Chapter 1: Introduction

Thank you for purchasing RapidPath, Invarion's swept path analysis tool.

RapidPath is an extension for RapidPlan, the World's leading software for creating traffic control plans. It was developed to meet the needs of users whose traffic plans require swept path analysis to comply with project requirements.

With RapidPath you will be able to simultaneously create a traffic control plan and directly overlay a Swept Path Analysis evaluation.

RapidPath runs in the RapidPlan software, if you are also learning how to use RapidPlan for the first time, you can review the RapidPlan user manual here.

If you need help with RapidPath you can communicate with us over contact form on our webpage https://rapidplan.com/Home/ContactUs or contact the Invarion technical support line in your country - please check out our website https://invarion.com/locations for contact details.

Chapter 2: What is Swept Path Analysis?

Swept Path Analysis calculates and examines the behavior of a moving vehicle, with all its parts, during turning manoeuvres. This is required to determine whether the surrounding infrastructure provides the vehicle enough space to navigate through safely.

Swept Path Analysis can be used to assess if:

- Large vehicles can pass through a junction or road work without causing damage;
- Vehicles are likely to encroach upon pedestrian space while moving through turns;
- Emergency vehicles can quickly access buildings;
- Large vehicles can pass each other side-by-side when turning;
- Buses can accommodate the routes they serve;
- There is enough space to reduce the need of vehicles reversing;
- There is enough space for vehicles to reverse;
- Delivery vehicles can safely approach loading bays;
- Parking bays can accommodate different types of vehicles;
- And many more.

Chapter 3: Definitions

Term	Definition
Vehicle	The chosen object from the Vehicle Library. Can be freely placed on the plan and rotated like any other object in RapidPlan. It can't be resized, its size is automatically adjusted to the scale of the current canvas area.
Vehicle Path	Steering path for the vehicle. The path consists of user control points that reflect subsequent vehicle positions during the manoeuvre. The path consists of sections that can have different parameters such as speed, friction and turn on stop setting (on/off) within a single path.
Vehicle Profile	An object that can be placed onto the document to represent the vehicle used in Swept Path Analysis. Vehicle profile consists of vehicle's name, basic properties, and side diagram with key dimensions.
Path Section	These are the sections between the user control points of the Vehicle Path. You can select and edit a Path Section by selecting the whole path and then clicking on a section that interests you with the left mouse button while holding the "Ctrl" key. Each segment has properties such as speed, friction and turn on stop setting (on/off).
Sweep Envelope	The result of the swept path analysis. Defined as the visible turning space needed for a specific vehicle on a specific path to operate safely on the road network and to avoid causing damage to roadside furniture.
Evaluated Vehicle Path	To see the Sweep Envelope, the Vehicle Path needs to be calculated. Adding any changes to the Vehicle Path will remove the Sweep Envelope and a recalculation will be required. Sweep Envelope is not saved within the ".tcp" file, which means that upon opening the plan Vehicle Paths inside should be reevaluated manually.
Clearance Envelope	Clearance Envelope is a zone outside the actual Sweep Envelope. It allows you to add an extra offset to accommodate for driver error or real-world situations.
Lock To Lock Time	Time in seconds that it takes the driver of the vehicle to turn the steering from full lock in one direction to full lock in the opposite direction in a single continuous movement. This may differ depending on which standards and vehicle types are used.
Speed and Friction Link	The lateral friction factor is dependent on the vehicle speed and is calculated according to the chosen vehicle and its related standards. You can disable this behavior by clicking on the link/unlink toggle button in the "Section details" window while drawing the vehicle path.
Turn on Stop	The option that allows the vehicle to make a stop and turn the front wheels between different sections of the Vehicle Path.
Steering Angle	The steering angle is defined as the angle between the front of the vehicle and the wheels direction. Value of max steering angle for each vehicle can be found inside the Vehicle Library.
Turning Radius - Curb to Curb	The radius of the turning circle that denotes how wide a street would need to be so the vehicle can make a U- turn without hitting the street curb with the wheel. Value of minimum turning radius (curb to curb) for each vehicle can be found inside the Vehicle Library.
Turning Radius - Wall to Wall	The radius of the turning circle that denotes how far apart two walls would need to be so the vehicle can make a U-turn without scraping the walls with the bumper. Value of minimum turning radius (wall to wall) for each vehicle can be found inside the Vehicle Library.
Min Radius	Centerline radius of the smallest circular turn that the vehicle is capable of making at a given speed.

Chapter 4: Vehicle Library

Vehicle Library lets you browse through available standards and their predefined vehicles.

4.1 Using Vehicle Library

To open the RapidPath Vehicle Library you need to select the Vehicle tool from the Tools Palette.



Figure 4.1 Swept Path tool in Tools Palette

The Vehicle Library window is divided into two parts. The left section is used for browsing through available standards/guidelines and their predefined vehicles. Standards available to you will depend on which country you are operating in and/or which vehicle bundles you have included in your subscription. The right section displays information about the currently selected vehicle. It shows a side view diagram of the vehicle, key dimensions and parameters necessary for the swept path analysis. The unit system used (metric or imperial) is dependent on your application settings (under Preferences).

Use the buttons at the top left to choose the vehicle package (country standard, etc), then appropriate vehicles will appear below. Select the vehicle to see its details. Vehicle's dimensions are visible at the bottom of the right section. If the vehicle consists of many parts, or contains trailers, use the select box to choose the part you are interested in. Changing the vehicle part will also adjust dimension markers on the side view, so they refer to the appropriate part. The selected part will be highlighted in red.



Figure 4.2 Vehicle Library Window

All of these parameters can be modified when editing already placed vehicles. Read more about it in Chapter 5.1 Adding Vehicle to The Plan and 5.2 Editing an Existing Vehicle.

Note: Changes made to the vehicle will not be saved to the Vehicle Library.

You can bookmark frequently used vehicles by clicking on them with the right mouse button and choosing "Add to Bookmarks". Bookmarked vehicles are displayed at the top of the vehicles grid regardless of the chosen standard. You can also hide unwanted or unused vehicles by choosing "Hide panel".

Bookmarking and hiding vehicles]	
Add vehicle		x
Available vehicles		
AASHTO (2018) Auckland Transport Austroads (2013)		
Land Transport		
Bookmarked vehicles:	Already bookmarked vehicles	-
Add to Bookmarks 50th - Car B5th Milde vehicle	Bookmark vehicle WB R	J
85th - Car with Ca 85th - Car with VIT 95th - Car	Length: 12.50 Hide vehicle	
	Lock to lock: 6 \$ s Turn radius (wall to wall): 11.75 \$ m	
ADL 12.5m Double Airbus 13.5m Kiwi Articulated bus 19	Dimensions	
	Front: 2.36 A m	
Bus - 11.3m Com Bus - 13.5m Tour Bus - Tour Coach	Wheel bares 6.82	
	Rear: 3.32 Ø m	
Show hidden 😥 Show names		
	Add Cased	

Figure 4.3 Bookmark and Hide vehicle option inside the Vehicle Library Window

Chapter 5: Preparing Swept Path Analysis

5.1 Adding Vehicle to the Plan

The first step in creating the Swept Path Analysis is adding a vehicle to your plan. To do this, open the Vehicle Library by selecting the Vehicle tool from the Tools Palette. In the Vehicle Library window, choose the standard and vehicle you are interested in and click the "Add" button at the bottom of the window. Now place the vehicle onto your plan with the left mouse button.



Figure 5.1 Adding Vehicle

If you want to use different vehicle's parameters you can change them in Vehicle Library before clicking the "Add" button. These changes will not be saved into the Library, they will only apply to the vehicle that will be added to the plan.

Vehicles in RapidPath can be positioned and rotated just like any other object. But, their size is automatically adjusted to the plan's scale and cannot be changed. You can also copy/cut and paste vehicles.



Figure 5.2 Vehicle object on the plan

When clicking on a vehicle you can check its most important parameters inside the Object Properties window.

5.2 Editing an Existing Vehicle

To edit the existing vehicle double click on it with the left mouse button. The Edit Vehicle window will appear. Here you can change all the parameters and save them to the vehicle object on your plan. You can also use the same window to replace the current vehicle with another one.



Figure 5.3 Edit Vehicle window

If you want to only edit the "Lock to Lock" parameter you can select the vehicle and do it inside an Object Properties window. Object Properties can also be used to style the vehicle which is very useful when using multiple vehicles with similar shapes on the same plan.



Figure 5.4 Vehicle object and its properties

5.3 Drawing a Vehicle Path

To start drawing a Vehicle Path select the vehicle on your plan and click on the arrow in front of it. Arrow indicates the forward movement direction of the vehicle. You can also click on the vehicle with the right mouse button and choose "Vehicle" submenu and "Draw Path" option.



Figure 5.5 Selected Vehicle object with the arrow that indicates forward movement direction

When in "Draw Path" mode a special window called "Section details" will appear with settings for:

- Speed Vehicle speed.
- **Friction** Lateral friction factor dependent on the vehicle speed and calculated according to the chosen standard. To set a custom value disable speed and friction dependency by clicking on the link/unlink toggle button on the left and enter the desired value in the field.
- **Turn on Stop** Turning this option on ("True") allows the vehicle to make a stop and turn the front wheels between different sections (at control points) of the Vehicle Path.

and info such as:

- **Min radius** Minimum turning radius (centerline) of the vehicle at the given speed and friction.
- Max angle Maximum turn angle of the vehicle at the given speed and friction.
- **Max speed** Maximum speed for the vehicle taking into account standard guidelines, given speed, friction and current turn radius.



Figure 5.6 Sections details window

After setting the speed, friction and "Turn on Stop" option you can start drawing the path. To do this, indicate the points on the canvas area by clicking the left mouse button. These points are called "Control Points" and can be adjusted later (Chapter 5.7

Editing a Vehicle Path). Each point creates another section of the Vehicle Path. Each section can have different parameters such as speed, friction and turn on stop setting. You can adjust section parameters before making each point to create a path that consists of sections with different speeds, friction and other parameters. Alternatively, the section parameters can be adjusted after drawing the path.



Figure 5.7 Drawing a vehicle path

You can only create a path within the maneuverability capabilities of the current vehicle at given parameters such as speed, friction, lock to lock time, etc. Observing a real-time preview of the vehicle and turn angle indicator during drawing will help you make the desired path. The turn angle indicator will turn red when the maximum turn angle is reached.



Figure 5.8 Angle indicator when drawing the path

Use Undo ("Ctrl+z") and Redo ("Ctrl+y") options while creating Vehicle Path to avoid wrongly placed or unwanted points. Additionally, you can edit your path later, when it is finished. More about this in Chapter 5.7 Editing a Vehicle Path. Finish drawing the path by clicking with the right mouse button or pressing the "Esc" key. Once the Vehicle Path is finished it turns into a separate object that can be freely moved and rotated. You can delete the Vehicle Path without deleting the vehicle.



Figure 5.9 Finished vehicle path

5.4 Evaluating a Path

In order to obtain Sweep Envelope (the result of the analysis), the Vehicle Path needs to be evaluated. To evaluate a path, select it with the right mouse button, choose "Vehicle Path" sub-menu and then "Evaluate" option. You can also use the "Evaluate" button inside the Vehicle Path's properties in the Object Properties window. To do so, search for "Swept path" group and "Show" property.



Figure 5.10 Evaluate button in the context menu and Object Properties window

Note that the evaluation process can take a while for particularly long paths. You can track the green progress bar that goes along the path during the calculation.



Figure 5.11 Evaluation progress bar and sweep envelope

Making changes to the already evaluated path will cause the existing Sweep Envelope (now obsolete) to disappear, requiring the path to be re-evaluated. Sweep Envelopes are not saved to the plan's file but are visible in the print and export upon evaluation. You can evaluate all the Vehicle Paths in the active diagram by clicking the right mouse button anywhere on the canvas area and choosing the "Evaluate Paths" option.

Sweep Envelope can be styled using Vehicle Path's properties in the Object Properties window.

5.5 Clearance Envelope

Clearance Envelope will allow you to add offset to the Sweep Envelope to accommodate for driver error or real world situations. It can only be displayed on the evaluated Vehicle Path. To turn on Clearance Envelope go to the "Clearance" section in path's properties and change "Show" property to "Filled" or "Outline". You can edit the clearance envelope offset distances in the "Clearance" section of the path's properties. Making changes to the clearance offset will require re-evaluation of the path.



Figure 5.12 Clearance Envelope and its offset settings in the Object Properties window

5.6 Styling Vehicle Path, Sweep Envelope and Clearance

Vehicle Path, Sweep Envelope and Clearance can be styled in many different ways using Vehicle Path's properties in the Object Properties window. Aside from visual customization, you can also:

- Add wheel paths separately for front and rear wheels;
- Add speed information to path sections;
- Show/hide directional arrows that indicate the start of each path section; and
- Show/hide vehicles along the path.



Figure 5.13 Extra styling options for vehicle path - 1



5.7 Editing a Vehicle Path

After the Vehicle Path is finished you can edit and adjust it using these methods:

 Editing the parameters of the path's sections - You can edit each section's parameters such as Speed, Friction and Turn on Stop. To select a section, first select the path, then click on the section you want to change with the left mouse button while holding "Ctrl" key. Once the section is selected, it will highlight red and a "Section details" window will appear. You can also select multiple sections by clicking on them one by one while holding "Ctrl" key.



Figure 5.15 Selected section of the vehicle path

 Editing control points - You can change Vehicle Path's geometry by moving control points. Select the path, then click on one of the red circles and drag while holding the left mouse button. It is possible that you won't be able to move it freely because its position can be bounded by vehicle's manoeuvrability capabilities (sections' properties, other control points). You can also remove the control point by clicking on it with the right mouse button and choosing "Remove control point" option from the context menu.

3. **Continuing the path** - You can continue drawing already finished path. To do this simply click with the right mouse button on the path you want to expand, then choose the "Continue path" option from the "Vehicle path" sub-menu. Continuing the path works the same way as drawing the path.



Figure 5.16 Continuing the path option in the context menu

5.8 Adding Additional Vehicles to the Path

You can add additional vehicle objects to the path to:

- Better visualize results of your analysis;
- Check position/behavior of the vehicle and trailers at a specific point along the path; and
- Start a new analysis from a selected point on the existing path to make multiple connected analyses or different route variants.

To add additional vehicles to the path, click on it with the right mouse button and choose the "Add vehicle" option from the "Vehicle path" sub-menu. Now place the vehicles along the path by clicking with the left mouse button. When finished press the right mouse button or "Esc" key. These are ordinary vehicle objects that can be moved, edited and even replaced with other vehicles. You can also start a new swept path analysis from them.



Figure 5.17 Additional vehicles added to the existing vehicle path



Figure 5.18 Swept path analysis with different route variant

5.9 Adding Vehicle Profile to the Plan

It is always a good idea to add the description of the vehicle used for the Swept Path Analysis to your document. You can easily do this by clicking with the right mouse button on the vehicle or Vehicle Path and choosing "Add profile" from the appropriate sub-menu ("Vehicle" or "Vehicle path").



Figure 5.19 Vehicle profile option in the context menu

The Vehicle Profile displays the:

- Vehicle's name;
- Vehicle's side view with the most important dimensions; and
- Vehicle's properties crucial for the Swept Path Analysis.

Vehicle profile on the plan		10
	I Children Coop	
	Vehicle dimensions	
	0.91 7.77 1.37 0.91 0.70 0.00 0.91 3.81 0.70 Intermediate Semitrailer (WB-40) Length: 13.87 m Width: 2.44 m Lock to lock time: 6.0 s Max steering angle: 20.24° Tum radius (curb to curb): 12.16 m Tum radius (wall to wall): 12.48 m	

Figure 5.20 Vehicle profile added to the plan

You can ungroup the vehicle profile, then edit and style its parts - just like you would any other RapidPlan objects.



Figure 5.21 Styled vehicle profile

Chapter 6: Manual Drive

Manual Drive mode allows you to drive the vehicle manually around the canvas area. You can drive in forward and reverse and check how the vehicle behaves at different speeds.

This tool was originally developed to test RapidPath's algorithms. Please let us know if you find it useful and you would like it to be further developed.

6.1 Using Manual Drive

To manually drive a vehicle you first need to add a vehicle to the canvas area. For this, please follow the directions in Chapter 5.1 Adding Vehicle to the Plan. When you have a vehicle on the canvas area, click on it with the right mouse button and choose the "Drive" option from the "Vehicle" sub-menu. A dialog box will appear. Choose the direction in which you want to drive, lateral friction factor and steering method (Mouse or Keyboard). You can now click on the canvas and start driving the vehicle. Press "Esc" key if you want to quit Manual Drive mode. Controls for different steering modes are presented below.



Figure 6.1 Manual Drive mode

Mouse Controls	
Left Mouse Button	Increase vehicle's speed by holding the left mouse button.
Right Mouse Button	Decrease vehicle's speed by holding the right mouse button on the canvas area.
Double-Click with Left Mouse Button	Stop the vehicle
Move cursor around the canvas	Turning the wheels
R	Switch between forward and reverse direction. Can be switched only when stopped.

Keyboard Controls	
Left Arrow	Turn the wheels to the left, hold for tighter turn
Right Arrow	Turn the wheels to the right
Up Arrow	Accelerate
Down Arrow	Lower the speed
R	Switch between forward and reverse direction. Can be switched only when stopped.

Table 6.2

While in driving mode, please pay attention to the "Speed" and "Wheel angle" information displayed in the "Drive mode" window. There may be a situation in which you won't be able to increase the speed any further because of your current wheel angle, and vice versa.