Most Important Turn
(and why races are so close)

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March 23, 2002

A few decades ago Alan Johnson wrote a book entitled “Driving in Competition”. This was a useful introduction to SCCA road racing and included a description of turns as Type I, Type II and Type III. This analysis also determined the Most Important Turn to be the one leading onto the longest straight.

There was a certain logic to this argument. If you come off a turn faster than the competition then the longer you can use that advantage the greater the time gain. But the analysis is faulty because race cars accelerate towards a maximum speed.

Let us consider how we determine the most important turn on a road course. We are going to deal with lap times, not the tactics involved in passing another competitive car.

This is going to be a mental exercise, though there will be a few numbers to flesh out the thought process.

Consider two identical cars. One will exit a corner at a speed S, the other at S* (which is slower than S). Both cars have identical engine, gears, mass and aerodynamic properties and are able to use full throttle. They travel a distance D along a flat track before braking for the next turn. What is the time difference between the two cars?

The straight-forward way to answer this question would be to calculate how long it takes each car to travel the distance D. But this would involve a detailed knowledge of the engine characteristics, the drivetrain loss, the gears, and the aerodynamics of the vehicle. But there is an easier way to answer the question.

The second car comes off the turn slower (S* is less than S). How much time T and track X does it take the car to accelerate to a speed S? The time required to travel the distance X will be approximately $T2 = X / ((S + S^*) / 2)$, or distance divided by average speed. Since the second car comes off the turn at speed S* and accelerates to a speed S after distance X the average speed will be close to $(S + S^*) / 2$.

Once the cars reach a speed S they both accelerate identically for a distance D - X. At this point the second car has reached the braking point and a speed F. The first car still has to travel the distance X while accelerating from speed F to a final speed of F*. The time required for car One to travel the distance X is $T1 = X / ((F + F^*) / 2)$, or distance divided by average speed.

Compare the speed of the two cars at a given point on the track:

```
Distance  0       X                            D-X     D
Car one   S  ---------------------------------- F ---- F*
Car two   S* ---- S ---------------------------------- F
Time         T1   .                              .  T2
```

Or compare the cars by matching speed:

```
Distance  0       X                            D-X     D
Car one           S ---------- . . . ---------- F ---- F*
Car two   S* ---- S ---------- . . . ---------- F
Time         T1   .                              .  T2
```

The two cars both require exactly the same time to accelerate from speed S to F. But car one gets to travel an additional distance X at a speed ranging from F to F*. Car two, which comes off the turn slower, has to travel a distance X at a speed ranging from S* to S. Since the speed F at the end of the straight is larger than the speed S at the exit of the turn, Car One has a considerable advantage.

The time difference is $T2 - T1$

$$ET = T2 - T1 = X /((S + S^*)/2) - X / ((F + F^*)/2)$$

The Elapsed Time will be largest when X is large (usually a fast turn) and when the difference between starting speed S and Final Speed F is largest. This is usually a long straight. The most important turn is a fast turn leading onto a long straight.

X will be largest in high speed turns because the cars accelerate slower at high speed. This is due to gearing and aerodynamic drag. In addition, S and S* will be farthest apart in high speed because I suspect there is more difference in driver performance in high speed turns than slow speed. I can not prove this but it seems reasonable, but the argument does not depend upon this assumption.

Consider a Trans-Am or GT1 car. One comes off the turn at 60 mph, the other at 55 mph. The time required to accelerate from 55 to 60 at 0.75g is about 0.30 seconds. The distance is 26 feet. The car is traveling 180 at the end of the straight. Covering 26 feet at 180 mph requires 0.10 seconds. The difference in time is 0.20 seconds.

Notice that the length of the straight does not enter into this equation. If you come off Turn Seven at Road Atlanta five mph faster then you will have a 0.20 second advantage at the end of the mile-long straight. If you come off Turn Seven and race to Los Angeles the time advantage will be nearly the same because most cars are very close to their maximum speed at the end of Road Atlanta's back straight.

This argument helps explain why road racing lap times are so close. A significant difference in cornering performance does not make a big difference in lap time. A five mph difference in exit speed is HUGE, yet it only produces a 0.20 second difference in lap time.

Consider a lower powered car. This car requires a 0.91 seconds to accelerate from 55 to 60 mph at 0.25g and requires 77 feet. At the end of the straight it is going 120 mph,

ET = T2 – T1 where T2 is 0.91 second. T2 is 0.44 second so the difference is 0.47 seconds. Horsepower can mask performance in corners. Had the 5 mph difference held for the entire mile the time difference would be over 3 seconds.

But if you want to WIN races then you must be competitive in every turn. Giving up 0.20 seconds in a GT1 car leaves you 0.20 seconds behind at the end of a lap.

This argument can be used to decide how to tune your car. It can suggest what turn to concentrate on when tuning your car (and driver). It is not an excuse to give up speed in any position.

Braking for the Next Turn

Interestingly, the same analysis can be applied to braking for a turn at the end of the straight. Here S becomes the Stop Speed, the speed at which the car comes off the brakes and enters the turn. Carrying more speed into the turn extends the straight and allows the car to spend more time at Final Speed F.

Compare the speed of the two cars at a given point on the track:

```
Distance  0       X                            D-X     D
Car one   F* ---- F ---------------------------------- S
Car two   F   ---------------------------------- S ---- S*
Time         T2   .                              .  T1
```

Or compare the cars by matching speed:

```
Distance  0       X                            D-X     D
Car one   F* ---- F ---------- . . . ---------- S
Car two           F ---------- . . . ---------- S ---- S*
Time         T2   .                              .  T1
```

The two cars both require exactly the same time to brake from speed F to S. But car One gets to travel an additional distance X at a speed ranging from F* to F. Car Two, which enters the turn slower, has to travel a distance X at a speed ranging from S to S*. Since the speed F at the end of the straight is larger than the speed S at the entry of the turn, Car One has a considerable advantage.

The math for braking is exactly the same. The time difference is T2 – T1

$$ET = T2 - T1 = X /((S + S^*)/2) - X / ((F + F^*)/2)$$

The Elapsed Time will be largest when X is large and when the difference between stopping speed S and Final Speed F is largest.

For a Trans-Am car braking at 1.5g T2 is 0.05 seconds and X is 13 feet. T1 is 0.15 seconds and ET is 0.10 seconds. It is tempting to think that acceleration off a turn is more important because any advantage can be used all the way down the straight. But that is part of the fallacy. Braking is also important but the ET is less because the deceleration to achieve the difference in speed between S and S* is much greater than the acceleration.

The time difference in braking is half that of accelerating off the turn because the G forces for braking are twice as large.

For the less powerful car braking from 120 mph to 60 mph at 1.0g the ET is 0.12 seconds. The braking ET is one-quarter of the accelerating ET because the G forces for braking are four times as large.

Exceptions

This argument breaks down when you deal with very fast cars that do not accelerate much. This can be either very fast cars, such as Indy cars on big ovals, or very low powered cars. If the acceleration is so small that the car can not gain speed then exit speed becomes everything. Then one mph advantage may be maintained all the way down the next straight.

The end