

# LEVERAGING CLOUD COMPUTING FOR HEAVY VEHICLE OPTIMIZATION AND IN-SERVICE PERFORMANCE ASSESSMENT



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## **Abstract**

This paper describes the design, development and implementation of a software platform to facilitate the use, evaluation, and design of regulatory frameworks and vehicle combinations related to Performance-Based Standards (PBS). While PBS is playing a pivotal role in Australian supply chain logistics the implementation of the scheme has been challenging. Complexity relies on multiple government departments and back-and-forth interactions of industry stakeholders in addition to a steep learning curve of numerical modelling techniques. A novel approach has been developed to assist procedures and mechanisms in the assessment of innovative designs of High Productivity Freight Vehicles (HPFVs). The solution provides users the ability to self-assess innovative ideas by facilitating the assembly, simulation and optimization of heavy vehicle combinations. The platform vision is to act as a Digital Ecosystem (DES) to promote innovative collaboration among the main economic actors to store, share and access technical information and provide capabilities of self-organisation, scalability and sustainability.

**Keywords:** High Productivity Vehicles, Performance Based Standards, Multibody Dynamics, Modelling, Simulation, SaaS, Cloud Computing, Digital Ecosystem

## **1. Introduction**

Australian logistics industry has directly contributed \$131.6 billion dollars to Australia's economy in 2013, representing 9 per cent of the nation's GDP. The freight task is projected to increase by 80 per cent between 2010 and 2030 mainly because every industry in Australia depends on transport and logistics to some degree (ALC 2014). Moreover, over 95 per cent of Australia's road freight is carried by heavy vehicle combinations (ABS 2013). However, there are many issues that need to be addressed by stakeholders in this industry, including: 1162 road deaths in 2014, an estimated 15 billion dollars of economic cost from congestion per annum, population growth to 30 million people by 2030, and divergent federal, state and territory transport laws (NTC 2015). These issues and objectives of productivity, efficiency, safety and sustainability are not isolated to the Australian freight industry, they are common global logistic challenges.

Performance Based Standards (PBS) is a scheme that has been successfully implemented in Australia to promote heavy vehicle productivity, safety and innovation (Kharrazi and Karlsson. 2015). PBS provides a framework for allowing high productivity, typically longer and heavier, vehicles access to the road network. The scheme provides the flexibility and allows vehicles outside of typical design limits to later be assessed using a performance-based approach. Under the scheme there are 20 safety and infrastructure standards which can be grouped in powertrain requirements, high speed stability, low speed requirements, and infrastructure impact and limits (NTC 2007).

Even though PBS plays a pivotal role in supply chain logistics and has been fully legislated and supported by the Australia National Heavy Vehicle Regulator (NHVR). The implementation of the scheme has been challenging. Moreover, users of the PBS scheme have reported that the scheme is time-consuming, complex, expensive and resource-intensive (NTC 2017). Complexity not only relies in dealing with multiple government departments but also in the non-standard application and techniques of multi-body dynamics modelling to recreate the behavior of several heavy vehicle combinations. These factors affect the promotion and exchange of knowledge among the different stakeholders in the industry, thus inhibiting the progress of the PBS scheme and slowing down the safety and productivity benefits that might otherwise accrue.

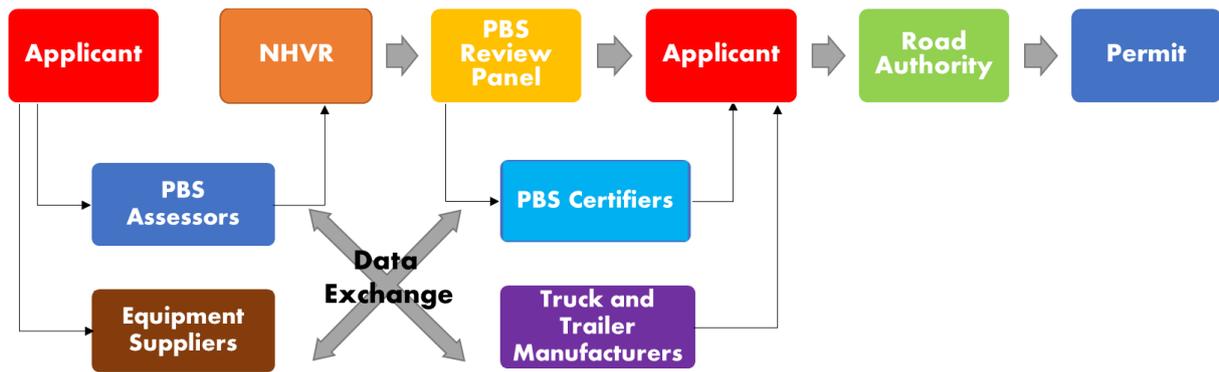
Tiger Spider has introduced a Software as a Service (SaaS) to assist the procedures and mechanisms to assess innovative and high productivity vehicle designs. The platform architecture allows different stakeholders to self-assess new ideas, share specific data and collaborate to design, configure, and simulate a vehicle combination.

## **2. Design Approach**

The software design considered the identification of industry stakeholders, interactions modeling between them and implementation and validation of different abstraction layers to simplify the modelling of PBS.

### **2.1 Freight Industry Stakeholders**

Kannan (2016) has identified participants in the current PBS scheme developed and implemented in Australia. However, this research has identified more complex interactions and back-and-forth workflows associated with the process of modelling, assessment, certification and road access of a PBS combination. More specifically, interactions between the Applicants, PBS Assessors, PBS Certifiers, Component, Truck and Trailer manufacturers and Regulators should be considered as highly iterative and asynchronous communication cycles.



**Figure 1 - Modified process diagram proposed by Kannan (2016) which emphasize more complex communications between stakeholders of the Australian PBS scene**

Even though the industry and governments are introducing improvements to the scheme to streamline administrative processes through PBS Blueprints, Gazette notices and PBS networks (Kannan, 2016), each of these stakeholders is using their own tools and methodologies to comply with their business processes. More importantly, information exchange is a key issue between them as a lot of business communications is performed using different medias or channels. Intellectual Property, sensitive modelling information and lack of standardization for data gathering is promoting information silos around stakeholders.

## 2.2 PBS Digital Ecosystem in the Cloud

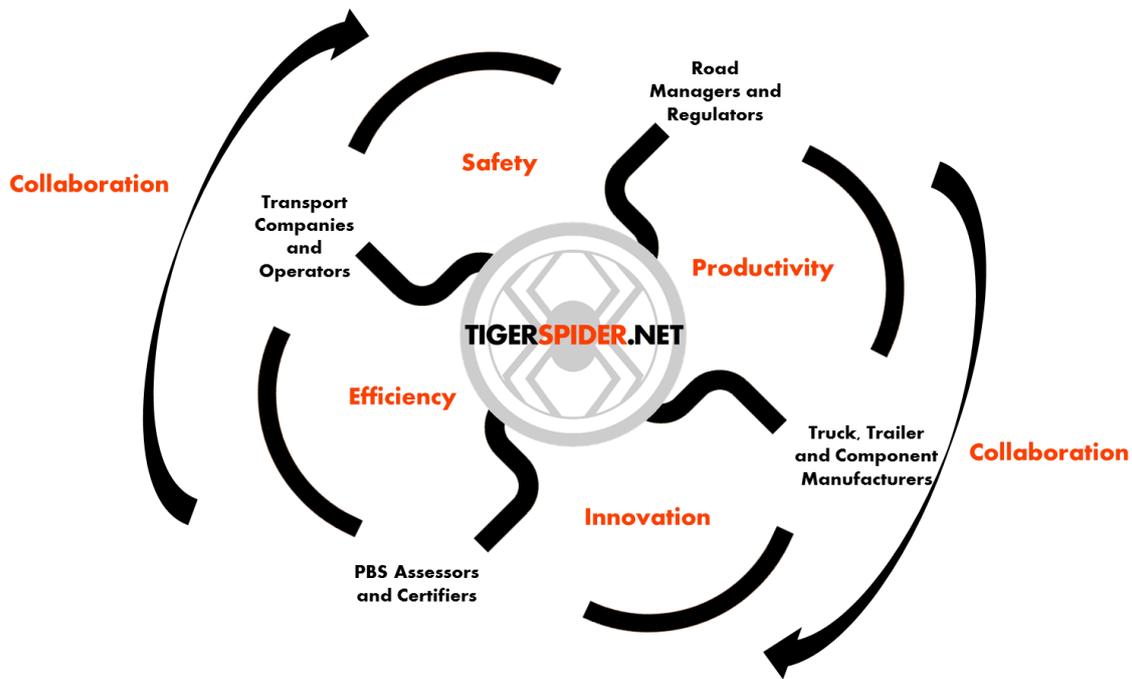
The shift to cloud computing may unlock and influence how these stakeholders develop, distribute, and implement their business models as well as how the PBS scheme could evolve over time. However, to maximize the value creation through Cloud Computing it is necessary to design a Digital Ecosystem (DES) and populate it with the industry stakeholders as Digital Species (DS). A DS, emulates biological species, by imitating mechanisms like autonomy, viability, and self-organisation to arrive at novel knowledge architectures (Hadzic et al. 2010).

A well-designed DES should be loosely coupled, domain-specific, and address demand-driven interactions and innovation between economic actors. Weill (2015) has defined that digital ecosystems are multi-dimensional and multi-directional and unlock the potential of a customer experience with increased “stickiness” and adoption, data-driven customer intimacy with faster feedback for quick learning, greater scale, and multidimensional mutual value creation between participants as well as opportunities in capitalizing on other emerging technologies.

A PBS Digital Ecosystem may not only unlock the inherent benefits of PBS combinations but also will improve the overall experience by offering an enhanced market access, rapid innovation, greater productivity growth and more importantly a streamlined, transparent and timely bounded process for the vehicle operator.

## 2.3 Tiger Spider Web: A novel approach to promote innovation

Within this context, a novel SaaS platform is proposed. This web application pursues the promotion of safer, more productive and sustainable freight vehicles by using the PBS scheme. Key architectural principles in this approach consider the principles of a DES to promote innovation and collaboration between industry stakeholders.

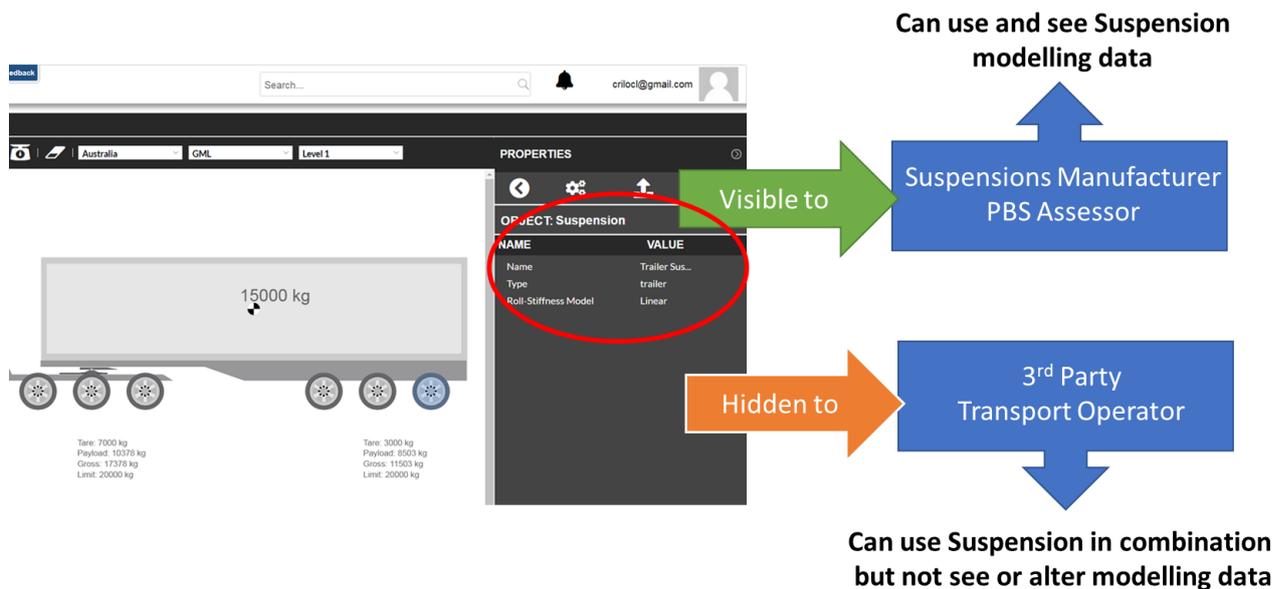


**Figure 2 – Collaboration for different stakeholders involved in the freight industry**

Challenges in the design of a DES were identified. The following points consider architectural decisions in the development of the software.

**Privacy Concerns**

The data and models used within the platform are encrypted and hashed. Moreover, the platform allows to hide specific sensitive data when sharing components, models, or other entities in the platform.



**Figure 3 – Visibility and data protection from unauthorized users**

**Model Library Structure**

A nested component isolation for the embedded simulator in the cloud was considered. Tradeoff between complexity and accuracy are part of the modelling assumptions and given models of

the platform. However, users can also improve each model independently using advanced modelling tools.

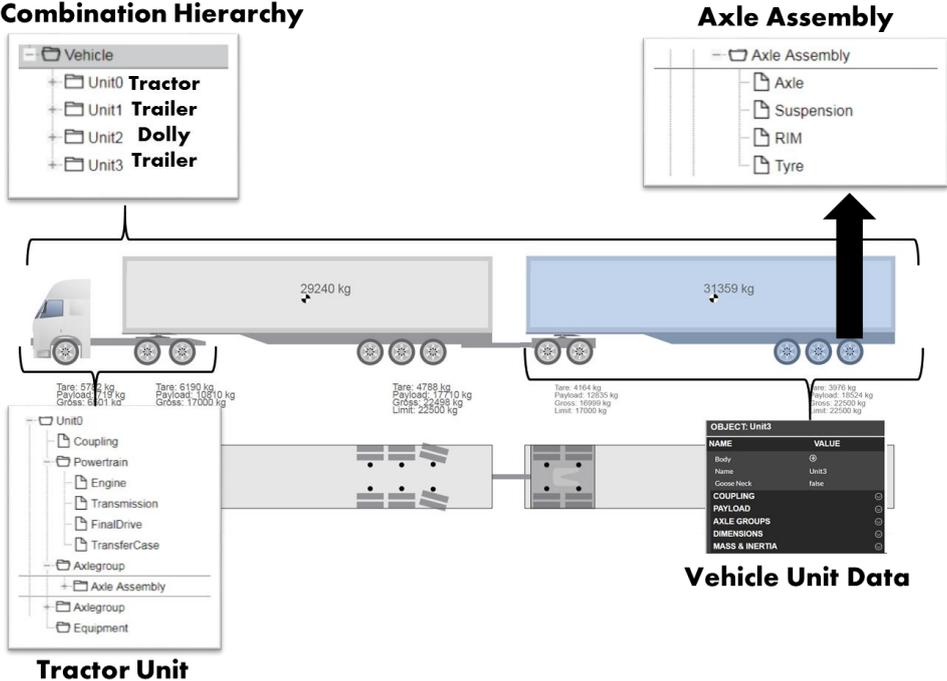


Figure 4 – Visibility and data protection from unauthorized users

**Loosely Coupled Innovation**

Advanced modelling is a feature that allows the end user to download the Cloud model to analyse, improve or test components or vehicle units in The Universal Mechanism (UM) physics engine. UM is a powerful multi-body dynamics software used for the simulation of kinematics and dynamics of planar and spatial mechanical systems. UM is used for computer-aided modelling of multibody and hybrid systems of various types, including complex aerospace structures, robots, railway vehicles, automobiles, heavy trucks, military vehicles and cable systems.

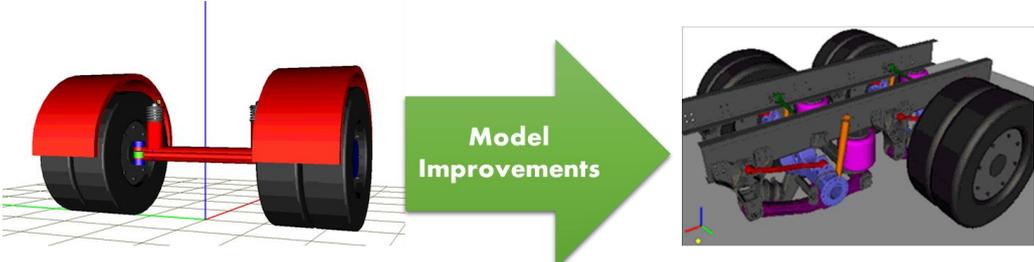


Figure 5 – Model enhancement when downloading the model from the cloud

**Collaboration**

Users can exchange models and results by leveraging all the previous architectural assumptions. Data can be hidden when necessary and this can allow users to share only PBS results (3rd party or assessors) and hide sensitive modelling data. Specific mechanical models can also be hidden

from the central model library structure when downloaded. At the same time, users can provide access in later stages or to different users if they wish to start collaborating.

**Cloud Scalability**

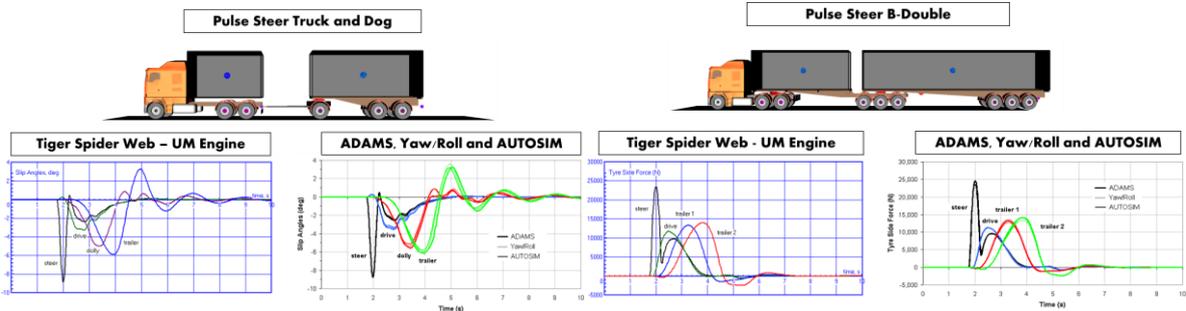
The application can scale out or scale up depending on the type of simulation and workload intensity as the application is running in a heterogeneous cluster (Wang, W. 2015). Adaptive algorithms scale out and process multiple simulations at the same time or to scale up to accelerate processing time when running more complex vehicle combinations. Moreover, users do not need significant computational power as simulations can be triggered by any web enabled mobile device.

**Ease to use**

The steep learning curve and computer modelling expertise required is reduced by absorbing the complexity when dealing with PBS concepts. Further analysis and modelling can be performed when downloading the model into the desktop application.

**2.4 Physics Engine Validations**

Cloud models assessed by the National Transport Commission of Australia (NTC (2001)) in other commercial packages were reproduced and created using the Cloud Application. Part of the dynamic results are displayed in the following figures for a Pulse Input test in an open-loop steer simulation. Output results are consistent in a total of four simulations when modelling identical input data in Tiger Spider Web, (refer Figure 6).



**Figure 6 – Model validation for a Truck and Dog and B-Double. Physics Engine (UM) of Tiger Spider Web (left) and NTC validation paper between other modelling packages (right)**

Further validation was also performed against field test data and the software package Altair MotionSolve in the Austroads research report AP-R483-15. The following figures are part of the different test and sensitivity studies explored in the report.



### 3.1 Assemble and combine different vehicle units

The proposed solution offers a diverse range of commercial vehicle units and allows the user to assemble bigger combinations by combining pre-built and ready to use models. Each of these units are highly customisable and are initially loaded with generic components, dimensions, and inertial properties. Units can be assembled by clicking on the icons of the simulator panel and a full 3D representation of the model will be created in the cloud.

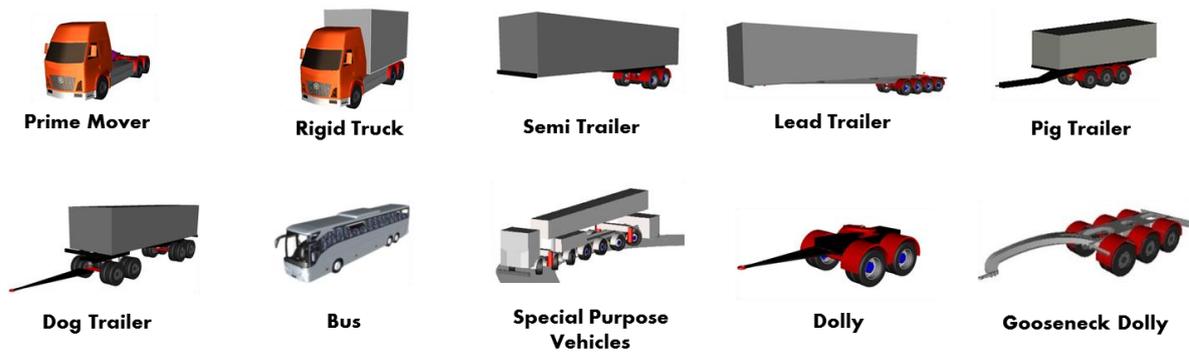


Figure 8 – Pre-made vehicle units in the web portal

### 3.2 Modification of geometry and payloads of the entire vehicle combination

Changes in axles, dimensions, geometry, and weight distribution are reflected in 3D models allowing the user to quickly test different batches of simulation studies and view the results upon completion. Different regional schemes, legal limits, and bridge formulas can also be applied, and the whole combination can be optimised to comply with these limits. The application allows the user to perform parametric and sensitivity studies and assess how each parameter affects vehicle performance.

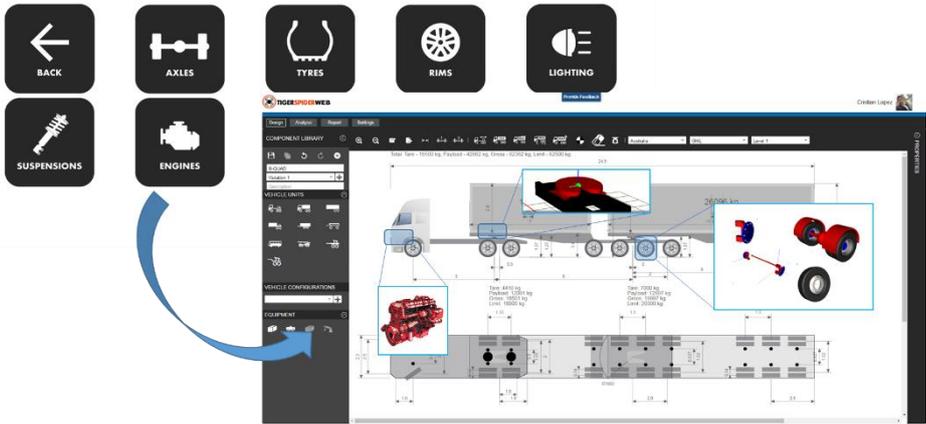
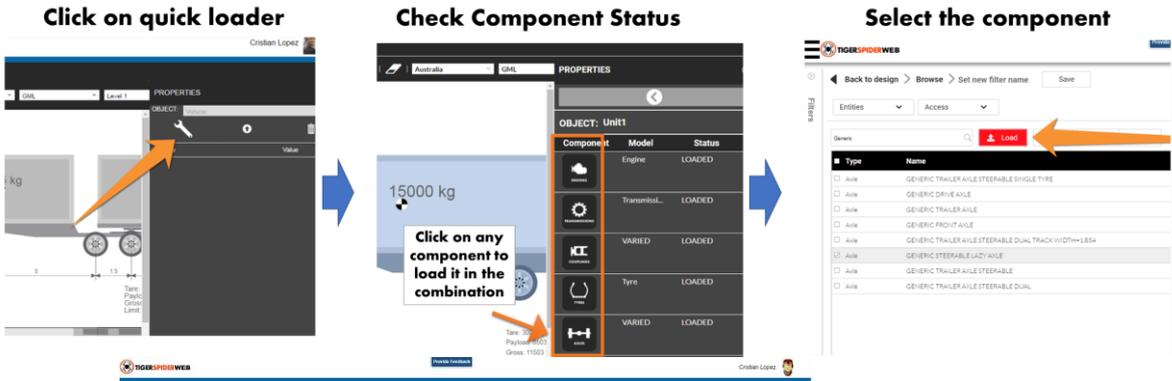


Figure 9 – Variations in modelling techniques are reflected in the cloud model

Several analytical tools are implemented in the application to intelligently change the geometry or loads in the vehicle combination. Weight distribution optimisation and compliance, D-rating calculators, bridge assessments tools, and the possibility to check a vehicle combination against federal, state or institutional regulatory frameworks are just a few examples of applications that are being used in the platform.

### 3.3 Addition of premade manufacturer components

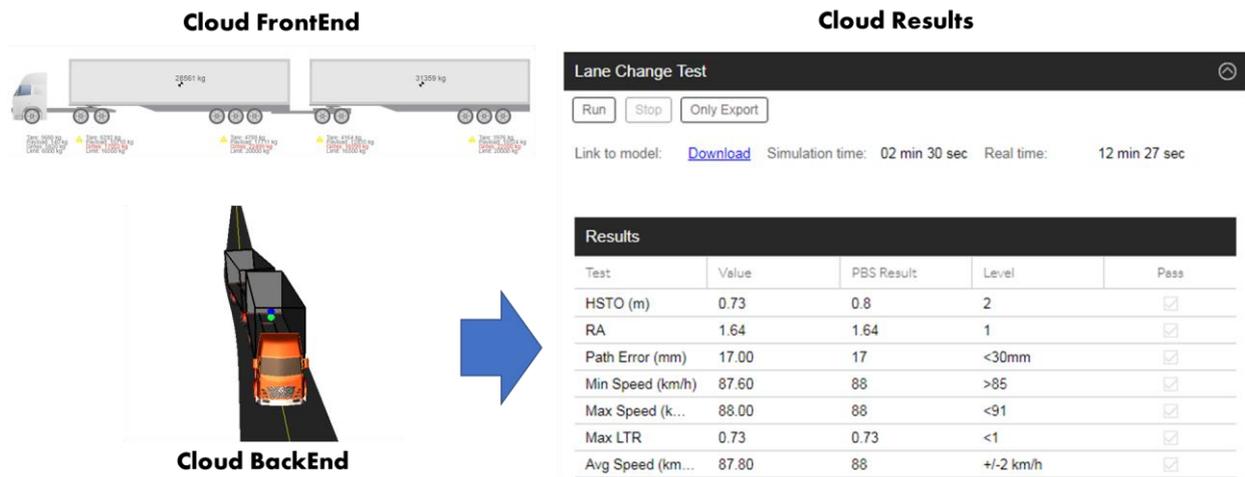
The solution offers a repository of technical information for generic components as well as a product listing capability to allow manufacturers to directly control their component and share it with specific users or collaborators. The interface can display valuable information of each component such as specifications, documentation and preview pictures. More importantly, it provides the right architecture to control and hide specific data of target users whilst allowing them to load the component in their models.



**Figure 10 – Component selection can be made through a Quick Loader feature. It allows users to browse, explore and filter the database that the user can see**

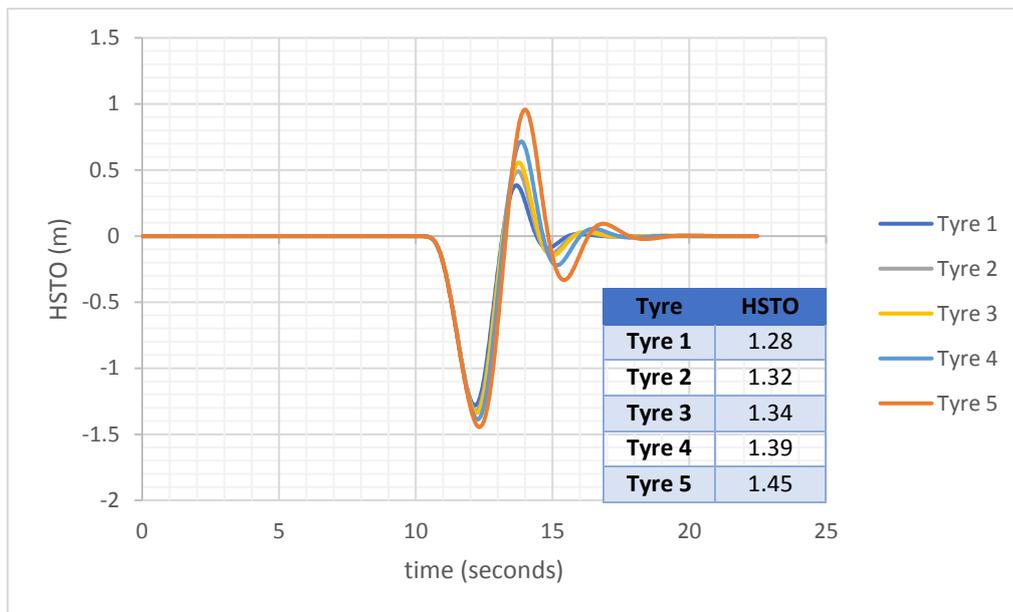
### 4. Results, Simulation and Analysis of the Dynamic Behaviour of a Vehicle Combination

The application has the complete PBS scheme ready to be used with the model created by the user. The software builds a technical drawing in the user interface and then creates each part of the model in the backend. Data such as number of bodies, geometry, components and test variables such as speed or friction coefficient is taken as input data and combined with the pre-built model in the cloud. The entire mechanical system is saved to perform different types of tests. All kinematical and dynamical performances are recorded by the application, analysed and then displayed as part of the simulation results.



**Figure 11 – Example of simulation results for an A-double in a Lane Change**

A “scanning study” was performed by loading different tyres in a generic A-double in the web application. HSTO behavior is displayed in the following figure.



**Figure 12 – Example of a variability in the results for A-double in a Lane Change with different tyres**

Multiple lane change tests replacing tyres with different cornering stiffness were simulated and different HSTO behavior was obtained. Variability was also detected in Rearward Amplification (RA) and Load Transfer Ratios (LTR) results. Even though this experiment demonstrates the input-output effect by changing one specific component in the vehicle combination, further analysis of data relationships is outside the scope of this paper.

#### 4.1 Prescriptive Approvals and Regulatory Frameworks

In addition to the vehicle design, simulation tools and engineering calculators the Platform provides the ability to describe and automatically check prescriptive truck size and weight limits. This means that users can leverage existing pre-approved blueprint designs without having to re-assess a combination using computer simulation. This is a key feature for

streamlining the PBS access application process so that approved designs can be linked to restricted road networks.

#### **4.1 Quality Assurance and Digital Certification Records**

The Digital Certification Record (DCR) is a virtual representation of a physical asset that has been inspected and verified to comply with PBS requirements. By maintaining a DCR data associated with the actual vehicle, i.e. photos and check measurements can be recorded on a capture on a mobile device and uploaded to the cloud for future reference. The DCR also retains a computer model on file in a central repository that can be accessed via the internet so that a trailer can be recombined with a different towing unit in the future and easily re-assessed to verify PBS compliance. This process allows for higher utilization of existing vehicles across a fleet without the need settle with sub-optimal designs to allow for compatibility with other fleet assets. By storing asset records and automating the assessment process, fleets can assess new vehicles in conjunction with their entire existing fleet to gauge compatibility and expected future utilization.

Currently, Tiger Spider is researching the implementation of DCR using blockchain technology which is expected to further enhance trust in the PBS DES and enable future automation of PBS application processing.

#### **5. Discussion**

Vehicle design concepts and variations in the study of PBS are almost limitless. Variations and cloud capabilities have shown the potential to create unlimited possibilities and variations to obtain different results. Development of sensitivity studies in all dimensions of the PBS spectrum can be performed easily and reiteratively. This enables the possibility to develop prediction models using neural networks as proposed by Berman et. Al (2016) to quickly predicts new PBS results without running simulations and providing instant PBS performance. Component classification tests, systems and frameworks can be formulated by studying large quantities of data generated by the webportal. Tiger Spider has been leveraging these capabilities to develop a tyre performance framework (Coleman, M. 2018). In practice, similar studies could be applied to practically any type of component who influence in the end performance of a vehicle. Furthermore, modelling accuracy and sensitivity may dictate new testing criteria for components and data standarisation to obtain better results in the overall PBS modelling process.

Model validation shows good performance against other software packages and field testing data. Moreover, further modification and improvement of models is also possible since privacy has been addressed in architectural decisions. Work is still being done to complete and improve the overall UI/UX in the application to simplify even more the creation of vehicle combinations to date.

#### **6. Conclusions**

Tiger Spider Web has facilitated the improvement and design of HPFVs in Australia. Key architectural decisions were considered as well as stakeholder interactions when outlining the application. Privacy concerns were particularly addressed to enable the storage, share and use of technical information. Variability in results when exchanging components and changing dimensions is promising. All these features will allow self-organization and encourage innovation among the economic actors. Outcomes may include speeding up the overall process and increased certainty for transport operators. Hence, increasing the adoption of the framework

by the rest of the industry. The Web Portal has presented the potential to help the industry to improve its products, provide better laws, model better components, and create safer and more productive vehicles around Australia and the world in a loosely coupled, demand-driven, and collaborative environment.

## References

- Australian Bureau of Statistics. (2013). Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2012. Catalogue no.9208.0. Prepared by Australian Bureau of Statistics, Canberra
- Australian Logistics Council. (2014). The economic significance of the Australian logistics industry. Prepared by Australian logistics Council, Canberra
- Berman, R. J., Benade, R., Rosman, B., & Nordengen, P. A. (2016). Hyperperformance: predicting high-speed performance of a b-double.
- Briscoe, G., & Marinos, A. (2009). Digital ecosystems in the clouds: towards community cloud computing. In *Digital Ecosystems and Technologies, 2009. DEST'09. 3rd IEEE International Conference on* (pp. 103-108). IEEE.
- Coleman, M. (2018) A framework for heavy vehicle tyre cornering performance assessment and classification within the Performance-Based Standards Scheme. (HVTT15)
- Coleman, M., Kovalev, R., Buyval, A., & Longhurst, B. (2015). PBS Level 3 and 4 standards review (Austroads Publications Online. AP-R483/15).
- Hadzic, M., & Chang, E. (2010). Application of digital ecosystem design methodology within the health domain. *IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans*, 40(4), 779-788.
- Iyawa, G. E., Herselman, M., & Botha, A. (2016). Digital health innovation ecosystems: From systematic literature review to conceptual framework. *Procedia Computer Science*, 100, 244-252.
- Kannan, S. (2016). Allowing truck trailers at PBS mass limits. In *HVTT14: International Symposium on Heavy Vehicle Transport Technology*, 14th, 2016, Rotorua, New Zealand.
- Kharrazi, S., Karlsson, R., Sandin, J., & Aurell, J. (2015). Performance based standards for high capacity transports in Sweden: FIFFI project 2013-03881: Report 1: Review of existing regulations and literature. Statens väg-och transportforskningsinstitut.
- National Transport Commission (NTC) (2001). Comparison of modelling systems for Performance Based Assessments of Heavy Vehicles. (Performance Based Standards – NRTC/Austroads Project A3 and A4).
- National Transport Commission. (2007). Performance Based Standards Scheme–The Standards and Vehicle Assessment Rules. Prepared by National Transport Commission: Melbourne, Vic.
- National Transport Commission. (2015). Leading National Transport Reform. Annual Report 2014-2015. Prepared by National Transport Commission: Melbourne, Vic.
- National Transport Commission. (2017). Assessing the effectiveness of the PBS Scheme. Discussion Paper. Prepared by National Transport Commission: Melbourne, Vic.
- Nordengen, P. A., Prem, H., & Mai, L. (2008). Initiative to introduce a performance-based standards (PBS) approach for heavy vehicle design and operations in South Africa.
- Wang, W., Xu, L., & Gupta, I. (2015, March). Scale Up vs. scale out in cloud storage and graph processing systems. In *Cloud engineering (IC2E), 2015 IEEE international conference on* (pp. 428-433). IEEE.
- Weill, P., & Woerner, S. L. (2015). Thriving in an increasingly digital ecosystem. *MIT Sloan Management Review*, 56(4), 27.