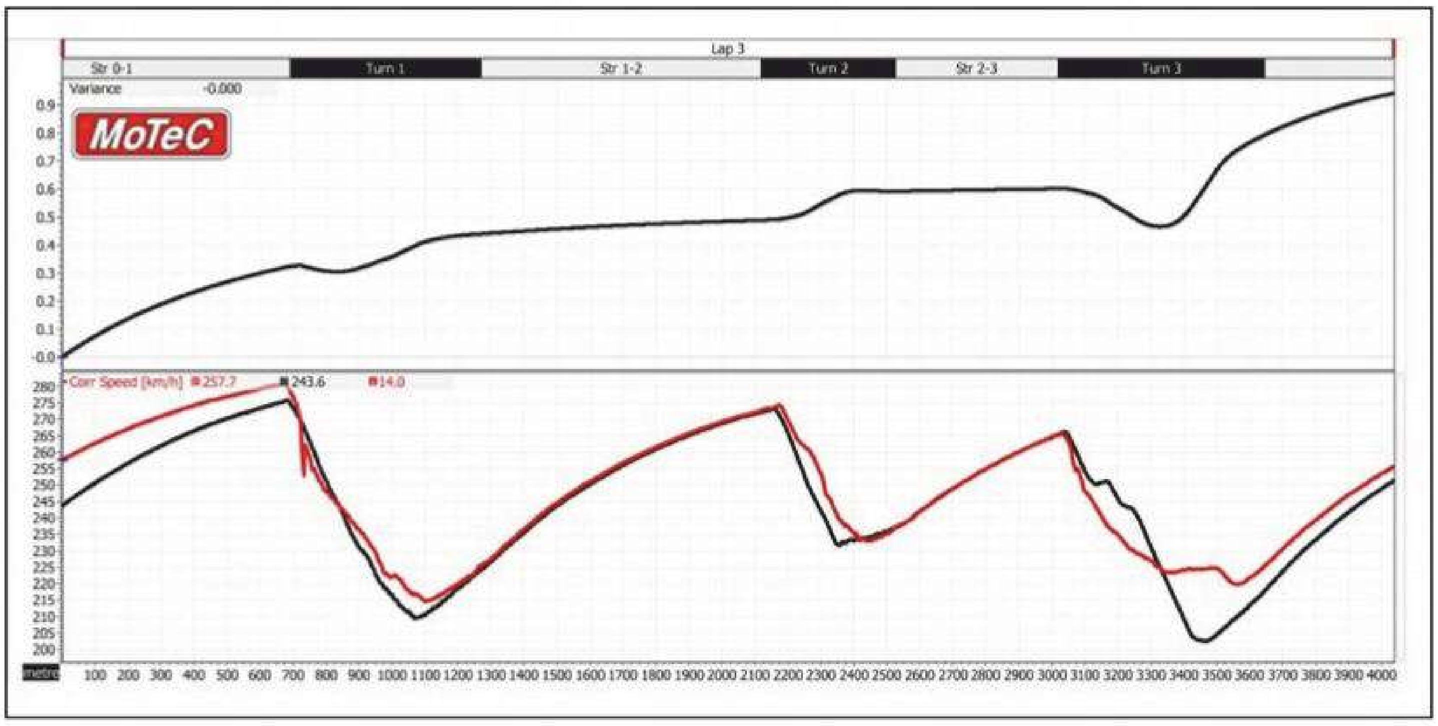

Figure 3: Speed traces of our drivers, also showing the difference. Note the speed that the red driver carries on to the main straight

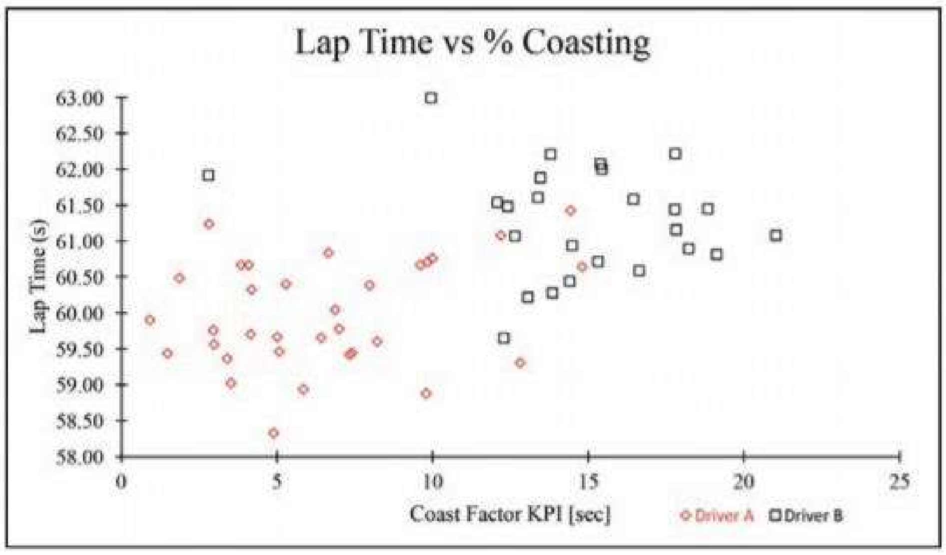

Figure 4: This shows the lap times relative to the time each driver spends coasting

strong understanding of the time delta between the two drivers as the race progresses. **Figure 4** shows the lap time of the two drivers relative to the amount of time that each driver spent coasting.

In this plot, we can see that there is a very gradual black driver lap time increase as the result of a higher amount of coasting. However, we can also see that there is a range of as much as two seconds between the fastest and slowest laps at the same coast factor. This is occurring as we are not considering other aspects of the course such as traffic, tyre wear, or driver error. While the coast factor can provide an indication of the level of performance of the driver during the race, it is important to consider the outside context when predicting driver performance.

In addition to its use as a single lap analysis tool, coasting can also be an effective technique for driving fast but doing so in an efficient manner, which allows for a driver to reach low fuel consumption goals. By lifting and coasting the driver can save fuel allowing for a longer stint, which could make a difference to the number of pit stops required. While there will still be circumstances in the driver performance that could inherently induce a greater amount of coasting through a session, by lifting entirely the driver will be saving fuel, which can have a direct effect on how far that driver is able to run into a stint.

To visualise how the drivers compared during the final fuel run of a race, we will compare the coast factor KPI during the complete lap to the level of fuel being saved. We can approximate the fuel saving by measuring the time in which the fuel flow of the vehicle is at its minimum. Note that in some racing series fuel flow sensors are forbidden during race weekends, but not necessarily during private practices. In contrast, some racing series require a car to have a fuel flow sensor so as to be able to hold the racecars to a maximum energy consumption. Therefore, it is important to check the regulations and have predictions ready depending on the circumstances of the event.

To begin with, we will look at the amount of fuel that the two drivers were using per lap during the event. When considering the fuel consumption, it is important to watch how the fuel consumption of two drivers could impact their final gap at the end of a race. If a driver can make one fewer pit stop, then they will have a significant advantage over their competitor, which could be the difference between winning or losing a race.

In **Figure 5** we can see the amount of fuel that was consumed by the black driver was regularly lower than the amount of fuel that was consumed by the red driver during the 37-lap stint. This will mean that the red driver, despite the greater pace that can be seen in their fastest laps in **Figure 4**, will have to pit earlier than the black driver. In the case that this was intended to be the final stint, this would mean that the red driver would be pulled out of contention due to over-consumption. Therefore, it can be imperative to track the fuel saving measures like coast factor to make sure that the driver is doing all that they can to maintain pace without sacrificing lap time excessively.

To determine the correlation between the coast factor and the amount of fuel saved, we will plot the amount of time with minimal fuel flow, the fuel savings on the y-axis and the coast factor on the x-axis, to determine the correlation the two variables have to each other. The goal with this plot is to track how much fuel is being saved just by coasting during the lap versus the amount being saved when off the throttle during braking.

Figure 6 plots the black and red drivers coast factors and fuel savings for each lap in a stint. Note that there is a strong correlation between the amount of time that is spent coasting and the amount of fuel saved, with the black driver saving more than the red. We can also see that there is about six seconds of constant fuel savings as a result of just braking during a corner. This can be correlated back to the fuel flow and can be used to determine the worst-case fuel economy for a lap, which can in turn be used for determining fuel cell sizing for a weekend (if this is allowed).

The last element of fuel saving that can be tracked using coast factor is the lap time the driver was able to perform versus the amount of fuel that was consumed. This can be especially useful when working on a racecar without telemetry as it can allow a race strategist to predict the lap time required in order to achieve a given stint length. While there will be noise in the data, this can still be the best estimate and will allow a strategist to advise the lap time goals for a driver to hit.

Table 2: MoTeC i2 fuel flow math channels

Name	Equation
Fuel flow	derivative('Fuel Level' [l])
Fuel saving	choose('Fuel Flow'>-0.01,1,0)
Fuel saving KPI	integrate('Fuel Saving',1,range_change("Outings:Laps"))

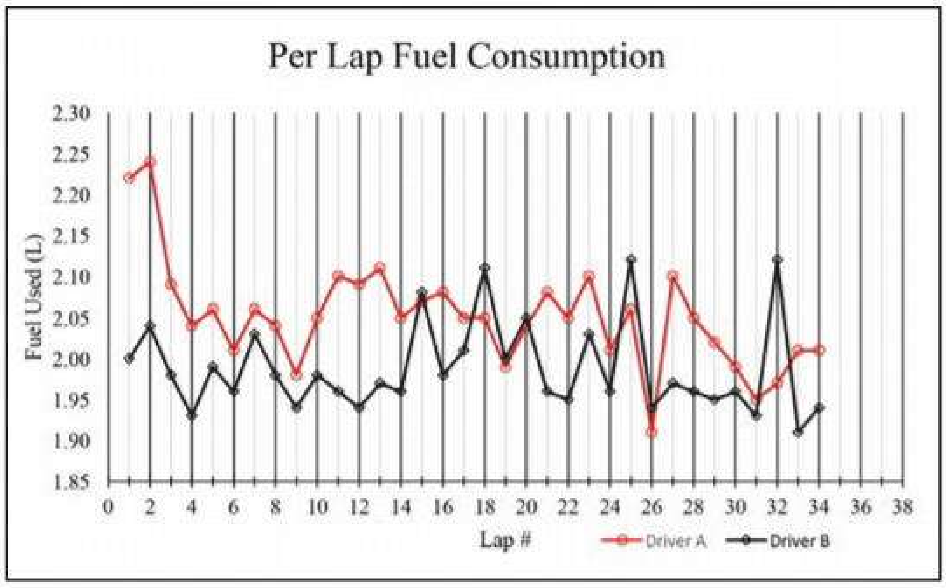

Figure 5: The fuel consumption for each lap. The black driver is usually using less fuel

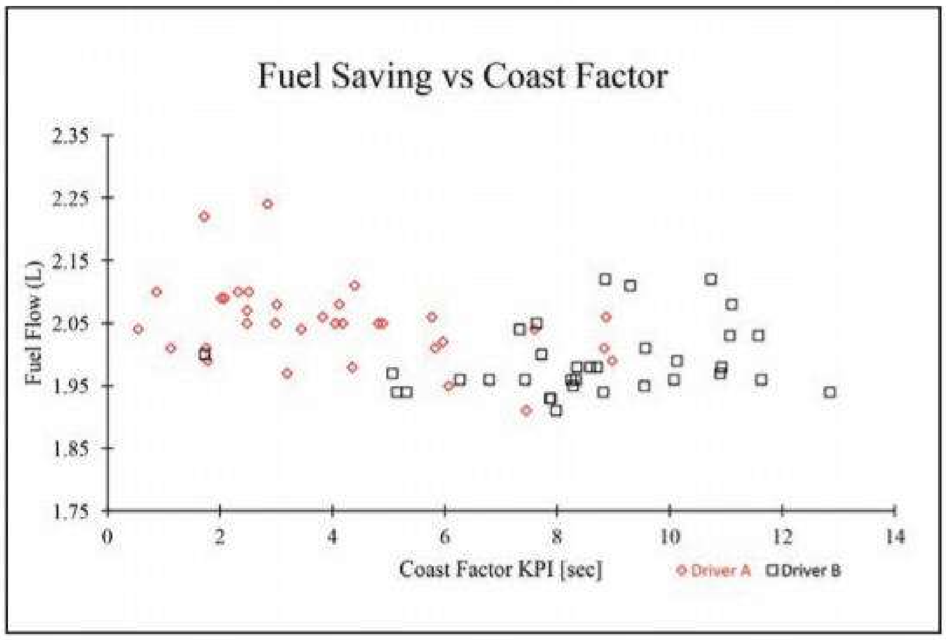

Figure 6: The correlation of coast factor to the fuel savings for each lap during a stint

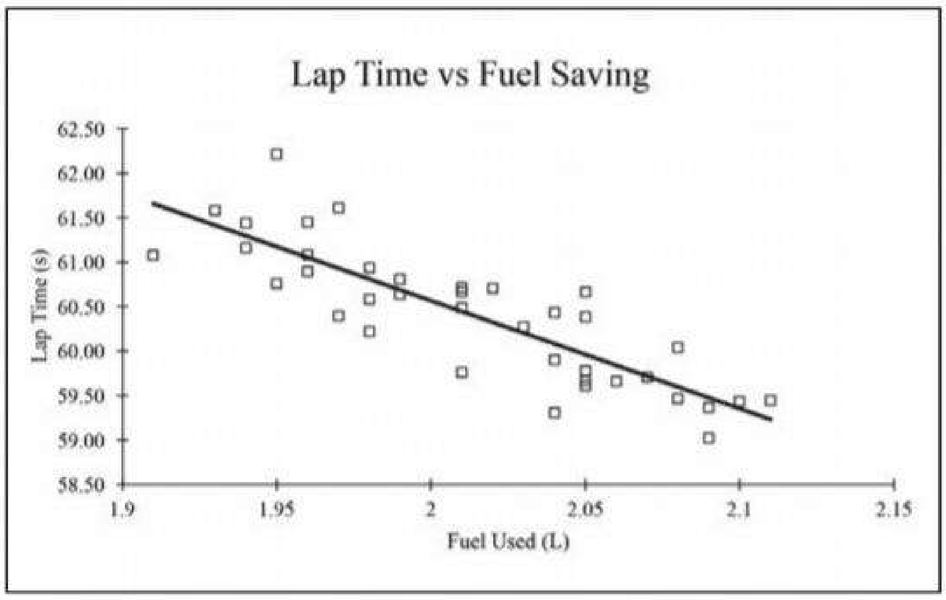

Figure 7: Comparison of lap time *vs* fuel used. This is very useful for devising strategies

Figure 7 shows the lap time that would be required for the driver to save a given amount of fuel. In this case, we see that the driver could save about 0.05-litre for every second slower they drive. This can in turn be used by a race strategist to plan when a driver starts to save fuel or whether the gains from coasting are actually worth it. This will vary for different conditions and for different courses, but it can be a strong asset to gauge when to pit and how aggressive a race driver can drive during a given fuel run. All of this can be learned from how much the driver is coasting.

In conclusion, coasting is a non-trivial technique that can be a balance between high performance and efficient driving. It can be a tool used by the race engineer to describe the intermediate area of a corner and show the causation of a higher corner exit speed. On the driver's side, it can be used as a strategy tool to gain an advantage on a competitor either in the pits or in overtaking. By having the driver practice coasting, the race strategist can then predict time targets that the driver should be hitting in order to conserve fuel during an event. When looking at the coast factor, the complexities of a vehicle become ever apparent, and the gains from even the smallest of areas can become ever more present.

Slip Angle is a summary of Claude Rouelle's OptimumG seminars.

OptimumG offers a complete solution for testing, simulating, and improving the dynamic performance of your vehicle. All consulting services can be sub-contracted or we can simply guide your race team through our methodology.

CONTACT
Claude Rouelle
Phone: + 1 303 752 1562
Enquiries: engineering@optimumg.com
Website: www.optimumg.com
OPTIMUMG