REPORT FOR NATIONAL HEAVY VEHICLE REGULATOR

HVSI 711 - Heavy Vehicle Safe Payload Height and Safe Speed Calculator

Project Draft Final Report

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About Advantia

Since its foundation in 2008, Advantia Transport Consulting has specialised in assessing the performance of high-productivity freight vehicles. Advantia now boasts over a decade of heavy vehicle performance intellectual property and has developed an international profile as experts in mechanical engineering simulation and assessment, and for supporting the expansion of freight productivity. Advantia has since gone beyond mastering the design and assessment of high-productivity freight vehicles, having made significant contributions in areas such as heavy vehicle policy development, road access facilitation and knowledge transfer. Advantia is recognised across both the heavy vehicle industry and transport-related government departments and agencies for the specialised work that it does to advance the productivity and safety of road freight transport, primarily by supporting transport policy reform and improved heavy vehicle operations. The company is known for its tenacity and a deep motivation to push boundaries when the evidence supports it. That spirit has enabled the company to make an everlasting impression on Australia's heavy vehicle industry, which is acknowledged internationally.

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Executive summary

In 2022, Advantia was engaged by the National Heavy Vehicle Regulator (NHVR) to create a tool that would allow members of the heavy vehicle industry to calculate the Static Rollover Threshold (SRT) of their heavy vehicle combinations. The project was funded under Round 7 of the Heavy Vehicle Safety Initiative (HVSI) to make the tool freely available for a period of two years.

Over the life of the project, the tool became known as 'Payload Pilot', and associated branding has been developed around this name. The tool can be accessed through a dedicated website where users can enter in information for their heavy vehicle, choosing from a wide range of combinations. The results of the simulation are then emailed to the user.

The online tool can be accessed at the following URL: https://payloadpilot.com.au/

Payload Pilot is based on the methodology Advantia completes already under the national Performance Based Standards (PBS) scheme as an accredited PBS assessor.

As part of validating the tool, Advantia conducted a field test of a common heavy vehicle combination on the tilt table Anglesea Automotive Research Centre (AARC) proving ground, mirroring the simulation environment. A comparison of the field test and simulation results showed that the simulation gave a conservative result between 1 to 6 per cent lower than the measured values. This is within what Advantia considers to be an acceptable result in that the Payload Pilot provides a conservative value without being overly conservative.

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Revision history

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1. Introduction

Advantia has a long history as a Performance Based Standards (PBS) assessor within the heavy vehicle industry, and one of the key parameters that we calculate as part of PBS assessment is Static Rollover Threshold (SRT), a measure of rollover stability. SRT has been shown to be a key factor when evaluating the safety of a vehicle (Mueller, de Pont, & Baas, 1999) (Winkler, 2000). Calculation of SRT requires specialised engineering skills and software that isn't typically available to many industry members, or is prohibitively expensive.

To address this industry need, as part of Round 7 of Heavy Vehicle Safety Initiative (HVSI) Advantia put in a proposal to create a new online tool, designed for Australian heavy vehicle industry members, which can easily output SRT and associated results. It was funded under the Heavy Vehicle Safety Initiative (HVSI), Round 7, in 2022, with final delivery of the tool in April 2024.

By providing an accessible tool to industry to calculate the SRT of their vehicle, it will allow the wider heavy vehicle industry to better understand the rollover risk associated with their vehicle. In doing so, low-performing vehicles or load configurations may be easily identified, and the risk of these situations mitigated. It is expected that this will increase the SRT these low-performing vehicles and decrease the occurrence of rollover and handling related issues for heavy vehicles on Australian roads.

To create a tool that is useful to, and useable by, the wider heavy vehicle industry, a number of key requirements were identified:

- It must output usable results
- It must be technically sound and accurate
- It must be user friendly
- It must cater for users of varying technical capability
- It must cover a wide range of vehicles used in Australia.

The details of these requirements were discussed with industry and then confirmed with the NHVR. Advantia achieved all major requirements as part of this project, and this report outlines how these were achieved.

2. Key objectives

The overarching goal of the project is to improve the safety of the Australian heavy vehicle fleet. SRT was identified as a key performance metric of vehicle safety that has poor availability to the heavy vehicle industry, especially outside of the PBS scheme. As a PBS assessment specialist, Advantia is very familiar with SRT calculations. This placed Advantia is a prime position to provide industry with to SRT assessments of their vehicles to support the broader goal of improving safety within the industry.

While the SRT calculations from Advantia as part of PBS assessments have been shown to be accurate in the past, they have required the work of a specialist engineer to produce, placing a relatively high barrier to entry for the broader heavy vehicle industry outside of those who participate in the PBS scheme. To this end, it was determined that this same degree of accuracy needed to be made available in such a way that people without specialised training could calculate the SRT of their vehicle.

While maintaining the accuracy and usability of the tool, it must also remain versatile enough to support the wide range of vehicles used by the heavy vehicle industry in Australia. The combinations listed below were identified as those most commonly used in Australia.

- Truck
- Truck and dog
- Truck and two dogs
- Prime mover and semi-trailer
- A-double
- A-triple
- AB-triple
- B-double
- B-triple
- BA-triple.

To cater for combinations outside of this broad range, two additional options were included, as shown below. These are not complete combinations, but rather a subset of units that, in conjunction with the combinations listed above, allow for an even wider range of heavy vehicle combinations to be assessed by breaking them down into groups of units.

- Dolly and semi-trailer
- Dolly and two semi-trailers.

This list was proposed to, and agreed to, by the National Heavy Vehicle Regulator (NHVR) as part of the initial scoping meeting for the project.

Figure 1: A photograph of a prime mover and semi-trailer combination, a common prescriptive heavy vehicle in Australia

3. A tool for all members of industry

A key challenge to this project was taking an assessment that has historically been conducted by specialised engineers, and making it available to people with only a broad understanding of heavy vehicles. The difficulties faced by people without specialised training come down to three aspects:

- Having access to software capable of performing SRT simulations
- Knowing what information to use in an SRT simulation
- Having access to the requisite data to construct the simulation.

The first point was solved by creating a freely available tool that provides a pathway to submit simulation data to Advantia's simulation server. As Advantia is not experienced in the field of website development, a sub-contractor, Blake Digital, was brought into the project proposal to create the user-facing website.

Over the life of the project, the website and the calculation tool became known as 'Payload Pilot'. To address industry access to SRT simulations, it is also necessary to raise awareness that the opportunity exists. To achieve this, associated branding has been developed around the Payload Pilot name, and Advantia will be exhibiting the tool at industry events post-launch.

Secondly, users may not necessarily know what information needs to go into an SRT simulation. Again, a web interface provided a solution to this problem by summarising the required inputs, and also providing data validation to ensure that reasonable inputs are provided.

Finally, the simulations must be able to be constructed from information that is reasonably available to members of the general public. This can be supplemented by providing the option for users to use reasonable estimations, where possible.

Most data required for an SRT simulation can be reasonably acquired by someone with a familiarity with heavy vehicles by inspecting the vehicle. However, a key performance set of parameters for an SRT simulation is the suspension performance. This data is not publicly available, and manufacturers are generally unwilling to share it with the public. To overcome this issue Advantia leveraged our extensive experience to create a range of generic suspension datasets that can be selected by users as part of the data input process. For those with the data, advanced input fields are available. Users may also choose to modify a generic suspension if they have some, but not all of the suspension parameters for their vehicle.

4. Simulation Method

All simulations are conducted using 'TruckSim' heavy vehicle simulation software on the back-end. For more information about TruckSim, see Appendix A. The construction of the simulations from the input data is automated, with no direct input from an engineer. This constitutes the simulation engine powering the SRT calculator.

4.1 Vehicle Inputs

The input data is comprised of vehicle data provided by users, and generic data from Advantia that goes into both the vehicle and the broader simulation environment.

Users input the most critical parameters for the simulation. These include mass properties of the vehicle and payload, as well as vehicle suspension properties for each axle. Axle suspension properties may be entered manually by the user, or they may select from a range of predefined 'generic' suspension datasets. These predefined suspension datasets have been developed by Advantia as representative of the range of suspensions currently used by the Australian heavy vehicle industry and do not represent the properties of any specific suspension.

Some other parameters that have a low impact on the simulation results, such as tyre and hitch properties, use a set of generic datasets. Tyre data is drawn from the NHVR's PPBS scheme that adopts a 'generic tyre approach', other vehicle properties use a standard dataset developed by Advantia.

4.2 Simulation Procedure

The simulation is conducted according to the SRT standard, as defined in the PBS scheme standards and assessment rules (NHVR, 2022), using the tilt table test procedure.

The test is simulated by placing the subject vehicle on a tilt table under dry sealed road conditions. The angle of the tilt table is increased until the vehicle is algorithmically determined to be at the 'point of no return' before rolling over. The angle of the tilt table at this point is recorded and then used to calculate the SRT result. For combination with multiple roll-coupled sets of units, a separate simulation is conducted for each set.

If the user requested that the maximum payload height be determined for a specific SRT value, the test is conducted multiple times with the payload height iteratively adjusted until the SRT result is within an acceptable tolerance of the target SRT value given the by user. The iterative process of Maximum Payload Height (MPH) simulations results in a much greater simulation run time than an SRT assessment which only requires a single run per roll-coupled unit.

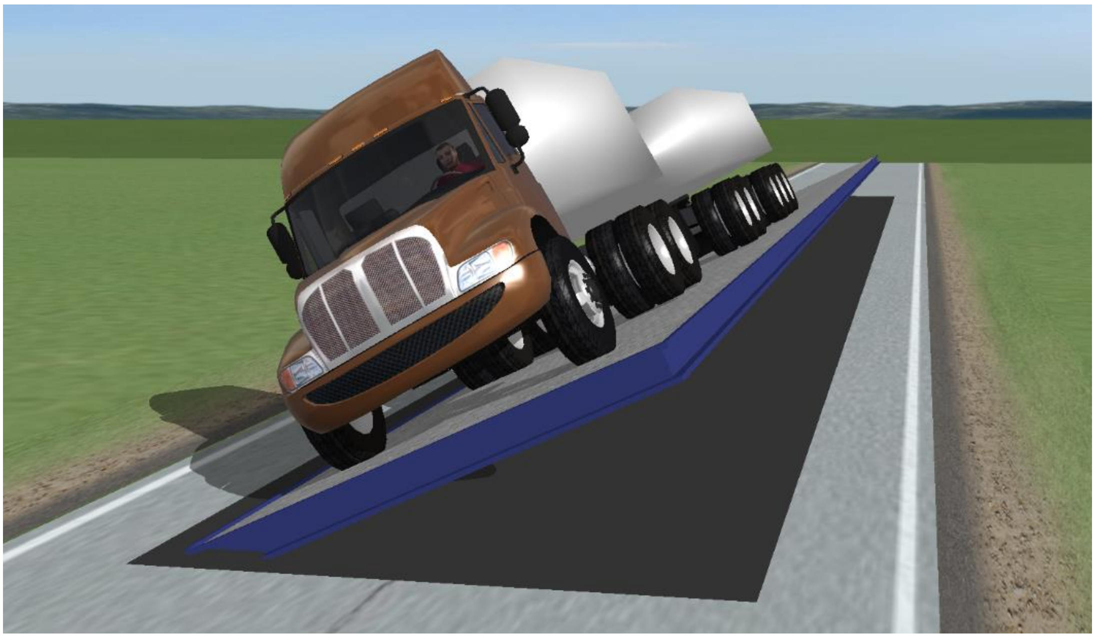


Figure 2: An image of a truck and dog in the simulation environment

5. Validation

As part of the validation process for Payload Pilot, a field test was conducted at the Anglesea Automotive Research Centre (AARC) proving ground using a tilt table to measure the rollover stability of a real heavy vehicle. Alongside the field test, a simulation of the same subject vehicle was also conducted. This was used to compare the results of real-world testing to the simulation environment.

5.1 Test Vehicle

The subject test vehicle consisted of a 6x4 prime mover and tri-axle semi-trailer combination. The combination included units which have already been certified under a PBS assessment as part of an existing A-double assessment. Use of the vehicle was provided by AMK Container Services. A layout drawing of the combination is shown below in Figure 3. A larger version of this drawing has also been included in Appendix B.

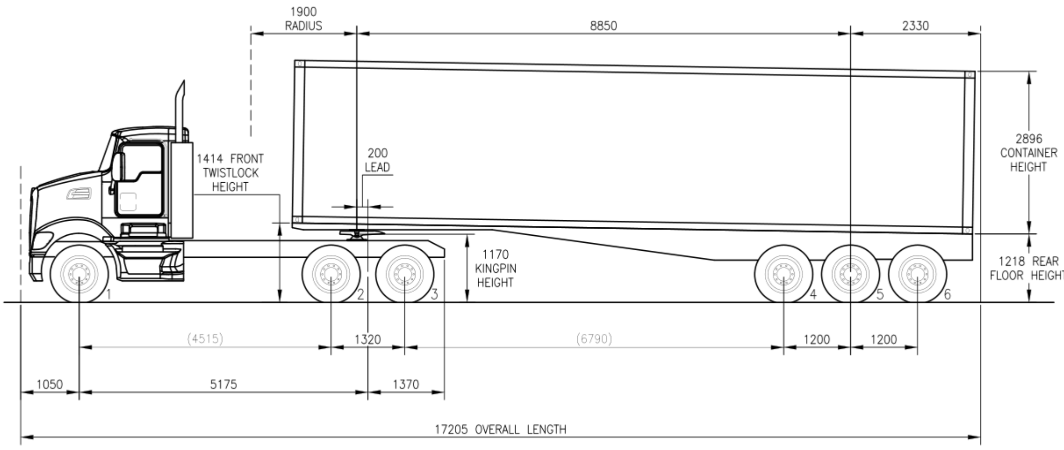


Figure 3: A layout drawing of the test vehicle.

The vehicle consisted of a Kenworth prime mover hauling a Freighter skeletal trailer carrying a 40-foot container. The original plan had the container fully loaded for maximum axle loads (46 tonnes Gross Combination Mass) however the tilt table at AARC has a maximum capacity of 40 tonnes. On the day of testing the combination was weighed on a weighbridge and the total weight was found to be 38.62 tonnes Gross Combination Mass (GCM). However, this had no impact on the testing procedure. The payload within the 40-foot container consisted of hay bound for export. A photograph of the load inside the container is shown below in Figure 4.

Figure 4: A photo of the interior of the container that was used as payload

5.2 Method

The prescribed testing procedure for the SRT standard under the PBS scheme requires that a vehicle is tilted to the point of rollover. This was not done during the field testing carried out by Advantia due to safety concerns. Instead, the vehicle was tilted until the load on the outer tyre on any axle reached zero. While this doesn't exactly conform to the testing procedure for the

SRT standard, it is only a change of reference point that still allows a comparison between simulation and field testing results with respect to rollover performance.

To account for any asymmetry in the vehicle, tests were conducted with the vehicle being tipped to each side.

Figure 5: A photograph of an in-progress field test from the rear of the vehicle as it is tipped to the right

Specifications of the combination and the environmental conditions were recorded and then fed into TruckSim to conduct a simulation matching the field test conditions. While the field test tipped the vehicle to each side to account for asymmetry, all simulation parameters were symmetrical, so the vehicle was only tipped on one side, giving a single result. The simulated test was conducted according to the PBS standards, but the final lateral acceleration result was taken as when the first axle reached zero load on the outer tyre.

5.3 Results

In all cases, the last axle of the semi-trailer (axle 6) was found to be the first axle to reach a load of zero on the outer tyre. Within the simulation, like the field test, the last axle of the semi-trailer was found to be the first axle to lift off the tilt table. This was found to occur at 0.305 g in the simulation.

A total of eight physical tilt table tests were conducted, with results shown below in Table 1. Half of these tests tipped the vehicle to the right, while the other half tipped the vehicle to the left. A positive value for "Percentage difference to simulation" indicates that the field test result is higher than the simulation result.

Table 1: Summary of field test results

Test	Subject vehicle tilt direction	Final lateral acceleration (g)	Percentage difference to simulation
1	Right	0.319	4.6%
2	Right	0.310	1.5%
3	Right	0.310	1.5%
4	Right	0.306	0.2%
5	Left	0.321	5.3%
6	Left	0.323	5.9%
7	Left	0.323	5.9%
8	Left	0.321	5.3%
Average	Right	0.311	2.0%
Average	Left	0.322	5.6%
Average	All	0.317	3.8%

It can be seen from Table 1 that when the vehicle was tipped to the left, it produced higher results (0.322g vs. 0.311g, on average). This indicates that there is some asymmetry in the vehicle. On the day of the test, it was identified that one of the semi-trailer tyres was flat, which may have contributed this this observed difference.

In comparison to the simulation result, the field test results were up to 5.9 per cent higher, indicating that the simulation parameters are conservative. This level of conservatism is considered acceptable by Advantia.

6. Payload Pilot

6.1 Technical overview

To effectively manage all incoming requests for use of the tool, it was necessary to implement a simulation management engine. The simulation management engine was developed in-house by Advantia, while the user-facing website was developed by Blake Digital, a sub-consultant under Advantia's direction. Figure 6 below shows the path the user's input (blue arrows) takes, passing through to the calculation node. After the simulation is complete, the output is then passed back through the chain, culminating in a PDF report that is emailed to the client.

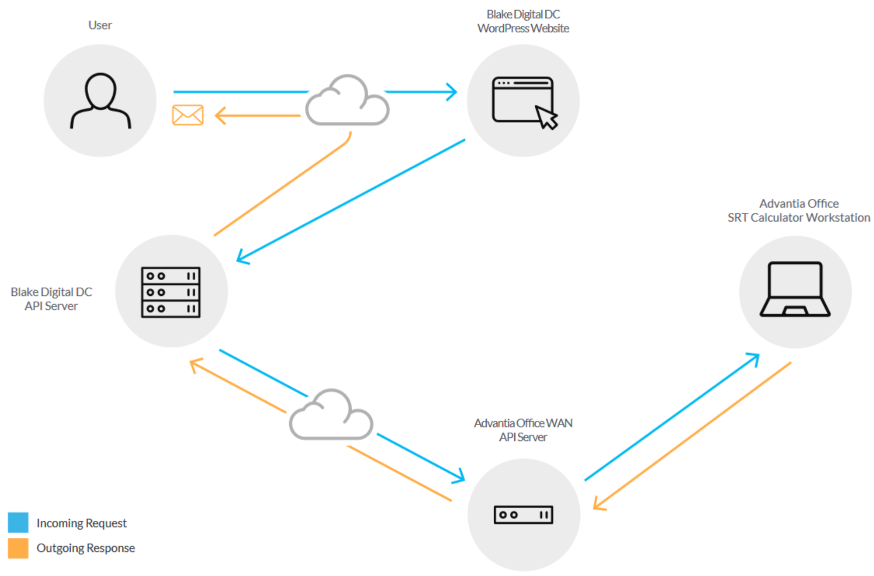


Figure 6: Overview of simulation process

6.2 User experience

To access Payload Pilot, users navigate to the dedicated Payload Pilot website at www.payloadpilot.com.au. From there, they are greeted by a welcome page that allows them to enter their details, select a combination for simulation, and select a simulation output. A screenshot of this page is shown below in Figure 7. The simulation output allows for two options, SRT, or MPH. For the first option, the user inputs the height of their payloads and is given the resultant SRT. For the second option, the user specifies a target SRT value and Payload Pilot calculates the maximum payload heights to meet this target.

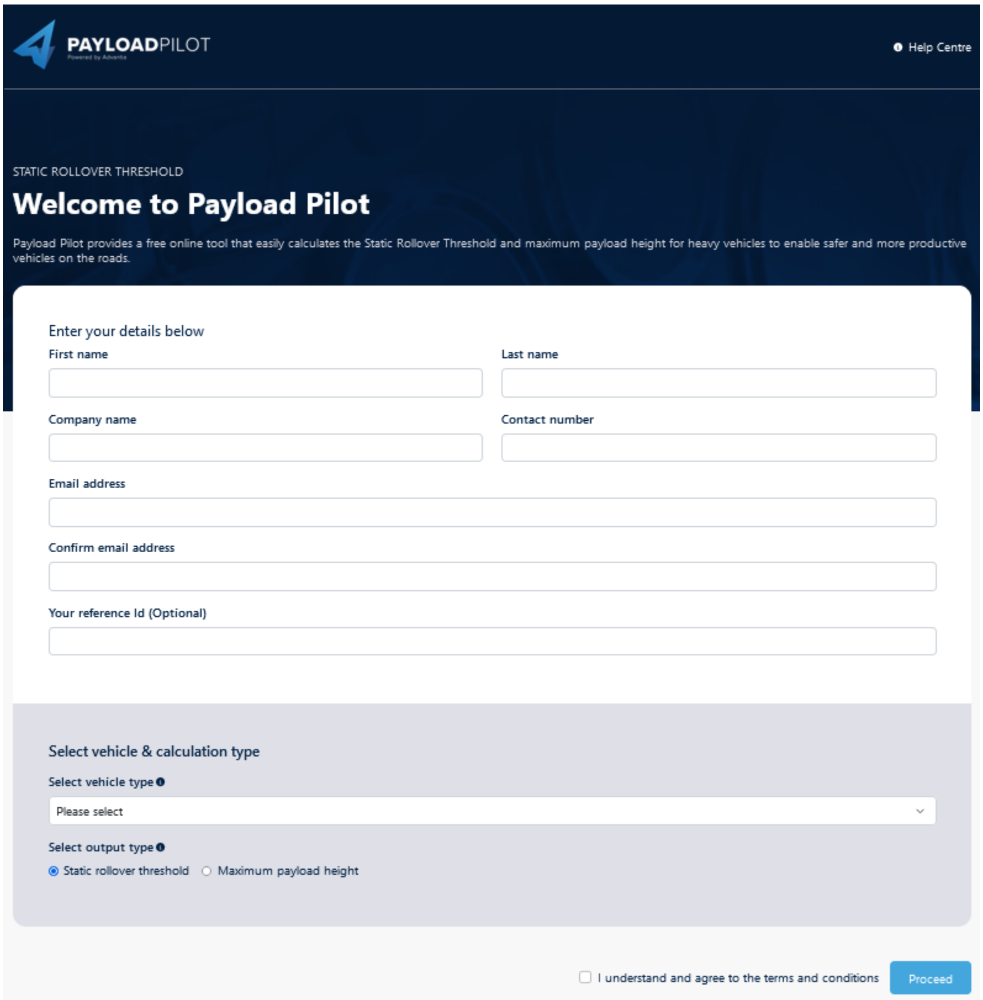


Figure 7: A screenshot of the Payload Pilot landing page

The combinations available for simulation are listed as follows:

- Truck
- Truck and dog
- Truck and two dogs
- Prime mover and semi-trailer
- A-double
- A-triple
- AB-triple
- B-double
- B-triple
- BA-triple
- Dolly and semi-trailer
- Dolly and two semi-trailers.

The last two options aren't complete combinations that would operate independently, but are instead intended to allow users to focus on a single component of their combination, or to produce results for niche combinations that aren't supported directly, such as A-quads.

After clicking on the 'Proceed' button, users are taken to the simulation input page for their chosen combination.

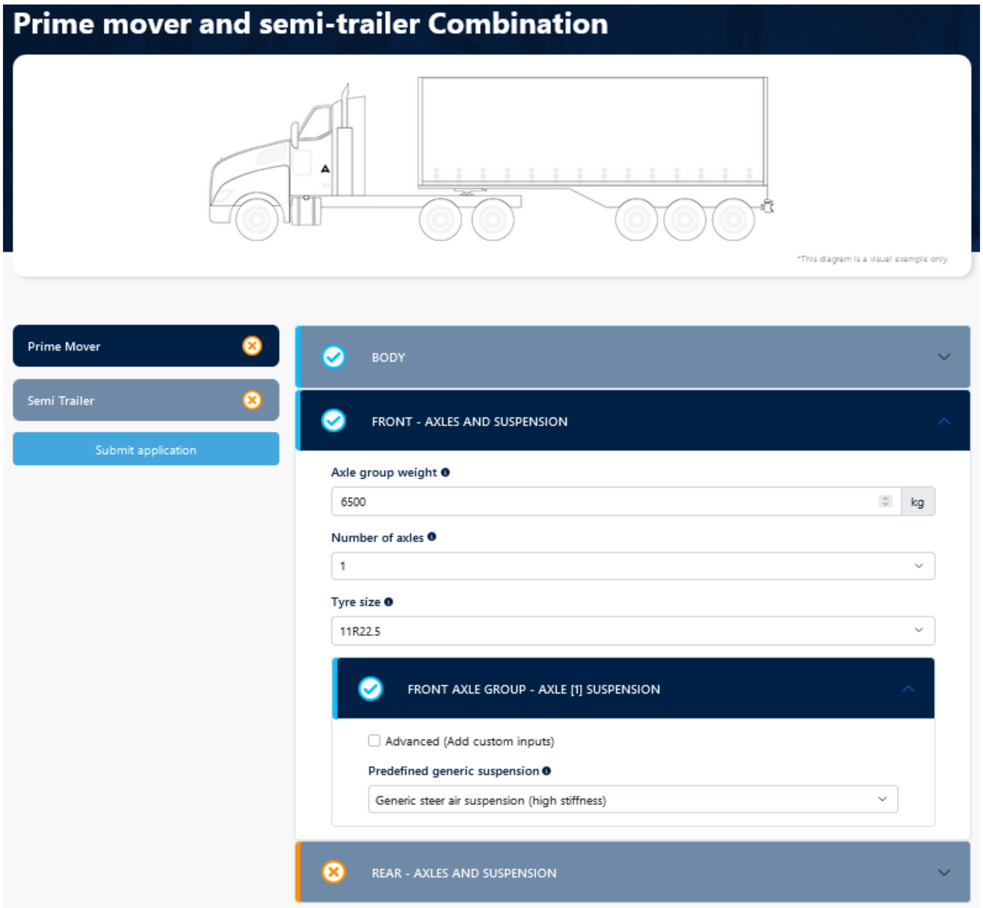


Figure 8: A screenshot of the simulation input page for a prime mover and semi-trailer combination

Users must input data in each field provided on this page. Every field has some form of input validation to ensure that users are providing somewhat realistic values that are free of typos. Each input section shows a tick or a cross to indicate whether the section has been satisfactorily filled out. The same is also shown for each unit.

While the interface has been built to be accessible to users with a general familiarity with heavy vehicles, each input field also has a tooltip with a brief description of the required data, as well as a link to a larger help document that goes into more technical detail.

Of particular note are the suspension input fields. Suspension performance parameters are a critical factor in determining heavy vehicle rollover, however they often require a high level of understanding, as well as performance data that is generally not available to the public. To circumvent this issue, Advantia has provided a range of pre-defined 'generic' suspension options for users to choose from. For advanced users with this level of information available, optional inputs are available to input this data, shown below in Figure 9.

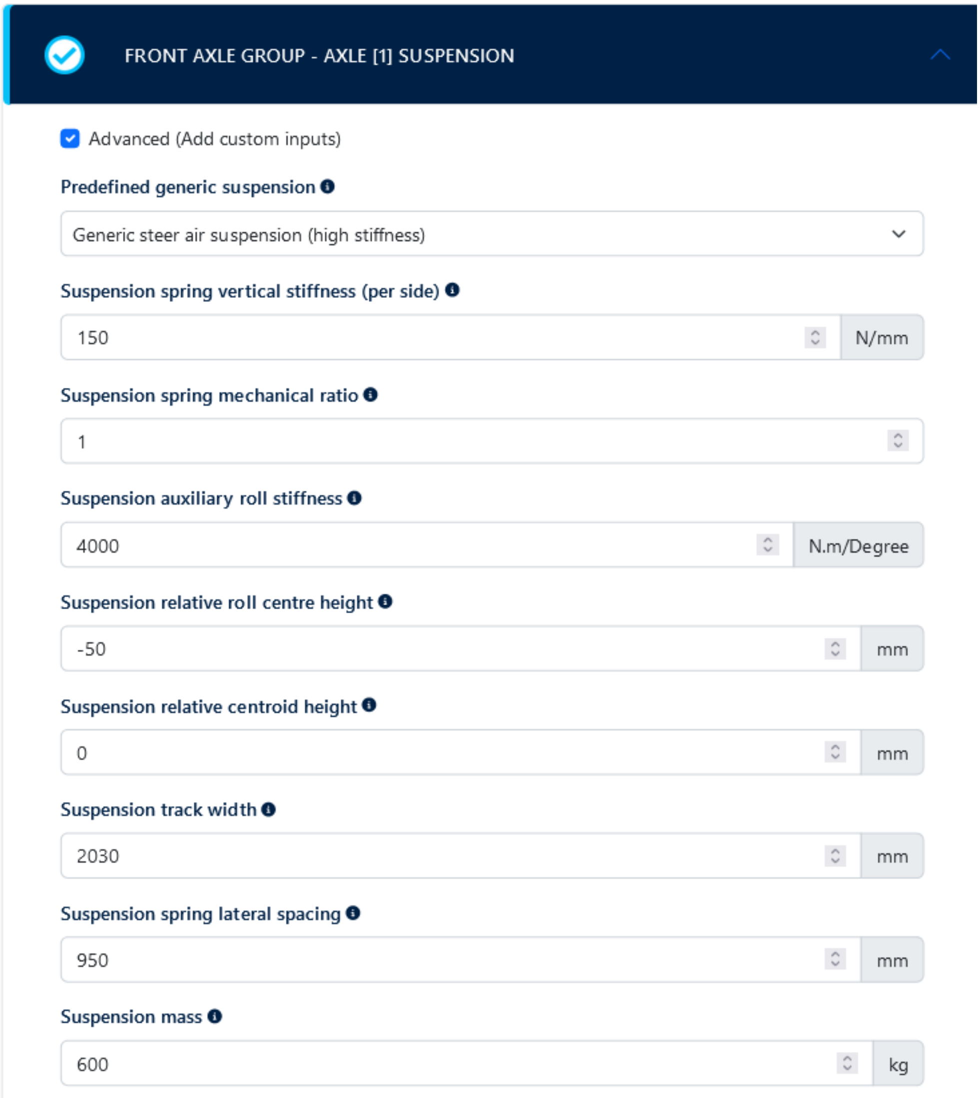
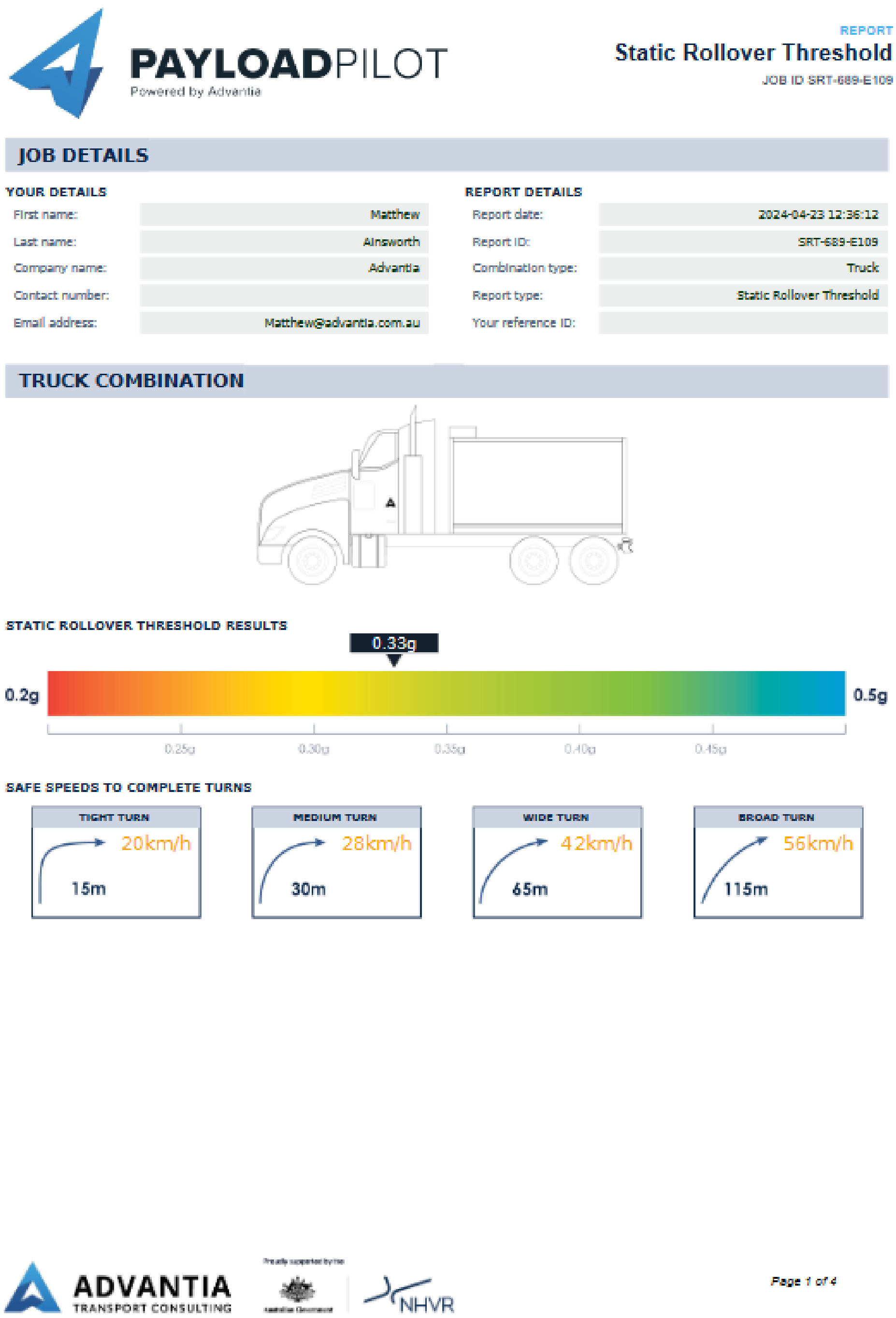


Figure 9: A screenshot of advanced suspension parameters

After the user has submitted their application, a report will be emailed to the email address that they gave on the landing page. Simulation time can range from a few minutes when determining the SRT value of smaller combinations to up to an hour to determine the maximum payload height for larger combinations, particularly if there is heavy server load. See section 4. Simulation Method for more details about the simulation methodology. It is anticipated that the resources provisioned for simulations will be sufficient to meet demand without significant queue times. Furthermore, Advantia is able to allocate additional resources to Payload Pilot should the need arise.


PAYLOADPILOT
Powered by Advantia

REPORT
Static Rollover Threshold
JOB ID SRT-689-E109

JOB DETAILS

YOUR DETAILS		REPORT DETAILS	
First name:	Matthew	Report date:	2024-04-23 12:36:12
Last name:	Ainsworth	Report ID:	SRT-689-E109
Company name:	Advantia	Combination type:	Truck
Contact number:		Report type:	Static Rollover Threshold
Email address:	Matthew@advantia.com.au	Your reference ID:	

TRUCK COMBINATION

STATIC ROLLOVER THRESHOLD RESULTS

0.33g

0.2g 0.25g 0.30g 0.35g 0.40g 0.45g 0.5g

SAFE SPEEDS TO COMPLETE TURNS

TIGHT TURN	MEDIUM TURN	WIDE TURN	BROAD TURN
20km/h 15m	28km/h 30m	42km/h 65m	56km/h 115m

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Figure 10: A screenshot of the front page of a Payload Pilot Report

Figure 10 shows the front page of an SRT report. It clearly shows the SRT result for the user to see. Subsequent pages in the report provide the inputs that were provided to the simulation to provide context to the result. The report also gives safe turning speeds for the vehicle. These speeds are calculated using the SRT result and assume a dry, flat, sealed road and a constant turn radius. The report also includes a glossary of terms to assist in scenarios where it has been printed out and internet access is unavailable.

7. Expected benefits

Payload Pilot allows members of the industry to calculate the SRT and safe payload height of a heavy vehicle combination. This especially aids small and medium industry participants who previously may not have otherwise been able to afford to engage a specialist to perform these assessments for them.

Access to SRT results allows industry to identify poor-performing combinations and adjust loading procedures to compensate. It also allows manufacturers to fine-tune their designs to have higher levels of rollover resistance. This has a direct link with safer road use through a reduction in rollover incidents as a result of improved SRT as well as other road related trauma due to the close relation between improved SRT and improved vehicle dynamic handling, particularly on curves.

A significant advantage of this method is that it allows not only new combinations but also existing vehicles to be analysed using this tool. By calculating their safe operating conditions, vehicles can be loaded and operated securely on roads, enhancing road safety.

This aspect is especially critical given that rollover and associated crashes significantly contribute to road trauma in Australia. Such incidents accounted for 12.5 per cent of all heavy vehicle accidents in Victoria in 2019, and in half of these cases, other road users including cyclists, pedestrians, and car drivers are involved (Australian Road Research Board, 2021). Between 2012 and 2021, a total of 1,881 people died in crashes involving a heavy truck, of which, over half were articulated combinations (BITRE, 2023). Assuming the same rate of rollover incidents across the country as Victoria, and a consistent proportion of rollover incidents over the time period, this gives approximately 235 deaths in rollover incidences. Many of these may have been avoided or mitigated through the use of tools like Payload Pilot.

8. Conclusion

Payload Pilot is a freely available online tool that allows users to input data for their heavy vehicle to determine either the SRT, a measure of rollover stability, or the maximum height of payload that can be achieved for a given SRT value. This tool caters to a wide range of skillsets and knowledge levels, making it suitable for most members of the industry.

It is anticipated that by providing a means for members of the heavy vehicle industry to evaluate the rollover risk of their combinations, they will be able to better structure their payload management plans and procedures to reduce incidents of rollover. As rollover incidents account for a significant portion of heavy vehicle accidents, a reduction would lead to safer roads for all road users.

The launch of Payload Pilot will provide a critical tool that will improve the safety of the Australian heavy vehicle fleet. This tool provides access simulations that were previously only possible with specialized engineering skills and expensive software. By enabling the calculation of the SRT, Payload Pilot helps industry members better assess rollover risks and highlight those which require additional mitigation.

Payload Pilot was successfully validated with a field trial, with results from the field being 1 to 6 per cent higher than the simulated result, indicating an acceptable conservative result being provided by Payload Pilot while not being overly conservative.

The wide array of heavy vehicle combinations available within Payload Pilot covers the majority of vehicles in use in Australia. The user-friendly interface ensures that even those with only general knowledge of heavy vehicles can use the tool, while also catering to more advanced users with additional input options.

Following the launch of Payload Pilot, Advantia will continue to maintain and improve the functionality of the tool over the next two years. Advantia will also be attending marketing and industry events to promote and demonstrate Payload Pilot to the heavy vehicle industry. This is part of an awareness-raising campaign to be conducted to ensure that the existence of Payload Pilot is known to industry so that its full benefits are realised.

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Appendix A Computer simulation of heavy vehicle dynamics

TruckSim

Computer simulation has been used to evaluate the dynamics of heavy vehicles since the 1980s. The University of Michigan Transportation Research Institute (UMTRI) initially developed simplified numerical models for researching some of the key aspects of truck stability, such as rollover threshold. The UMTRI researchers ultimately founded a software company and developed a full-featured commercial software package known as TruckSim. TruckSim has been on the market since the 1990s and is now recognised as the world's most advanced dedicated heavy vehicle simulation software package.

Computer simulation in Australia

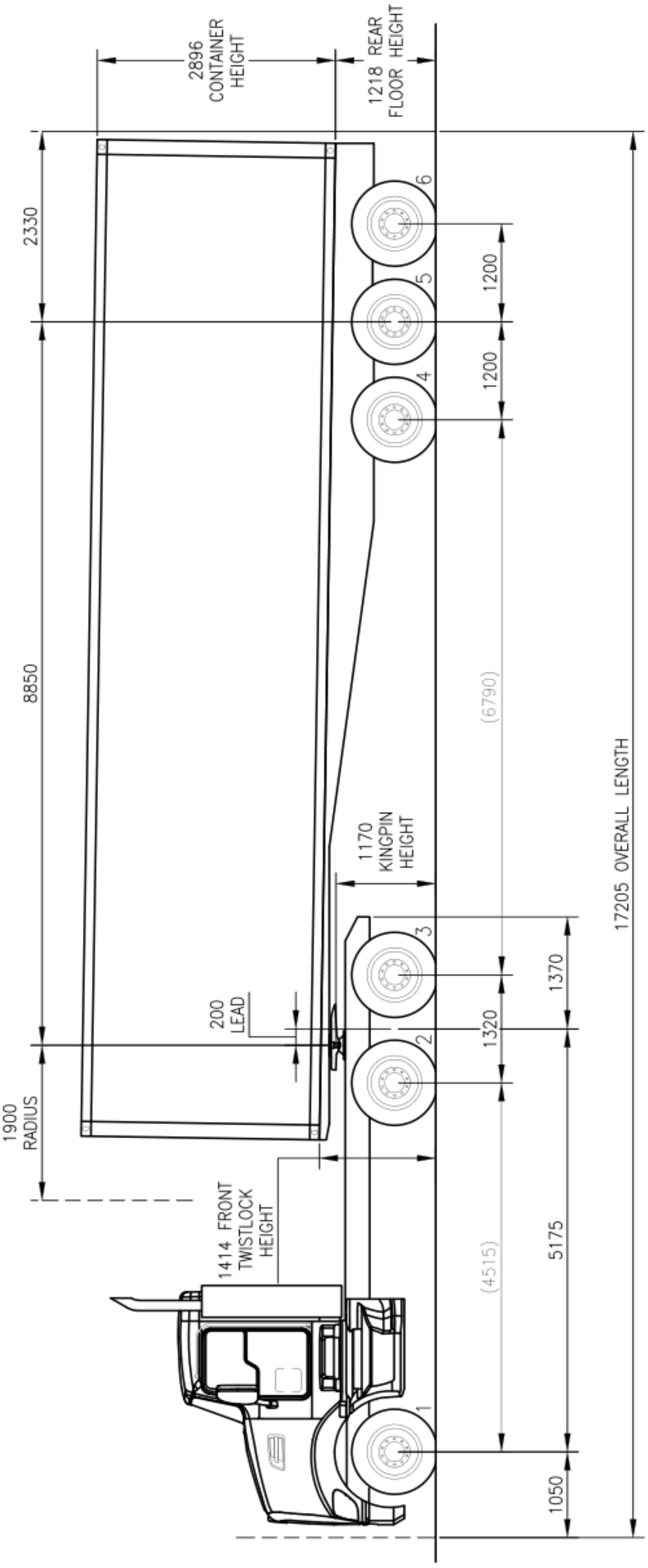
In Australia, computer simulation has been used since the 1990s to demonstrate the safety and productivity benefits of longer and heavier vehicle configurations. Multi-trailer road trains with up to six trailers were the focus of early work, where computer simulation compared their on-road performance with that of existing three-trailer road trains.

In the 2000s the focus shifted to smaller combinations such as semi-trailers, truck and dogs and B-doubles. Now there is a national Performance Based Standards (PBS) Scheme in place to manage these computer-based assessments.

Performance Based Standards (PBS)

The PBS Scheme was introduced in 2007. Its purpose is to enable road access approval for innovative heavy vehicle configurations that are more productive than regulation vehicles because they exceed certain conventional mass and dimension limits. A vehicle safety assessment demonstrates that the vehicle meets a set of safety-related performance standards. Service providers are accredited to perform these assessments by computer simulation.

Appendix B Test vehicle layout drawing



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