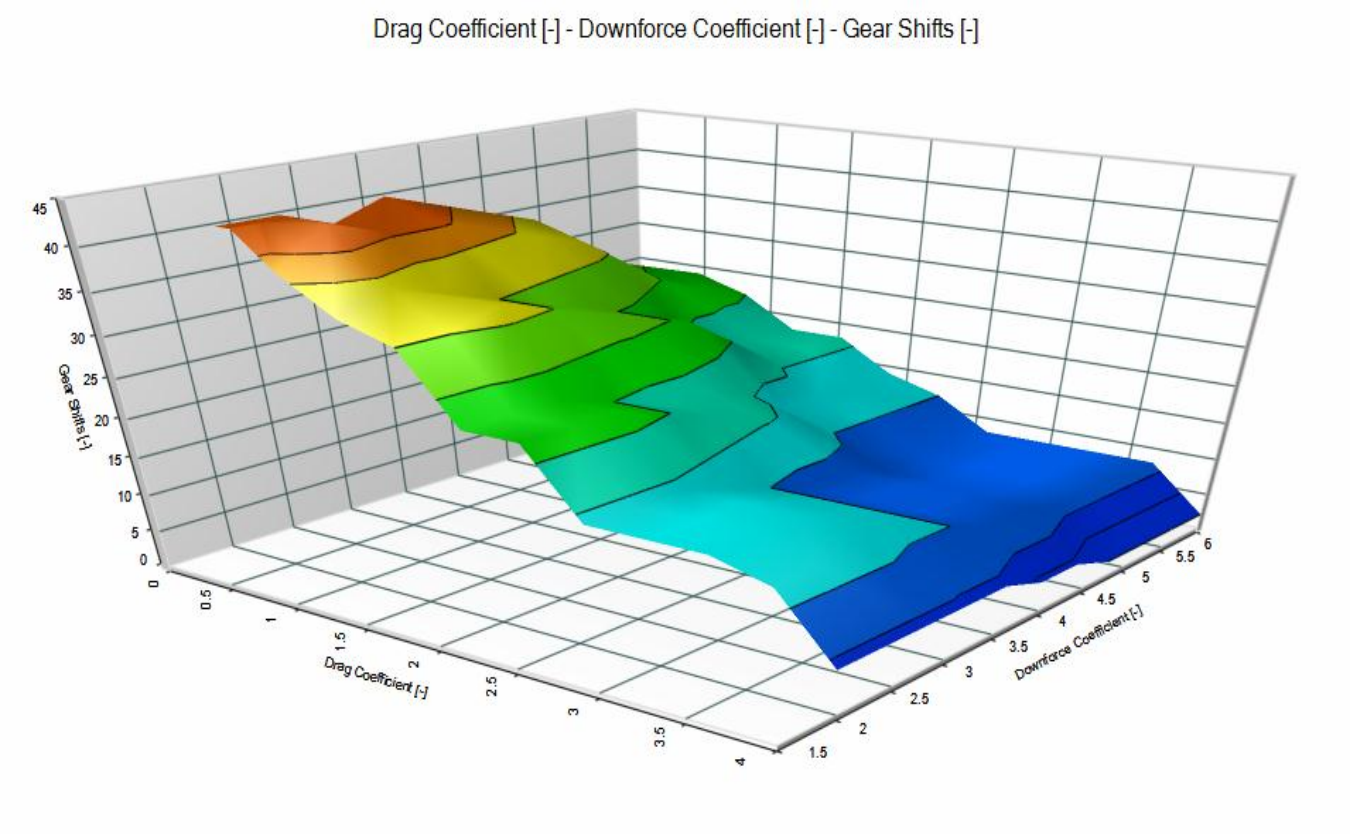
OptimumLap

Vehicle Dynamics Simulation. Simplified.



OPTIMUM
vehicle dynamics solutions

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1 Welcome

Thank you for your interest in OptimumLap. This help file contains information regarding the features and functions of OptimumLap.

1.1 Feedback

OptimumLap is a continually evolving program and we give high regard to any suggestions, comments, complaints and/or criticisms that OptimumLap users might have. Please contact us at engineering@optimumg.com and we will endeavor to improve OptimumLap based on your feedback.

Within OptimumLap the user is able to report any issues, features, ideas or feedback.

2 Introduction

OptimumLap has been developed with the goal of providing users with an easy to use lap time estimation tool that utilizes a basic quasi-steady state vehicle model.

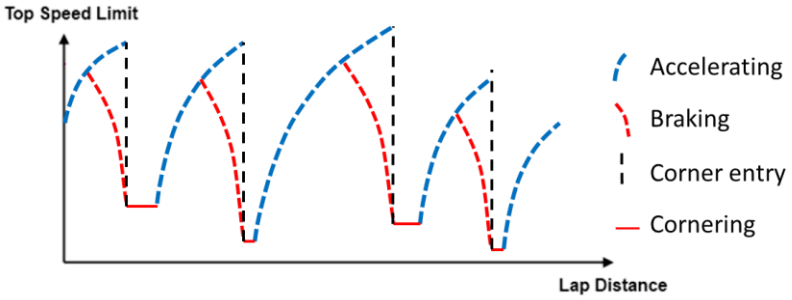
It can be used to rapidly analyze characteristics of a vehicle on a given track. The user will be able to visually see and interpret the effects of changing vehicle parameters.

2.1 Model Definition and Limitations

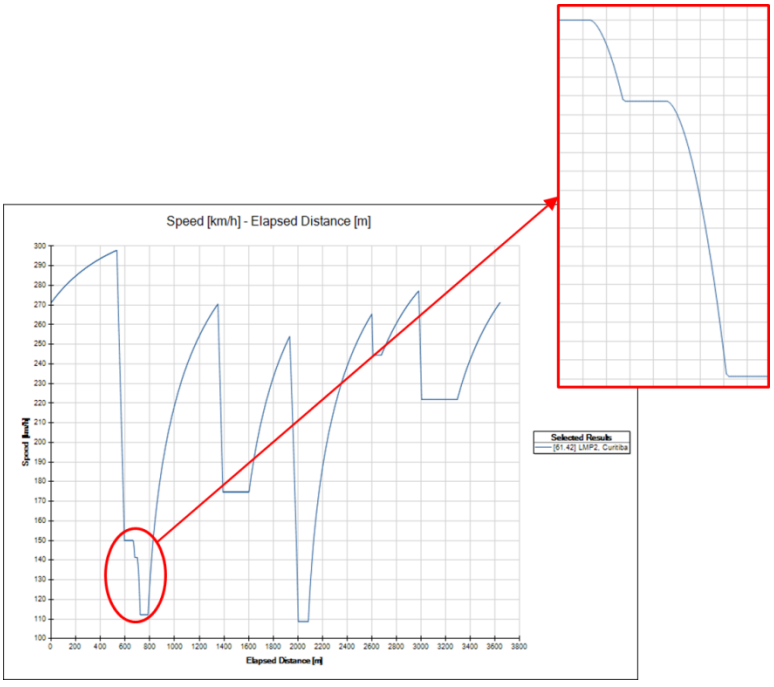
OptimumLap utilizes a quasi-steady-state point mass vehicle model. What this means to the user is that though the model is simplistic mathematically, it has the ability to be accurate due to the combined states that the vehicle can achieve. The vehicle is able to accelerate and corner simultaneously as well as decelerate and corner simultaneously.

OptimumLap does this process in three major steps:

1. Calculate the corner speeds
2. Calculate the speed accelerating out of the corners
3. Calculate the distance needed in order to decelerate the car for the corners



Once the combined states are applied we are able to achieve a smoother transition between track sections. Utilizing combined states ensures that there will be no unrealistic leaps in vehicle speed.

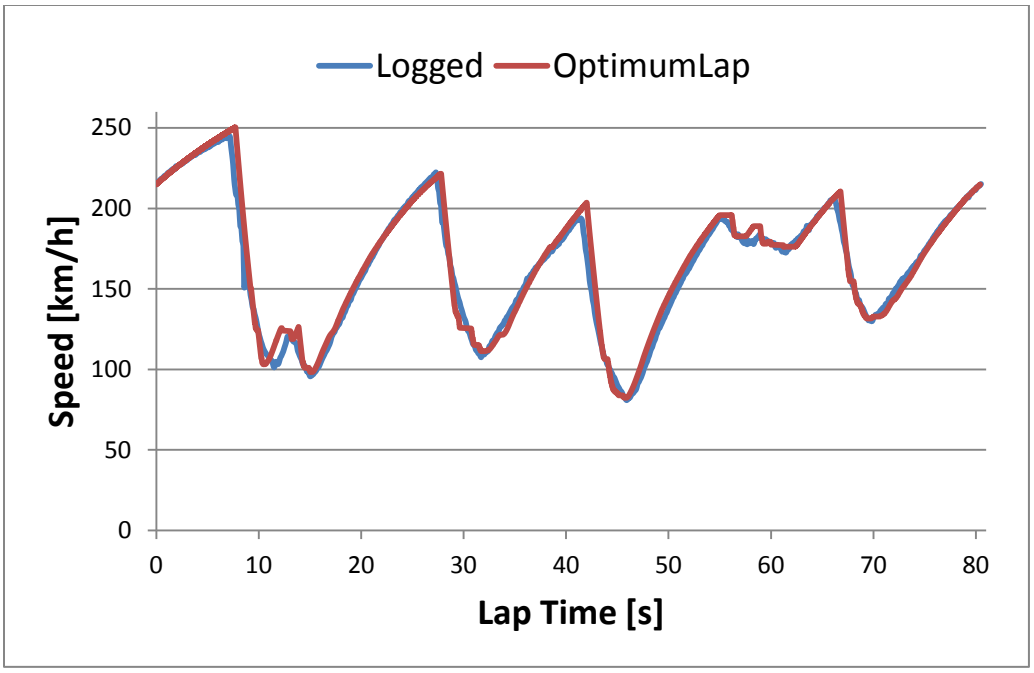


It is important to understand that OptimumLap utilizes both the vehicle and the driver at 100% of their capabilities! This means that the lap time calculated by OptimumLap will always be faster than what will actually happen on the track. It is crucial that you think in 'Delta' and less in 'Absolute', meaning utilizing a simplified model you are able to determine which parameters are most sensitive to lap time (IE – Increasing tire grip is more important than increasing engine power), but the values that you attain in OptimumLap will be different than the actual values used on the vehicle. With any software that you use, it is important to understand the limitations from the vehicle model. OptimumLap for example:

1. Doesn't account for weight transfer (lateral or longitudinal).
    a. No suspension affects.
    b. No Inertia
    c. Tire grip is a linear function.
    (IE – $Tractive\ Force = \mu_{Longitudinal} * Normal\ Load + Downforce$)
2. Doesn't utilize a real tire model.
    a. The effects of camber, slip ratio and slip angle not taken into account.
    b. The effects of temperature and pressures not taken into account.
    c. The effect of adding weight and over saturating the tire can be taken into account by utilizing the 'Tire Load Sensitivity' parameters in the vehicle. These can be turned on in the Options Menu.
3. Doesn't account for vehicle yaw.
    a. Since there is no CoG (Center of Gravity) location or wheelbase entered the vehicle doesn't have the capacity to oversteer or understeer.
4. Doesn't account for banking or grade on the track.
    a. No increase or decrease in traction due to centrifugal forces or added weight transfer.
    b. Doesn't take into account transient effects (IE - damping or inerter).

Given these limitations it is still possible to achieve a greater understanding of your vehicle and the sensitivities of vehicle parameters. You will be able to determine whether your time and money should be spent more on Aerodynamics, Vehicle Mass, Tire Grip, Gear Ratios or Engine Power.

What we have noticed using the methods described above are very close (within 10%) correlations between logged data and OptimumLap results as shown in the following figure. Of course, the closeness of the data relies on having an accurate vehicle model as well as an accurate track representation.


Logged
OptimumLap
Speed [km/h]
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
Lap Time [s]

2.2 Installation Requirements

2.2.1 Hardware Requirements

Processor

- Intel® Pentium 4™, Intel® Xeon™ and Intel® Core™
- AMD® Athlon™, AMD® Opteron™ and AMD® Turion™

Memory

- Minimum: 512MB RAM
- Recommended: 1GB RAM or more
- Virtual Memory recommended to be twice the amount of RAM

Storage

- At least 100MB of free disk space. Includes installation of OptimumLap and required software components (see Software Requirements)

Network

- Internet connectivity for License Activation and Deactivation.

Display Adapter

- Minimum: Microsoft® DirectX® 9.0c capable card with 32MB RAM
- Recommended: Microsoft® DirectX® 9.0c capable NVIDIA® GeForce® or ATI® Radeon® with 128MB RAM or higher.

Display Unit

- Minimum: 15” screen with resolution of 1024 x 768 pixels
- Recommended: 19” screen with resolution of 1280 x 1024 pixels
  21” screen with resolution of 1280 x 1200 pixels

Other

- Mouse or other pointing device.

2.2.2 Software Requirements

Operating System

- Microsoft® Windows® XP (32 or 64-bit) or Microsoft® Windows® Vista (32 or 64-bit) or Microsoft® Windows® 7 (32 or 64-bit)

Components

- Microsoft® .NET® Framework 4.0 or higher
- Microsoft® Windows Installer 3.1 or higher

3 Getting Started

3.1 Enter License Information

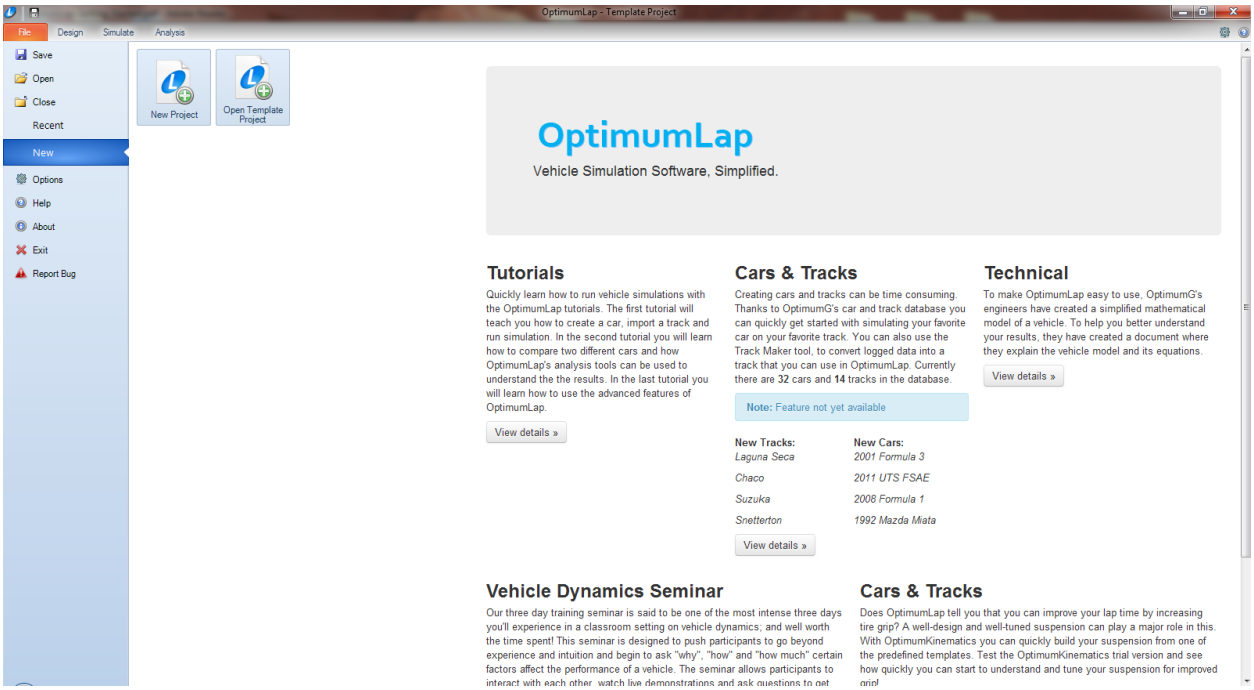
This is the first screen that you will see when you are starting the software for the first time. To continue:

1. Enter the email address where you received the license key.
2. Enter the license key from within the email
3. Click 'Apply Key'

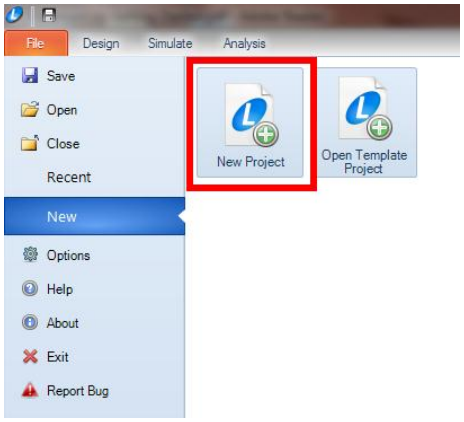
You will only be asked to enter the email address and license key once. If you choose to click 'Close', the application will exit.

3.2 Creating a project

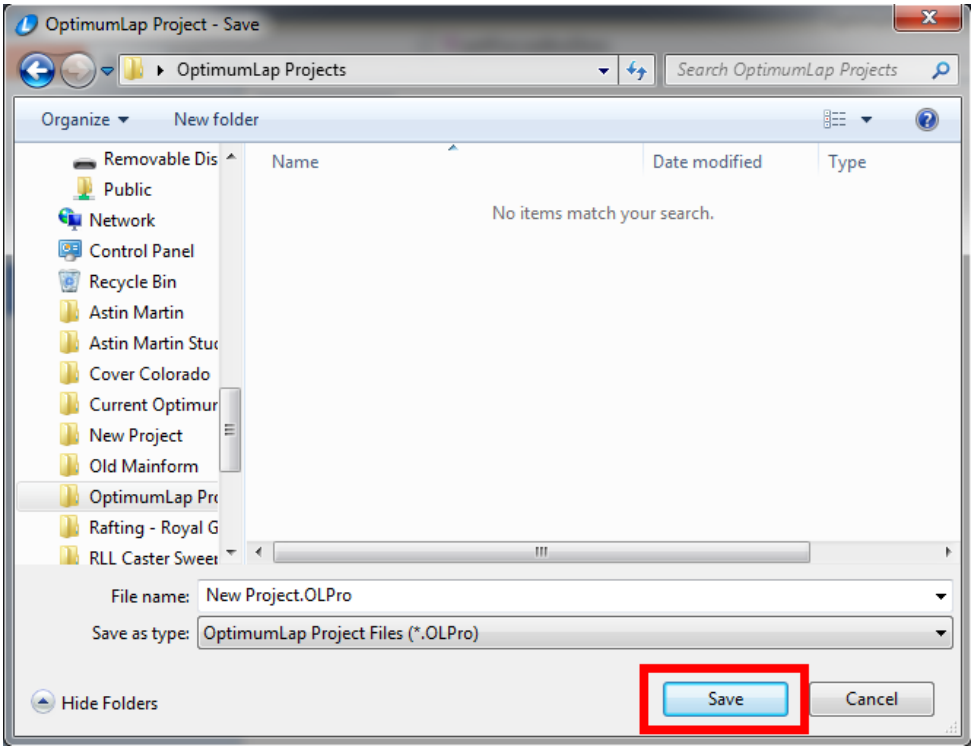
Every time the software is loaded the first screen you will see is the following:



To create a new project first click on the 'New Project' button:

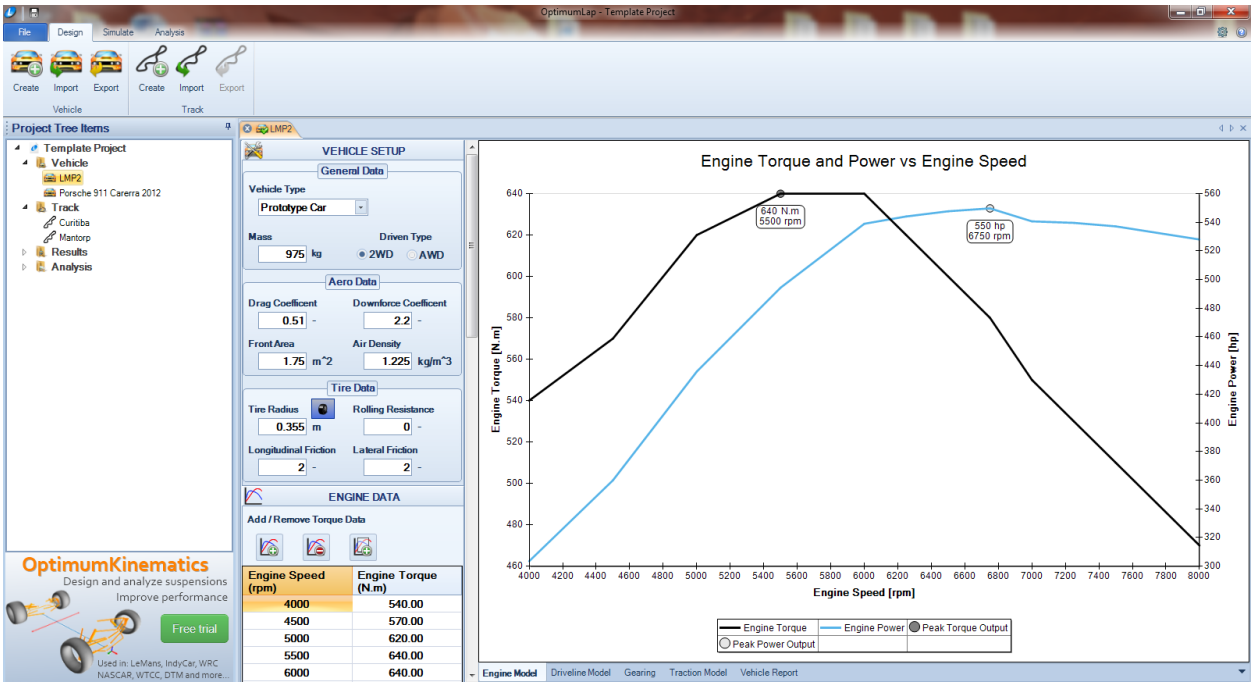


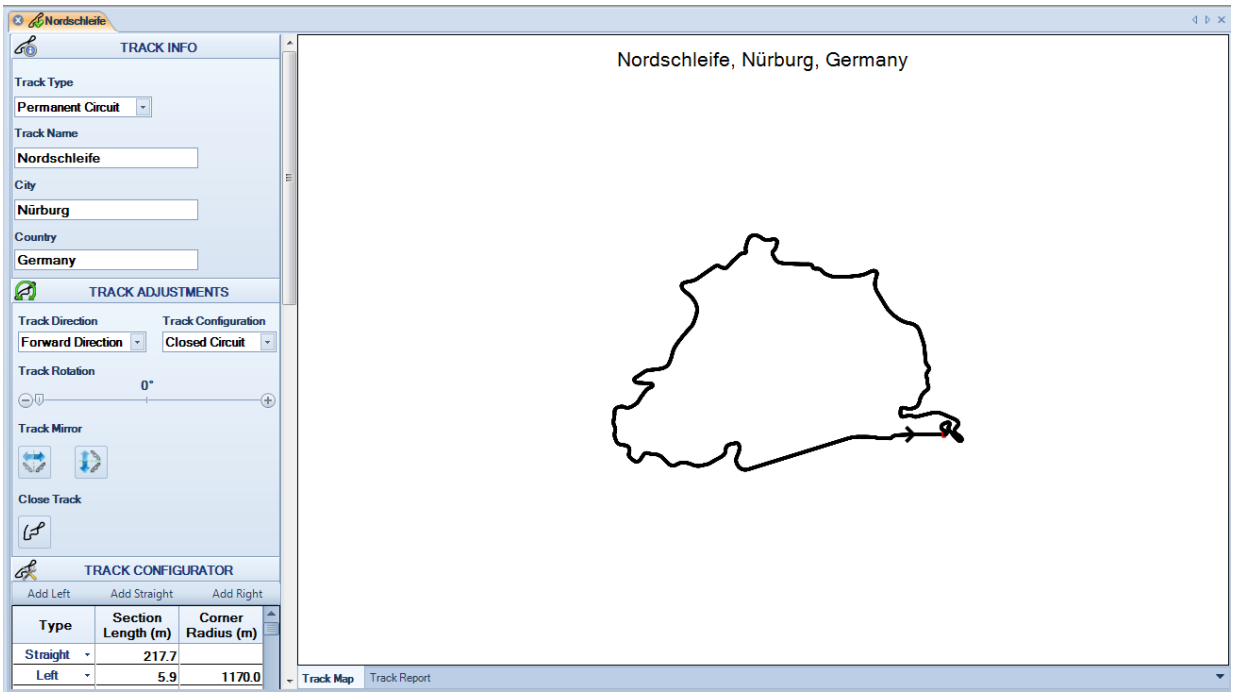
This will bring up a save file dialog screen where you will need to choose a location for your project. Remember to select a location where you have Read/Write access. This is particularly important for any users that are not using their personal computer. Once you have selected your location click on the 'Save' button.



3.3 Design Tab

The design tab is where you can choose to create, import or export Vehicles and Tracks.

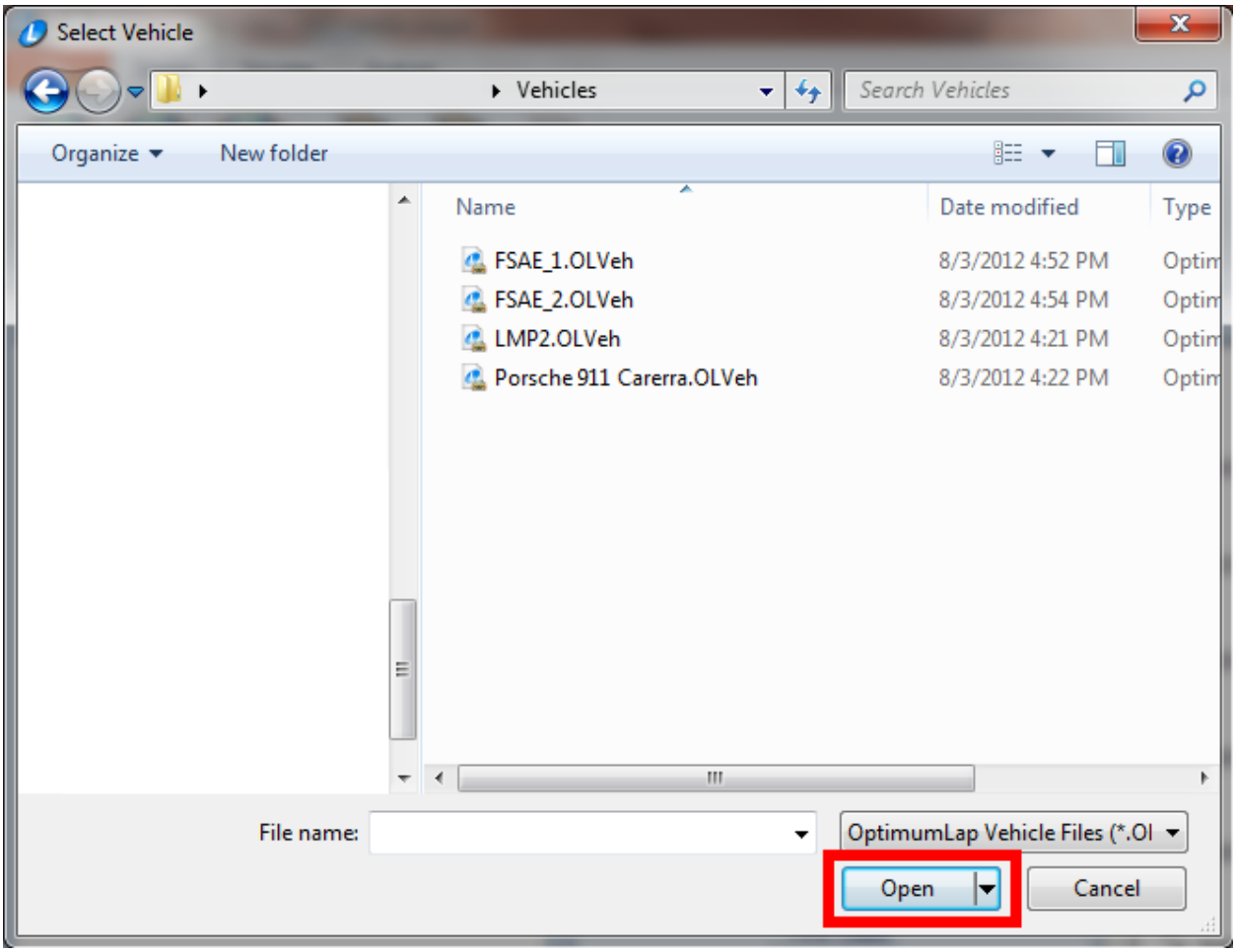




3.3.1 Importing a Vehicle

Click on the 'Import' button whilst within the design tab:

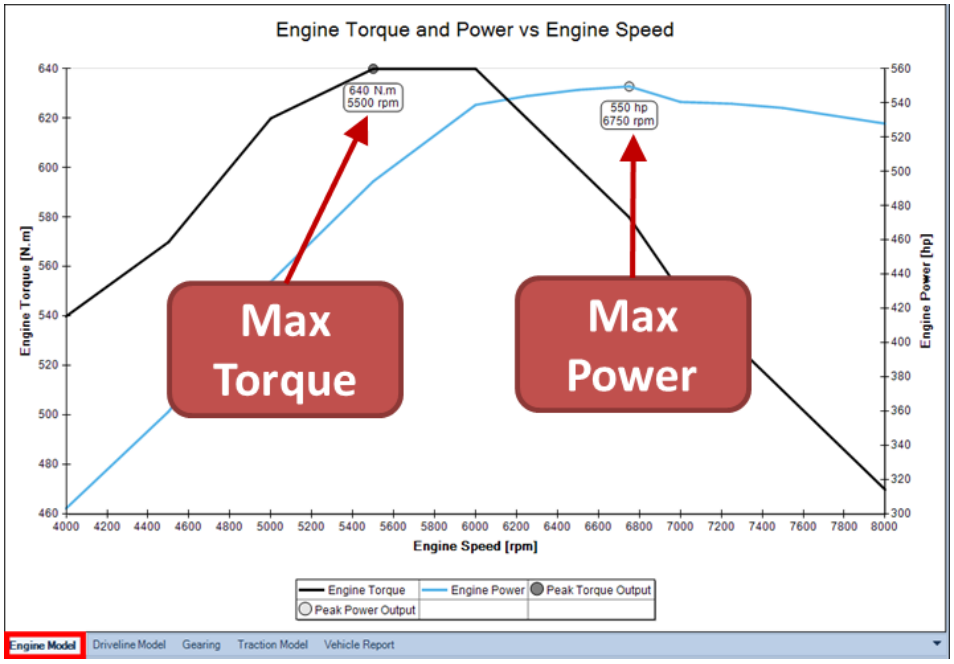
The next window you will see will be a file browser dialog:



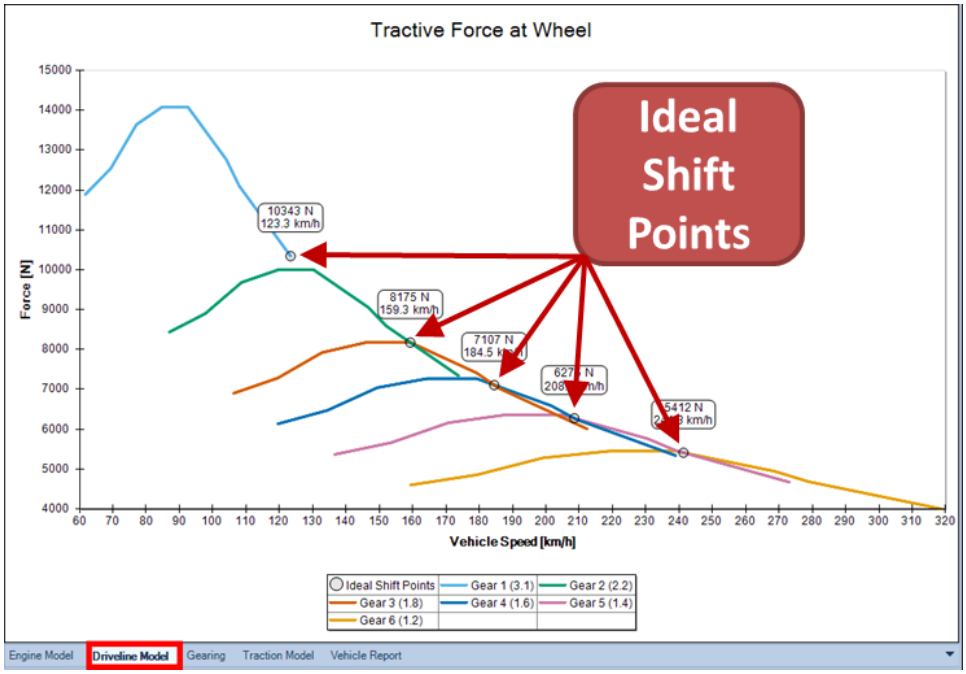
The only files that you will be able to open are of the *.OLVeh which are OptimumLap Vehicle files. Once the vehicle has been imported it will automatically open within the program so that you can view and/or modify any parameters you desire.

3.3.2 Viewing and Modifying a Vehicle

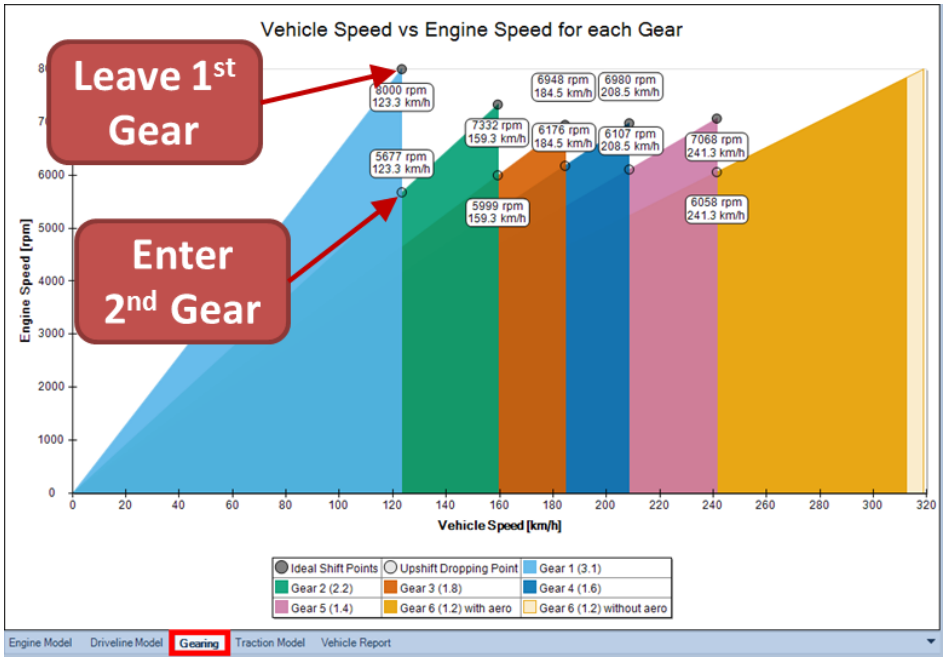
3.3.2.1 Engine Model Chart



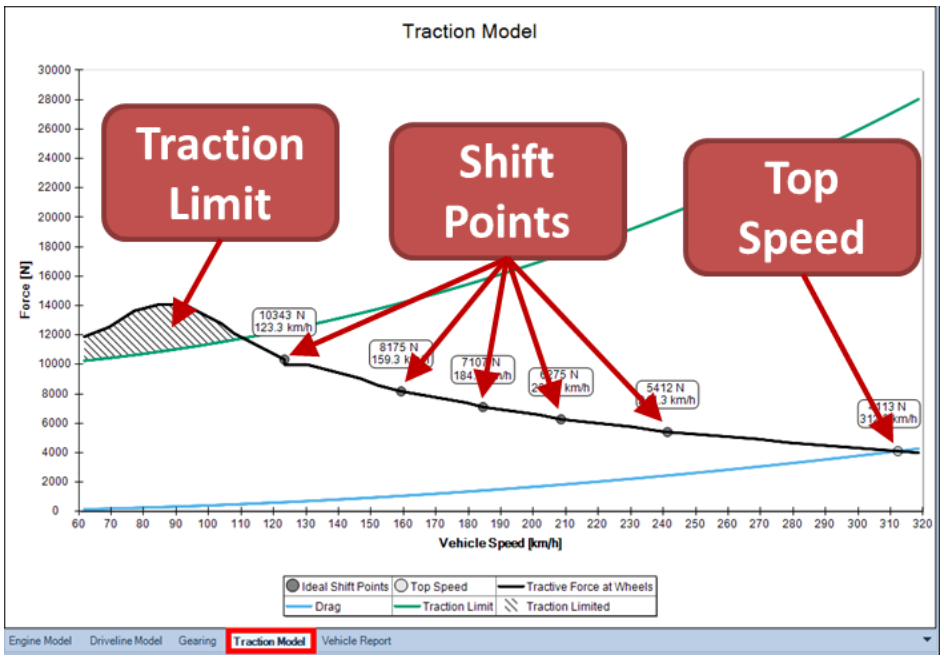
3.3.2.2 Driveline Model Chart



3.3.2.3 Gearing Chart

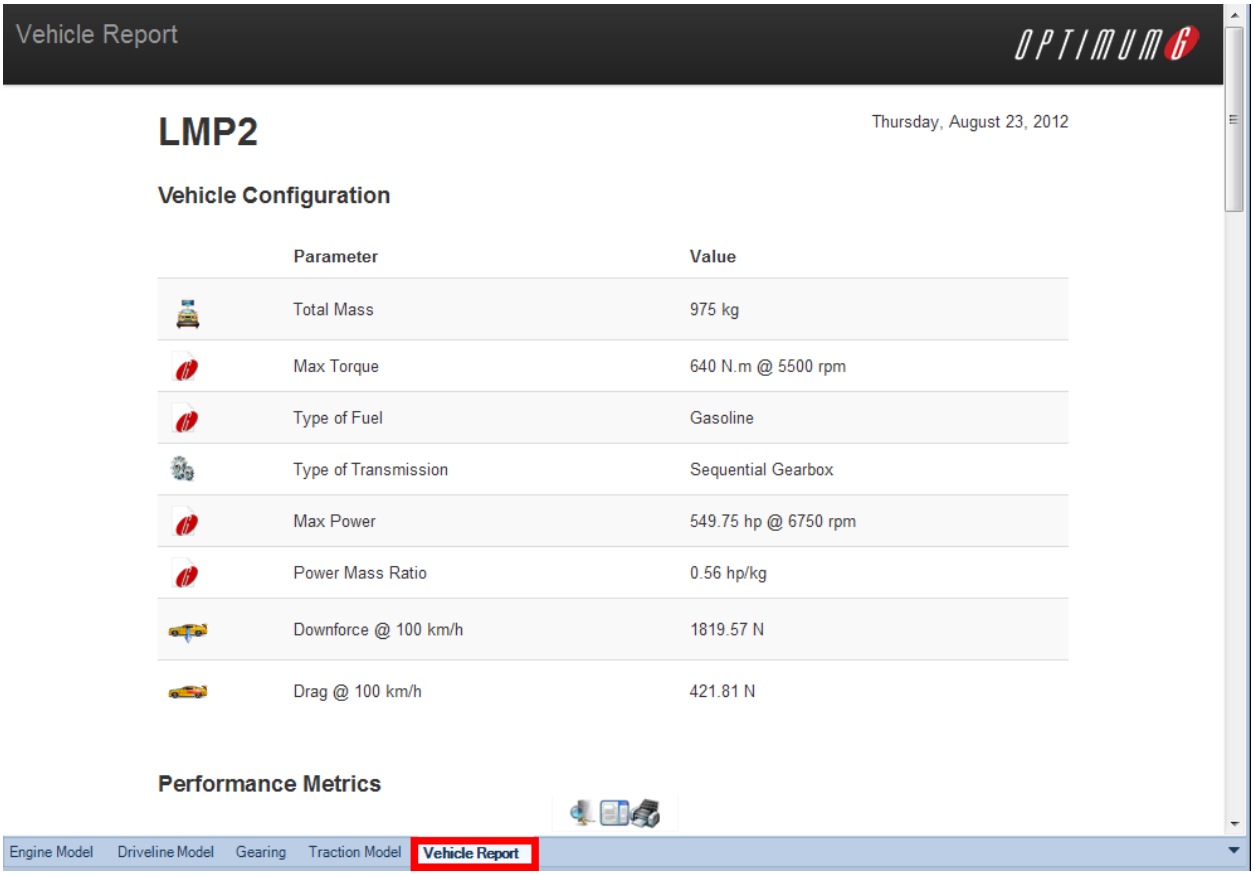


3.3.2.4 Traction Model Chart



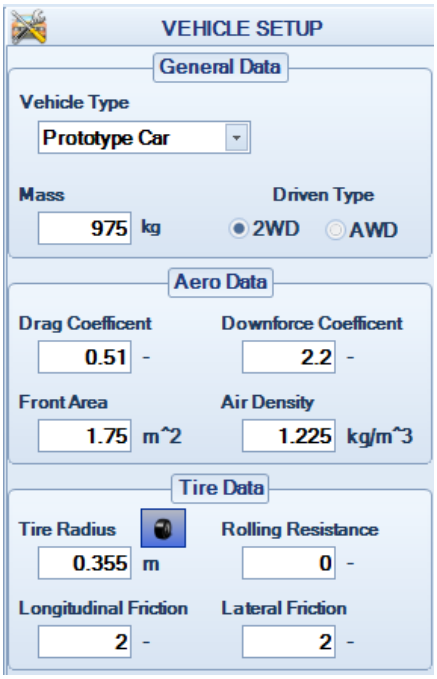
3.3.2.5 Vehicle Report

Within the 'Vehicle Report':



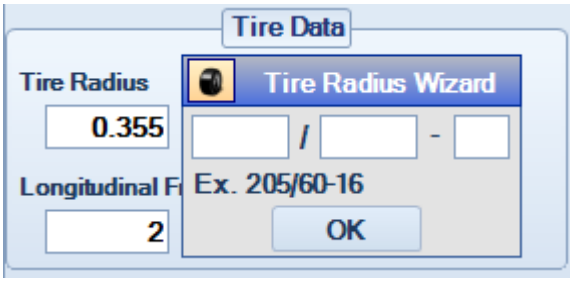
Here is where you can have a fully detailed summary of your vehicle. To determine what is shown in the 'Vehicle Report' please refer to the '**User Options**' section of this guide.

3.3.2.6 Vehicle Setup



Within the 'Vehicle Setup' you have the following options:

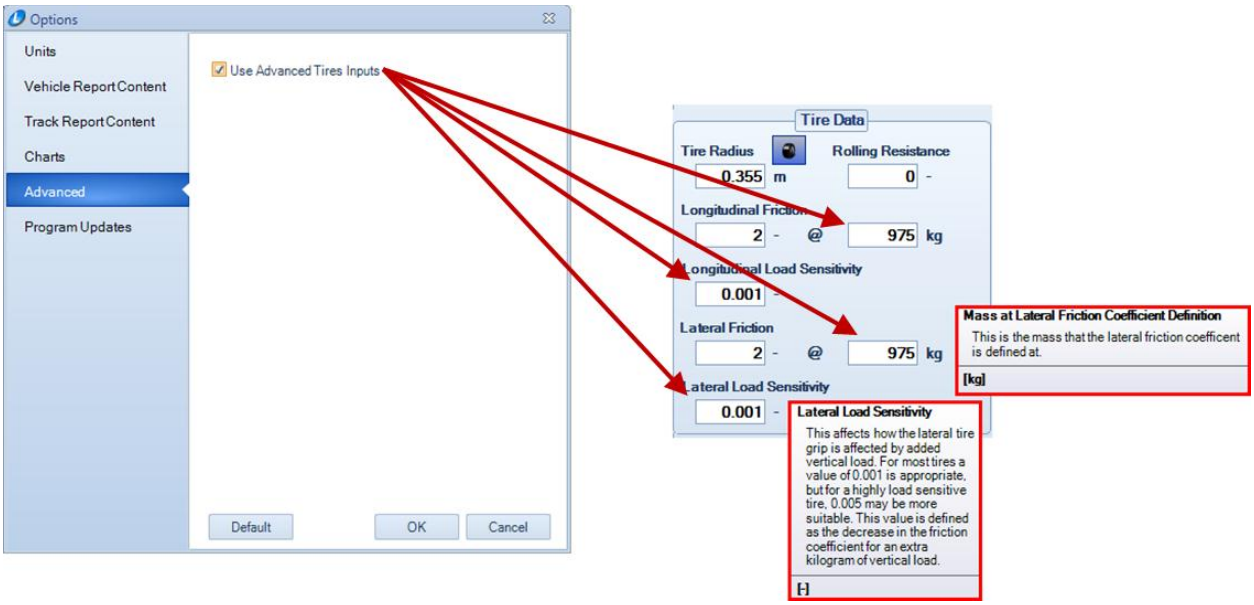
1. (optional) Vehicle Type → This is a way for you to distinguish between all of your vehicles.
2. Mass → Enter the mass of your vehicle
3. Driven Type → Two options exist:
    a. 2WD (refers to 50% of the weight is on the driven wheels)
    b. 4WD (refers to 100% of the weight is on the driven wheels)
4. Drag Coefficient → Some typical values for drag coefficient can be found here http://en.wikipedia.org/wiki/Automobile_drag_coefficient
5. Downforce Coefficient → Some typical values for downforce coefficient are:
    a. Sedan: -0.28
    b. LMP1: 2.2
    c. NASCAR: 0.2-0.36
    d. Indy Car: 1.6-3.6
6. Front Area → The area of the car view from the front.
7. Air Density → The value for air density at sea level is 1.2255 kg/m^3
8. Tire Radius → The rolling radius of your tires. You may enter this value as the radius or the tire size. To enter as the tire size simply click on the tire:



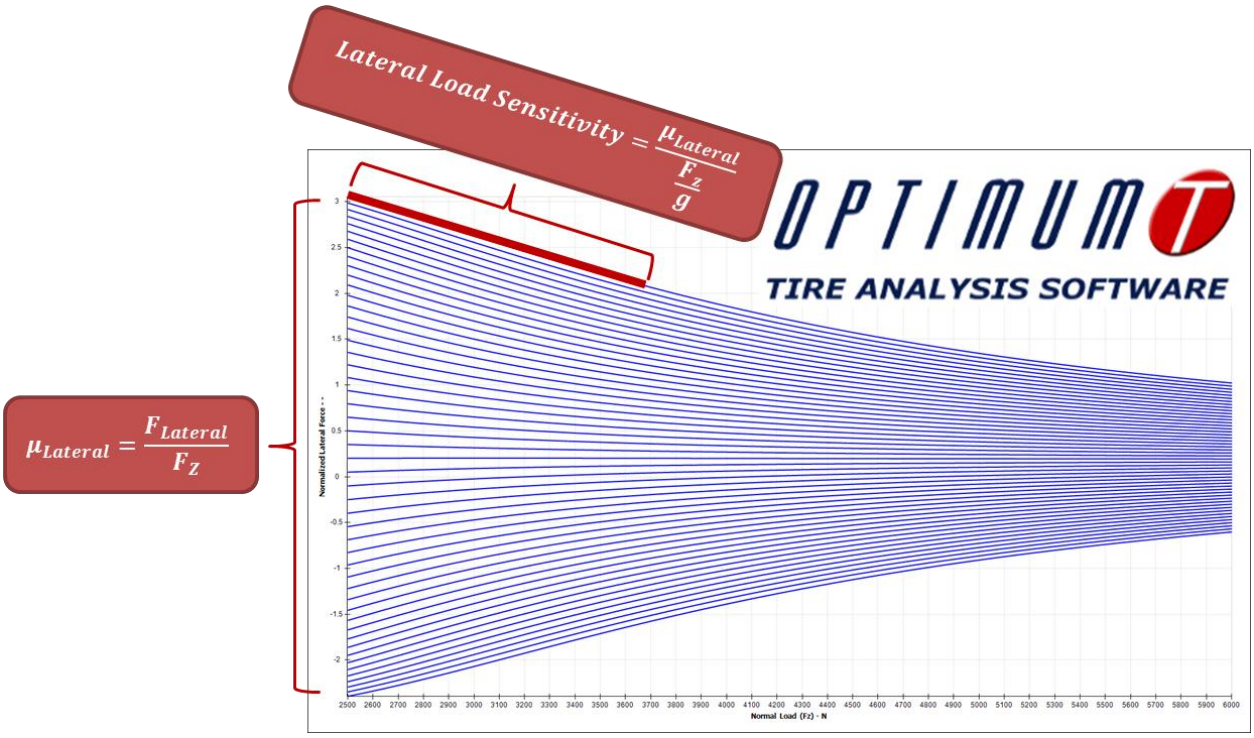
9. (optional) Rolling Resistance → This is the resistance that your tire gives to oppose motion. Typical values for this can be found:
http://en.wikipedia.org/wiki/Rolling_resistance

10. Longitudinal and Lateral Friction → What is the coefficient of friction of your tires? Typical values are:
    a. Street Tires – 0.7
    b. R Compound Tires – 1.2
    c. Slicks – 2.2
    d. If you are unsure of the difference between the Longitudinal and Lateral, use the same value for both.
    e. If you have logged data from your vehicle than another way to attain your coefficient of friction is to modify the values until both your Longitudinal G and Lateral G in OptimumLap almost matches that of logged data.

3.3.2.7 Advanced Tire Inputs

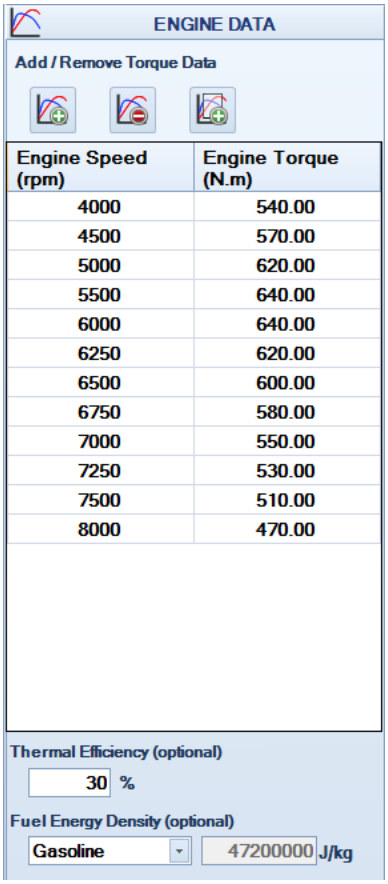


The advanced tire inputs for the vehicle are available to help imitate an actual tire model. They will affect the coefficient of friction by allowing it to fluctuate depending on the force applied to the tire. The following is an image of how to use a tire modeling software to determine your load sensitivities.



This is an image of the Normalized Lateral Force vs. Normal Load, or $\frac{F_{Lateral}}{F_Z}\ vs. F_Z$. What this tells you is the lateral coefficient of friction vs. normal load. To input this into OptimumLap it needs to be in the form $\frac{Coefficient\ of\ Friction\ Loss}{kg\ of\ weight\ change}$ which is equal to the Lateral Load Sensitivity.

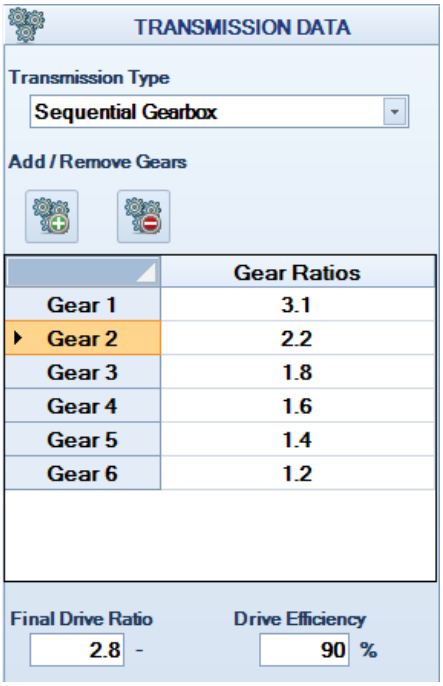
3.3.2.8 Engine Data



Here is where you enter the data for your engine. This data will come from either dyno data, the manufacturer (for electric motors) or from Google. People are always posting dyno sheets for their street cars and they can easily be found in order to input the data into OptimumLap. You can copy data from Excel via CTRL + C → CTRL + V directly into OptimumLap for the engine data.

1. (Optional) Thermal Efficiency → Here you can enter (if known) the ratio of the amount of fuel that is burned during combustion / the amount of fuel that doesn't burn and just exists out the exhaust. OptimumLap contains typical values for Gasoline, E85, Ethanol, electrical systems and many more.
2. (Optional) Fuel Energy Density → This number is used so that we can predict the fuel consumption of the vehicle. If you do NOT enter a value here, you will not get any fuel consumption in the results.

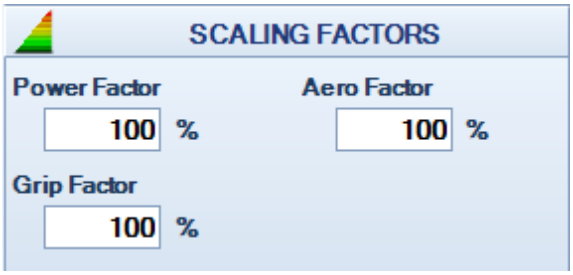
3.3.2.9 Transmission Data



'Transmission Data' is where you have the ability to input the following information:

1. Transmission Type → Does your vehicle have a Sequential Gearbox (IE – 5 speed, 6 speed, etc.) or is it a Continuously Variable Gearbox (CVT)
    a. If your vehicle has a Sequential Gearbox then you will need to enter the 'Gear Ratios'
        i. Typically these values can also be found by a Google search, or your vehicle service manual.
        ii. This information can be entered as a decimal value, or a ratio (either #:# or #/#)
    b. If your vehicle has a CVT then you need not enter any information into the 'Gear Ratios' field or 'Final Drive Ratio'.
2. Final Drive Ratio → This information can also be found by a Google search.
    a. For a motorcycle this value is $\frac{\#\ of\ teeth\ of\ Drive\ Sprocket}{\#\ of\ teeth\ of\ Countershaft\ Sprocket}$. NOTE – If you are using a motorcycle engine please include the 'Primary Reduction' in the 'Final Drive Ratio'.
3. Drive Efficiency → How much of your engine power actually makes it to the wheels. Typical values for this are:
    a. 80% - 92%

3.3.2.10Scaling Factors



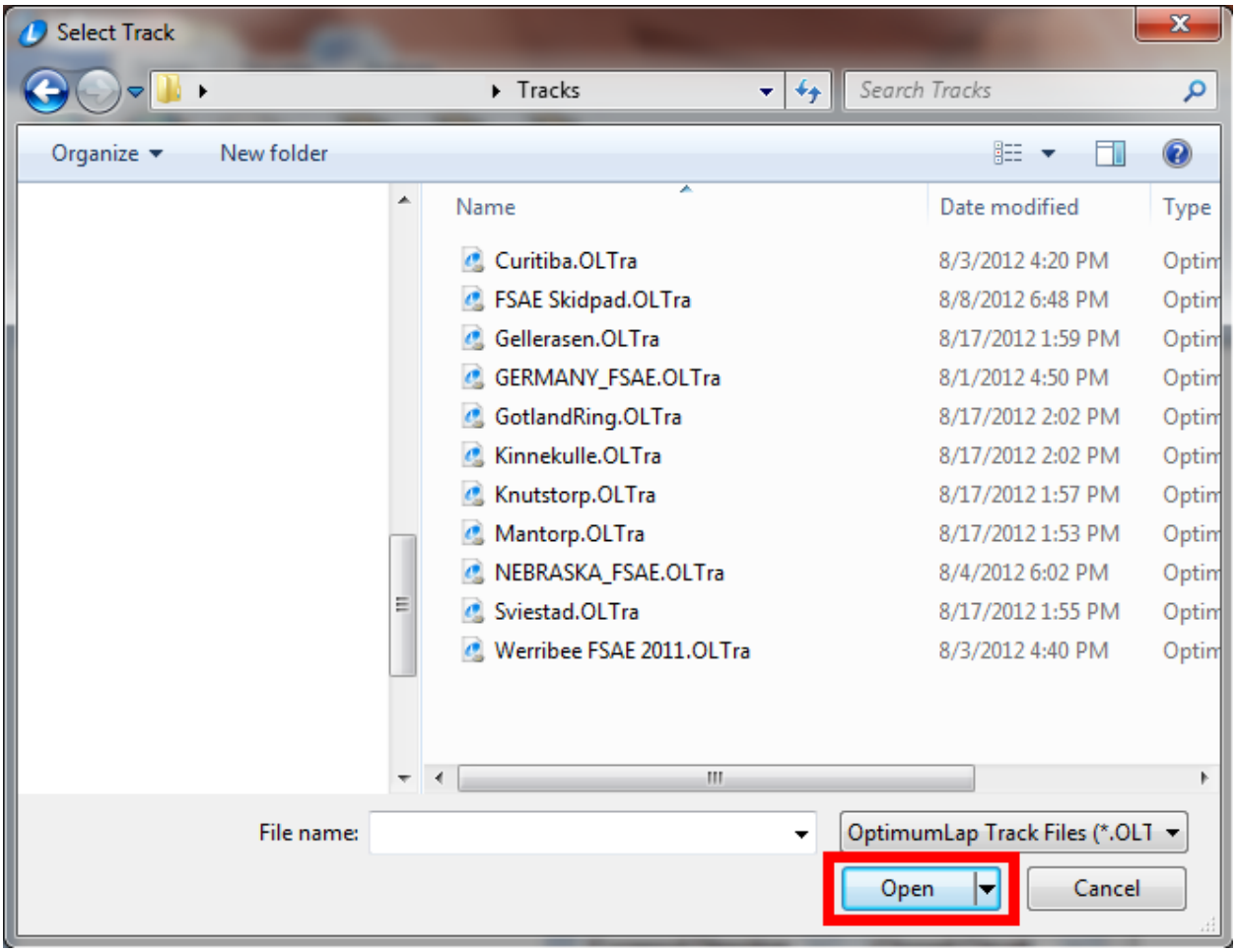
Scaling factors will give you an easy way to add power, drag and downforce, and lateral and longitudinal coefficient of friction.

1. Power Factor → This will increase or decrease your power and torque.
2. Aero Factor → This will increase or decrease both your Drag Coefficient and Downforce Coefficient.
3. Grip Factor → This will increase or decrease both your Longitudinal and Lateral Coefficient of Friction of your tires.

The scaling factors can have a value between 10% - 500%.

3.3.3 Importing a Track

Once you have clicked on the 'Import' button you will see the open file dialog and be able to locate the track that you desire to open.



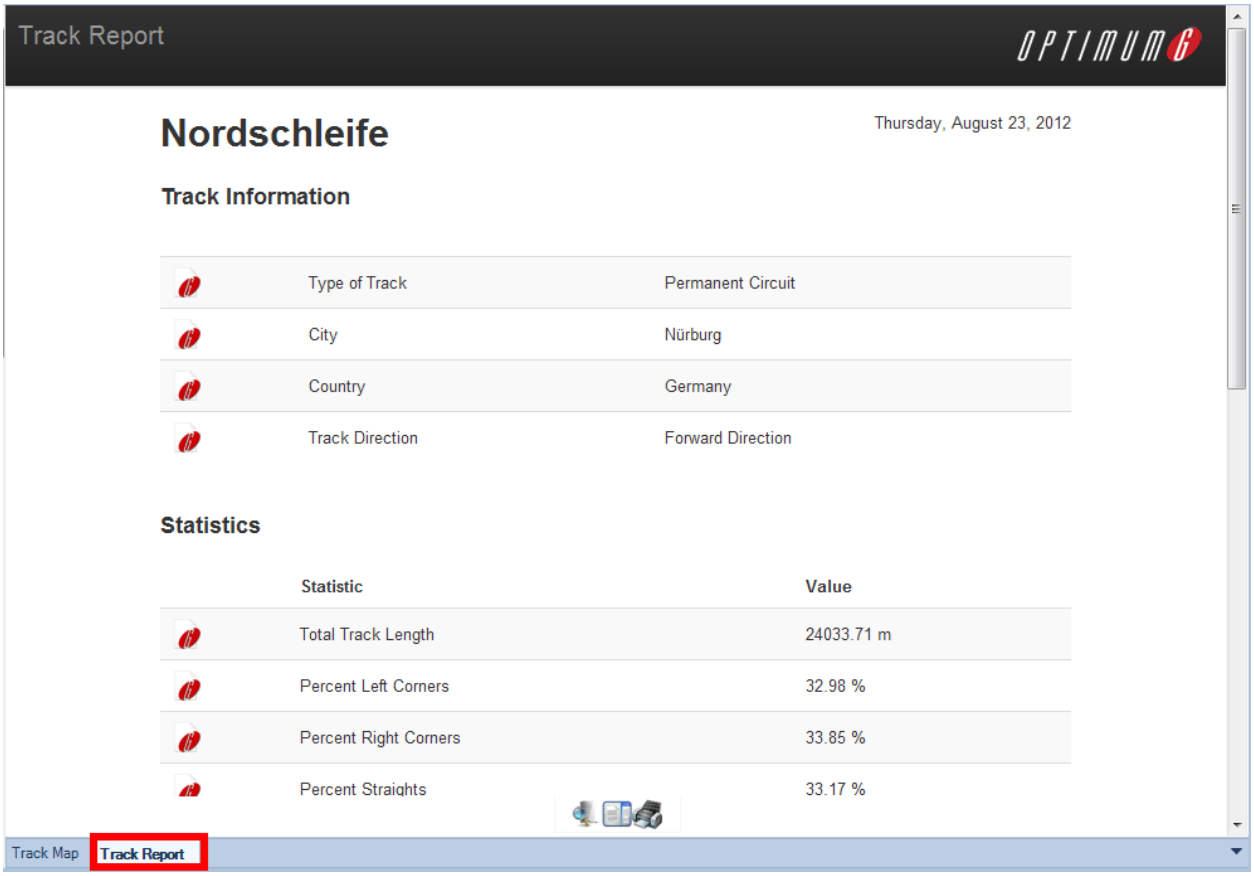
The only files that you will be able to open are of the *.OLTra which are OptimumLap Track files. Once the track has been imported it will automatically open within the program so that you can view and/or modify any parameters you desire.

3.3.4 Viewing and Modifying Tracks

3.3.4.1 Track Map

The first thing you will notice is the 'Track Map'. This will update every time a track section is modified or a visual appearance change is made.

3.3.4.2 Track Report



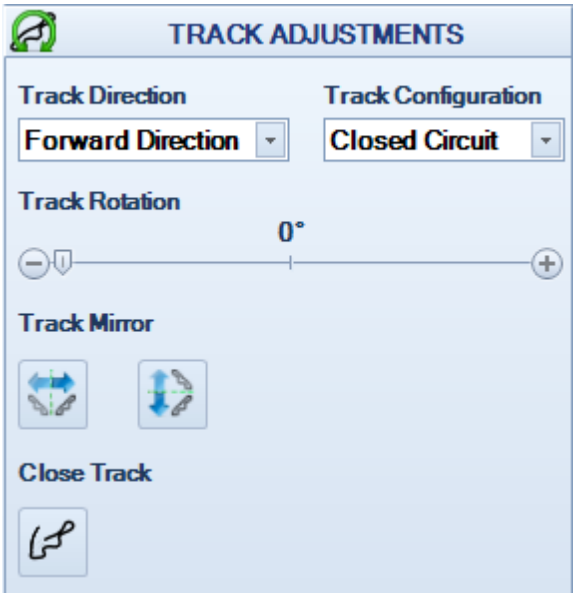
The 'Track Report' will summarize your track. There will be values such as Total Track Length, Percent Left Corners, Percent Right Corners, Percent Straights, Average Corner Radius, Minimum Corner Radius and Longest Straight. To adjust what is shown in the 'Track Report' please refer to the '**User Options**' section of this help file.

3.3.4.3 Track Info

From within the 'Track Info' you have the ability to enter:

1. (Optional) Track Type
2. Track Name → What name do you want to show up in the Project Tree and on the 'Track Report'
3. (Optional) City → What city is the track located in.
4. (Optional) Country → What country is the track located in.

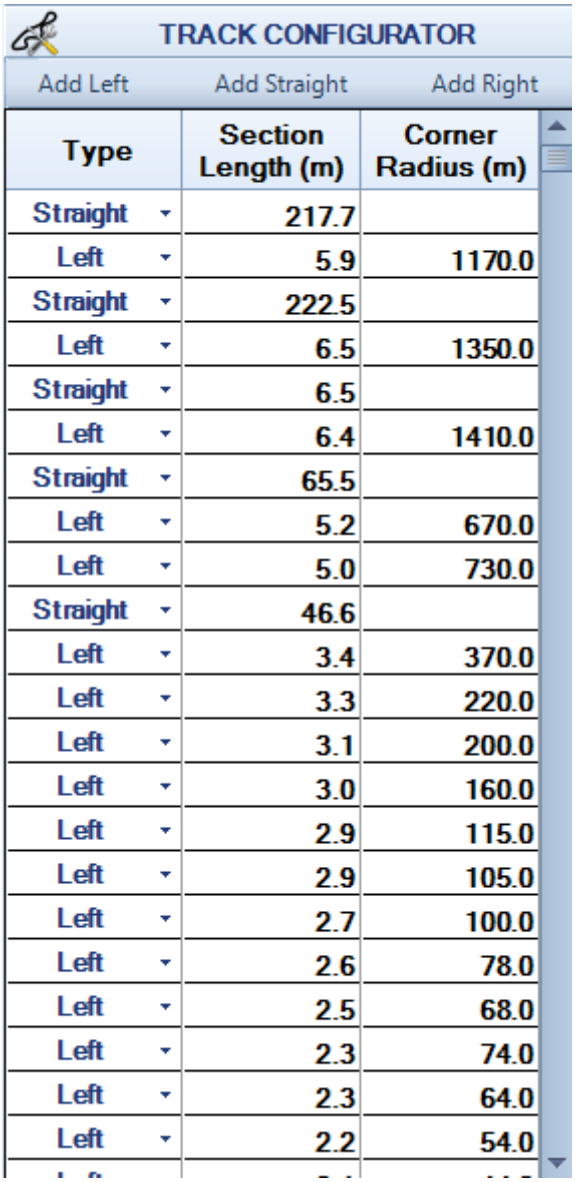
3.3.4.4 Track Adjustments



The 'Track Adjustments' section gives you the ability to determine the following:

1. Track Direction → If you would like to run the track in the Forward Direction or the Reverse Direction. Changing this option will re-order the sections of the track.
2. Track Configuration → This is what determines whether the program will start at the lowest possible speed (for Open Circuit) or whether it will start at the speed it finishes at (for Closed Circuit)
3. Track Rotation → Visually rotate the track between 0 – 360 degrees.
4. Track Mirror → Visually mirror the track either vertically or horizontally.
5. Close Track → Only available for 'Closed Circuits' this will visually force the track to close.

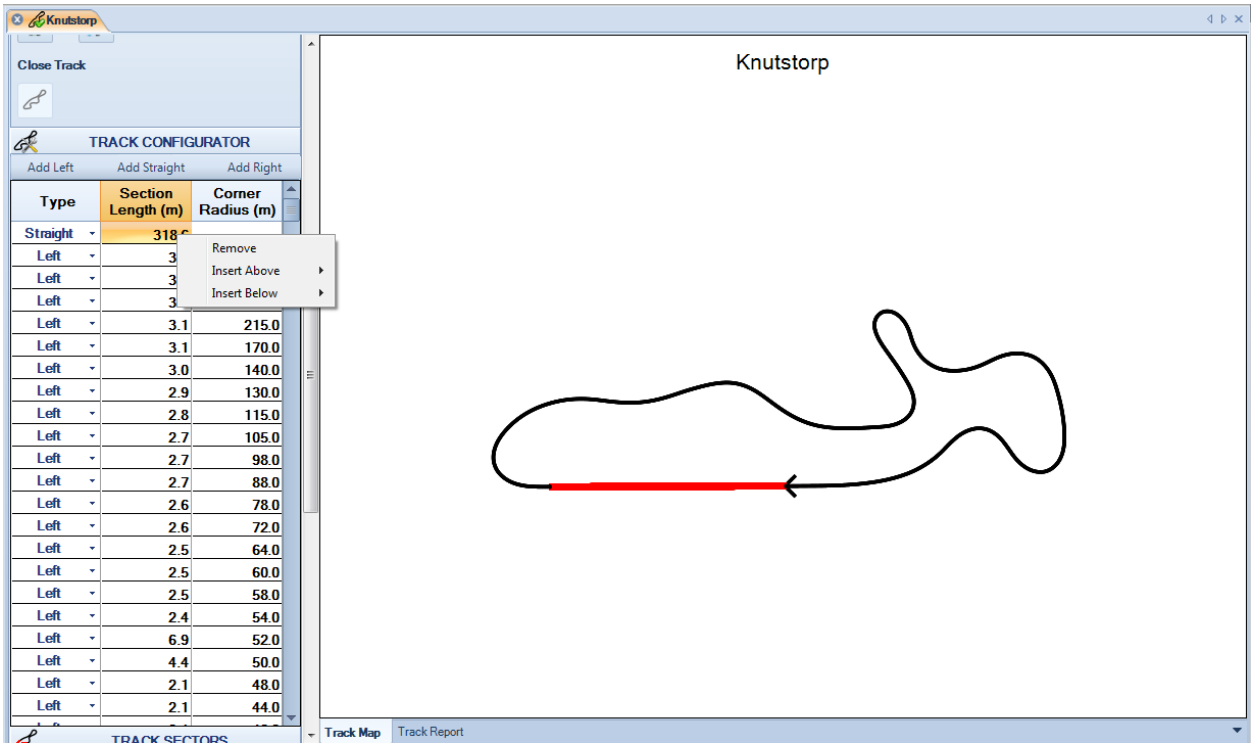
3.3.4.5 Track Configurator



Type	Section Length (m)	Corner Radius (m)
Straight	217.7	
Left	5.9	1170.0
Straight	222.5	
Left	6.5	1350.0
Straight	6.5	
Left	6.4	1410.0
Straight	65.5	
Left	5.2	670.0
Left	5.0	730.0
Straight	46.6	
Left	3.4	370.0
Left	3.3	220.0
Left	3.1	200.0
Left	3.0	160.0
Left	2.9	115.0
Left	2.9	105.0
Left	2.7	100.0
Left	2.6	78.0
Left	2.5	68.0
Left	2.3	74.0
Left	2.3	64.0
Left	2.2	54.0

This is where you can manually enter or adjust the sections that together make up your track. The following options exist here:

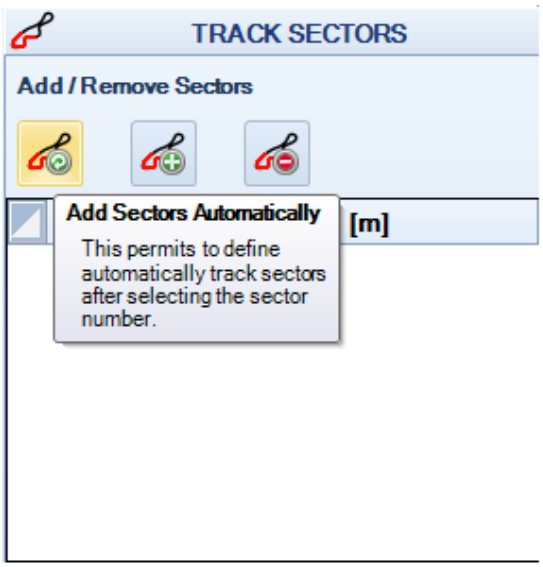
1. Add Left → Add a left turn section to your track by defining the Section Length (circumference) and the Corner Radius.
2. Add Straight → Add a straight section to your track by defining only the Section Length
3. Add Right → Add a right turn section to your track by defining the Section Length (circumference) and the Corner Radius.

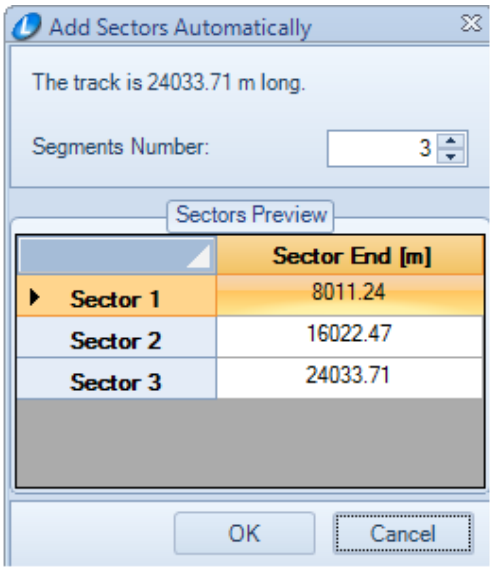


Highlighting a 'Section Length' will highlight its location on the track in red. Right clicking on a row will give you the ability to remove a section, or insert a section either above or below to assist in creating a track or editing an existing track.

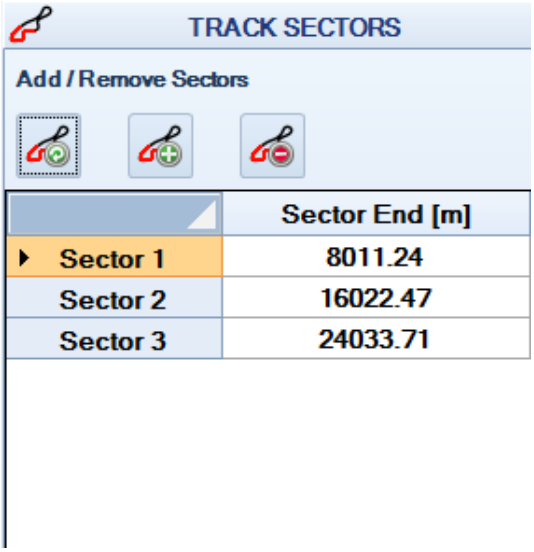
3.3.4.6 Track Sectors

You have the option to choose how many sectors you want and they will automatically be evenly spaced between the beginning and end of the track.

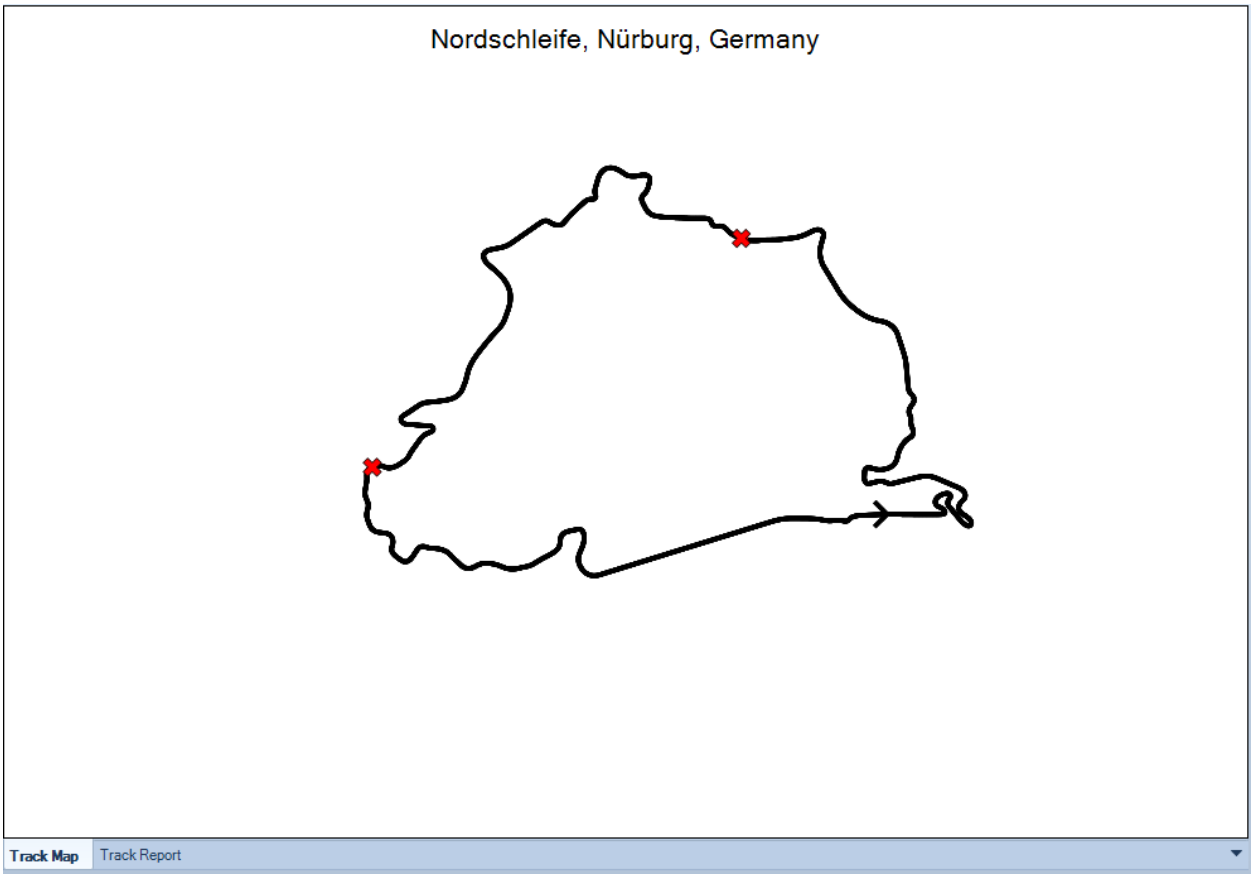




The other option that you have is to manually add individual sectors where you have to specify the length that the sector both starts and ends. You can also remove sectors.



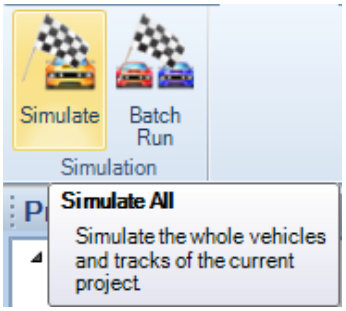
Track sectors allow you to break up your track into multiple larger sections. As soon as you have either automatically or manually created track sectors they will show up on your track map.



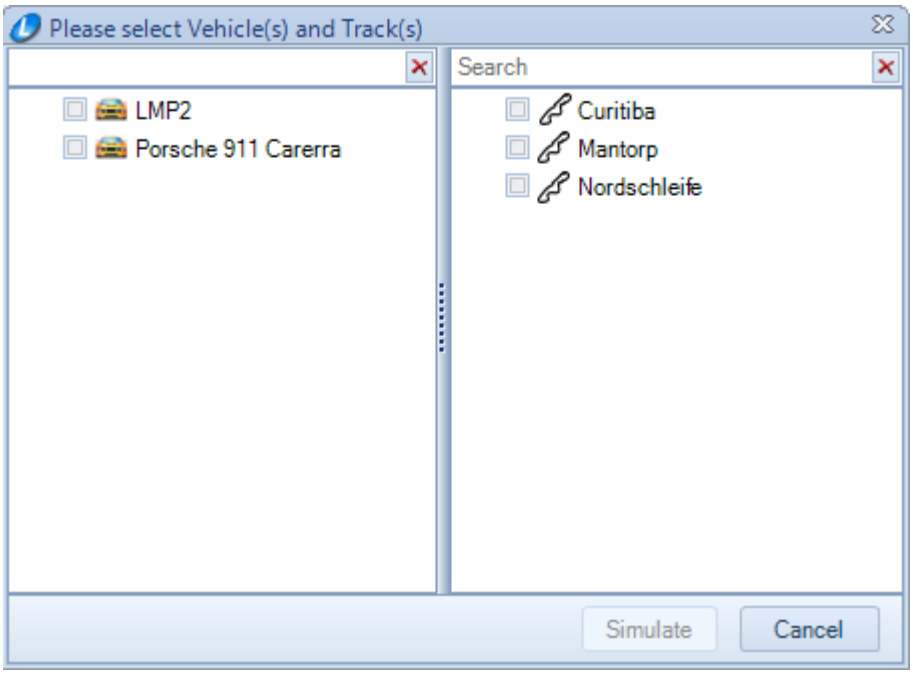
3.4 Simulate Tab

OptimumLap allows you to run two different types of simulations. The first type is 'Simulate'.

3.4.1 Simulate

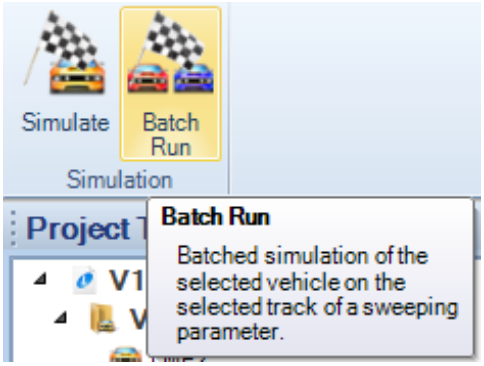


These buttons will be enabled anytime you have valid vehicles and tracks. Upon clicking the 'Simulate' button you will see the following window:

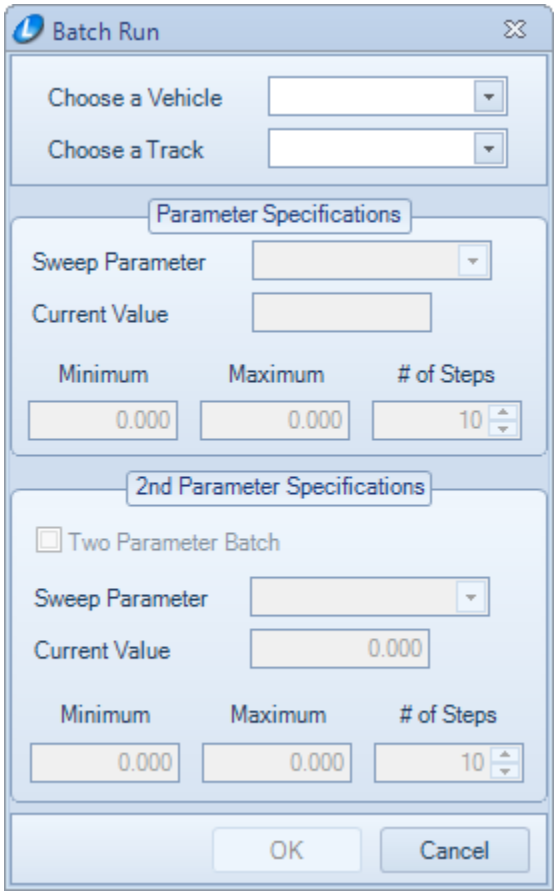


This window allows you to choose which vehicles and tracks you would like to gather results for. Results will be created for every combination of vehicles and tracks that are selected.

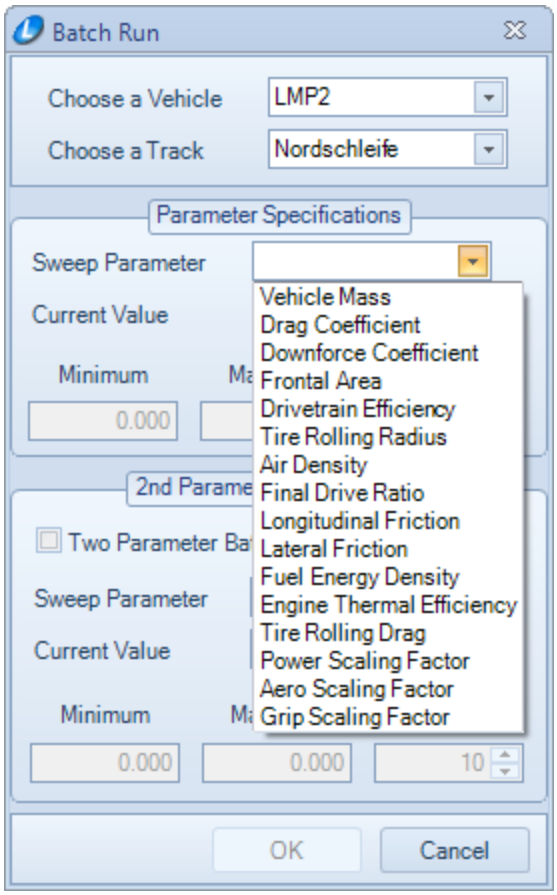
3.4.2 Batch Run Simulation



Batch run simulations give you the opportunity to sweep different vehicle parameters in order to determine the effects those parameters have on performance on the given circuit. Upon clicking the 'Batch Run' button the following window will appear:

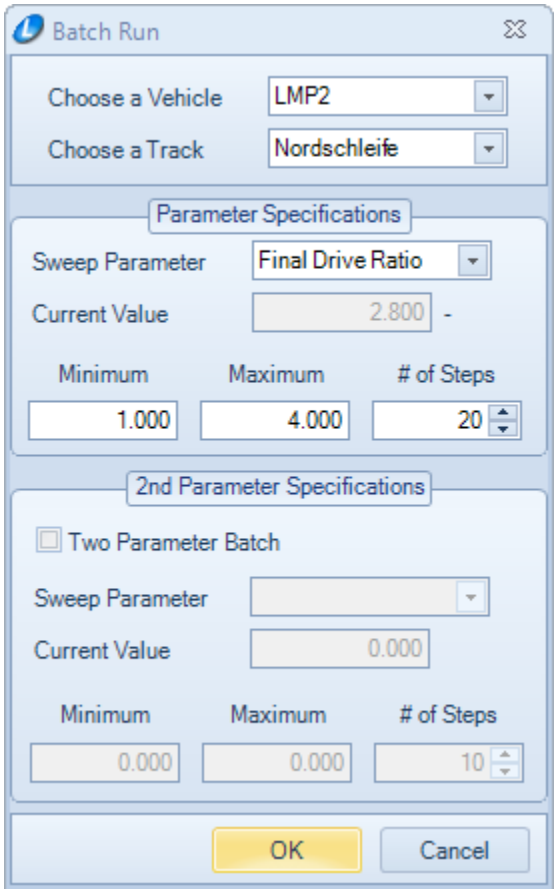


Only valid vehicles and tracks will populate the combo boxes in this window. The Parameter Specifications will become enabled as soon as you have selected both a vehicle and a track.

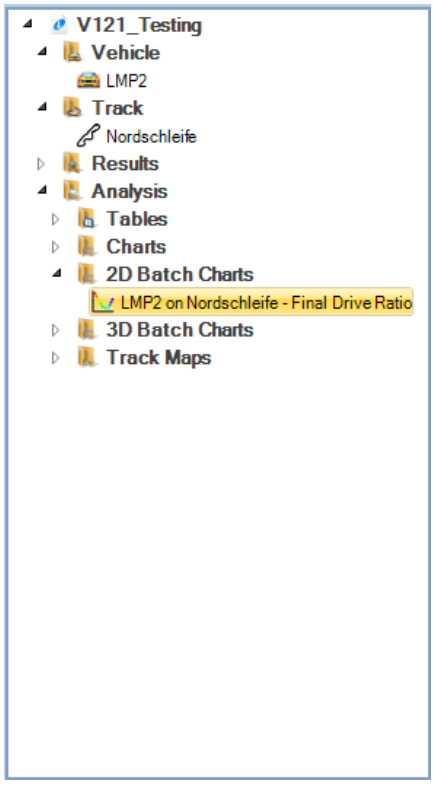


As soon as a parameter is selected the minimum and maximum will automatically populate with ±10% of the original value. This allows quick access to viewing of the sensitivity of the parameter on the vehicle performance.

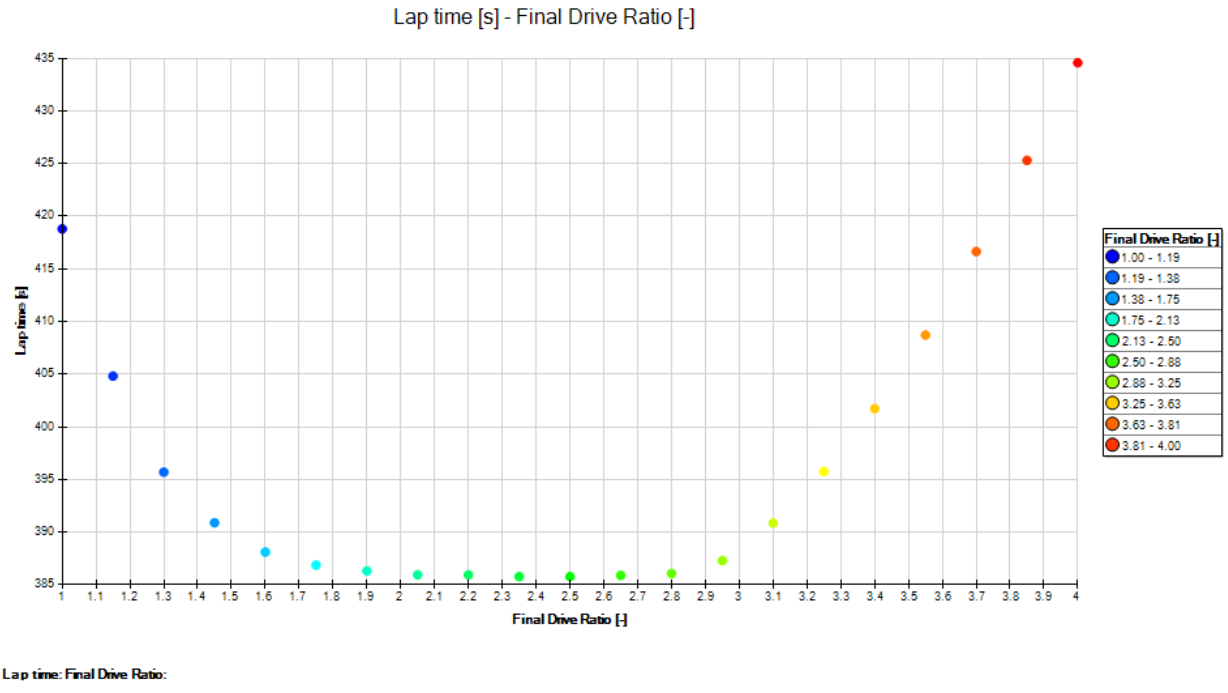
3.4.2.1 Single Parameter Batch Run



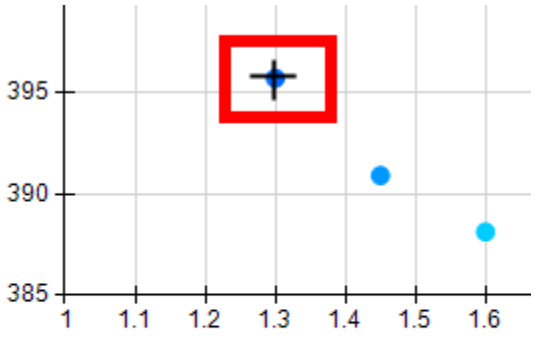
If you decide to run a batch run on only one parameter then upon completion of the simulation a '2D Batch Chart' will automatically be created.



The chart will automatically open up for viewing and analysis.

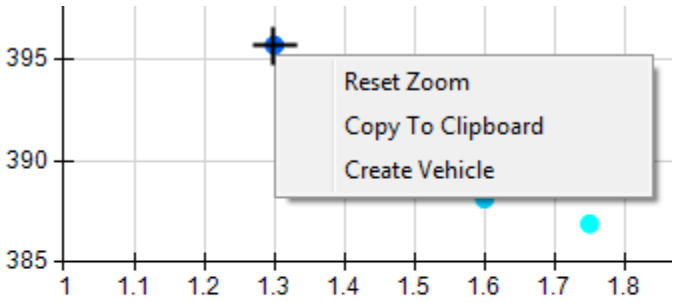


Every point on this chart refers to a lap around the selected track. The corresponding X-Channel and Y-Channel value can be quickly seen by simply positioning the mouse cursor directly over the desired point.



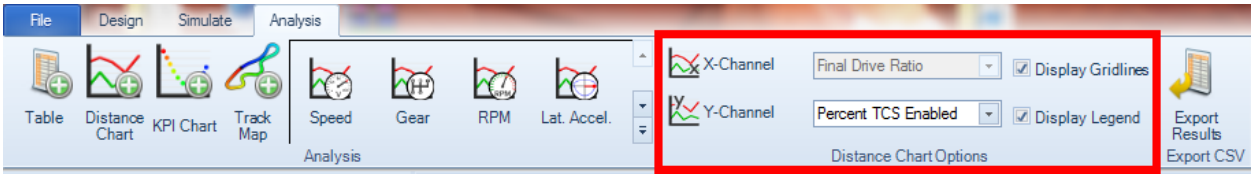
Laptime: 395.699 Final Drive Ratio: 1.300

If you were to right click using the mouse on this point the option to 'Create Vehicle from Point' will appear, along with the options to 'Reset Zoom' and 'Copy to Clipboard'.

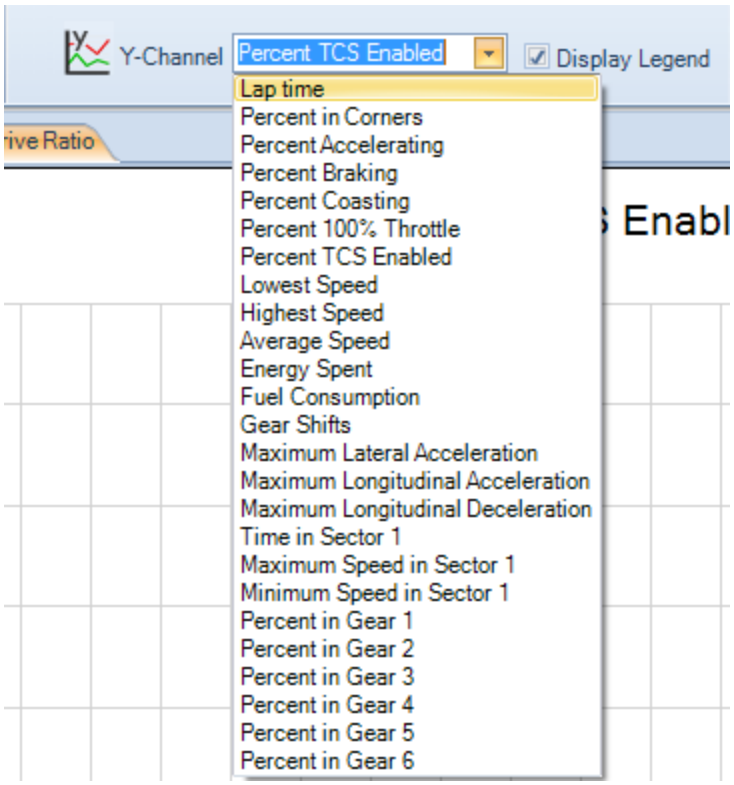


Laptime: 395.699 Final Drive Ratio: 1.300

Other options that exist while viewing a '2D Batch Chart' can be found on the Ribbon Bar and include, changing the Y-Channel, Displaying Gridlines and Displaying Legend:

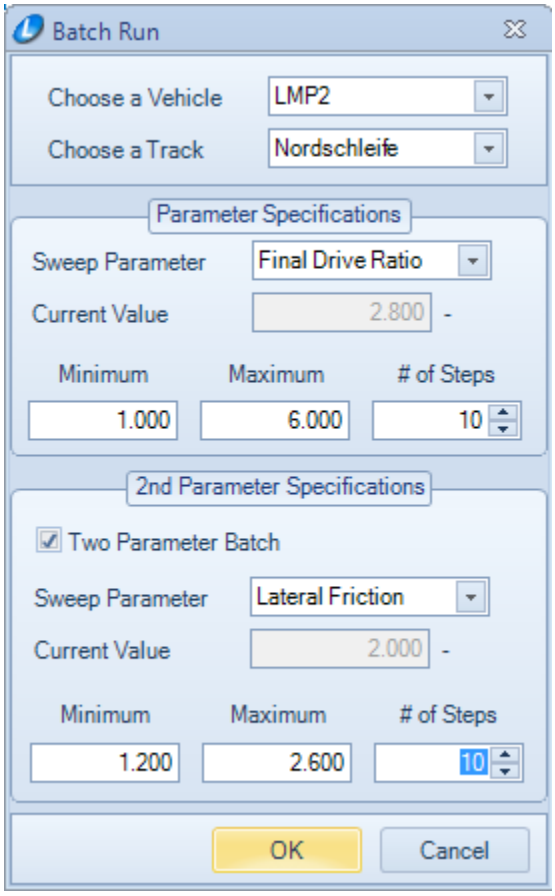


The following image shows you the available Y-Channels for this particular result. Had there been sectors on the track when the simulation was ran there would be additional channels available.

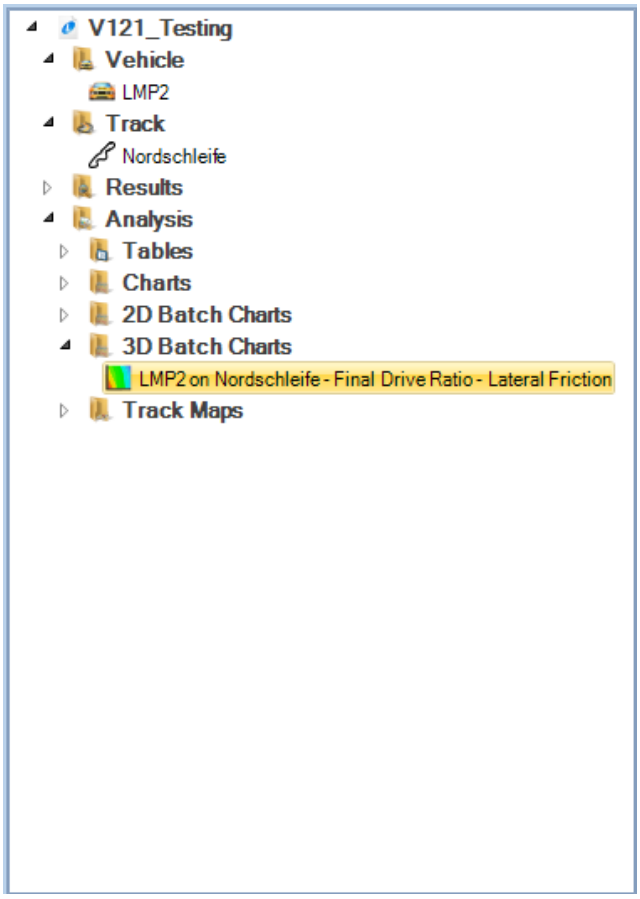


These channels correspond to the available KPI (Key Performance Index) outputs for the given simulation.

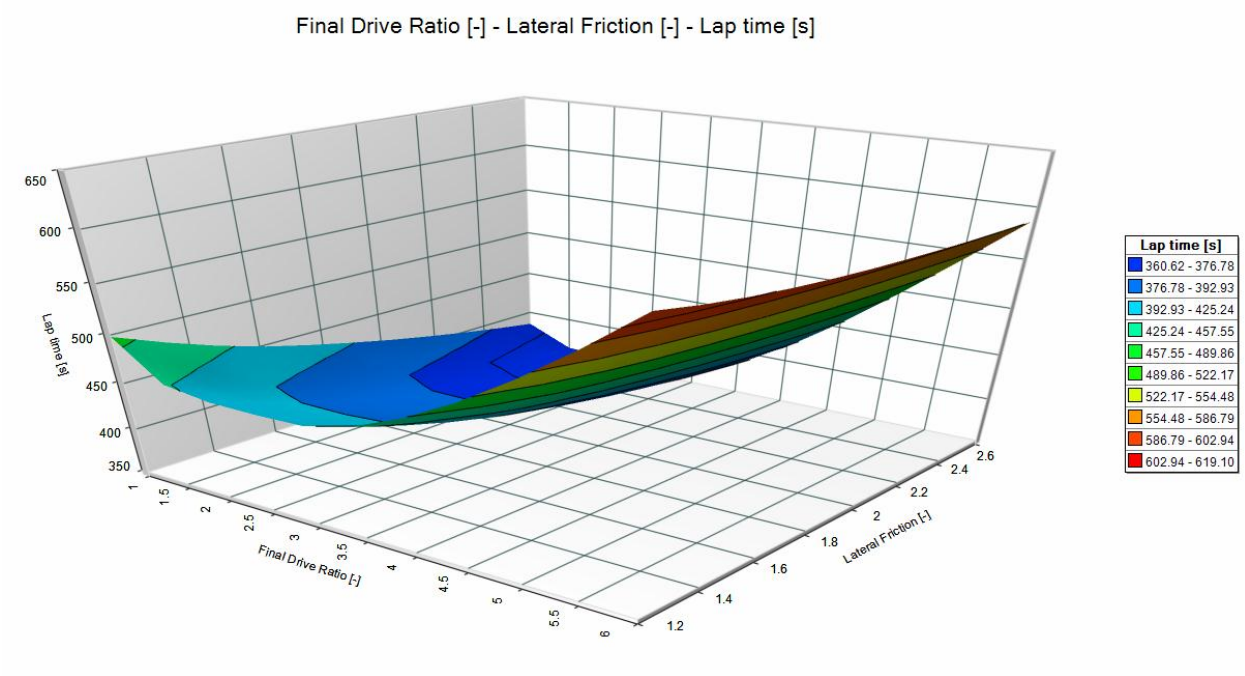
3.4.2.2 Two Parameter Batch Run



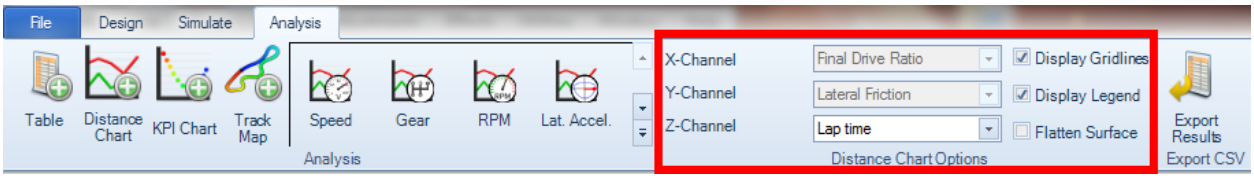
Running a two parameter batch run will automatically create a '3D Batch Chart'.



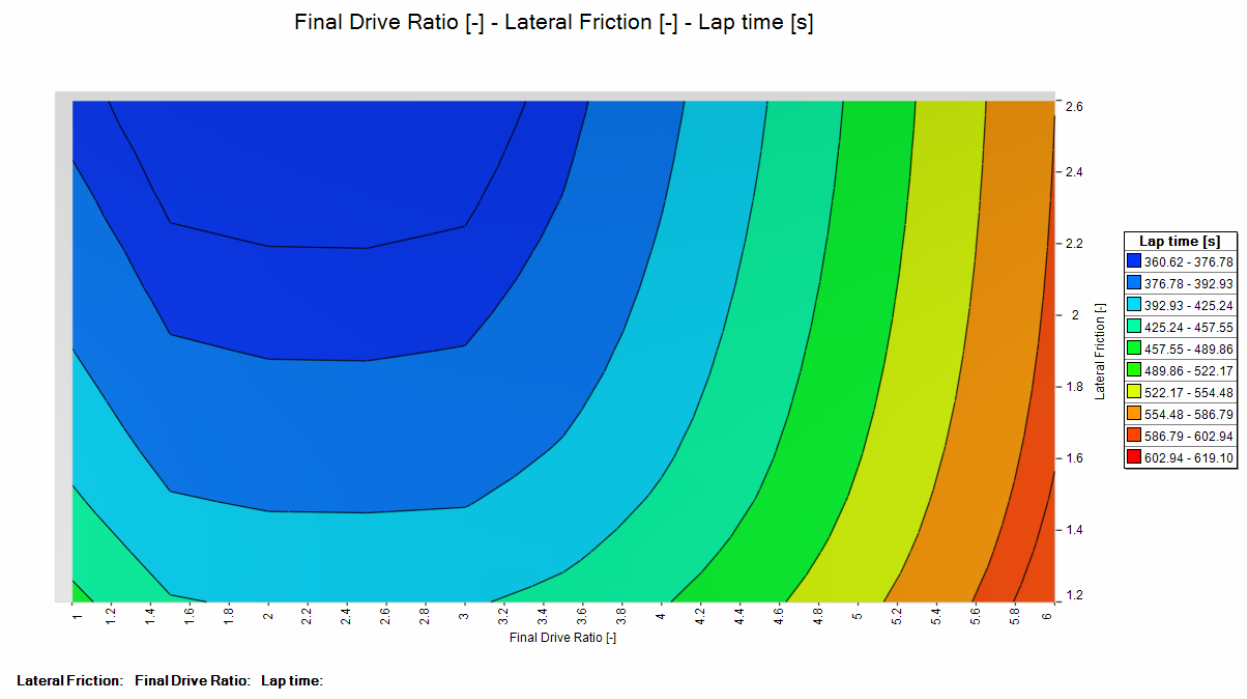
The surface chart will automatically open for viewing and analysis.



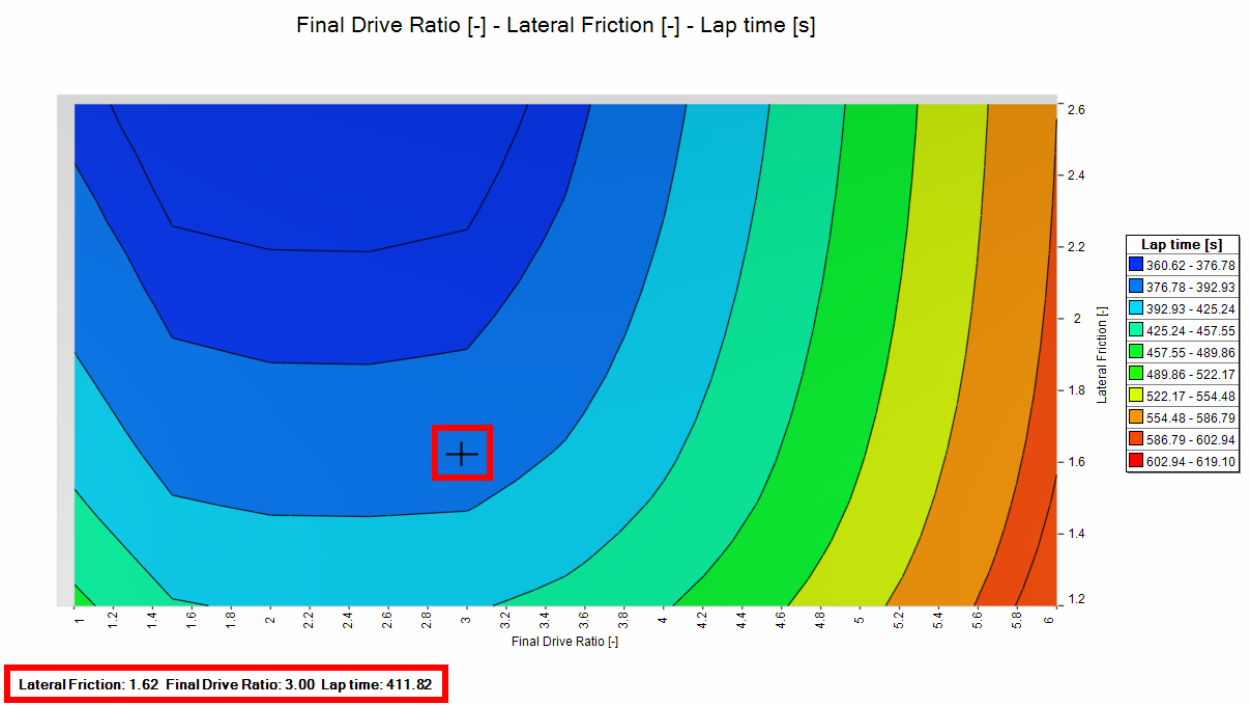
Very similar options exist here as were in the 2D Batch Charts. When looking at the options in the Ribbon Bar, you will find the option to change the Z-Channel, Display Gridlines, Display Legend and Flatten Surface.



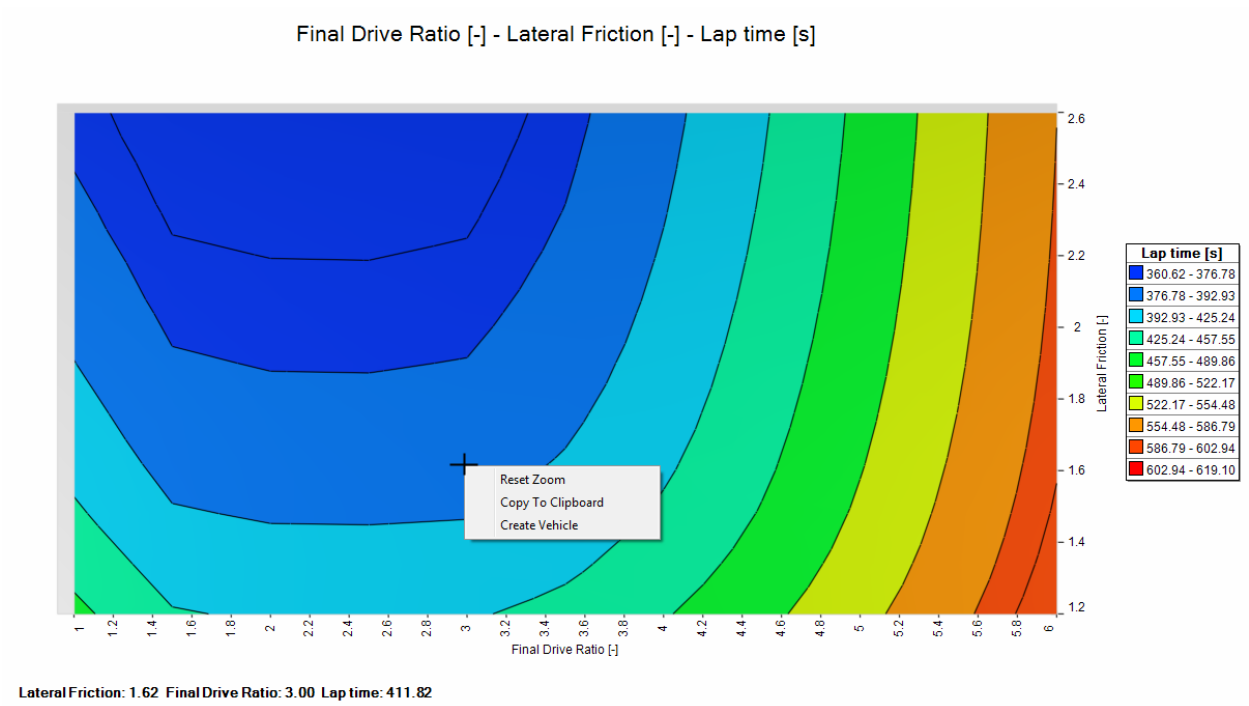
If you choose to Flatten the surface you will see the following:



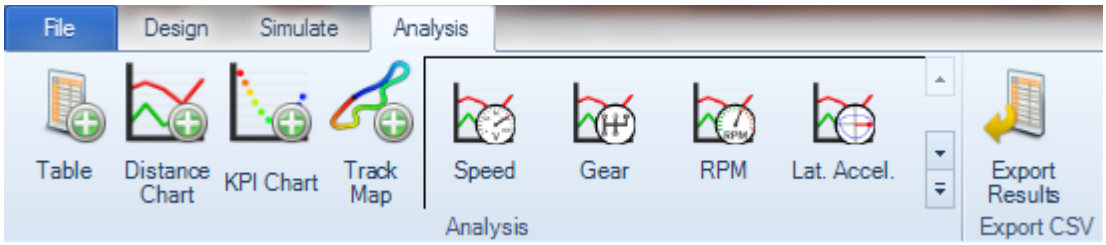
When in this view you can view the exact values by simply placing the mouse cursor over the chart:



Just as we did in the 2D Chart we can right click on any place on the surface while it is Flattened and 'Create a Vehicle', 'Reset Zoom' and 'Copy to Clipboard'.

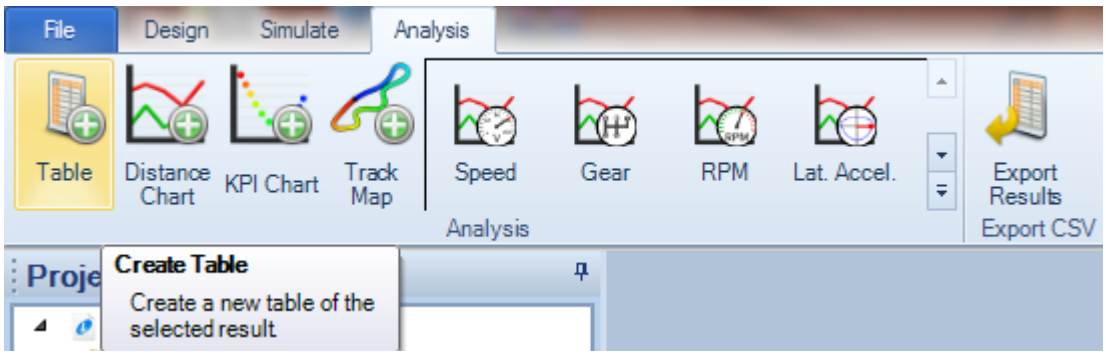


3.5 Analysis Tab

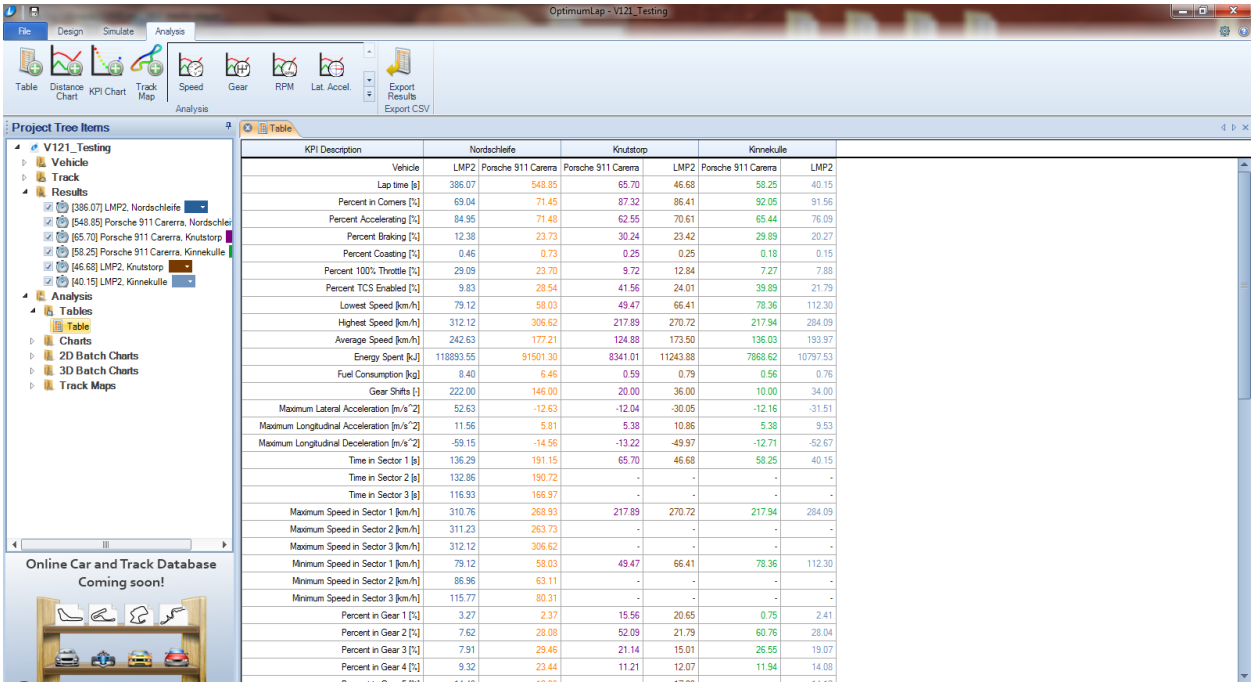


The 'Analysis Tab' is where you can create Tables, Distance Charts, KPI Charts or Track Maps. The ability to Export Results can also be located here.

3.5.1 Create a Table

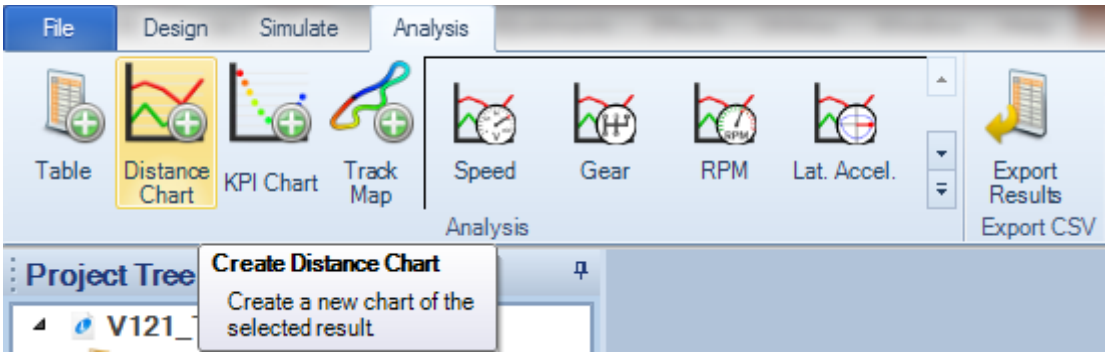


Upon clicking the 'Table' button a table will automatically be created and added to your project.

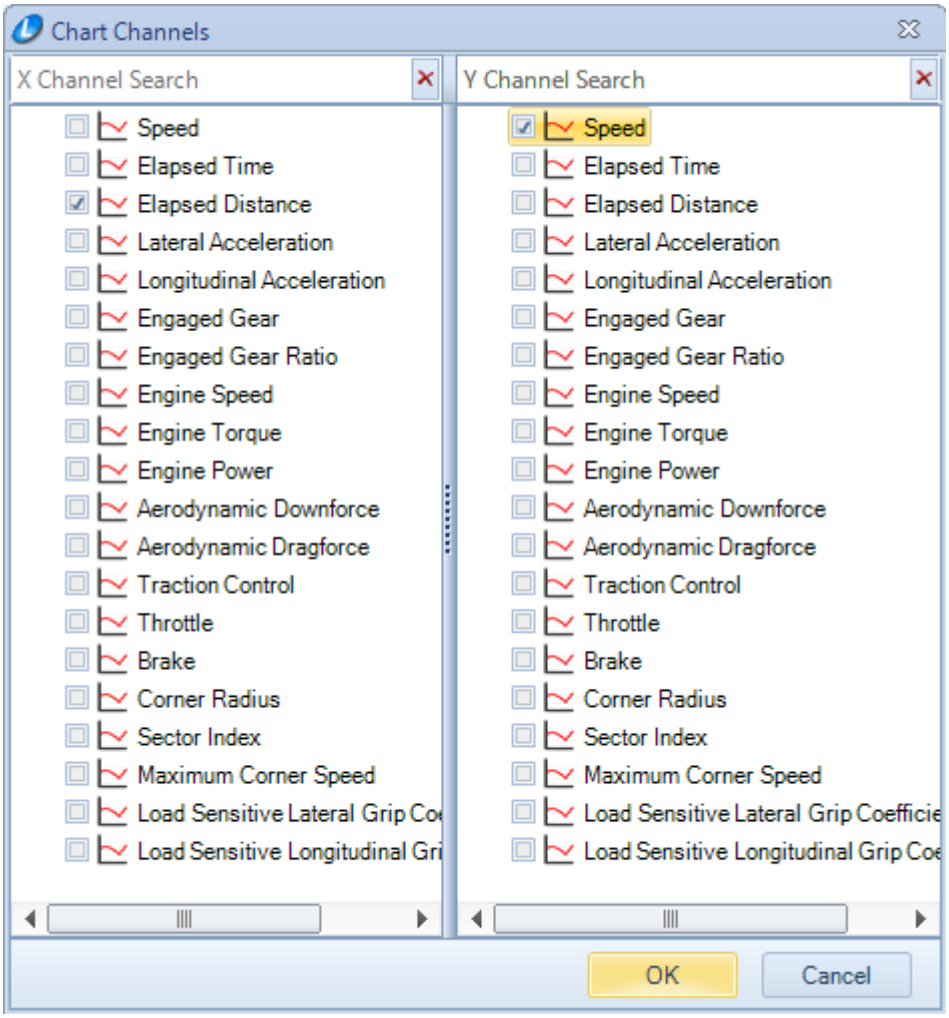


It is only necessary to create one table as it will show all selected results. The displayed values are that of all calculated KPI results for each simulation. It also includes Vehicle KPI's such as shift speeds, etc. If there is no data for that particular channel the value will appear as "-".

3.5.2 Create a Distance Chart

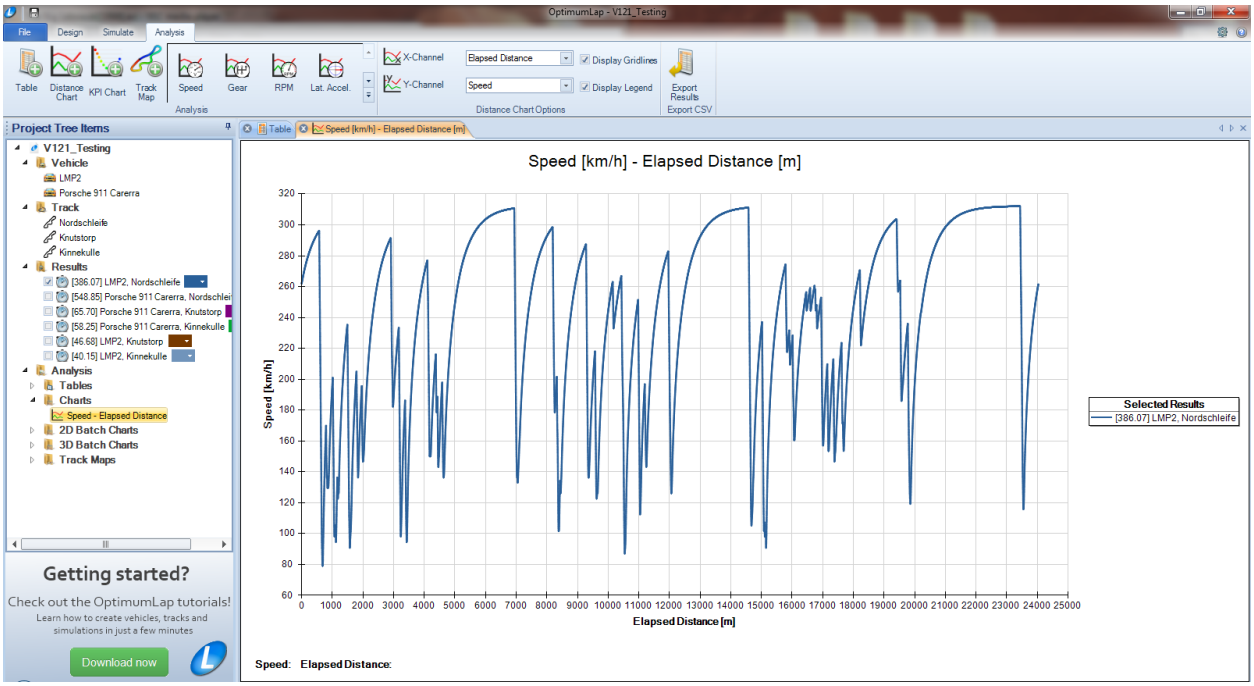


Upon clicking the 'Distance Chart' button you will be brought to the following window:

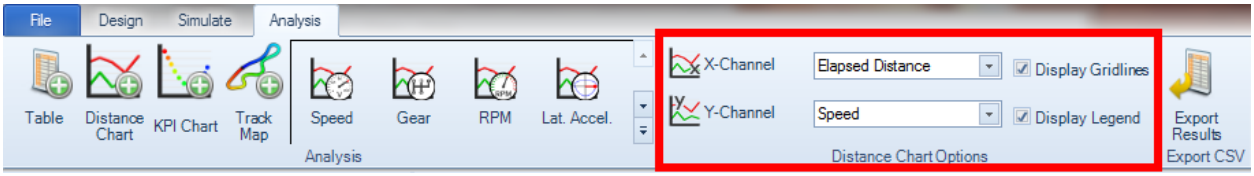


By default the X-Channel will have ‘Elapsed Distance’ selected. If you choose to create a chart with either ‘Elapsed Time’ or ‘Elapsed Distance’ for the X-Channel, then the chart displayed will be a line chart. Any other X-Channel selection will result in a X-Y scatter chart.

As soon as the ‘OK’ button is clicked the distance chart will automatically be added to your project.



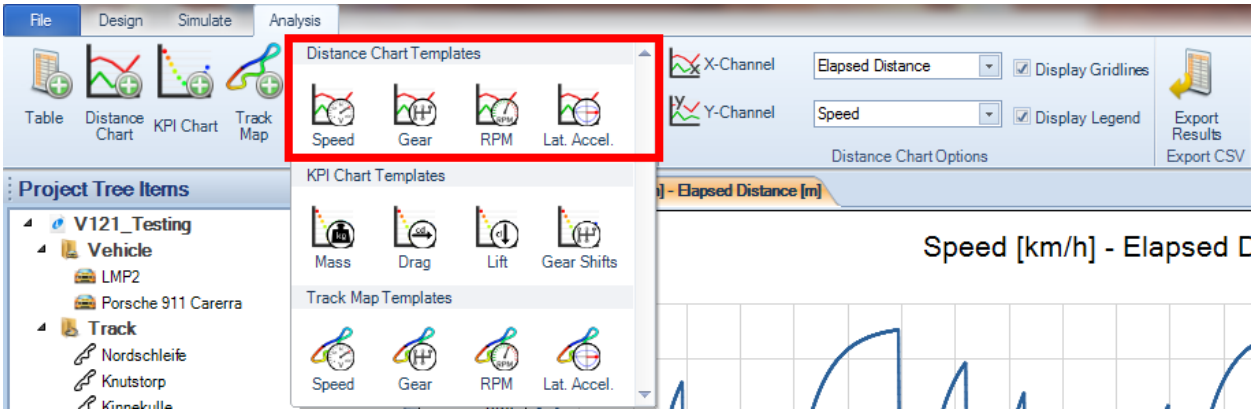
3.5.2.1 *Viewing and Modifying a Distance Chart*



When viewing a Distance Chart all of the options available will appear on the Ribbon Bar. These options include:

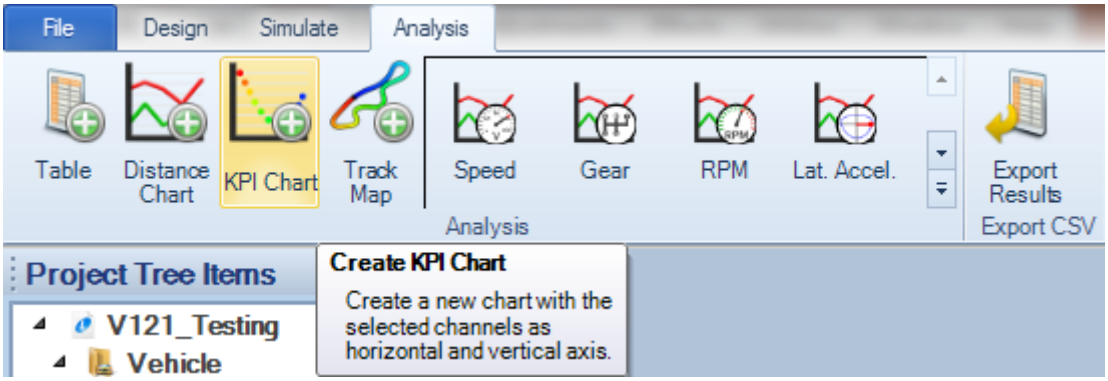
1. X-Channel → Please refer to ‘**Distance Outputs**’ for a full list of available channels.
2. Y-Channel → Please refer to ‘**Distance Outputs**’ for a full list of available channels.
3. Display Gridlines → Toggle on or off the chart gridlines.
4. Display Legends → Toggle on or off the chart legend.

3.5.2.2 Distance Chart Templates

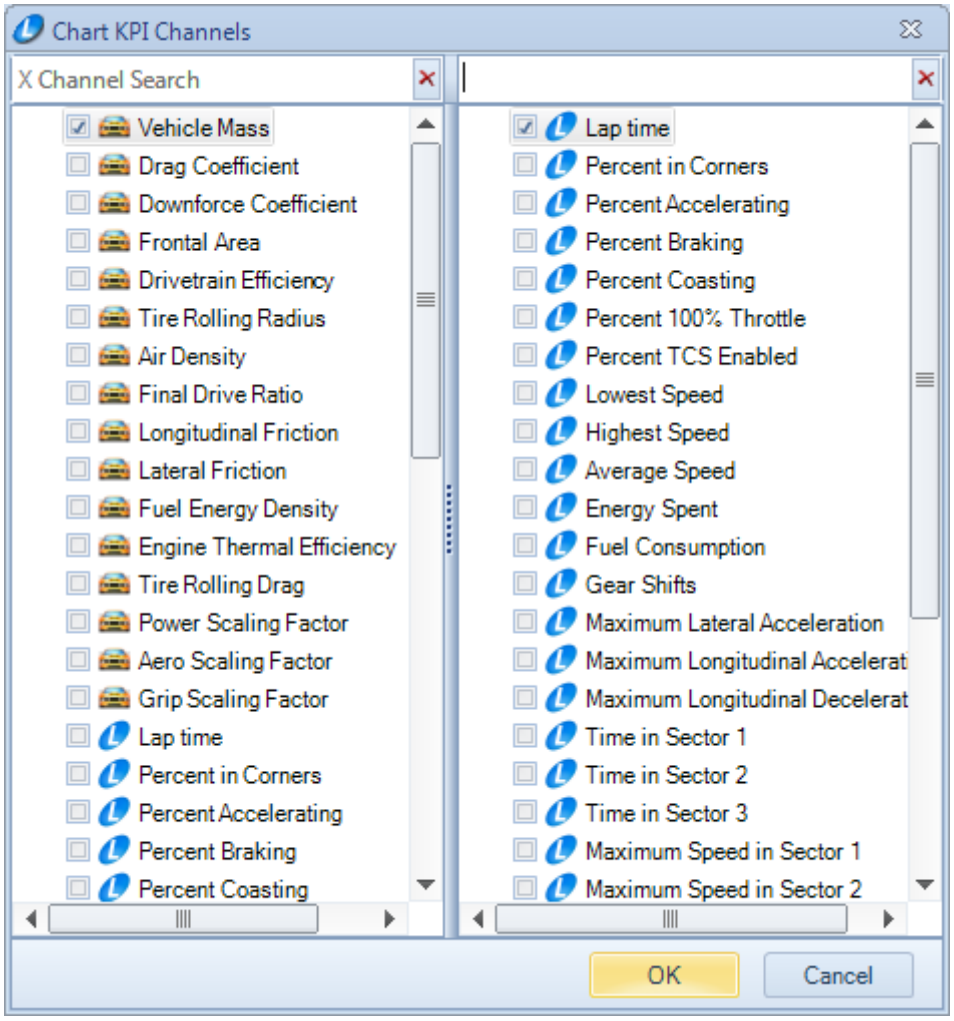


Choosing to create a Distance Chart from the template will automatically create the chart and add it to your project so that it can be viewed and/or modified.

3.5.3 Create a KPI Chart

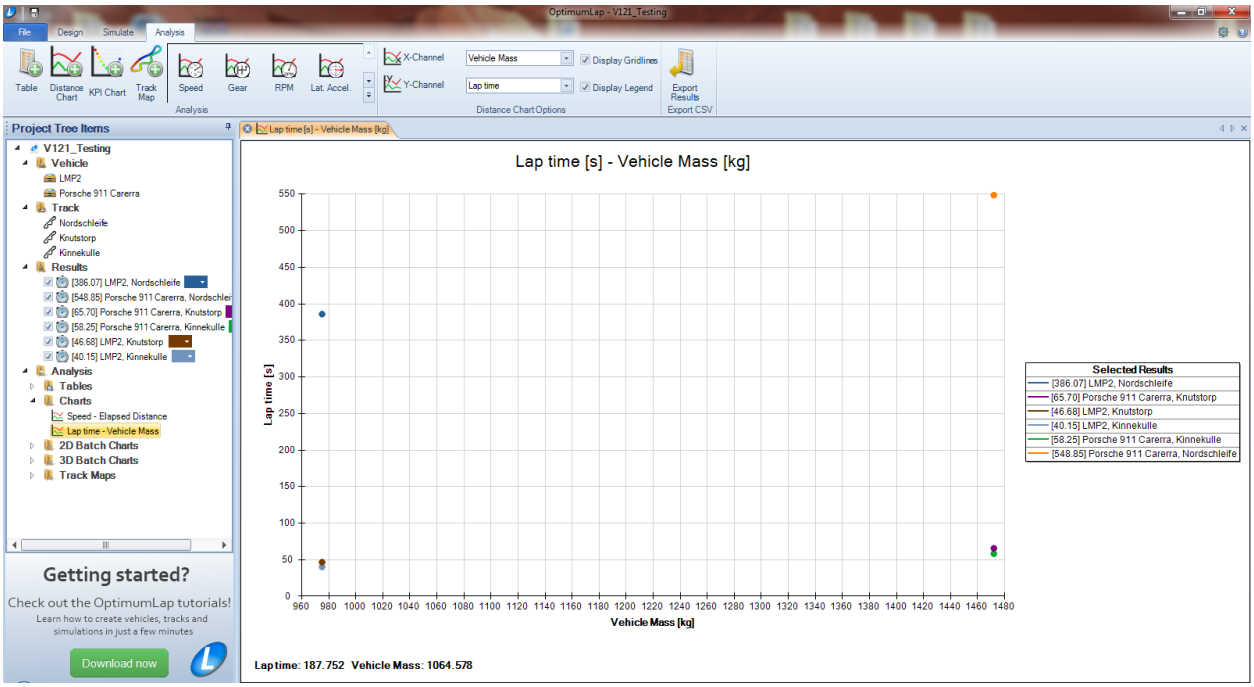


Once you have decided to create a KPI Chart you will be brought to the following window:

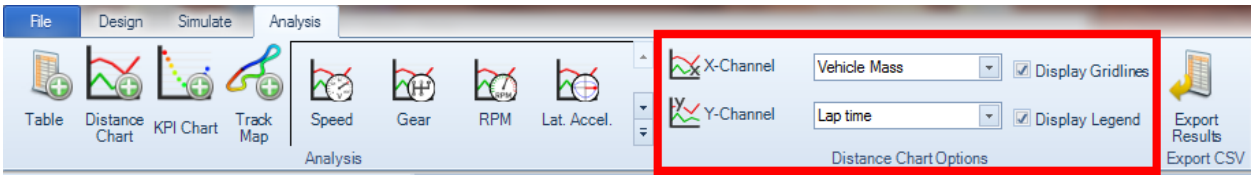


No channels are selected by default. The available X-Channels are Vehicle KPI's and Calculated KPI's. The available Y-Channels are Calculated KPI's.

Upon clicking the 'OK' button the chart will be created and automatically added to your project.



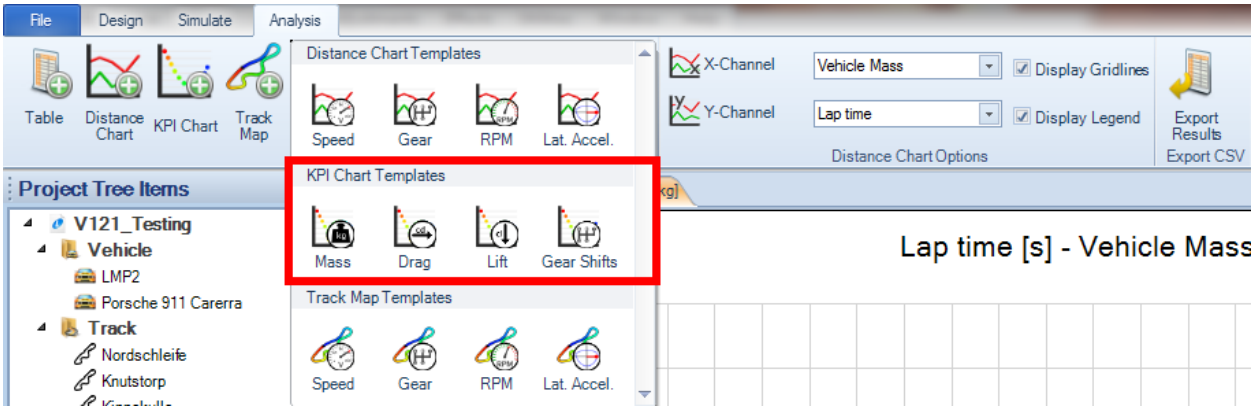
3.5.3.1 *Viewing and Modifying a KPI Chart*



When viewing a KPI Chart all of the options will appear on the Ribbon Bar. These options include:

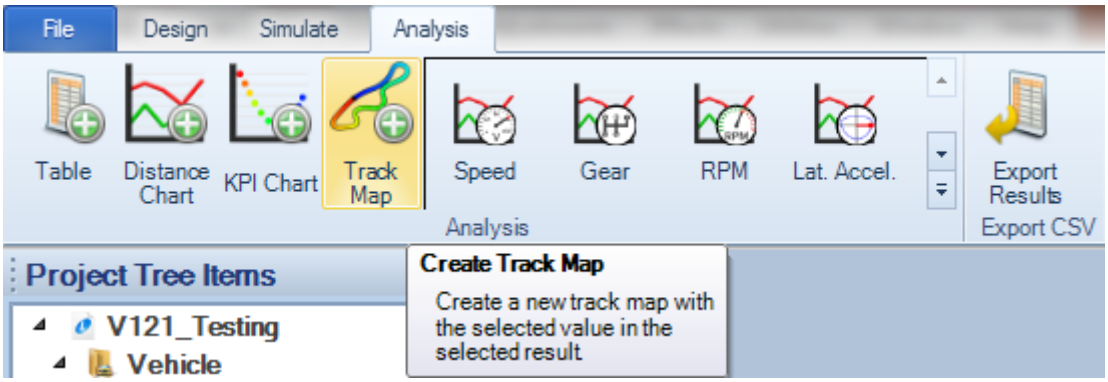
1. X-Channel → Please refer to '**KPI Outputs**' for a full list of available channels.
2. Y-Channel → Please refer to '**KPI Outputs**' for a full list of available channels.
3. Display Gridlines → Toggle on or off the chart gridlines.
4. Display Legends → Toggle on or off the chart legend.

3.5.3.2 KPI Chart Templates

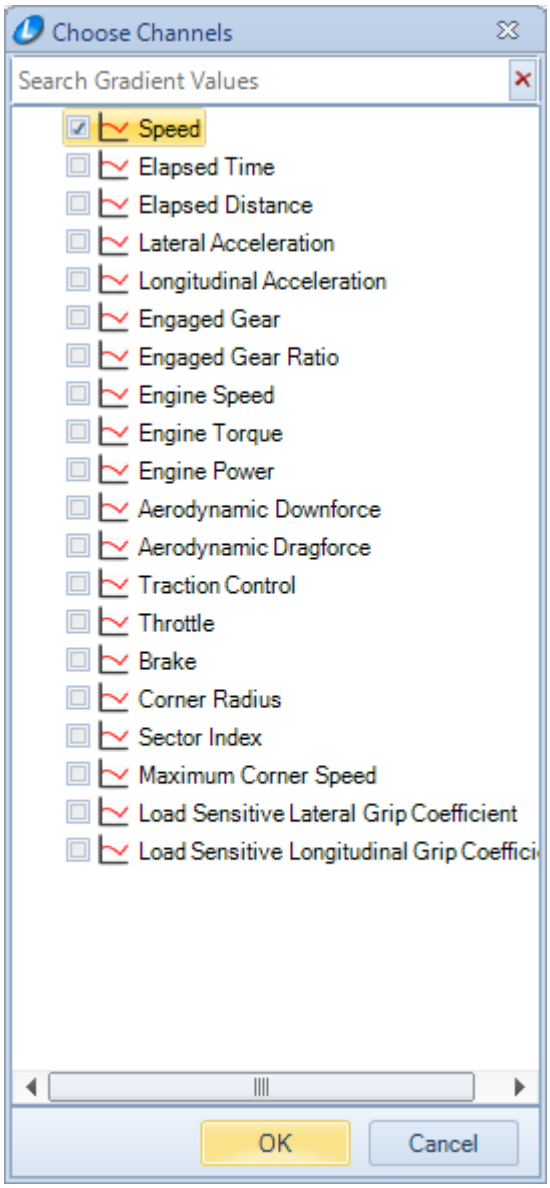


Choosing to create a KPI Chart from the template will automatically create the chart and add it to your project so that it can be viewed and/or modified.

3.5.4 Create a Colored Track Map

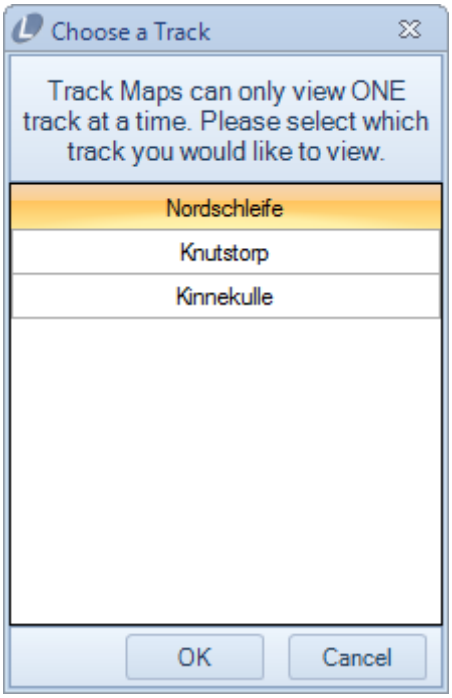


Upon clicking the 'Track Map' button the following window will appear:



The available channels here determine what the Track Map will be colored by. These channels are exactly the same channels as are available when creating a Distance Chart.

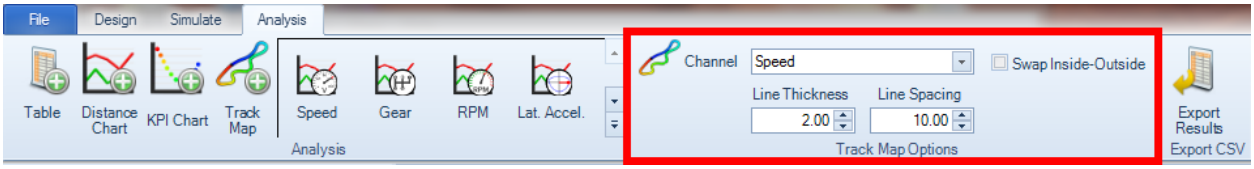
NOTE – Colored Track Maps can only utilize results that were created with the same tracks. If you have multiple results selected with different tracks the following window will appear:



The tracks that appear in this window will be all the tracks that correspond to the selected results in the project tree. When you choose a track in this window the results will automatically be selected in the project tree.

NOTE – If you plan on comparing results from different tracks you will need to close the Track Map tab before doing so, or else this window will force you to select results that contain the same tracks.

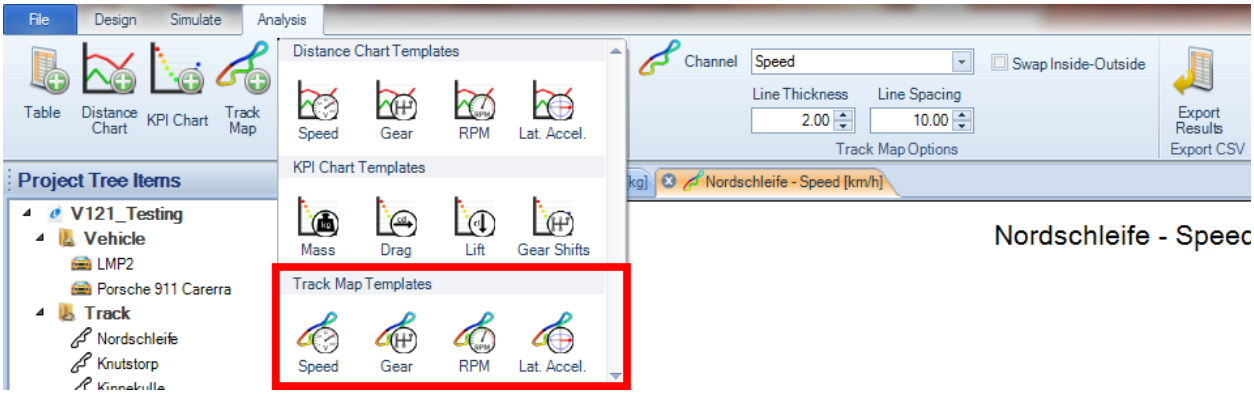
3.5.4.1 Viewing and Modifying Colored Track Maps



When viewing a Colored Track Map the following options exist:

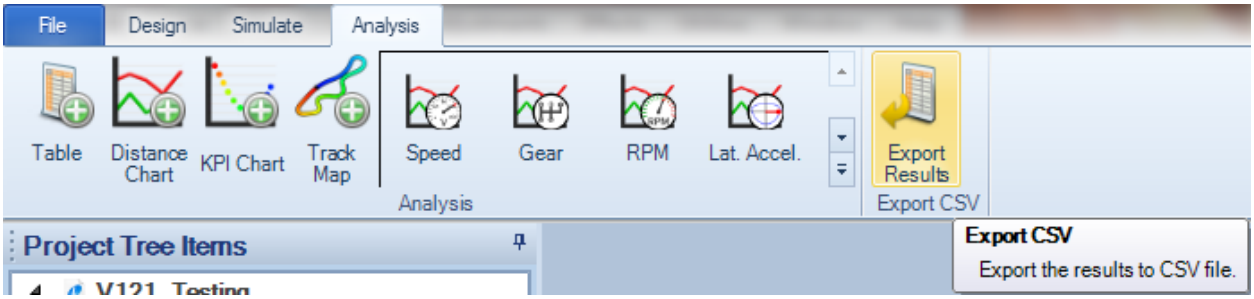
1. Channel → Please refer to '**Distance Outputs**' for a full list of Channels.
2. Line Thickness → Changing this value will adjust the thickness of the track.
3. Line Spacing → Changing this value will affect the gap between multiple selected results.
4. Swap Inside-Outside → Toggling this check box will result in either drawing the track maps on the inside or the outside.

3.5.4.2 *Colored Track Map Templates*

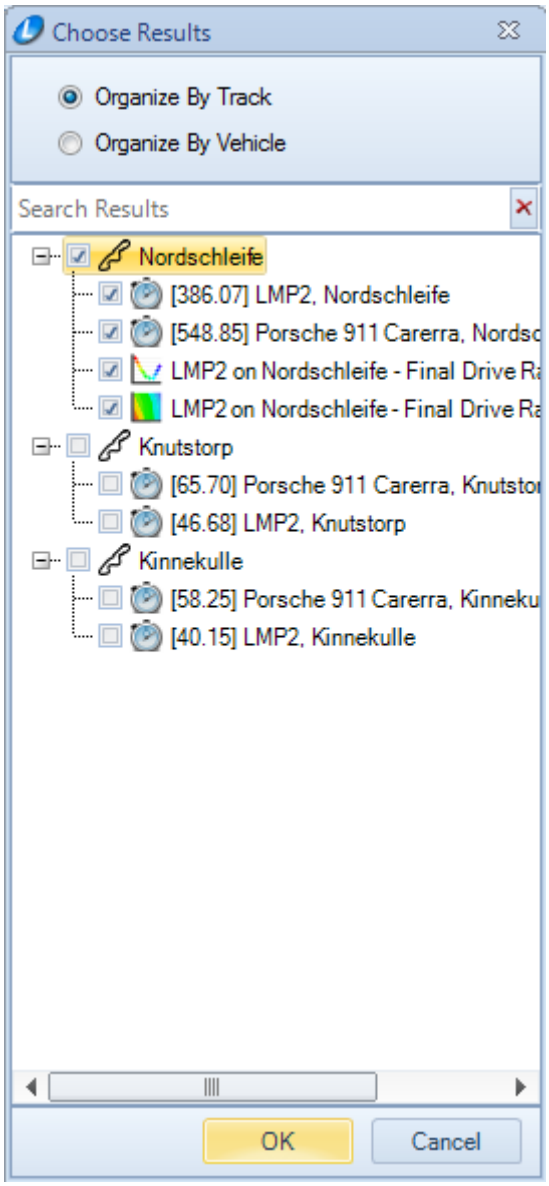


Choosing to create a Colored Track Map from the template will create the Track Map and automatically add it to your project.

3.5.5 Export Results

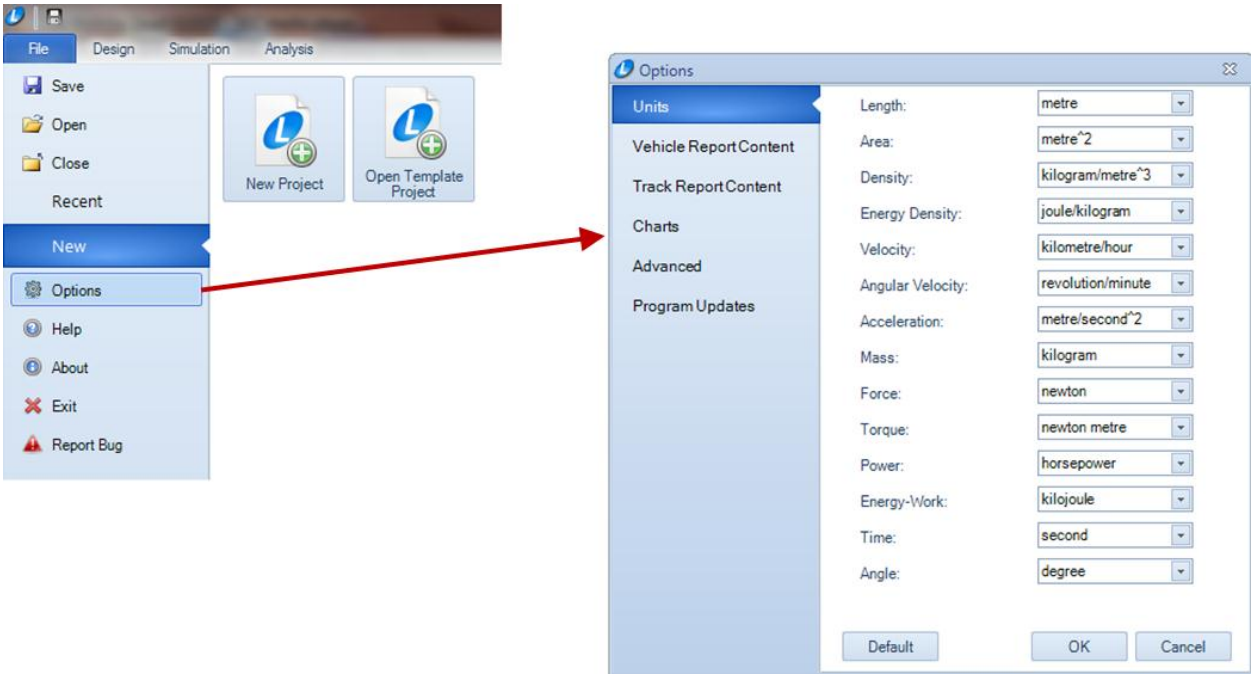


Upon clicking the 'Export Results' button the following window will appear:



You have the option to either organize the results by similar tracks or similar vehicles. All results will be shown. This includes Results, 2D Batch Charts and 3D Batch Charts. Exporting the results will result in a .CSV with all of the calculated values.

4 User Options



Within user options you can modify the following:

1. Units → Adjust output units for all calculated types.
2. Vehicle Report Content → Modify what content the Vehicle Report contains.
3. Track Report Content → Modify the content that the Track Report contains.
4. Charts → Set the defaults for the Charts.
5. Advanced → Use advanced vehicle parameters (Tire Load Sensitivity).
6. Program Updates → Automatically check for program updates upon starting the program.

5 Available Outputs

5.1 Distance Outputs

The following is a list of all available Distance Channel Outputs that are available in OptimumLap, as well as a brief description. All output channels are given for each segment of the track. The size of the segment varies from 0.25 - 1.00 meter depending on the total length of the track. This value is automatic and cannot be modified by the user.

Channel Name	Channel Description
Speed	Speed at each segment
Elapsed Time	Time at each segment
Elapsed Distance	Distance at each segment
Lateral Acceleration	Lateral Acceleration at each segment
Longitudinal Acceleration	Longitudinal Acceleration at each segment
Engaged Gear	Engaged Gear at each segment
Engaged Gear Ratio	Engaged Gear Ratio at each segment
Engine Speed	Engine Speed (RPM) at each segment
Engine Torque	Engine Torque at each segment
Engine Power	Engine Power at each segment
Aerodynamic Downforce	Downforce from aero at each segment
Aerodynamic Dragforce	Dragforce at each segment
Traction Control	Indicates whether the vehicle power is limited due to traction
Throttle	Indicates the percentage of throttle at each segment
Brake	Indicates the percentage of brake at each segment
Corner Radius	The Corner Radius at each segment
Sector Index	The Sector Index at each segment
Maximum Corner Speed	The Maximum Corner Speed at each segment
Load Sensitive Lateral Grip Coefficient	The lateral coefficient of friction at each segment
Load Sensitive Longitudinal Grip Coefficient	The longitudinal coefficient of friction at each segment

5.2 KPI Outputs

Channel Name	Channel Description
Lap Time	Calculated lap time
Percent in Corners	Percentage of time spent in corners
Percent Accelerating	Percentage of time spent accelerating
Percent Braking	Percentage of time spent braking
Percent Coasting	Percentage of time spent not accelerating or braking
Percent 100% Throttle	Percentage of time spent at 100% throttle
Percent TCS Enabled	Percentage of time not at 100% throttle due to traction limits
Lowest Speed	Lowest speed during the lap
Highest Speed	Highest speed during the lap
Average Speed	Average speed during the lap
Energy Spent	Amount of energy needed to accelerate during the lap
Fuel Consumption	Estimated mass of fuel consumed
Gear Shifts	Number of gear shifts during the lap
Maximum Lateral Acceleration	Maximum lateral acceleration during the lap
Maximum Longitudinal Acceleration	Maximum longitudinal acceleration during the lap
Maximum Longitudinal Deceleration	Maximum longitudinal deceleration during the lap
Time in Sector #	The amount of time spent in the particular sector
Maximum Speed in Sector #	Maximum speed in the particular sector
Minimum Speed in Sector #	Minimum speed in the particular sector
Percent in Gear #	Percentage of time spent in the particular gear

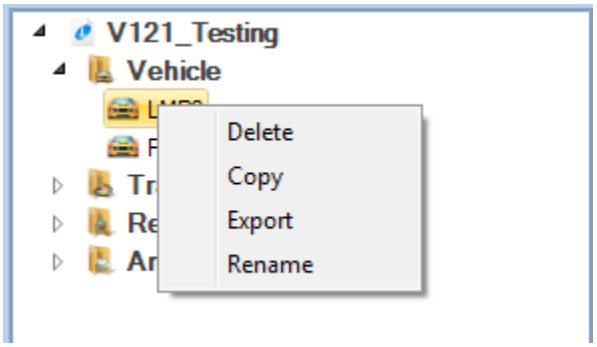
6 Hotkeys / Tips and Tricks

6.1 Hotkeys

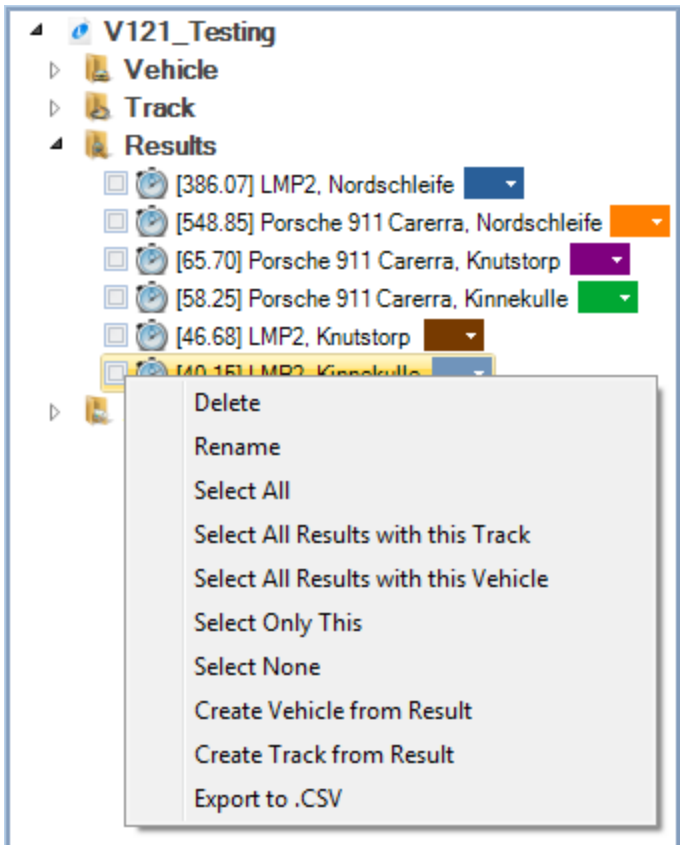
Key	Action
F2	Report a program bug, crash or feature idea
F4	Bring up the 'Simulate' window
F5	Bring up the 'Batch Run' window
F9	Bring up the 'Options Menu' window
CTRL + C	Will copy a selected item in the project tree
CTRL + S	Save the current project
Escape Key	Close the current window
Enter Key	Equivalent to clicking 'OK'
Space Bar	Toggle selected checked items
CTRL + Left Mouse Click	Select multiple items to delete from the project
SHIFT + Left Mouse Click	Select multiple items to delete from the project

6.2 Tips and Tricks

The program has a lot of 'Right Click' functionality. More options will become available if you right click on them. The following are a few examples.

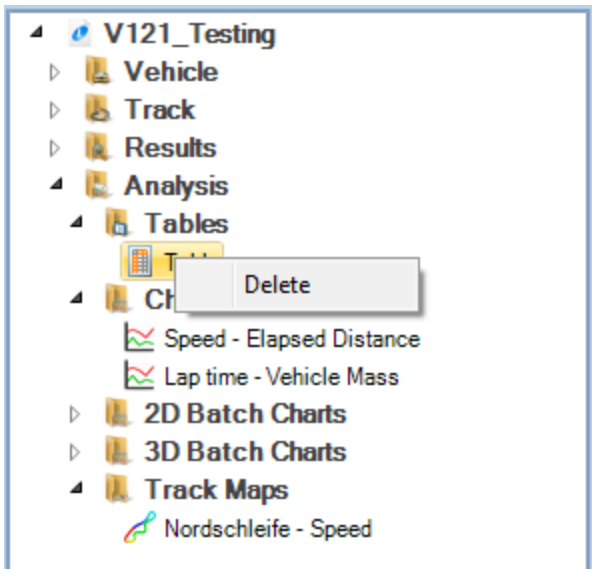


Same functionality exists for tracks as with vehicles.

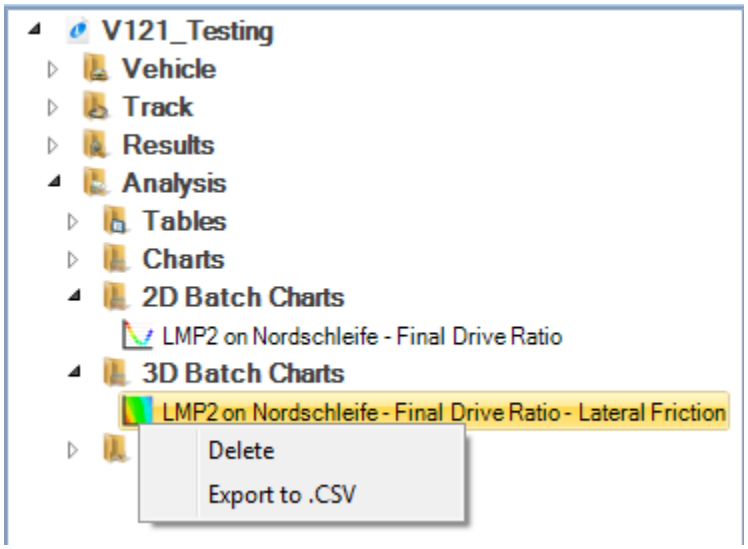


Right clicking on the result items in the project tree gives you the following options:

1. Delete → This will delete ALL SELECTED items.
2. Rename → Rename the selected item.
3. Select All → This will select all available results.
4. Select All Results with this Track → This will select every result with the same track.
5. Select All Results with this Vehicle → This will select every result with the same vehicle.
6. Select Only This → Helpful if multiple results are selected to select a single result instead.
7. Select None → This will deselect all selected results.
8. Create Vehicle from Result → This is helpful in case you have deleted your vehicle that was used to create this result. Clicking this will create the vehicle that was used to gather the selected result.
9. Create Track from Result → This is helpful in case you have deleted your track that was used to create this result. Clicking this will create the track that was used to gather the selected result.



Right clicking on Tables, Distance Charts, KPI Charts and Track Maps all will only allow you to delete the item.



Right clicking on the 2D Batch Charts and 3D Batch Charts will allow you to either delete the item or export to a .CSV.

7 Appendix

7.1 Mathematical Vehicle Model

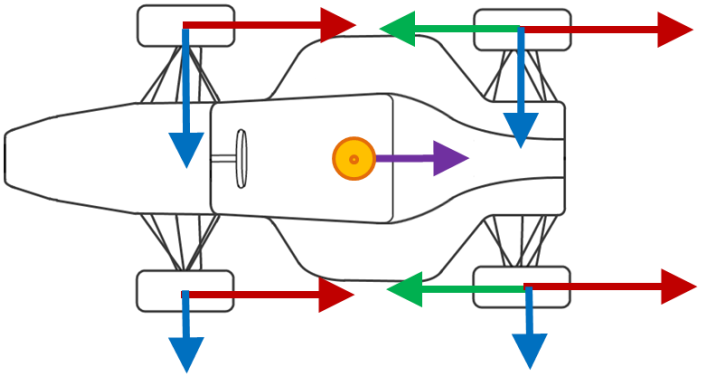
Driving Force
- **Tire longitudinal μ**
- **Normal load**
- **Engine Driving Force**

Braking Force
- **Tire longitudinal μ**
- **Normal load**

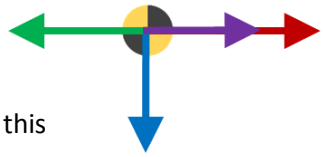
Cornering Force
- **Tire lateral μ**
- **Normal load**

Drag Force
- **Varies with speed**

Lift Force (downforce)
- **Varies with speed**
- **Changes Normal Load**



Let's do a small simplification…



Downforce and Rolling Resistance neglected in this example.

OptimumLap first breaks the track up into segments. It then determines which segments the vehicle is in the braking state, cornering state or accelerating state. Let's take a look at each of these vehicle states.

- Braking segment

$$F_t = Normal\ load \times \mu_x$$

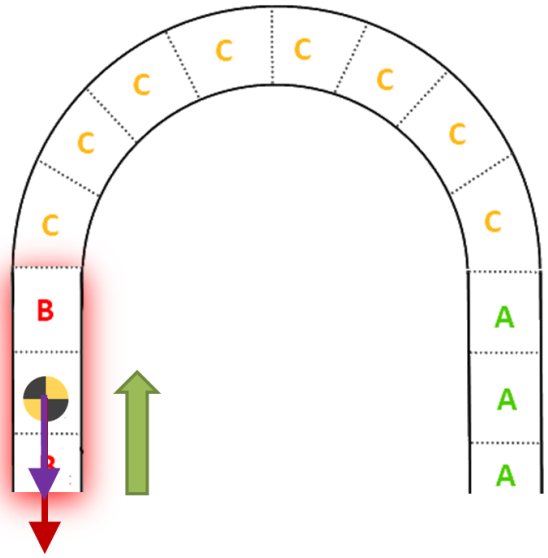
$$F_d = \frac{1}{2} \times \rho \times C_d \times A \times v^2$$

Newton 2nd law: $\sum F_{ext} = m \times a$

$$a = \frac{F_t + F_d}{m}$$

$$v = -a \times t + v_0$$

With:
ρ = Air density [kg/m³ or lb/ft³]
A = Front area [m² or ft²]
V = Vehicle speed [m/s or ft/s]
C_d = Drag coefficients
μ_x = Longitudinal friction coefficient



Downforce and Rolling Resistance neglected in this example.

To determine the tractive force under braking (F_t) we must know the Longitudinal friction coefficient and the Normal load. The Normal load under braking utilizes 100% of the vehicle weight.

The drag force will also be helping to slow the vehicle down. To know this value we need to know the density of the air, the drag coefficient of the vehicle, its frontal area and the speed at which the vehicle is traveling.

Then from Newton's 2nd Law we can determine the available deceleration the vehicle can attain. The equation for the velocity at the end of the first segment becomes the following when everything is substituted together:

$$v = -\left(\frac{F_t + F_d}{m}\right) t + v_o$$

The time will be dependent on the segment size, for example if we have a segment size of 1 m and the vehicle has started at a speed of 3 m/s:

$$t = \frac{x - x_o}{v_o} = \frac{1}{3} = 0.33\ s$$

- Corner segment

$$F_y = Normal\ load \times \mu_y$$

$$a = \frac{v^2}{R}$$

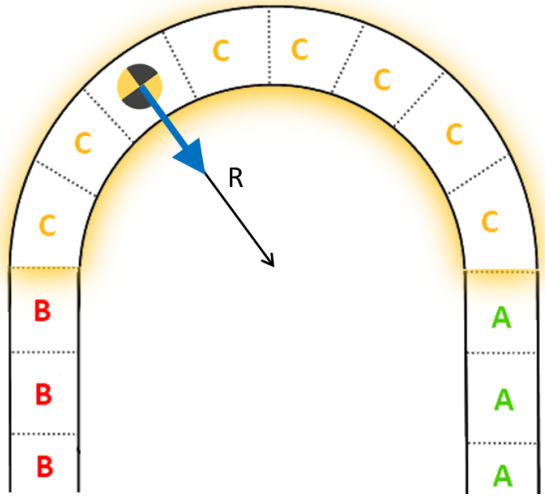
Newton 2nd law: $\sum F_{ext} = m \times a$

$$\rightarrow \sum F_{ext} = F_y = m \times a$$

$$\rightarrow a = \frac{F_y}{m}$$

$$v = \sqrt{\frac{F_y \times \mathrm{R}}{m}}$$

With:
m = vehicle mass [kg or lb]
μ_y = Lateral friction coefficient



Downforce and Rolling Resistance neglected in this example.

To know the lateral force that the vehicle can apply to the ground we need to know the lateral coefficient of friction (μ_y) and the normal load, which similarly to the tractive force under braking, the Normal load will take into account the entire weight of the vehicle.

When calculating the acceleration in a corner we have to remember the equation for centrifugal force:

$$a = \frac{v^2}{R}$$

Then when we apply Newton's 2nd Law and combine it with the equation for the centrifugal force we obtain:

$$a = \frac{v^2}{R} = \frac{F_y}{m} \rightarrow \boldsymbol{v = \sqrt{\frac{F_y * R}{m}}}$$

- Accelerating segment

$F_s = Engine\ Driving\ Force$

As long as it is smaller than Normal Load x μ_x

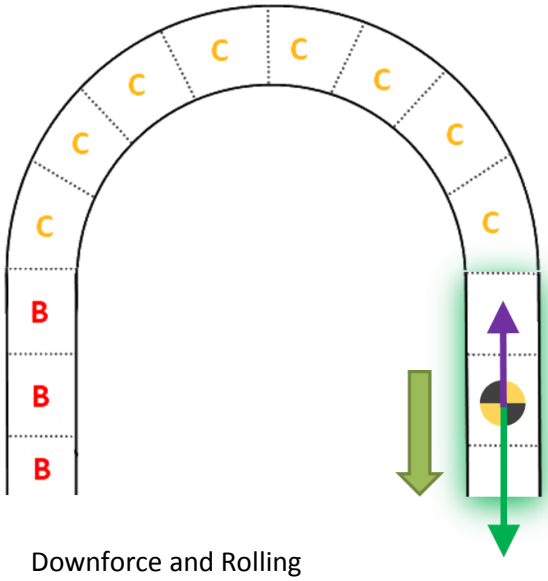
$$F_d = \frac{1}{2} \times \rho \times C_d \times A \times v^2$$

Newton 2nd law: $\sum F_{ext} = m \times a$

$$a = \frac{F_s - F_d}{m}$$

$$v = a \times t + v_0$$

With:
ρ = Air density [kg/m³ or lb/ft³]
A = Front area [m² or ft²]
V = Vehicle speed [m/s or ft/s]
C_d = Drag coefficients
μ_x = Longitudinal friction coefficient



Downforce and Rolling Resistance neglected in this example.

To determine the tractive force under acceleration (F_s) we must know the Longitudinal friction coefficient and the Normal load. The Normal load will depend on the driven type of the vehicle, if it is 2WD then it is assumed to be 50% of the weight of the vehicle and for AWD it is assumed to be 100% of the weight of the vehicle.

The drag force will also be working against the forward acceleration of the vehicle. To know this value we need to know the density of the air, the drag coefficient of the vehicle, its frontal area and the speed at which the vehicle is traveling.

Then from Newton's 2nd Law we can determine the available acceleration the vehicle can attain. The equation for the velocity at the end of the first segment becomes the following when everything is substituted together:

$$v = \left(\frac{F_t - F_d}{m}\right) t + v_o$$

The time will be dependent on the segment size, for example if we have a segment size of 1 m and the vehicle has started at a speed of 3 m/s:

$$t = \frac{x - x_o}{v_o} = \frac{1}{3} = 0.33\ s$$

To make this a quasi-steady state solver, the vehicle is allowed to accelerate in a corner until it reaches its maximum allowed corner speed. Similarly the vehicle is allowed to decelerate in a corner as well.