White Paper
An innovative leap in towage

The TRAnsverse Tug

SVITZER

Contents

Executive summary

As vessels become larger, weather conditions more extreme, and ports more congested, the demand for tugs to assist vessels safely in and out of ports and terminals continues to increase. The logical consequence is that the tugs gradually need to become more powerful – unless...

With its revolutionary design, Svitzer's TRAnsverse tug takes manoeuvrability and towing capabilities to the next level. For instance, in dynamic modes the TRAnsverse tug expands the operating envelope by around 50% compared to similar or larger ASD tugs. Furthermore, the TRAnsverse tug has shown a fuel efficiency gain of 15%. As a result, the TRAnsverse tug can perform a wider variety of jobs, do them faster and more fuel efficient, and generally deliver a higher level of safety.

The static Bollard Pull demonstrates the maximum force a tug can exert when stationary, which is an unlikely scenario during actual operations. The TRAnsverse tug design, while still achieving the static bollard pull requirements, also greatly improves the dynamic Bollard Pull capabilities (direct towing capabilities). This metric is more relevant for real-world performance as it reflects the force exerted during movement, aligning more closely with operational conditions.

The entire value chain across global sea trade relies on the shipping industry to tackle congestion, climate change and increased global trade together. That is why continuous engagement with customers, pilots, and other port stakeholders about their day-to-day challenges is deeply embedded in the innovation process that led to this multipurpose tug. We believe the TRAnsverse tug is better at solving many towage-related challenges that port stakeholders experience today. Svitzer's TRAnsverse tug answers todays and future towage needs.

This white paper explains how the TRAnsverse tug's design and technical features make it superior for current and future towage demands.

Kasper Karlsen
Chief Operating Officer

The need for a new tugboat design

Port congestion is a major challenge in global shipping, causing delays, driving up costs, and creating ripple effects throughout supply chains. One reason for this development is how vessels have become larger and larger; look at how large a container vessel is today, or an LNG carrier. Getting these major vessels in and out of ports takes much effort.

The answer has been to build larger and more powerful tugs to service these growing sizes of vessels as well as the increased trade activity. But what if we could build smarter? A tug with better operational capabilities enables it to handle any towage jobs faster, safer, and more fuel efficiently, despite extreme weather conditions.

The TRAnsverse design is a leap forward in tug design. Its high performance, advanced manoeuvrability, intuitive operation, exceptionally fast response time and inherent safety features will certainly contribute to safer, more efficient operations. And it can provide a tailored solution for key port challenges.

Aim of the new design

The initial concept for the Robert Allan-designed TRAnsverse tug was established in late 2019. The idea was to develop a fuel-efficient platform with enhanced manoeuvring and escort capabilities to improve service delivery to Svitzer's customers further. This should be achieved while employing well-known technology elements and as few moving parts as possible to improve safety, keep costs down, and maintain reliability.

Svitzer's development team took the approach of starting with the towing arrangement and defining what must be achieved concerning tow point placement and freedom of movement.

The core design concept was to establish a towing point that could maximise the benefit of indirect and direct towing forces. To achieve this, a towing stable was developed that increased the range of angles that could safely be achieved for the towing line leading from the main winch. Like other historical tug designs, this arrangement avoids additional mechanical equipment and other moving devices on deck, thereby improving crew safety and cutting maintenance complexity.

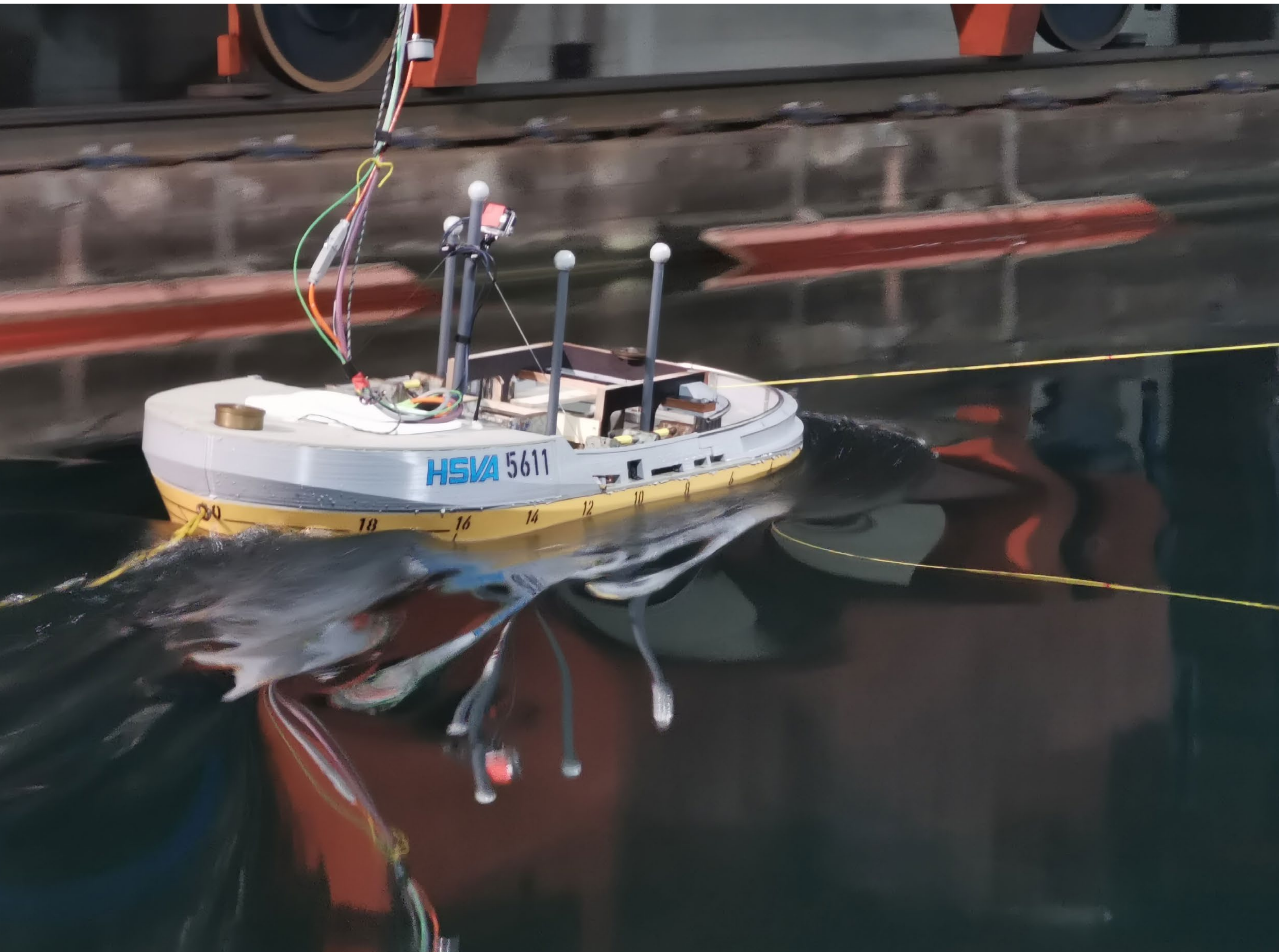
For any tug, the operational envelope and resulting performance are limited by:

- **Stability:** measured as a function of the resulting heeling angle under tension on the tow line.
- **Manoeuvrability:** defined by which manoeuvres can be carried out whilst unconnected or connected at any given speed.

Throughout the design process for the TRAnsverse tug, the intention was to widen the operational envelope and challenge preconceptions about tug design. The optimisation work was done by applying a holistic approach, where the design elements were assessed when combined.

Refining the design using tow-tank tests

Figure 1: TRAnsverse Scale model used in tow tank tests



In January 2021 and December 2022, a scale model of the design (Figure 1) was built to test the potential of the towing point and hull design. This remote-controlled model was put through a five-day test program at the Hamburgische Schiffbau-Versuchsanstalt (HSVA) tank test facility in Hamburg, Germany. The model was designed to accept several skeg designs as well as a movable tow point to allow refinement of the design and identify the optimal arrangement to maximise towing forces without compromising on stability and safety.

To operate the model tug, two experienced captains 'piloted' the model so that their real-world experience of sailing double-ended or omni-directional tugs was captured in the tests.

The main performance metrics measured were as follows:

- Directional stability and manoeuvrability of the tug in both directions (ahead/astern)
- Side stepping performance/manoeuvrability
- Direct towing, i.e. harbour push/pull operations over various speeds
- Indirect towing, i.e. Indirect steering and braking manoeuvres for escort operations both from the rotating tow point and at fixed positions

The optimal skeg configuration proved to be dual side skegs. In this configuration, we can sidestep up to 6-8 knots while achieving excellent directional stability.

Design	Side stepping speed
TRAnsverse 3200 – 80BP	6.5 knots
TRAnsverse 2600 – 60BP	8.0 knots

Live sea trials

Before the first TRAnsverse tug, Svitzer Taurus, entered service in the Port of Amsterdam (IJmuiden), the Netherlands, the design team from Svitzer and Robert Allan conducted live sea trials in the port. The trials aimed to document whether the tug's capabilities aligned with Tank Test results and correlated with Computational Fluid Dynamics (CFD) data points.

The trials were conducted over a week, allowing us to test the tug in various operational scenarios. The trials have confirmed that the TRAnsverse design has exceptional maneuverability, versatility and capability while performing all the operations it has been designed for.

Figure 2: Aerial view of design rendering showing the rear superstructure covering the winch and forming the towing staple.

Key design elements

The TRAnsverse tug's operational capabilities are based on several distinct design features that differentiate it from other tug designs and, in combination, enable it to manoeuvre and operate in ways no other tug can.

The Svitzer half-circle staple.
The towing staple was developed especially for the TRAnsverse tug and is a key element in this new vessel design. The aim was to develop a mechanical device supporting more advanced manoeuvres. The resulting staple design dictated the ideal hull and propulsion philosophy to maximise the benefits of the overall package.

The basic idea of the patented towing staple is to increase the tug's stability in operation (righting moment), improve its direct and indirect capabilities, and increase manoeuvrability when the tug is connected to the ship while also helping to avoid thruster-to-thruster interaction.

The shape and placement of the tow point are critical to the tug's overall performance. The design (see Figure 2) establishes a low-maintenance towing setup that allows for advanced manoeuvring while perfectly balancing the hull and propulsion layout.

Figure 3: Side view of design rendering showing the thruster location and skeg arrangement.

Double-ended hull and propulsion
Following the finalisation of the staple arrangement, a key priority has been a propulsion layout that maximises the benefit of the staple design. Propulsion units on either side of the tow point (see Figure 3) provide superior manoeuvrability under tension when comparing to predominant tug designs.

The selection of two thrusters also simplifies the mechanical layout for the power train and control of the tug for the Master. Control is highly intuitive as the Master operates one thruster with each hand, including both the power and direction of the thrust. Moreover, if the Master needs to turn around and sail in the opposite direction, the drive placement relative to the hand in control stays the same. Ease of operation has been considered in the design process as it generally increases safety margins and improves the familiarisation process and training time for new crew members. Also, the training of Masters has confirmed that the TRAnsverse is intuitive to operate, improving safety by allowing more attention to situational awareness.

The propulsion units selected for the design are the well-known azimuth thrusters seen on most tugs in the industry. However, the TRAnsverse tug design provides higher slewing rates than the industry norm to ensure high manoeuvring responsiveness.

The hull is designed to sail equally well in both directions, and considerable efforts have been made to optimise the placement of the thrusters to avoid thruster-to-thruster interaction when the tug carries out full bollard pull at 0 knots. Tow tank testing of the thruster placement allowed us to confirm that the tow point was correctly positioned for this configuration.

With one designated working end, it has been possible to design a slender profile allowing the tug to work close to pronounced flares on assisted vessels and use a high "bow" to ensure comfortable mobilisation in rough weather with minimum water on the foredeck.

Performance compared to the market

The Azimuth Stern Drive and Azimuth Tractor Drive tugs have become the most common designs on the market. These traditional designs perform well in challenging operations around the globe. The manufacture and performance of these designs are well understood in the industry, with ASD and ATD tugs being cost-effective solutions that will deliver acceptable performance over a wide range of operation profiles. However, some downsides with these designs are addressed with the TRAnsverse tug, enabling it to deliver more substantial capabilities across a wider speed range than the norm.

Predominant tug designs have the two drives placed next to each other, and the skeg and the tow point at the opposite end from the thrusters. This configuration limits the side-stepping capability at higher speeds and manoeuvrability when the towline is under tension. These design limitations significantly affect the traditional tug's capability for positioning during vessel assistance. By positioning the thrusters at both stern and bow and locating the tow point between them in the TRAnsverse tug, we have been able to address these limitations.

In the following pages, we will discuss the main business and operational benefits of the TRAnsverse Tug design.

More fuel-efficient operations

During the first months of operations the TRAnsverse tug, Svitzer Taurus, has been conducting over 200 tug jobs and while comparing with the existing Svitzer fleet of tugs working alongside the Taurus in Amsterdam, during the same period, a fuel efficiency gain averaging 15% under the given circumstances has been recorded. The precise fuel efficiency still needs to be defined because we do heavier work and 'joy rides' that are artificially increasing the fuel consumption compared to what we would expect under normal operation.

1

Direct and indirect force
More direct and indirect force across the range of vessel speeds for arrival and departure, resulting in less time and fuel needed to achieve the required rate of turn (ROT) for the assisted vessel.
The TRAnsverse tug is able to generate approximately 50% higher forces than an ASD of comparable size and engine power in dynamic modes (more than 3 knots). The abillity to side push over a wide range of speeds allow the tug to stay in position while being able to apply high forces instantly for pushing as well as pulling.

2

Push and sidestep
The ability to push and sidestep under the flare results in less time and fuel to achieve the required ROT for the assisted vessel. The distance between the tug's pushing point and the pivot point determines the turning lever, so a greater distance improves the manoeuvrability of the assisted vessel during operations. Turning moment equals turning force x turning lever, which means it is advantageous to extend the turning lever by applying force closer to the ends of the assisted vessel.

3

Manoeuvrability
Greater tug manoeuvrability means less power is required to position the tug as needed during operations.

4

Hydrodynamic force
Better usage of hydrodynamic force during pulling means free force during braking. The TRAnsverse design can generate usable hydrodynamic force from lower speeds than predominant tug designs.

5

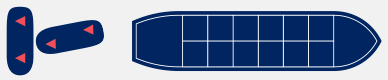
Transition capability
Improved transition capability e.g., during direct pulling CLA, changing from a 6 to a 3 o'clock position, will require less power and fuel than other tug designs.

Tug towing mode: operational capabilities

The following will explain the TRAnsverse tug's manoeuvrability benefits in more detail, using examples of different towage operations.

In general, in dynamic towage modes, the TRAnsverse tug design expands the operating envelope by around 50% compared to similar and larger ASD tugs. Especially prominent at speeds higher than 3kts where the forces are maintained and increasing. Connection, operation, and berthing can be delivered under a broader range of conditions than for a standard ASD, such as during higher wind speeds, stronger currents, and rougher seas. The ability to provide towing forces at higher speeds also means the job can be completed quicker than standard tugboats, on average.

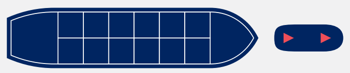
The first TRAnsverse tug, the Svitzer Taurus, is a 26m design while we have both 29, 32 and 35m versions in the new building pipeline dimensioned to serve the customer demands and operational conditions in their designated ports. These operational capabilities are explored below.



Centre lead aft direct and indirect braking

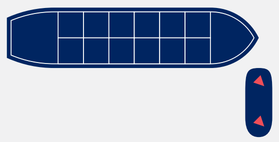
As the TRAnsverse name implies, the tug can easily be positioned transverse to the assisted vessel's travel direction. This maximises the opportunity to use the hydrodynamic forces of the hull and the thrusters in combination. This will ensure highly efficient TRAnsverse braking performance, superior to the capabilities of traditional omni-direction tug designs of the same size (Figure 8). Note, that in contrast to the TRAnsverse tug, an ASD tug usually uses arrest mode during braking.

The thruster location on the hull in relation to the towing point allows for quick, easy manoeuvring into position and can provide steering forces on either side of the towed vessel quickly and, most importantly, safely due to effective vessel positioning. The design ensures that under loss of power, the tug is pulled safely through the water due to the location of the towing point, naturally shifting to a 'bow forward' attitude in the water when the tow line is under tension.

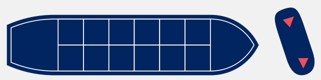


Centre lead forward

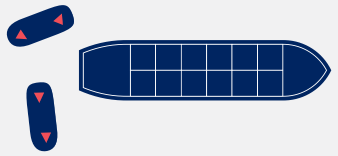
During centre-lead forward operation, the TRAnsverse tug can easily be controlled to maintain a heading and position due to the separated fore and aft thrusters. Combined with simple controls, the tug can maintain speed and position, saving time, which creates an operational advantage for our clients and the general running of the operation.



Unlike other tug designs, the TRAnsverse tug can create a controlled pulling effect, manoeuvre in all directions with increased speed, and effectively change modes from direct to indirect mode.



The TRAnsverse tug has high manoeuvrability capabilities and can be operated within confined spaces such as canals and locks. It can provide reverse indirect steering forces on the bow at low speeds and potentially reduce tug numbers and requirements within particular operations and port locations.



Centre lead aft indirect steering and direct pulling

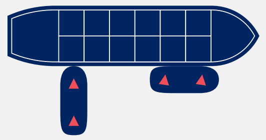
The TRAnsverse tug can easily manoeuvre into position to quickly and safely provide steering on either side of the towed vessel.

The omnidirectional propulsion system allows for a safe, quick, and smooth transition from one towing mode to another, both direct and indirect towage methods. Both styles can be used for bespoke towage operations and accurate manoeuvring while berthing and unberthing vessels of all sizes and characteristics.

Generally, indirect steering methods are incredibly effective at speeds above 8 knots, but traditional tug designs' manoeuvrability is not great. This is different for the TRAnsverse tug. The effect of the increased manoeuvrability of the TRAnsverse tug becomes evident in the transition between direct and indirect mode at speeds from 2 to 7 knots. The TRAnsverse tug can perform direct push and pull, generating high forces from 2–7 knots. It can remain effective at speeds up to 8 knots with a smooth transition from direct to indirect modes, ensuring rapid and effective towage response.

Figure 8 below compares a TRAnsverse tug to an ASD tug during different towing modes using Computational Fluid Dynamics. It shows that the TRAnsverse tug can provide direct assistance at higher speeds than the ASD tug and has a smoother transition to indirect mode. Furthermore, the generated forces are higher from 1-2 knots through the speed profile compared with the ASD tug. We saw a good correlation between CFD and tank test results and actual performance in the real-life trials.

These capabilities are a significant improvement and have the potential to become game-changing in the towage industry.



Push operations

The TRAnsverse tug can generate high forces over a wide speed range when pushing the assisted vessel. In these operations, the performance of predominant tug designs can deteriorate quite dramatically when the speed exceeds 4 knots; this is not the case for the TRAnsverse tug. Fore and aft thrusters reduced the amount of power expended on vectoring forces to hold the tug's position. This means that more power can be exerted on the pushing aspect of the operation as opposed to maintaining forward speed. This benefit is shown in Figure 9, which shows the magnitude of the pushing force at varying speeds for the TRAnsverse tug and traditional ASD designs. The size of the pushing force is maintained over a much wider speed range in both parallel and direct pushing operations. When the TRAnsverse tug is in a parallel position alongside the vessel and due to parallel push and pulling capabilities, the tug is ready to provide an immediate response to the Pilot order in pushing and pulling mode.

Furthermore, the TRAnsverse tug can easily escape the suction forces that will inevitably form between 2 vessels whilst working at close range while sailing due to its manoeuvrability.

For pushing operations, the general geometric layout of the tug with the superstructure far away from the working end provides a slender profile that makes work close to pronounced flares safer and the likelihood of collision with the superstructure is reduced

These key advantages of the TRAnsverse tug allow the Master to apply greater forces during dynamic towing across a broader range of speeds and greater flexibility over the working location of the tug against the assisted ship's hull – thus maximising the turning lever and turning moment that can be achieved. This dramatically changes the pilot's capability for safe, efficient manoeuvring of the assisted vessel.

The improved side-stepping capability of the TRAnsverse tug allows the tug to exert greater pushing forces as speed increases relative to the ASD. Power consumption levels are correspondingly higher for the ASD due to the higher vectoring thrust requirement to maintain position, therefore reducing direct pushing force as speed increases.

Figure 8A
Direct and indirect Steering comparison between TRAnsverse 32m and ASD 32m

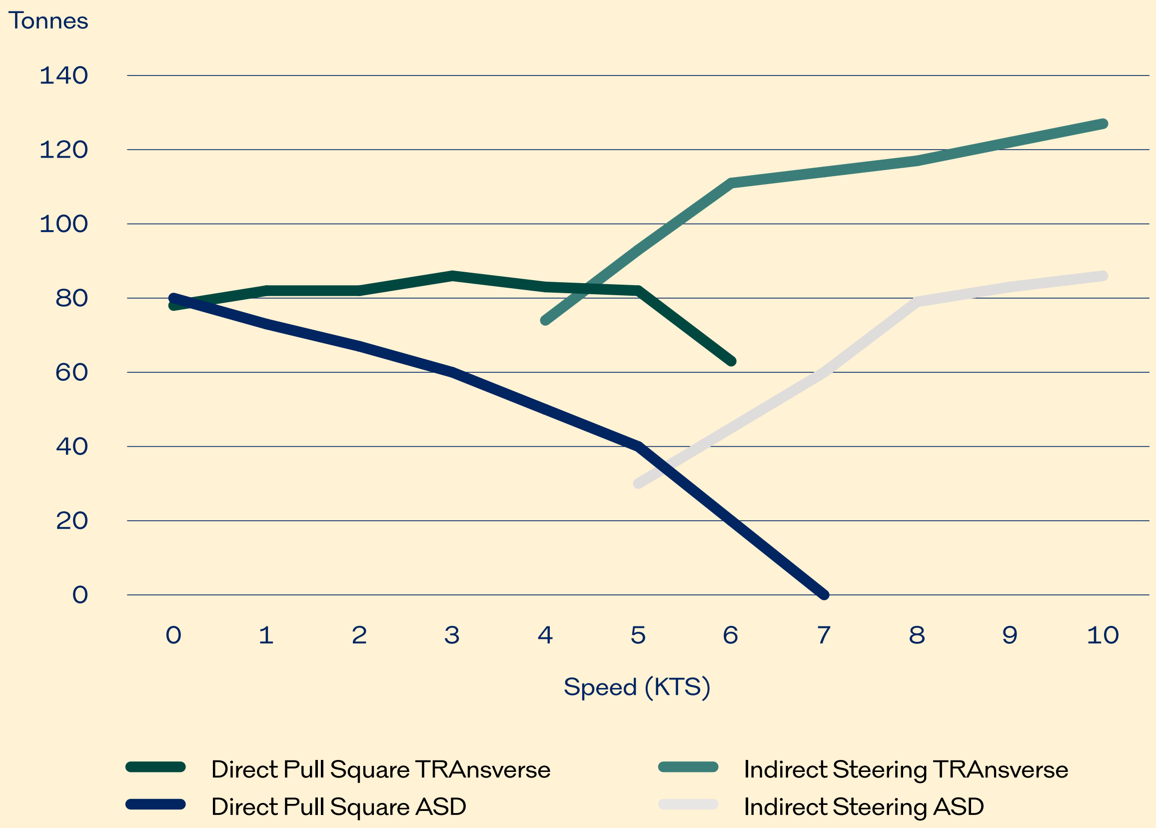


Figure 8B
Direct and indirect Braking comparison between TRAnsverse 32m and ASD 32m

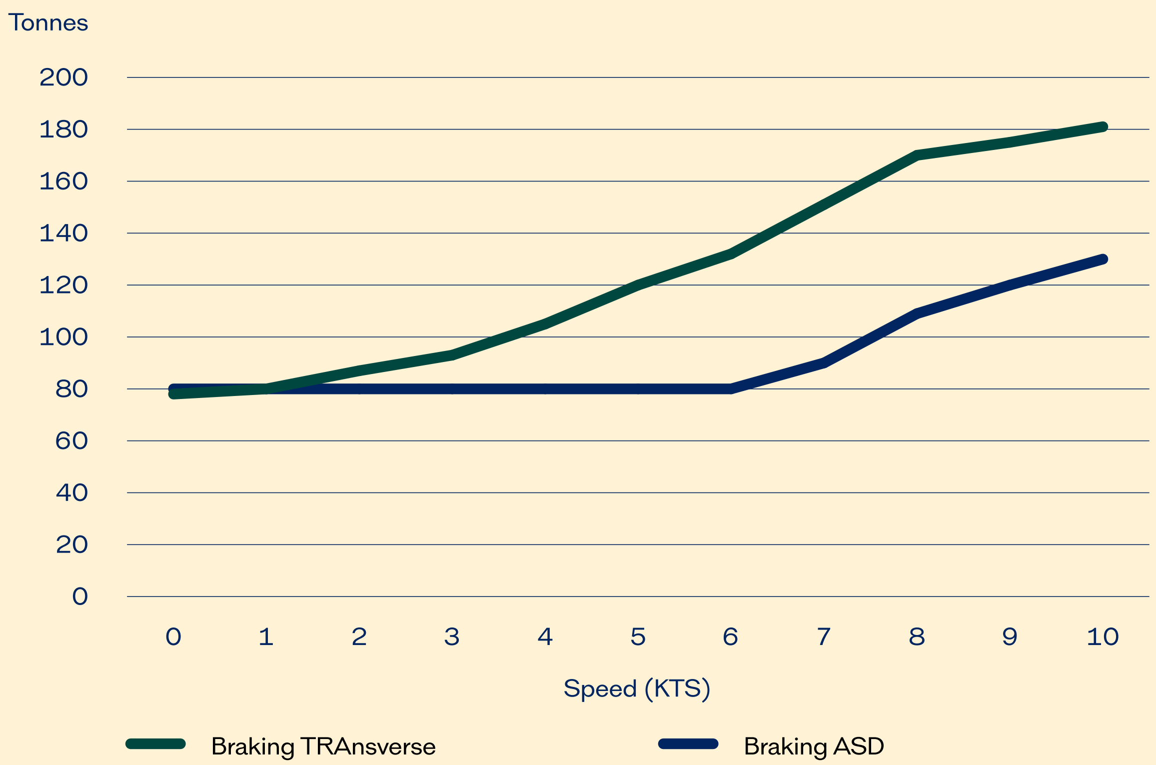


Figure 9
Direct and indirect Steering comparison between TRAnsverse 32m and ASD 32m

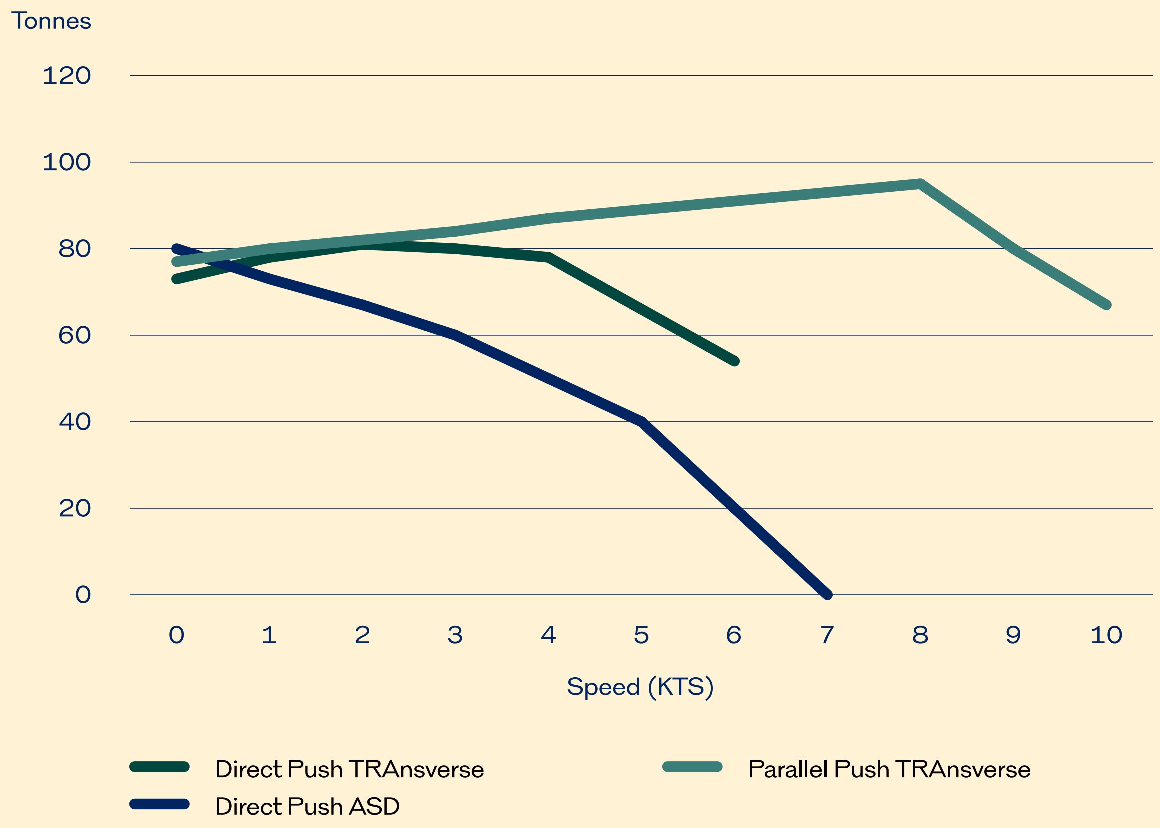


Figure 8: Relationship between bollard pull strength and speed during transition between different towing modes for TRAnsverse tug and high-performance ASD. The TRAnsverse tugs enhanced manoeuvrability allows much higher forces to be achieved across the whole speed range, especially between 2- 7 knots where direct assistance can be applied.

Figure 9: Relationship between pushing strength and speed during different towing modes for TRAnsverse tug and high-performance ASD.

The future perspectives

As global trade grows, port congestion is expected to become a more significant challenge in shipping, driving up costs and CO2 emissions. Tugs play a key role in tackling this challenge. With the TRAnsverse tug, Svitzer now offers the industry a tug that has the potential to become a game changer.

The tug is versatile and highly manoeuvrable, making it suitable for all harbour and terminal towage operations. Looking ahead, Svitzer has ordered several TRAnsverse tugs, and the expectation is that most future new builds will be based on the TRAnsverse tug design, ensuring that we can continue delivering quality service to our customers. At the same time, we contribute to decarbonising the shipping industry.

Svitzer is eager to engage in a dialogue to see how TRAnsverse can assist in your port operations.

If you are interested in learning more about the TRAnsverse tug design and how it may support your business, please reach out to:

Kasper Karlsen
kasper.karlsen@svitzer.com

Svitzer Group A/S
Sundkrogsgade 17, 2100 Copenhagen Ø, Denmark
Registration Number 44 79 14 47