



Analyzing Vehicle Movements with Vehicle Tracking 2015

Mike Hutt – Autodesk

CV5297-L Vehicle Tracking is a very comprehensive transportation analysis and design solution for vehicle swept path analysis. It enables engineers, designers, and planners to evaluate vehicle movements on transportation or site design projects. This class aims to aid professionals in utilizing Vehicle Tracking's swept-path tools, including a grounding in the foundational concepts of swept path analysis and vehicle behavior. Focus is on introducing maximum benefit through working with dynamic workflows to speed up design and add modeling intelligence.

Learning Objectives

At the end of this class, you will be able to:

- Analyze vehicle movements
- Visualize vehicle movements within designs in 3D
- Perform vehicle-to-surface conflict detection
- Speed up transportation-design processes

About the Speaker

Mike Hutt has worked on engineering projects, with experience served at a number of software vendors, for over 13 years; with specific expertise in the transportation and automotive industries. Mike currently sits within Autodesk's Infrastructure Sales Team covering solutions such as Vehicle Tracking, Structural Bridge Design and InfraWorks 360, in this role he helps Autodesk's customers realize greater potential through valuable technology partnerships and the strategic alignment of innovative new solutions against their business goals.

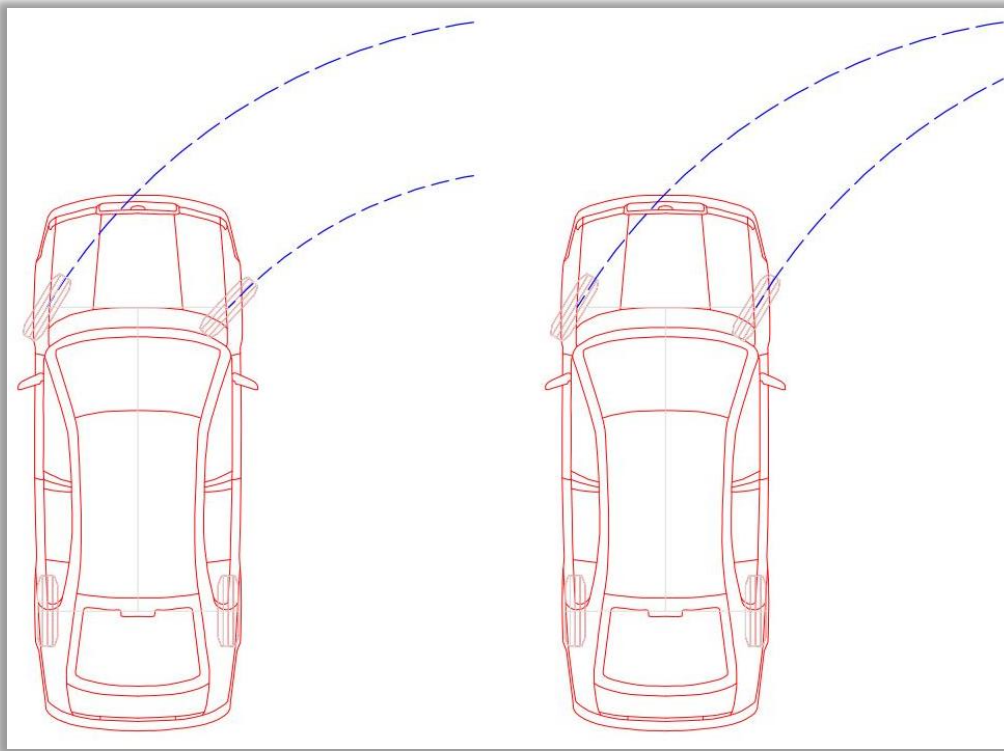
Analyze vehicle movements

Basic Swept Path Theory

Vehicle Tracking swept path simulations utilize various methodologies, below is an introduction of those that have greater influence and designers should be aware of.

The Ackerman principle

Ackerman steering geometry essentially allows the steered wheels to track the turning alignment of a vehicle without scrubbing. Without Ackerman geometry wheels on steering axles would turn at the same angle on both sides, instead of the inner wheel turning at a greater angle, and would be much less efficient.



Note how the non-Ackerman geometry on the right example would create tire scrubbing, limited grip and so probably a larger turning circle and the 2 wheels would eventually try to cross each other's path. The example on the left illustrates how the Ackerman steering setup allows the inner wheel to turn at a greater angle.

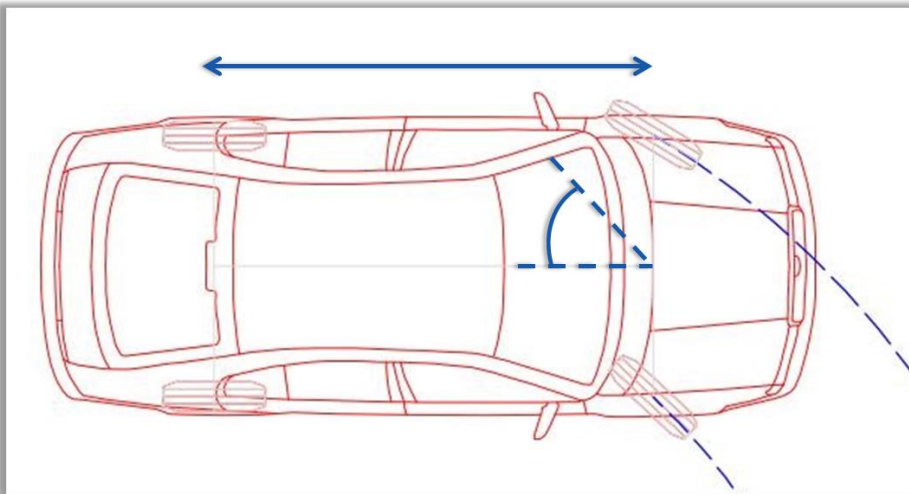
Critical Vehicle Parameters

There are normally three main parameters that will start to influence the maneuverability or turning capabilities of a vehicle; in most cases this also applies to articulated vehicles like semi-trucks with trailers, B-Doubles or drawbar configurations, etc.

First the **turning circle of the vehicle** as given by most vehicle manufacturers, you will need to identify whether this is “curb to curb” or “wall to wall”. In other words, whether this is measured from the wheels, in order to clear curbs or from the body extremities, in order for the vehicle body to avoid clashing with a vertical wall or building for example.

Secondly, the **steering angle**, this could be measured at the actual, physical wheel or be a virtual steering angle to represent the maximum, average steering angle across the whole axle (remember with Ackerman geometry the inside wheel turns at a greater angle, so the physical steering angle is normally measured on the inner wheel).

Finally **wheelbase**, which is measured from the front effective axle to the rear effective axle and controls how much the rear of the vehicle ‘cuts in’ or trails behind to follow a smaller turning circle than the front. Imagine a long bus or coach, the driver needs to oversteer past the corner apex in order for the rear wheels to also clear the corner – this is because those vehicles have long wheelbases.

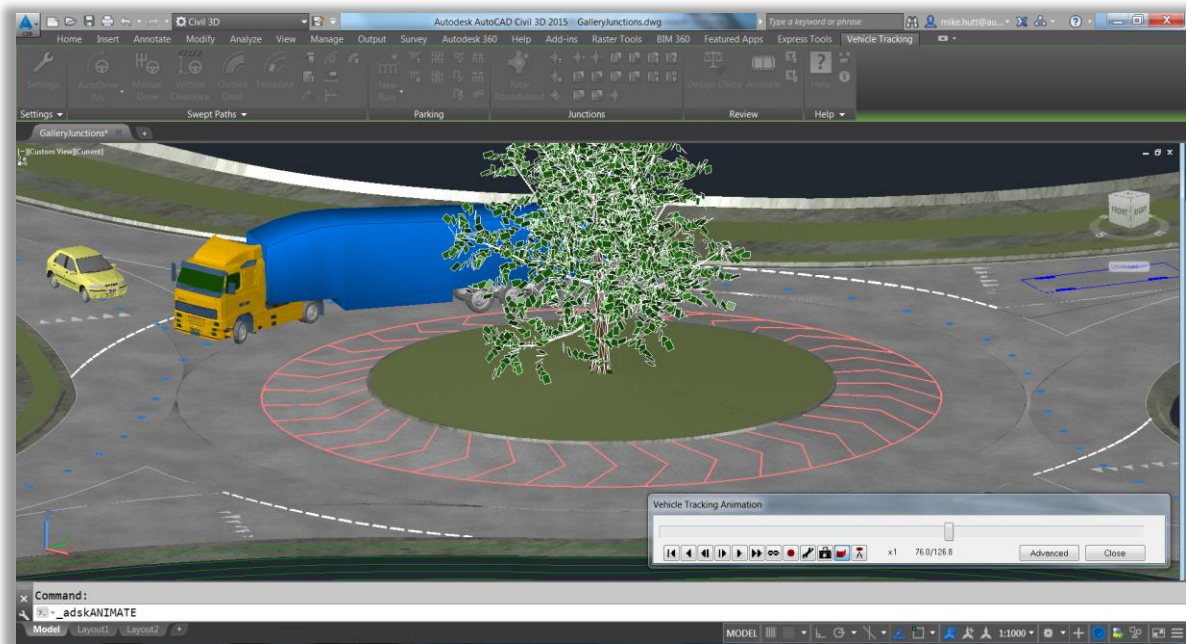


Transitions

Accurately analyzing turning movement's means taking account certain realisms.

First, we limit the turning capabilities to follow simulated steering input for drivers – this means that a vehicle cannot simply switch to the optimum turning angle instantaneously; we must allow enough time for the driver to have turned the steering wheel around to that position. Otherwise we risk designing sites that require unrealistic steering capabilities to navigate.

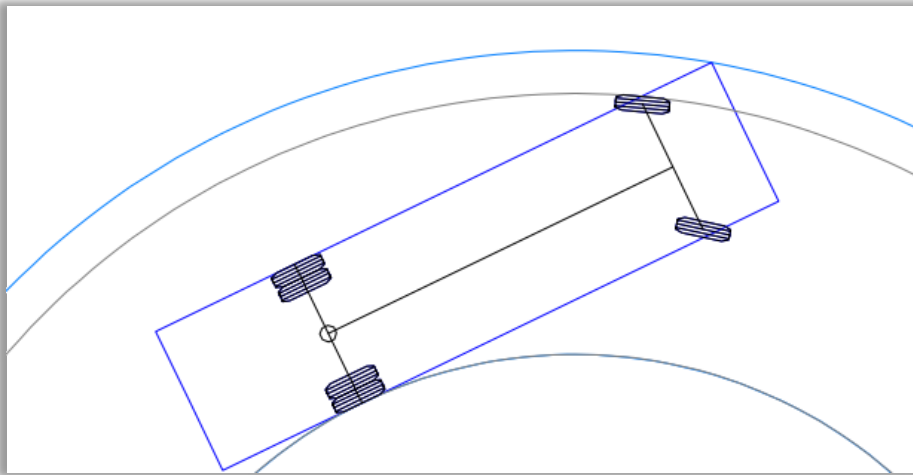
Think about it this way, how long does it really take you to turn from full steering lock one side, all the way to the other side (normally around 4 complete turns of a steering wheel) – you certainly cannot do this instantly as if the steering were controlled by a switch or joystick. If the average time for a PCE of 4 seconds sounds too quick to you, try it with your hands in front of you at a realistic speed – it takes longer than you would think!



Take the scenario above as an example, the truck is at speed and already turning its steered wheels to the left as it makes its way around the roundabout. In order to turn right to exit the roundabout, the driver needs to turn the steering wheel to recover from the left turn before the right, exit turn can be made; when you factor in the speed the truck is moving the ability to quickly swap directions in a short space is greatly diminished. Now compare this to the car, the driver can probably turn the wheel of this compact car much quicker than the truck and it is also stationary so any steering input would have much more immediate effect.

Transitions (continued)

From understanding these transitional constraints we can see how different vehicle parameters are likely to affect maneuverability.

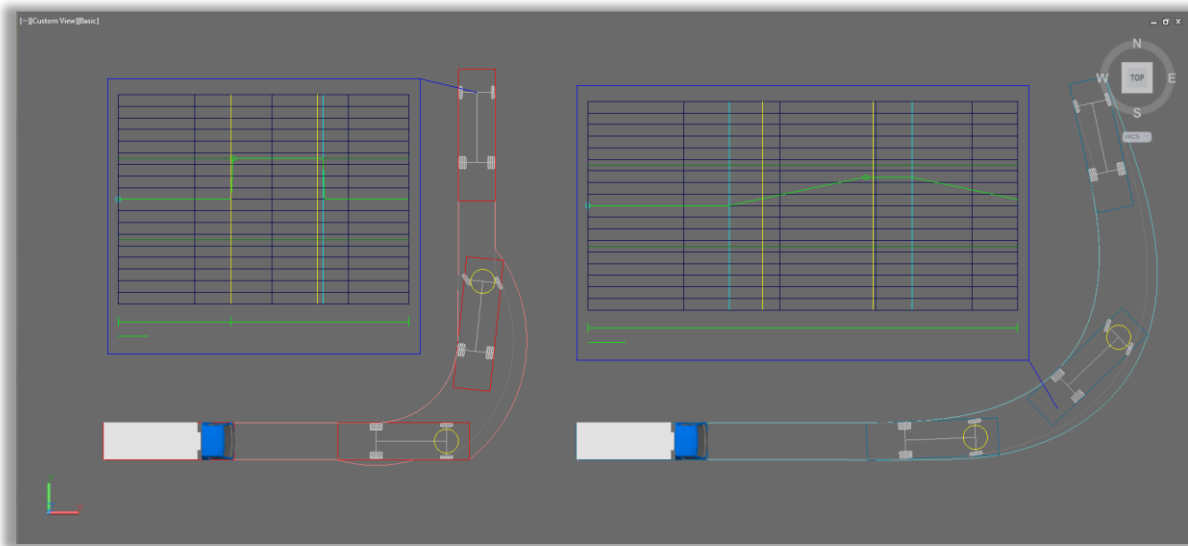


The front of the vehicle above (looking at the outer, blue body envelope arc plus the outer, grey chassis envelope line) will be affected mostly by the speed of the maneuver and the turn rate restriction that is applied.

The rear of the vehicle (the smaller radius body and chassis envelope cut in arcs) will be affected by the wheelbase of the vehicle.

Transitions (continued)

In the example below, the truck on the left has no transitional affects applied; the graph shows how the steering angle goes from 0 to 100% instantly when the left turn begins, and returns back to 0% instantly at the end of the turn (the green line). Is this realistic? Imagine whether would you want to be in that truck cab when that instantaneous turn is made...



The truck on the right has a much more calm and realistic maneuver, note how the graph illustrates much more gradual changes in steering angle along the green line. The downside of this realism is that much like real life the vehicle becomes less maneuverable. Now imagine trying to drive a site that had been designed without transitions applied, it may be acceptable for very low speed parking scenarios but it is generally not advised.

Dynamic effects are based on published AASHTO or TAC standards.

Different Drive Modes

When a vehicle is driven through a route, the driver doesn't use just one single type of turning maneuver, they react with multiple maneuvering skills according to the geometry of the road or site.

So we need to do the same when designing sites and simulating continuous turning movements. We also need to model the movements as a continuous simulation; this means that each maneuver is connected and not treated as separate. This is important as this also places constraints on the turning capability of a vehicle. Think about a car park, intersection or delivery bay where a right hand turn can immediately develop into a left hand turn or vice versa; when the vehicle is exiting the initial right hand turn the steered wheels are turned right, so in order for the vehicle to turn left the wheels first need to recover to a straight ahead angle and then turn left. This means the driver needs to turn earlier on and the vehicle subsequently needs more space.

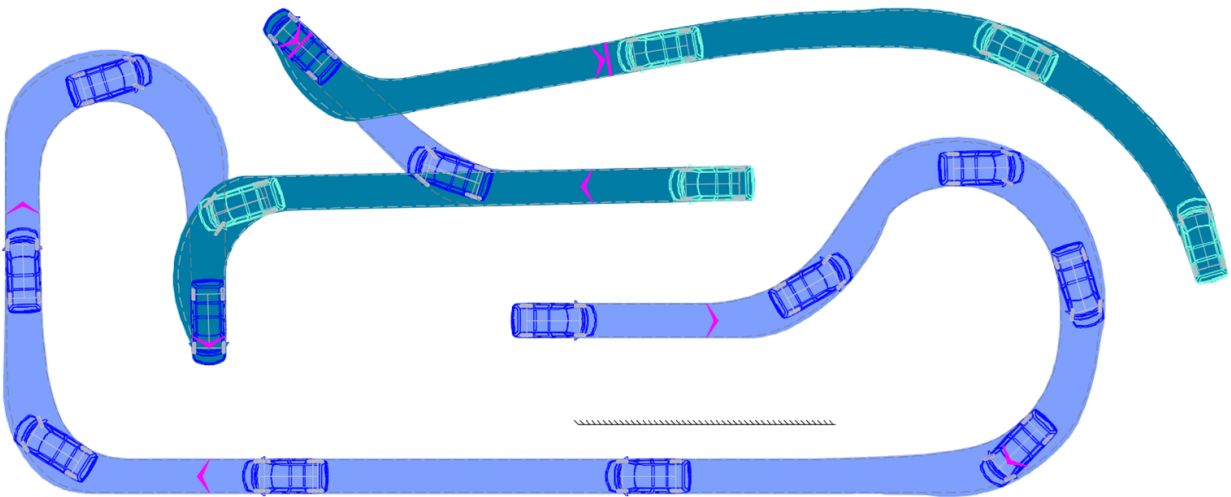
So in Vehicle Tracking we utilize different drive modes according to the geometry that we're dealing with:

- AutoDrive – this is normally the best option as it enables you to switch between drive modes dynamically just like a real driver
 - AutoDrive Arc – this starts in arc mode to create smooth arc turns between each target point. Target points are simply the locations where you click with your left mouse button as a point that the vehicle must pass through.
 - AutoDrive Bearing – starting in bearing mode is advised for when you need to turn through a specified angle such as 90 degree road alignments or 60 degree parking angles, etc.
 - As an extension of this mode, you are also given the option of picking an alignment to target for your turn, this is a great tool to use when you need to maneuver parallel to an alignment. For example, when lining up into a traffic lane, or when reversing an articulated vehicle into a loading bay.
- Manual drive is rarely used nowadays, this mode enables you to use an on screen tablet to move the vehicle according to your mouse position on the tablet (move your cursor forward a little to move forward slowly, a little more to pick up speed and move left to turn left, etc.). This drive mode pre-dates AutoDrive and is not generally recommended unless you want to complete a small maneuver in a complicated abnormal loads vehicle, for example, that requires very detailed inputs.
- Follow drive – this mode does as you would expect and follows an alignment (which may be a simple polyline) until the line ends or until Vehicle Tracking computes that the maneuver cannot be accomplished at the current speed and within current transitional settings. You can offset tracking positions from alignments to enable you to follow curb lines or lane markings as needed. A specific version of follow drive can be used with airplanes, in order to follow taxi markings through airfields.

Different Drive Modes (continued)

- Script drive allows you to write scripts that control vehicle paths, this is again less commonly used but may be useful if you need to repeat the exact same set of maneuvers with a large number of different vehicles. The Vehicle Tracking user guide contains script language help.
- Templates – templates are static blocks that can be placed in drawings, exported to files or printed directly. It's not recommended to design geometry based upon a static turning template over a dynamic swept path simulation, but templates are useful tools to present the general swept path capabilities of vehicles - especially when comparing multiple vehicles side by side within documentation.

There is a further drive mode not listed above called Guided Drive, this is specifically for rail vehicles and differs from Follow Drive in that each rail car unit on the vehicle is made to follow the tracks alignment, whereas with follow drive only one single tracking point (such as the drivers eye or the center of the front axle) follows the alignment and the rest of the vehicle's position is calculated accordingly.



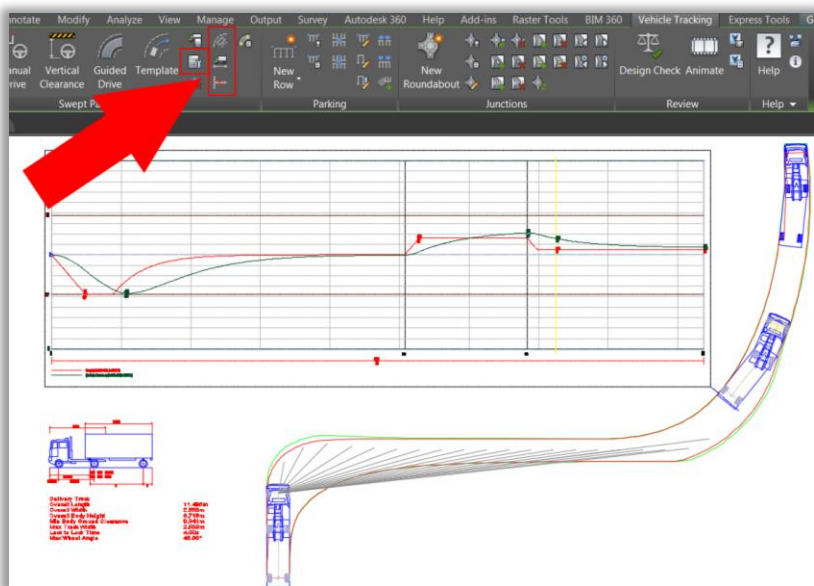
Visualize vehicle movements within designs in 3D

It's a relatively simple process to visualize a swept path within Vehicle Tracking

Presentation

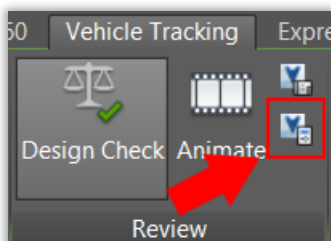
First experiment with this section of the Vehicle Tracking ribbon, within literally seconds, you can improve your presentation by including plan vehicle outlines along your swept path that illustrate vehicles bodies, chassis', and other items such as visibility splays. You can also insert a vehicle diagram for the current vehicle, a steering and articulation graph and even take a few extra minutes to alter the presentation of the vehicle path style to match your normal CAD template.

TIP Hover over buttons on the ribbon to see a tooltip explanation of their purpose.



Although there is a dedicated wizard to alter the path styles, you have more control and flexibility over the styles by selecting a path and editing via the Vehicle Tracking properties button on the right of the ribbon.

TIP Set up your preferred styles and save them as default within your organizations CAD templates and each of your users will have a consistent experience.

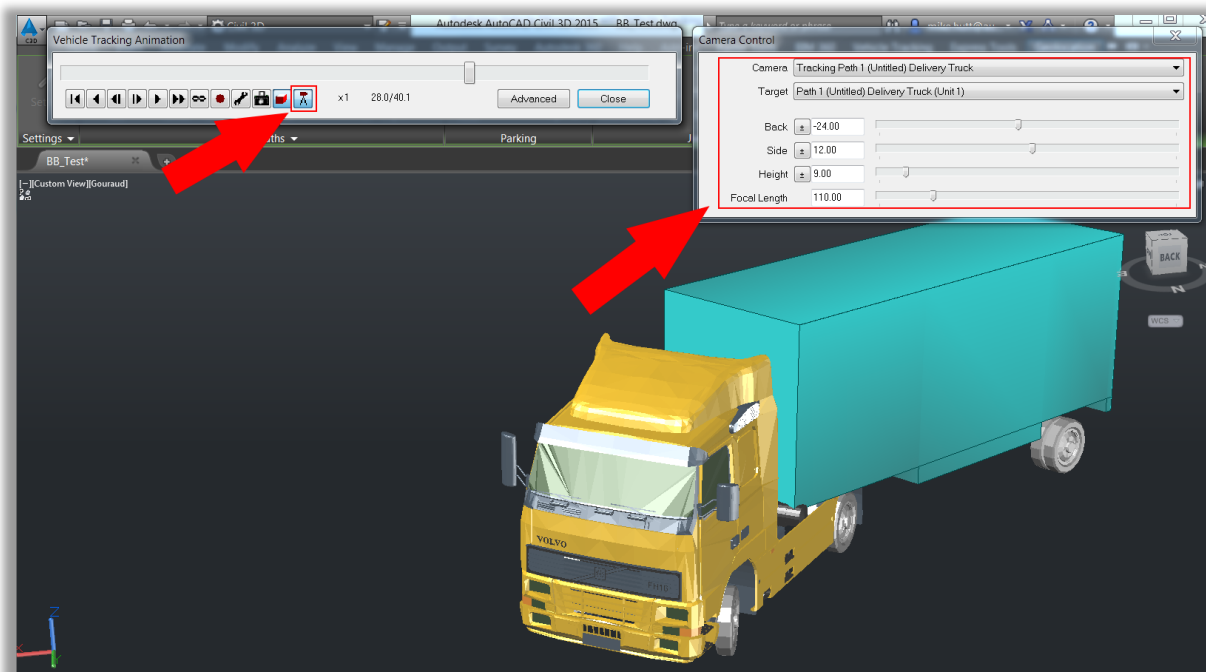


Animation

Select Animate, from the Review tab of the Vehicle Tracking ribbon. This will freeze the design and launch into animation mode in 2D. From here you can play the animation in model time, increase playback speed, play backward, take still images, record an AVI movie file using any of the installed codecs on your local computer or manually slide the time slider along to see the vehicle maneuver throughout the selected path.

If you have multiple paths within your drawing, select all that you wish to animate before animating and you will see each selected path in your animation.

If you select the furthestmost small, square button on the animation window (entitled Fly-by-camera) 3D mode will be enabled and your AutoCAD render engine will be utilized including any display and lighting settings. Experiment with the camera control window to focus on an individual vehicle unit (front, mid or rear sections) or to pick almost any location to watch your vehicle drive by.



From within the settings (the spanner/ wrench icon) and Advanced buttons on the Vehicle Tracking Animation window, you can gain access to more advanced settings such as hiding or displaying the 2d swept path envelope in the animation, changing vehicle colors and setting up vehicles pauses and acceleration to correspond to scenarios such as stop lines.

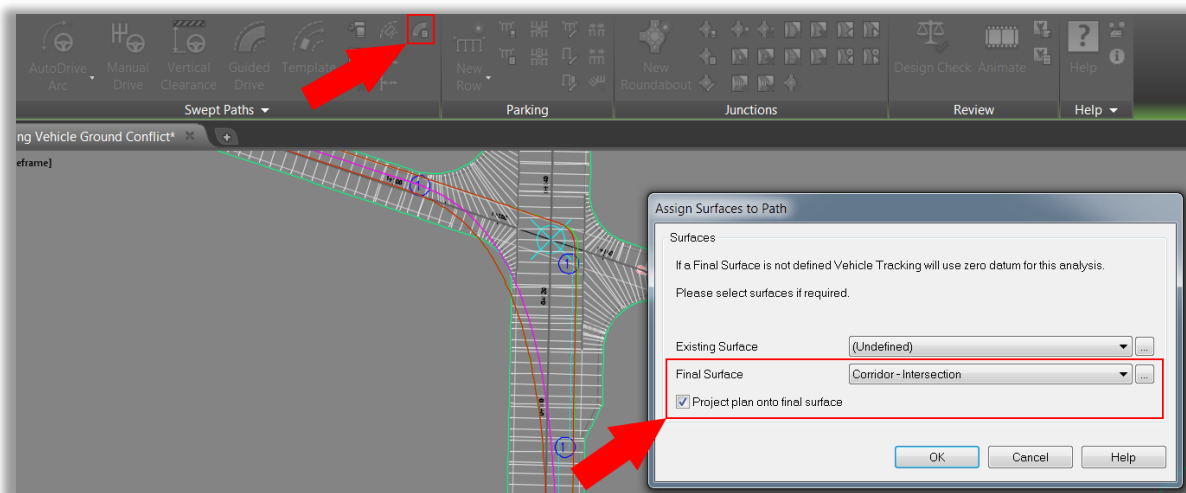
Perform vehicle-to-surface conflict detection

Requirements

You can use Vehicle Tracking to drive vehicles across AutoCAD Civil 3D corridors and surfaces, in addition to this you can also drive across AutoCAD surfaces. There is no need to rework surface or terrain geometry into different formats in order to analyze or visualize ground conflict.

Driving on top of 3D geometry

Vehicle Tracking calculates each wheel's location on the specified surface or corridor to give an accurate depiction of what is probable in real life. But the workflow is quite simple to locate the vehicle vertically. First drive the vehicle as you would normally, as per a standard two dimensional workflow. Once you have your path, select the Insert Ground Conflict Report button from the Swept Paths tab of the Vehicle Tracking ribbon. You will be asked to specify 2 surfaces, which unless they are AutoCAD surface format only, can be picked immediately from the drop down.

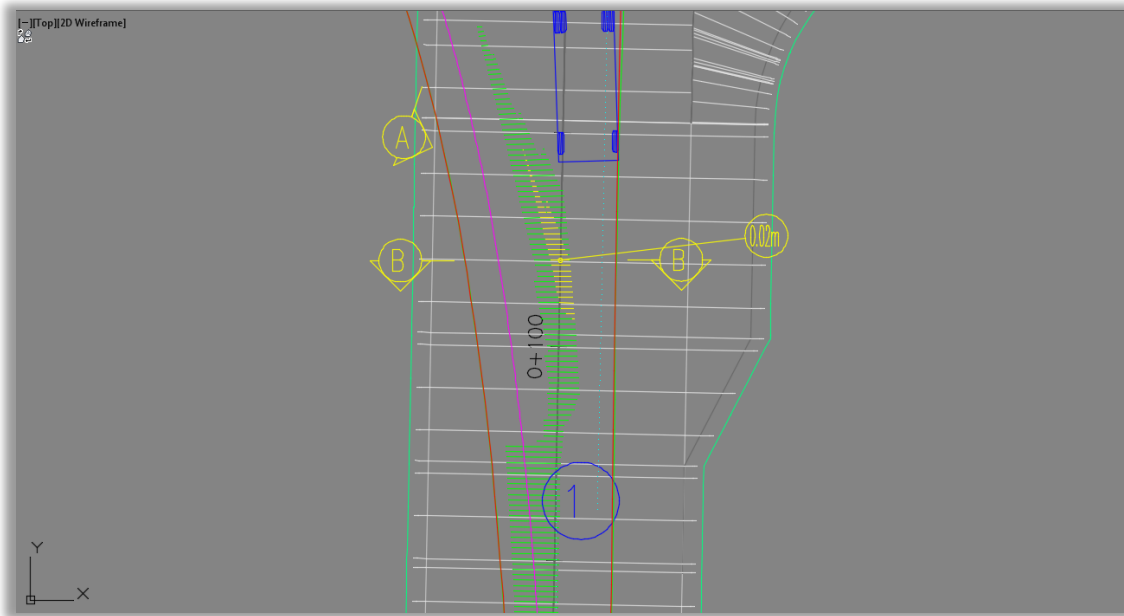


In most cases, for swept paths you actually only need to specify the Final Surface; the Existing Surface is used for designing roundabout corridors in Vehicle Tracking, when there is a need to tie into existing ground. Also, ensure you select the check box entitled Project plan onto final surface; this will ensure that your swept path is located on top of your surface and 2D lines are draped onto the surface for presentation and ease of modeling.

Unless you have specifically set up minimum body ground clearance measurements for all of your vehicle units, you will now see a message warning you that you are analyzing using default ground clearance values. Vehicle Tracking's ground conflict technology is in many cases newer than published design vehicle geometry, which in many cases does not include vertical vehicle measurement values. Hence it is the user's responsibility to ensure that they are happy with the values, otherwise they may always be edited using the Advanced Vehicle Editor in the Body/ Outline's tab.

Driving on top of 3D geometry (continued)

Once the ground conflict has been completed, a report will be added to the swept path to present areas of conflict or near conflict. In the example below a large flatbed truck trailer is simulated as penetrating the ground by 0.02m along a point on section B-B as illustrated in yellow.



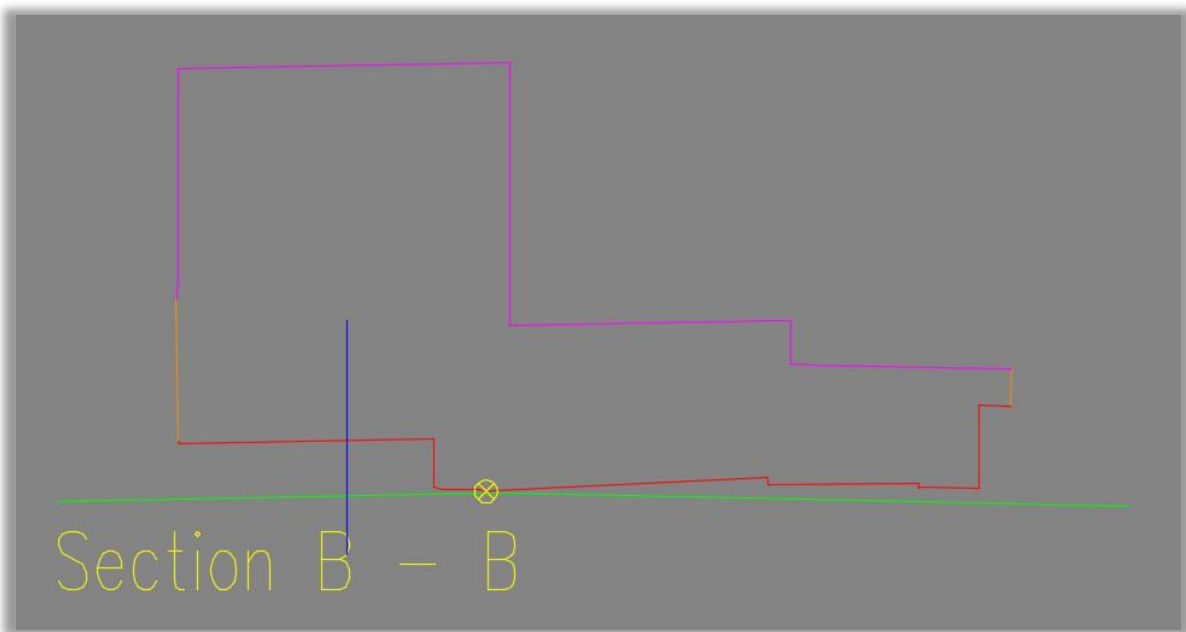
The contours that are displayed to represent either near conflict, conflict or complete ground penetration follow this scale:

	Conflict measurement/ penetration	Color
clearance	Greater than 3.94" (100mm)	{no contour}
	Between 1.97 & 3.94" (50 & 100mm)	green
	Between 0 & 1.97" (0 & 50mm)	yellow
penetration	Between 0 & 1.97" (0 & 50mm)	orange
	Between 1.97 & 3.94" (50 & 100mm)	magenta
	Greater than 3.94" (100mm)	red

Driving on top of 3D geometry (continued)

If you zoom out and locate the lower, right hand extents of your drawing you will also see that sections are plotted in the drawing to represent cross sections at any critical points. The green line represents the surface geometry, the blue line is the swept path's alignment, the red line is the bottom of the vehicle, the brown lines are the sides of the vehicle, the purple line is the top section of the vehicle and the point of conflict (or clear conflict) is represented with the yellow cross-hair.

Note how the complicated shape that the vehicle curves in 3D as it passes through section B-B is depicted, the lower section on the right is derived from the flatbed trailer units taking a wider path than the taller front tractor unit.



Speed up transportation-design processes

Understanding Vehicle Tracking

Vehicle Tracking is an 'add-on' software that requires a host CAD platform to run. The maximum benefit is gained through running in AutoCAD Civil 3D as additional functionality is Vehicle Tracking is made available, such as the ground conflict analysis that we have already covered.

However, although Vehicle Tracking runs on top of other software, it contains its own specific settings, options and control parameters. Whilst you can get by without taking much note of these, by understanding them a little, a marked improvement in design efficiency can be gained.

Settings

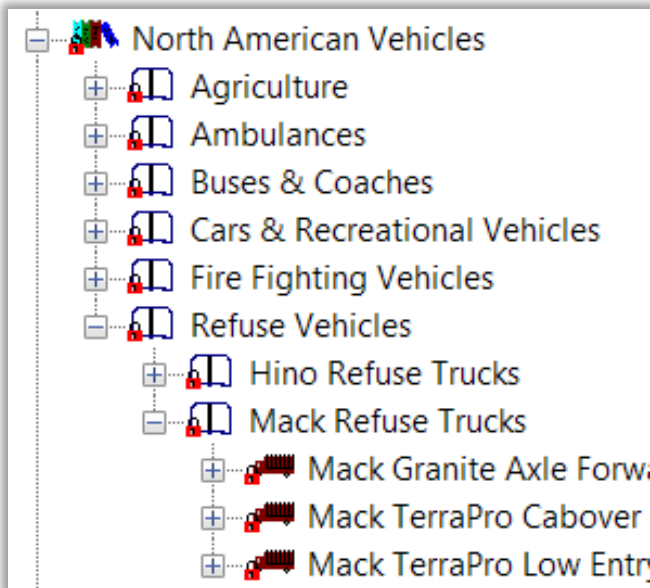
Vehicle Tracking contains two main levels of settings allowing you to set up your work environment as you wish, but also to accommodate project team or client specific needs in single or temporary project files and templates.

- System settings
 - These are the default, 'global' settings that apply to the Vehicle Tracking installation on a computer or workstation
 - These can be saved into corporate CAD templates for organization wide use or for sharing project file requirements with sub-contractors for example
- Drawing settings
 - These are saved in, and remain in, the current drawing/ project file
 - These can be exported separately
 - Custom design standards or entire vehicle libraries can also be shared inside drawing files

Note: Standards and libraries can also be shared outside drawing files within specific data library files.

Data Hierarchy

When picking vehicles or any other data in Vehicle Tracking, there is a hierarchy to the data library structure.



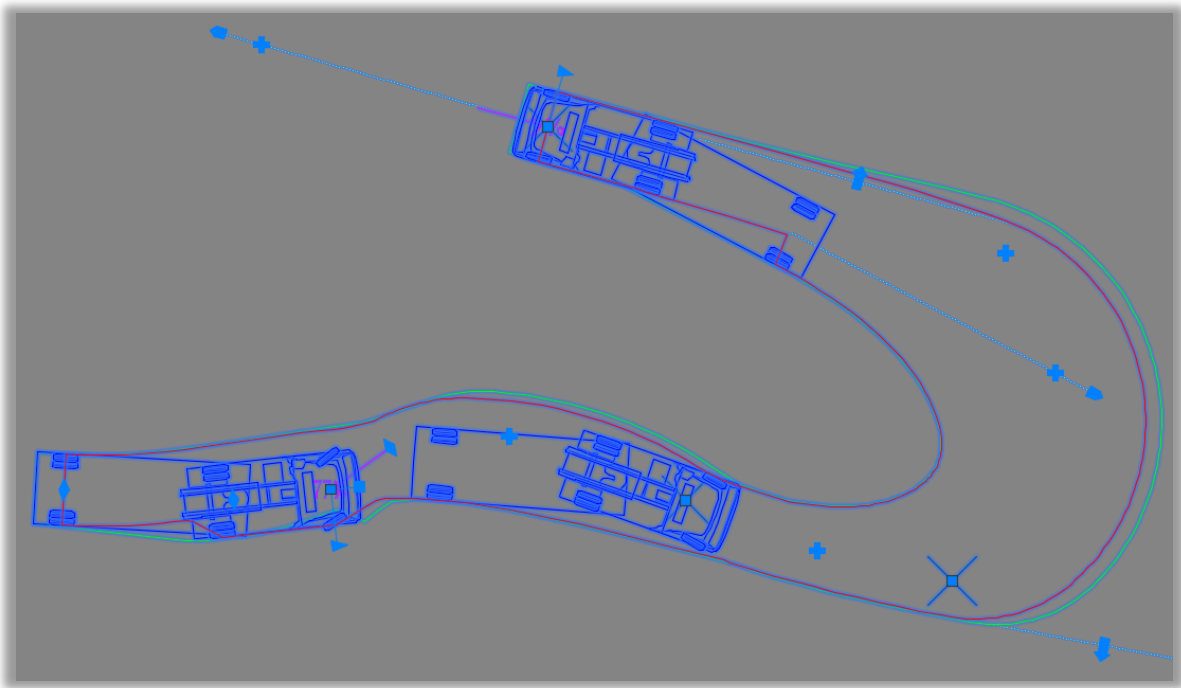
- First is the library level, this is the parent level; this could be national design vehicles, national parking standards or the parent level of a custom library that you created. In the example above this is the North American Vehicles Library.
 - Next is group and then sub-group level to further sort content, you do not need to use groups or sub-groups if you only have a small number of similar items within a library.
 - Most importantly, next is the actual design content – this could be the vehicle model that you wish to drive, a parking standard to use for laying out parking or a roundabout standard to apply to control design requirements. In the example above this corresponds to the 3 Mack truck models.

You can also go one level lower and examine individual vehicle units (such as a tractor unit only, then the trailer unit(s)), or for parking and roundabout standards this may dive down to individual component content such as signage, geometry or markings.

Editing

This is the most important area and the area where Vehicle Tracking's workflow benefits really come into their own. Unless you require a specific text font that Vehicle Tracking cannot accommodate, there seems no immediate reason to ever explode or delete a vehicle's swept path. If you think this is a strong statement, read on...

Firstly, each new swept path is by default placed onto a newly created layer in order to toggle quickly between paths and only display the relevant data. Secondly, once a path is exploded, all live simulation, visibility, speed related and presentation options are lost and the object's value is limited to line work. Perhaps most importantly, there is no longer an audit trail of how the path was created, edited and if limitations have been overridden.



■ Edit

⊕ Add

◀ Trim

↑ Overturn

Even rarer than needing to explode a path would be the need to delete and start again, if you use the following grips and tips you should be able to work quicker and more comfortably to fix issues in vehicle paths and also accomplish many more maneuvers than before. When you are editing, there is a useful choice of grips to choose from, some dependent on the drive mode that has been used. Hover over each grip in a model for tooltips and you will see the function of that grip.

Editing (continued)

TIP Don't try to get the path right first time, it's often quicker and easier to go back over the path and fine tune afterward.

- One of the first grips that you will generally always see are the square grips, these are the target points which are derived from your left mouse click positions when creating the swept path; these are points that the vehicles tracking point (by default the center of the front axle) *must* pass through.

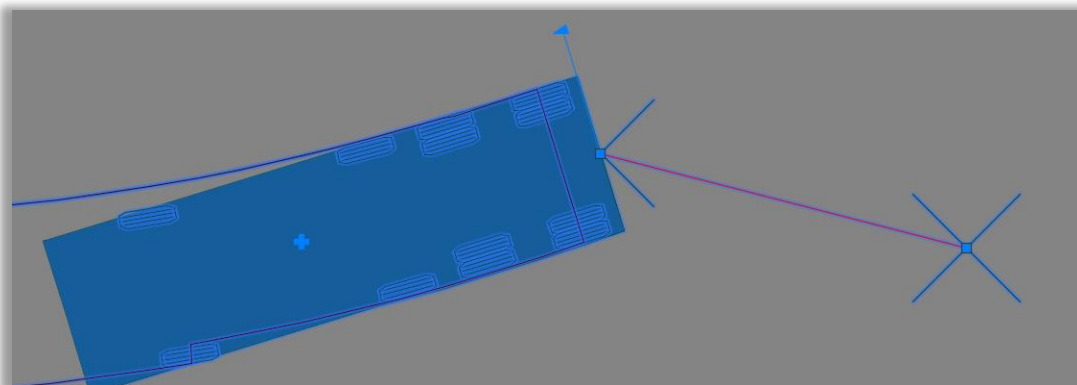
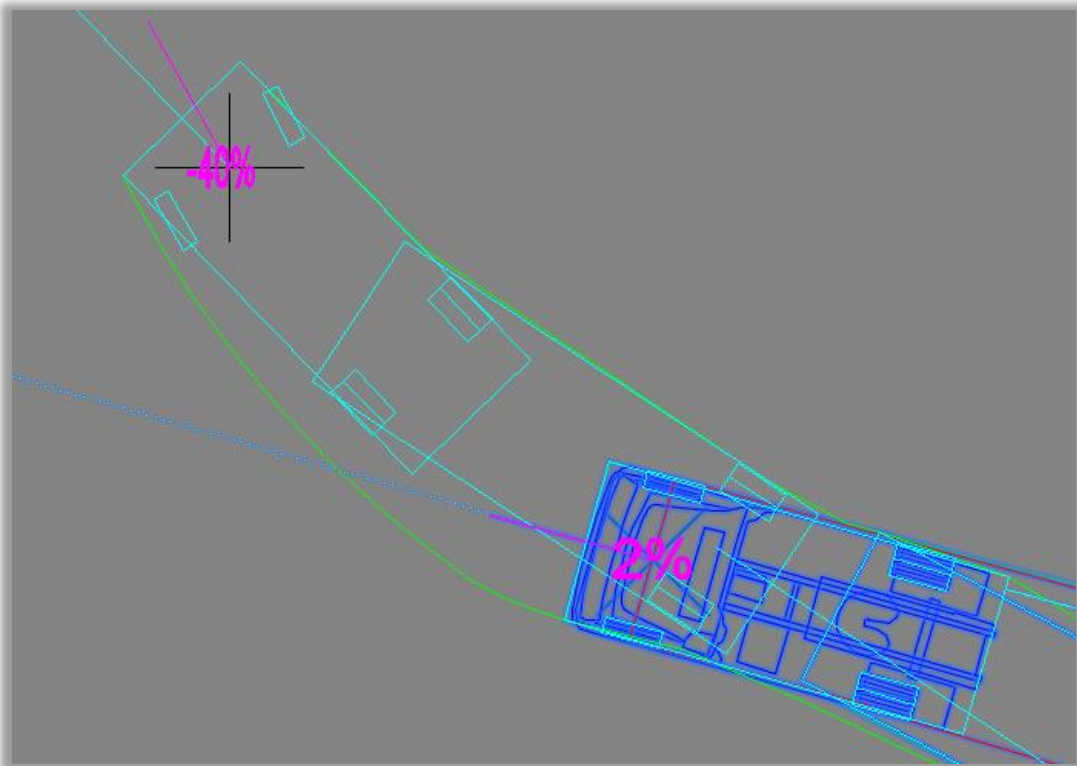
TIP Don't get trigger happy and click too much when creating an initial vehicle swept path, as this creates too much constrain on the path; try to only click where necessary. If you find you have too many target points to drive through because of this, don't delete and start over; you can drag a target point onto the next target point to remove it.

- The 'plus' symbol allows you to add a new target point in an intermediate location This can be handy when going back and fine tuning the vehicle location or orientation in the middle of the path. This will create a new and totally standard, editable square grip as above.
- In addition to these you will see triangular grips at the start and end of the path, these can be used to crop the start or end chainages of the path.
- If bearing turns were used in the path you will also see side and exit overturn grips, these increase or decrease the amount of oversteer that the vehicle uses to swing out wide before the turn or swing out wide past the turn. These are very useful for clearing items such as traffic islands or curbs on the inside of a turn.

TIP Another handy tip is for extending a path. Often, you will need to pick up where you or a colleague left off and continue an existing path. In the interests of modelling a continuous maneuver, you can simply select the path so that it is active and then select your drive mode from the Vehicle Tracking ribbon; rather than starting a new path you will resume where the existing path currently ends.

Editing (continued)

Finally, take note of how the new 'ghost' path follows your editing position before you click the new target point location, this is useful for reducing multiple edits. You'll also see that if you try to create path that your chosen vehicle cannot accommodate, a single red error line will appear after the last possible maneuver to represent the attempted operation (as below, bottom image).



These points, in addition to your abilities to analyze and derive road corridor geometry and interrogate 3D surface geometry should enable you to greatly reduce error and speed up your transportation design processes.