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Ref:	Init:	Date:
PB009394	SBM	21st June 2024

Large Vessel Transit Emissions Reduction Trials using NCOS ONLINE – Green Button

Dear Michael

This report contains a brief description of project Green Button and provides a status summary of works and full-scale trials done to date.

Background

Port of Brisbane has since 2017 used the Safe Transit Module of NCOS ONLINE to plan the safe transit of all deep drafted vessels that passes through its navigational channel from sea to berth. The planning service is operated through a secure web interface by VTS staff from Maritime Safety Queensland. When a vessel transit time has been locked, the confirmed vessel transit plan gets forwarded to the Poseidon Pilot by VTS, after which the vessel transit will take place in accordance with NCOS ONLINE recommendations for transit start time and variation in speed through the 90 km channel.

To provide safe passage planning and pilot support, NCOS ONLINE includes a detailed 7 day forecast of spatially and temporally varying tides, winds, currents and waves through the channel, which in combination with detailed vessel response calculations, provide evaluation of safe under keel clearance and seakeeping for each vessel transit.

A side benefit of this physics-based approach to port traffic planning is that the vessel fuel consumption and associated carbon emissions can be calculated at the same time considering variations in vessel configurations and very importantly, the impact of variations in water depth, currents, and winds during transit.

Vessel Emissions are highly sensitive to even modest differences in through water speed (TWS). Embedded in a system that is able to control the start time and speed profile of all vessel traffic, it provides a unique opportunity to plan vessel transit times and speed profiles in a manner that provides a significant opportunity to reduce vessel emissions while at the same time make sure that vessel transits can occur without delay and meeting industry standards for Just-in-Time arrival.

Project Green Button has the purpose of developing an upgrade to NCOS ONLINE to make significant emissions savings easily achievable for day-to-day large vessel traffic in Port of Brisbane, by providing small, but highly important, adjustments to transit times and speeds there are both safe and efficient for vessel operation.

Methodology

- Before the introduction of Green Button, the VTS operator would create a vessel transit scenario by inputting vessel and IMO number, draft and loading condition into the web dashboard. Unique vessel configuration particulars such as 3D vessel hull shape, hydrodynamic resistance matrix, rudder and propeller information would be automatically sourced from an extensive vessel database called NCOS Fleet Manager. The system will provide the VTS operator with a safe transit window based on forecasted weather and water level conditions for a generous buffer period on each side of the preferred ETA or ETD of the vessel.

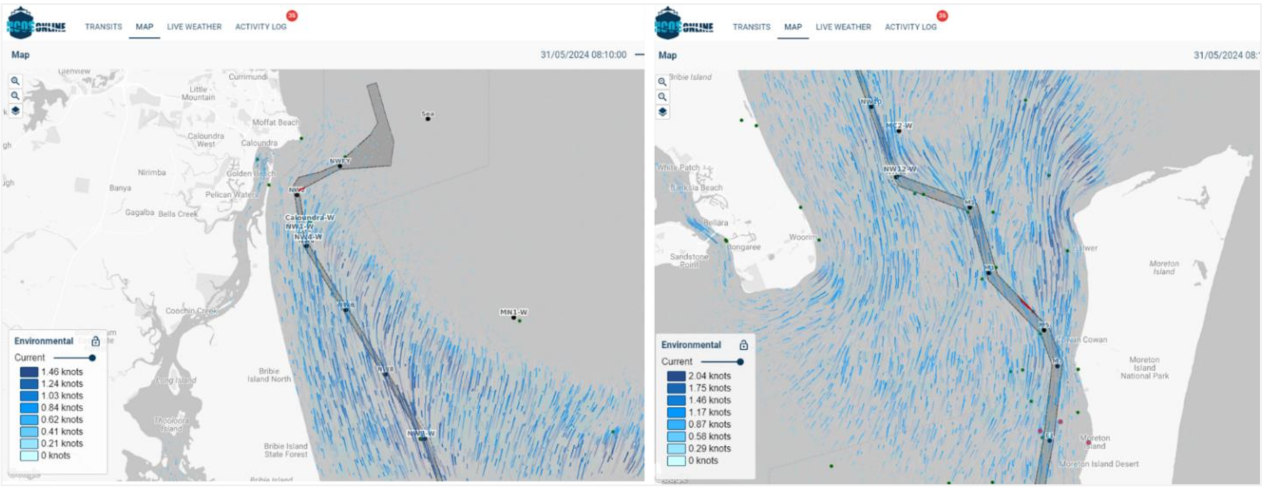

Figure 1 Example of predicted fields in NCOS ONLINE used to calculate safe passage times

- As a final input to this calculation, the VTS operator has also selected either a **Fast** or **Slow** speed profile. In most occurrences, the system will provide the VTS operator with safe transit window start times several hours wide, which provide flexibility to absorb last minute changes or delays to transit.

- To activate the **Green Button** feature, VTSO selects the **'Green Button Speed Profile'** as below.

Figure 2 View of Green Button activation in NCOS ONLINE dashboard. Top: Safe passage times using Green Button speed profile shown as blue windows. This keeps the view similar to the existing transit planning, minimising change for VTS. Bottom: The relative emissions savings are shown as a curve (green).

- The last step is for VTS to confirm pilot onboard time (within the safe start window) to lock in the vessel transit and generate the Pilot's PDF Passage plan.

  The PDF passage plans provide comprehensive guidance to the PSP pilots for safe speeds to be maintained through each leg of the passage. The image below shows an extract of the passage plan sent to the pilot for the Green Butto trial of the GSL KITHIRA.

PORT of BRISBANE
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Vessel Name: **GSL KITHIRA**
Forecast Issued: 26-May-24 07:59
Transit Description: NW Fairway to DP World Terminals
Commencement Window: 26-May-24 01:00 to 27-May-24 12:00
Selected Transit Start Time: 26-May-24 17:40

NCOS ONLINE

Vessel	
Name:	GSL KITHIRA
IMO No	9407885
Type	Container Vessel
Beam	32.29 m
LPP	282.45 m
Speed Setting	GREEN BUTTON

Stability Data	
Draft Fore	12.4 m
Draft Mid	12.5 m
Draft Aft	12.6 m
Displacement	78840 t
KGf	14.6 m
GMf	0.69 m

Type of Wave Input Used
Spectral Wave Correction

Environmental Conditions		
Station Name		MN1
Tide Residual		0.02
Time extracted		26-May-24 07:59
	Model (corrected)	Measured
HsSwell	0.4 m	0.4 m
TpSwell	14.64 s	9.47 s

Grounding Probability	0

Predicted Max Roll - Outside NWFW		
Vessel Heading	Speed	Worst Case
150 deg	10.0	0.30
170 deg	10.0	0.46

Safety Factors	
Safety Margin	0.5 m
Bottom Clearance	0.25 m
Manoeuvrability Margin	0.9 m
Bed Allowance	0 m
Dredging Tolerance	0 m

	Fast								Target UKC Profile									Slow							
Segment	Time	Speed	Depth	Tide	BC	MM	GR	MR	Time	ActTime	Speed	Depth	Tide	BC	MM	GR	MR	Time	Speed	Depth	Tide	BC	MM	GR	MR
SEA-NWFW	17:40	12.0	16.50	0.75	3.39	6.83	7.48	1.64	17:40		11.0	16.50	0.75	3.58	6.94	7.48	1.27	17:40	10.0	16.50	0.75	3.63	7.04	7.48	1.04
NWFW-NW2	17:47	11.8	15.10	0.79	1.42	3.35	4.09	2.20	17:48		10.7	15.10	0.80	1.75	3.48	4.10	1.68	17:49	9.7	15.10	0.81	2.00	3.59	4.10	1.35
NW2-NW4	17:57	10.5	15.00	0.84	1.30	3.31	3.98	0.85	17:59		9.5	15.00	0.85	1.65	3.47	3.99	0.71	18:01	8.5	15.00	0.87	1.84	3.59	4.00	0.57
NW4-NW6	18:06	11.8	15.00	0.89	1.65	3.11	3.85	0.76	18:09		10.8	15.00	0.91	1.85	3.25	3.87	0.60	18:12	9.8	15.00	0.94	2.04	3.39	3.89	0.50
NW6-NW8	18:20	12.0	15.00	0.94	1.99	3.37	4.08	0.66	18:24		11.0	15.00	0.97	2.15	3.52	4.11	0.59	18:28	10.0	15.00	1.00	2.28	3.66	4.14	0.55
NW8-NW3	18:32	12.0	15.00	0.97	2.06	3.57	4.21	0.77	18:37		11.0	15.00	1.00	2.19	3.72	4.25	0.67	18:43	10.0	15.00	1.05	2.42	3.87	4.29	0.62
NW3-NW10	18:43	11.9	15.40	0.99	2.44	5.73	6.29	1.03	18:49		10.9	15.40	1.04	2.54	5.88	6.33	0.88	18:57	9.9	15.40	1.09	2.62	6.02	6.38	0.75
NW10-NW12	18:57	11.9	15.20	1.01	2.13	6.00	6.55	1.04	19:04		10.9	15.20	1.06	2.35	6.15	6.60	0.88	19:12	9.9	15.20	1.12	2.52	6.31	6.66	0.75
NW12-M1	19:09	11.5	15.10	1.04	2.01	4.76	5.33	0.97	19:17		10.5	15.10	1.10	2.26	4.93	5.39	0.81	19:27	9.5	15.10	1.17	2.46	5.09	5.45	0.67
M1-M3	19:21	10.4	15.10	1.09	2.13	6.74	7.19	0.86	19:31		9.4	15.10	1.16	2.36	6.89	7.25	0.71	19:42	8.4	15.10	1.24	2.65	7.05	7.32	0.58
M3-M5	19:33	11.6	15.70	1.16	3.36	6.22	6.77	0.74	19:44		10.6	15.70	1.24	3.56	6.41	6.85	0.60	19:57	9.6	15.70	1.33	3.75	6.59	6.94	0.50
M5-M7	19:48	11.5	17.80	1.22	5.40	15.02	15.38	0.37	20:00		10.5	17.80	1.30	5.61	15.17	15.46	0.32	20:14	9.5	17.80	1.40	5.84	15.33	15.55	0.26
M7-E1	19:53	11.8	19.80	1.27	7.35	11.81	12.21	0.38	20:06		10.8	19.80	1.36	7.55	11.99	12.31	0.31	20:21	9.8	19.80	1.47	7.77	12.17	12.42	0.26
E1-E5	20:06	12.0	15.20	1.36	2.80	8.67	9.11	0.46	20:19		11.0	15.20	1.46	3.06	8.87	9.22	0.37	20:36	9.9	15.20	1.59	3.36	9.08	9.35	0.31
E5-EB	20:22	11.6	14.40	1.62	2.35	4.36	4.90	0.55	20:37		10.5	14.40	1.75	2.67	4.60	5.03	0.44	20:56	9.5	14.40	1.90	3.00	4.84	5.19	0.36
EB-IBB	21:05	9.9	13.90	1.88	2.45	3.54	4.00	0.25	21:24		8.9	13.90	2.02	2.70	3.78	4.14	0.19	21:48	7.9	13.90	2.18	2.95	4.01	4.30	0.14
IBB-DP World T..	21:19	2.7	13.80	2.08	2.90	4.18	4.25	0.06	21:40		2.1	13.80	2.25	3.10	4.36	4.40	0.05	22:05	1.6	13.80	2.41	3.30	4.55	4.57	0.05

Figure 3 Pilot Passage Plan for the Green Button trial of the GSL KITHIRA

- With Green Button activated, the system will calculate the total fuel consumption for each transit start time opportunity inside the safe window.

  All of these transits will have the same ground speed profile and steaming during in the channel, but due to especially variations in water level and current speed and direction during the tidal cycle, the actual through water speed and hydrodynamic resistance of the vessel will be different for each transit start time opportunity.

  Using scientifically derived datasets from full bridge simulator engine already embedded in NCOS it is possible for the green button to calculate the variations in hydraulic resistance due the transit and the relationship between vessel speed and engine RPMs.

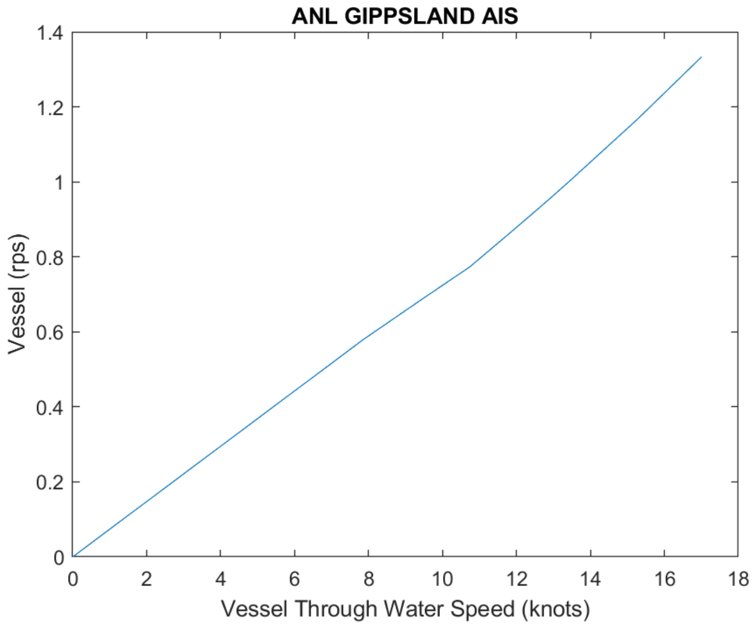


Figure 4 Vertical Through Water Speed for the Green Button transit of the ANL GIPPSLAND

- In some sections of the navigational channel in Port of Brisbane, the tidal currents will run almost parallel to the vessel transit direction and with magnitude of typically 1 to 2 knots but able to exceed 4 knots on mid tide. Vessel ground speed is typically between 9 and 16 knots. During the tide, the vessel through water speed will vary as much as 1 to 2 knots in certain areas of the channel. Fuel consumption and emissions depends on Engine RPMs which is a function of vessel through water speed only.

- From the table below showing an example for hourly CO2 emissions for a 300 m LOA container vessel it is clear to see how even modest changes significant positive impacts on reducing emissions can have if an inbound or outbound transit is planned to occur during a favourite time on the tidal cycle. As example, reducing through water speed from **14 knots to 12 knots** will cause reductions of approximately **59%.**

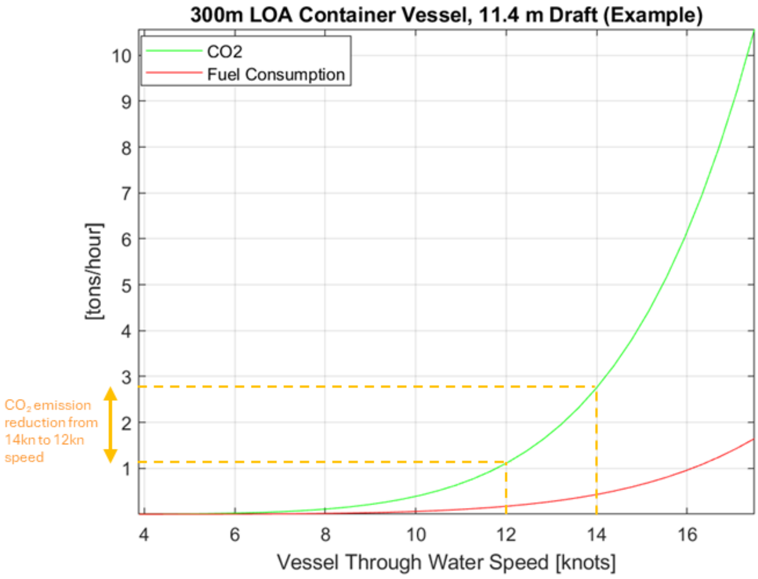


Figure 5 CO2 emissions against Vessel Through Water speeds for a 300m LOA container vessel at 11.4m draft

- The Green Button has two ways of providing savings:

  I. For each vessel transit window displayed in the VTS planning dashboard, NCOS ONLINE will make the user aware of how much fuel can be saved if a vessel transit is shifted with a few hours to benefit as much as possible from reduction in through water speed.

  II. Secondly, the Green Button also calculates an optimized speed profile, which is different from the static fast and slow profiles currently used in the system.

  The dynamic speed profiles use an advanced iterative numerical solver that for each channel segment calculates the envelope of safe transit speeds both with regards to UKC subject to wave action and heel and Seakeeping which can depends strongly on variations in wind conditions and water depth all which are captured by the NCOS ONLINE system.

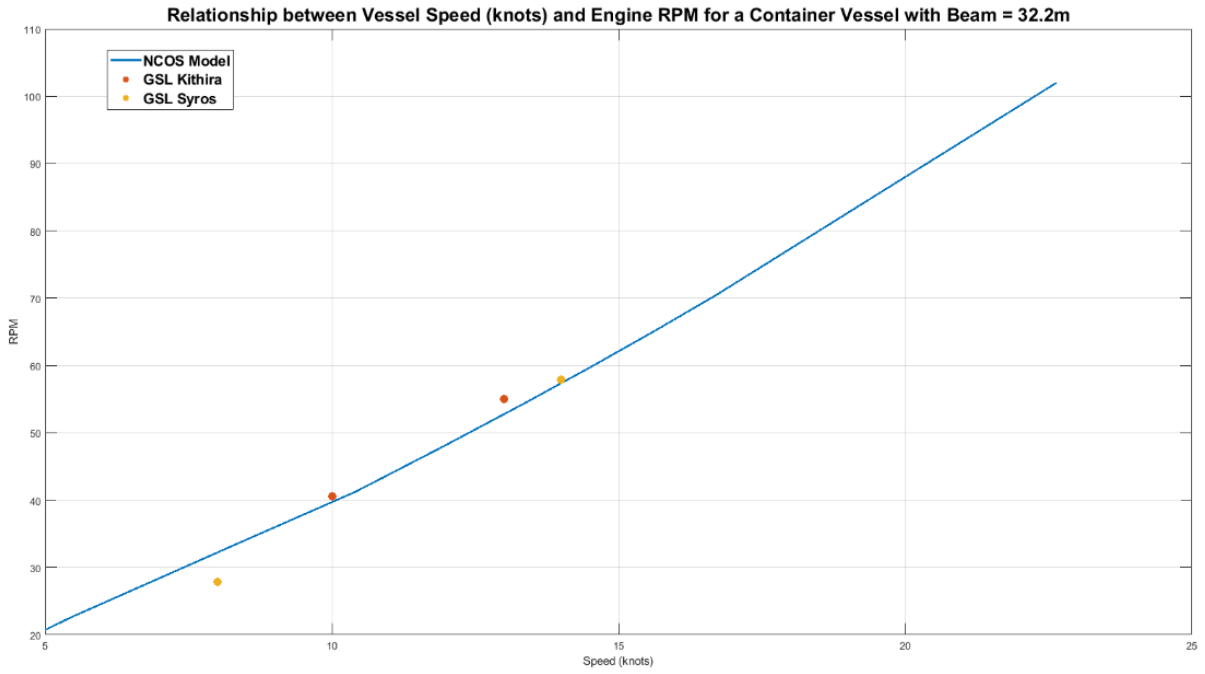
- Finally, the algorithm stitches together the optimized profile that optimized for both emissions savings and Just In Time arrival also incorporating for realistic speed losses during turning in channel bends. Potential emissions savings to CO_2, NOx, CO, HC, SOx, PM25, PM100 and VOC are all evaluated.

In summary Green Button is aspiring in its design to provide a flexible and robust suite of automated options to make sure that vessel transits through Port of Brisbane are optimised for emission reducing without compromising commercial requirements to safety and just in time arrival.

Validation of the Green Button predictions was carried out by asking vessel Masters to complete provided fuel consumption tables where they logged key parameters that was easily accessible such as speed over ground, water depth, RPS, duration of the test and fuel gauge start and end readings at the beginning and end of each tests. Where possible, logs were also provided of the associated weather conditions. Where time was permitting, fuel logs at the start and end of each vessel transit were completed. However most fuel log savings were carried out during open ocean voyages, which allowed for a steady record to be completed comparing vessel speed versus fuel consumption.

At the time of writing. Fuel consumption log recordings are still ongoing in careful consideration not to cause too much disturbance to the daily workload of vessel Masters. Comparison so far demonstrates excellent agreement between predicted and recorded RPS (RPM) and vessel speed and theoretical predictions of fuel consumption that lies within 9-10% of what has been recorded for transits into Port of Brisbane.

Technical reference to paper publications describing emissions calculation approach can be found under References.



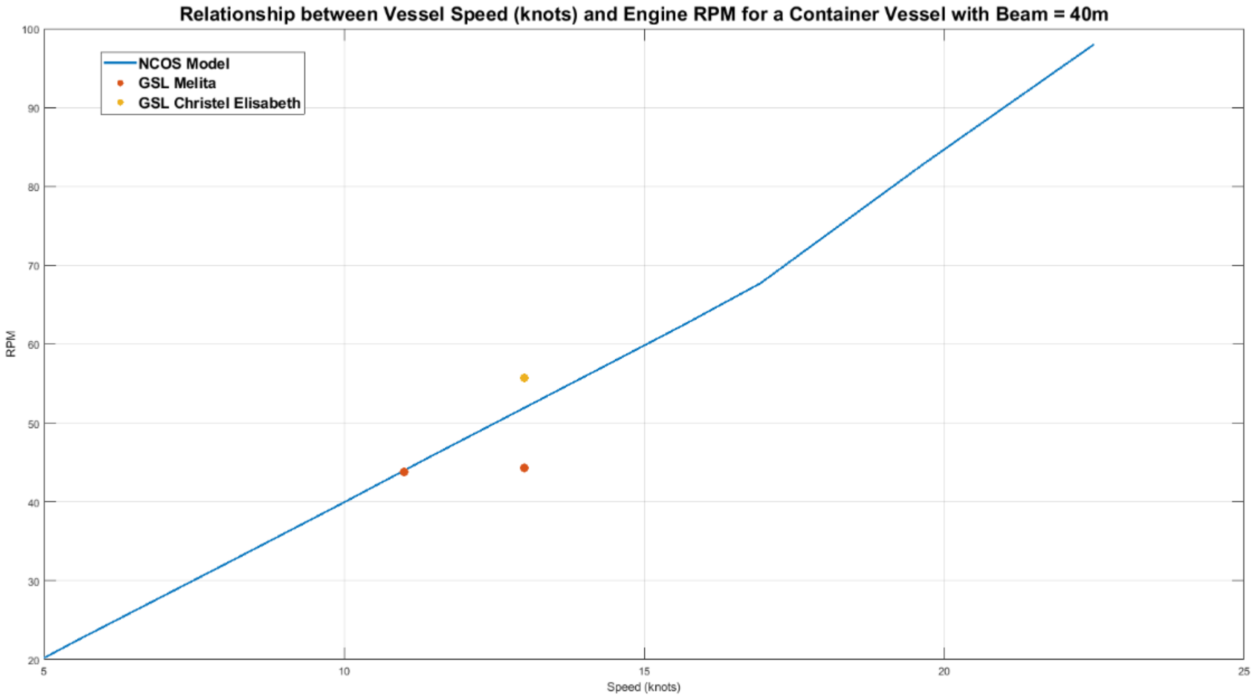


Figure 6 The two figures above presents the comparison between the theoretical relationship between through water speed and RPMs for a 32.2 m and 40 m beam container vessels compared to what physically recorded for 4 actual container ships, three of those being used in the trial

Full Scale Trials

To date, five full scale vessel trials in Port of Brisbane have occurred in collaboration with MAERSK LINE, CMA CGM, Maritime Safety Queensland, and Poseidon Pilots.

All five trials were conducted on inbound containership transits, with a focus on deep drafted (draft>11m) ships. Details of all five transits are shown below.

	ANL GIPPSLAND	GSL KITHIRA	GSL MELITA	GSL SYROS	CMA CGM CORNEILLE
Date	20/05	26/05	31/05	02/06	07/06
IMO	9532800	9407885	9214226	9437062	9409170
LOA (m)	320	294	277	294	299
Lpp (m)	304	282	263	282	287
Breadth Moulded (m)	46.0	32.3	40	32.2	40
Scantling Draft (m)	14.5	13.5	14.5	13.50	14.5
Target Draft (m)	11.4 AP / 11.5 Mid / 12.0 FP	12.4 AP / 12.5 Mid / 12.6 FP	12.2 AP / 12.13 Mid / 12.05 FP	12.3 AP / 12.05 Mid / 11.8 FP	10.78 AP / 10.2 Mid / 10.78 FP
DWT (tons)	56534	56181	49645	53386	45453
Displacement (tons)	89536	78440	74504	75485	70490
Engine MCR (KW)	36,000	41,000	55680	40,040	57,100
Propeller Diameter (mm)	8500	8500	8500	8500	8500

A weekly stakeholder meeting was established for the duration of the trial to discuss logistical and operational aspects of each transit. With both the shipping lines and MSQ (VTS) on the same call, it was a very efficient way to evaluate options and clear any concerns from either party.

A key finding was that, contrary to initial understanding, vessel operators would most often only accept small changes to arrival time at berth of **less than 15 minutes** due to constraints with allocation of labour. At such a small margin, this challenge was a significant risk to the trial.

Upon discussion with the stakeholder group, a second solution was identified where the trial would focus on matching the **planned time alongside** of each transit and instead shift the planned Pilot on Board (PoB) time. Both shipping lines and MSQ were able to accommodate an earlier PoB time as long as the vessel was waiting at anchor prior to that time. **This proposed method was adopted for all five trials**.

This allowed the green button to balance improving the transit timing with regards to finding the most favourable tide conditions and more importantly using the dynamic speed profile to slighting increase transit duration and reduce changes in speed during transit. Especially with regards avoiding time periods of high speeds in deep water.

Trial Results

Figure 7 to Figure 11 presents the comparison between the Optimized Green Button vessel transit speed profile and the standard transit profile that the vessel would be expected to follow without considering emissions reduction optimization. Profiles are plotted against a horizontal time axis that includes the start and end time of the transit as well as the speed variation through the channel. Standard speed profiles follows either a fast or slow profile depending on what is required to assure safe UKC while overall minimize the duration of the transit. The optimized transit profile is dynamically calculated to use the environmental conditions as much as possible to reduce emissions while at the same time assure safe manoeuvring and UKC. As an advanced feature the optimized transit profile also accounts for the temporary speed loss experienced during turns, which makes the speed profile more realistic to follow and avoid pilots having to increase speed intermittently to meet their arrival times.

The optimized speed profile will most often lead to slightly longer transit times, which for inbound vessels means that pilotage needs to commence earlier to meet the planned arrival time at berth.

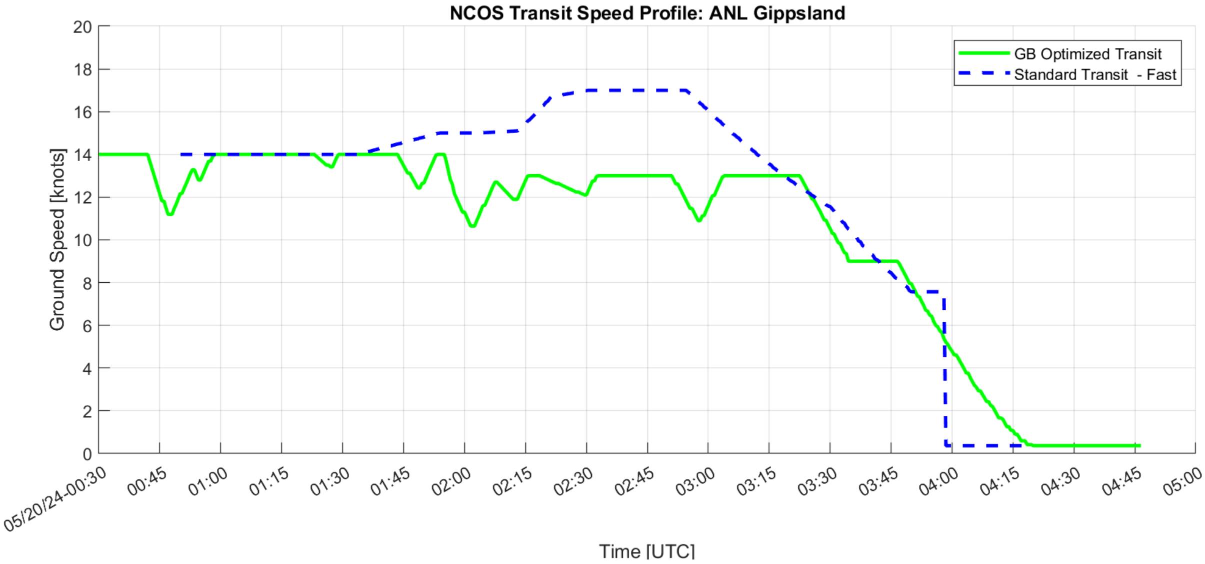


Figure 7 Speed profile for the ANL GIPPSLAND under Standard NCOS transit (Fast) versus Green Button profile

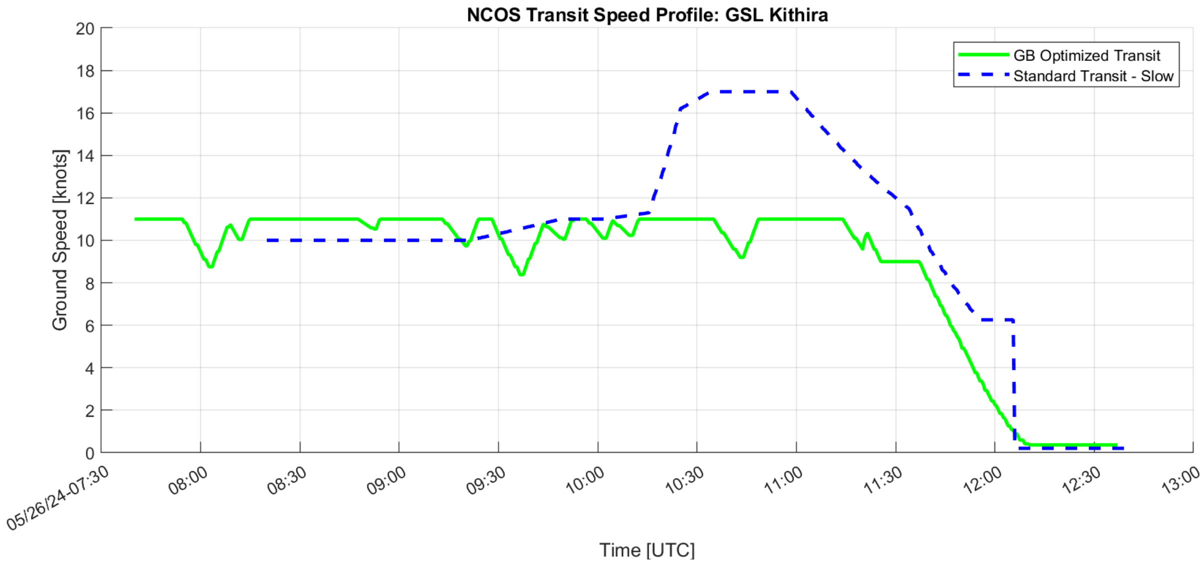


Figure 8 Speed profile for the GSL KITHIRA under Standard NCOS transit (Slow) versus Green Button profile

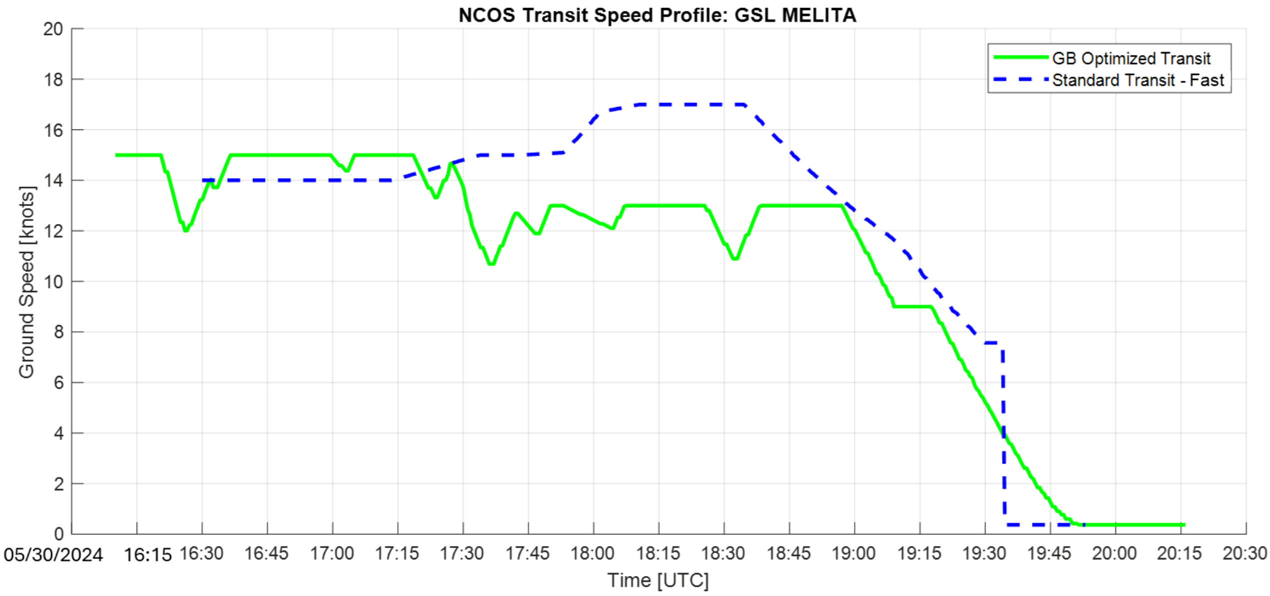


Figure 9 Speed profile for the GSL KITHIRAMELITA under Standard NCOS transit (Fast) versus Green Button profile

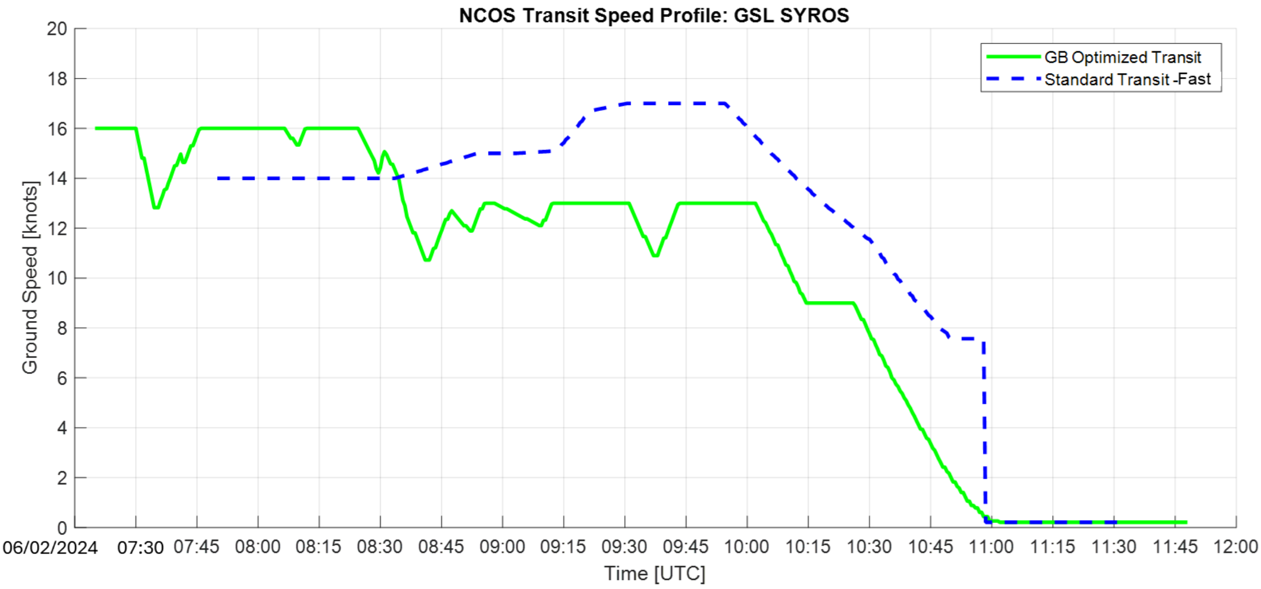


Figure 10 Speed profile for the GSL SYROS under Standard NCOS transit (Fast) versus Green Button profile

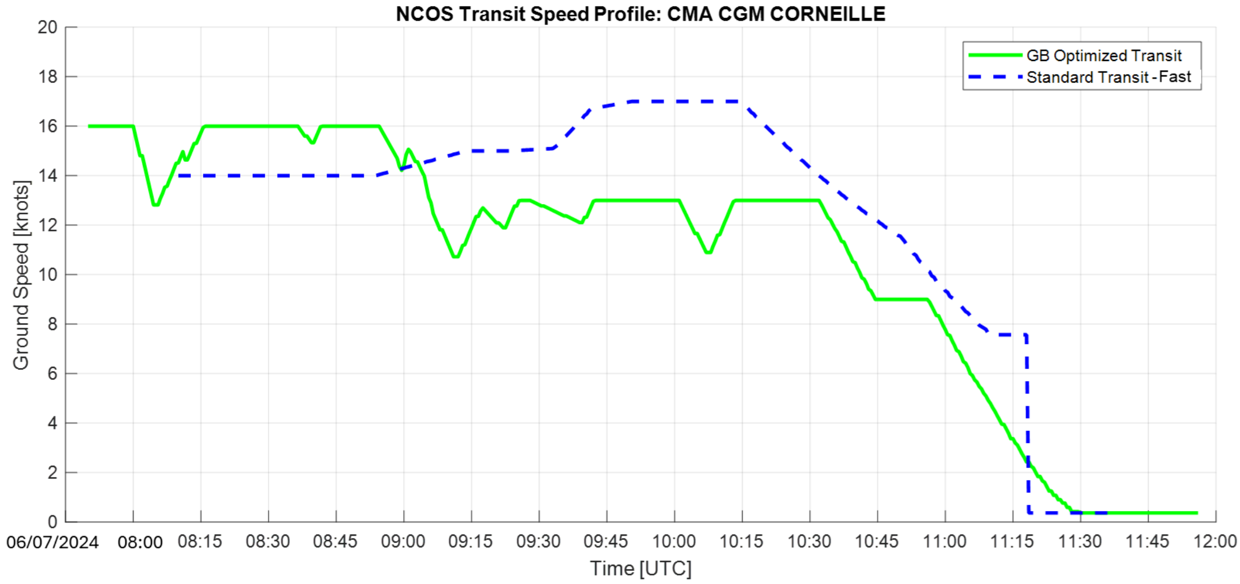


Figure 11 Speed profile for the CMA CGM CORNEILLE under Standard NCOS transit (Fast) versus Green Button profile

The table below presents the changes to vessel transit times for each of the 5 vessels and lists the positive achievements to emissions and fuel savings of using green button. The table also provides an overview of changes to start and end times of the pilotage against what would have been originally planned without the use of green button as this is an important aspect of limiting potential disruptions to the overall traffic flow through the port. The last column contains transit notes describing the pilot's ability to follow the updated transit plan and speed profile provided by Green Button.

Vessel Name Transit Date	*Pilotage Start Time*	*Arrival at berth*	*Potential Emissions Savings*	*Potential CO2 Savings*	*Transit notes*
ANL GIPPSLAND **20th May 2024**	20 minutes early	On time	50%.	8.2 tons	Pilotage started on time. Vessel speed was much too fast first half of the transit before following GB profile. Resulting no net saving as result.
GSL KITHIRA **26th May 2024**	45 minutes early	On time	71%.	2.1 tons	Pilotage started on time. Vessel speed too fast first third of the transit before following GB profile. Improvement from first trial. Net savings of 26% achieved.
GSL MELITA **30th May 2024**	20 minutes early	On time	47%.	4.7 tons	Pilotage started on time. Vessel followed GB profile perfectly for most of the transit. Net savings achieved in full.
GSL SYROS **2nd June 2024**	30 minutes early	10 minutes late	36%.	3.5 tons	Pilotage started on time. Vessel followed GB profile very well for most of the transit but went approximately 1 knot slower for the last half of the transit. Net savings achieved were

					as a result larger (51%) than projected but caused a minor delay in arrival.
CMA CGM CORNEILLE **7th June 2024**	20 minutes early	On time	23%.	1.3 tons	Pilotage started on time. Vessel speed went approximately 2 knots too fast during the first half of the transit compared to GB profile and similar to ANL Gippsland tried to compensate by reducing speed proportionally below GB profile for the last half of the transit but without success. No net saving achieved.
Transit Trial Summary				Potential Total Savings **19.8 Tons**	Achieved Total Savings **11.4 Tons**

As noted in the transit notes it was found that some pilots were experiencing difficulties following the new speed profiles while others managed to follow them almost perfectly as illustrated in Figure 12 and Figure 13. Changes to start of the pilotage times were followed very well in all transits. Achieved emissions savings were very close to theoretical potential emissions savings when speed profiles were being followed within reasonable limits. In some cases, some savings were made despite only following part of the profile, due to the earlier start times utilizing tidal currents more effectively. At the same time it was also observed how emissions savings could quickly disappear if the vessel started going too fast in the beginning of the transit without ability to make it up for it by going slow later.

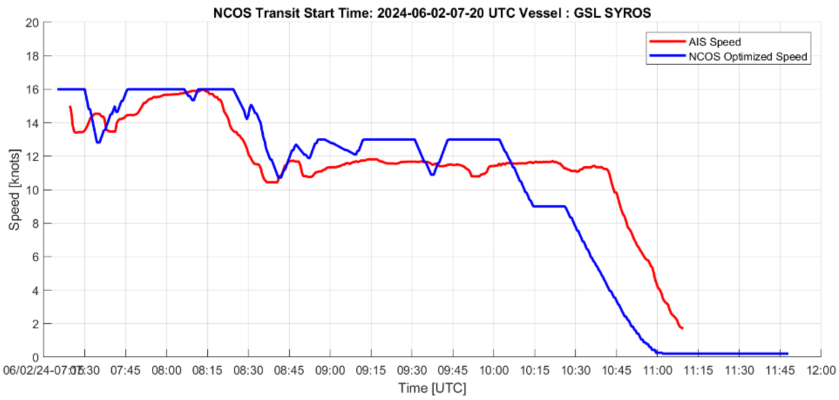


Figure 12 The figure above presents for GSL SYROS the differences between the GB Speed profile and the speed profile against the actual AIS logged transit. For this transit the vessel followed the provided GB profile very well for most of the transit but approximately 1 knots slower for the last half.

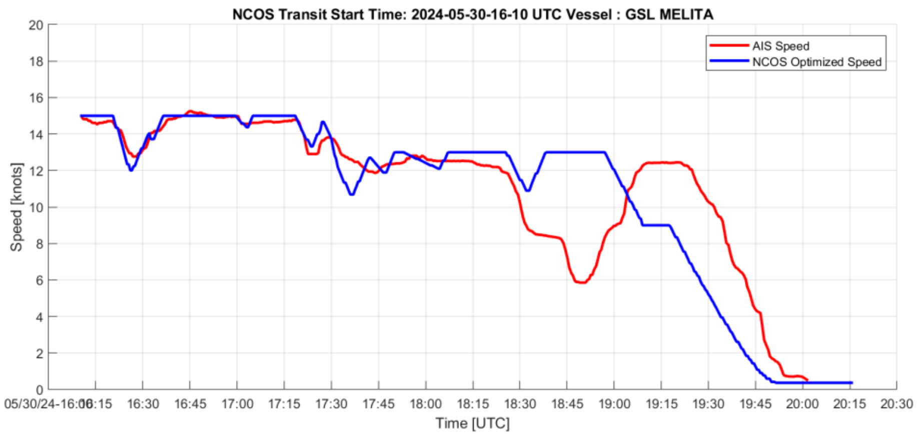


Figure 13 The figure above presents for GSL MELITA the differences between the GB Speed profile and the speed profile against the actual AIS logged transit. For this transit, the vessel followed the provided GB profile almost perfectly for most of the transit.

Conclusions

The conclusions of the five transit field trials of the green button are a demonstrated capability for achieving tangible reductions in carbon emissions for piloted transits without compromising the ability to meet scheduled arrival time at berth. At the same time the trials confirmed that more work is needed to make sure that pilots are better supported in following green button profiles and that their feedback is diligently incorporated to make speed profiles easier to follow without causing excess strain on the pilot's workload.

Even with consideration to the challenges with following the Green Button profile for some transits, the average achieved saving to CO_2 emission was 2.3 tons per vessel transit. With a total approximate of 5,000 ship movements per year in Port of Brisbane[1], this would equal an annual reduction of 11,500 tons of CO_2. This equals approximately the annual absorption of 12,700 m3 of trees, the average emission of 766 Australians[2] and a value estimation of 813,000 EUR according to EUs Emissions trading system[3].

If the Green Button profile was followed to its fullest the savings can be almost doubled and without causing delays in arrival or departure.

Project Green Button to date has provide a remarkable insight into how much vessel emissions savings are possible by just providing slight adjustments to timing of the vessel transit and the associated vessel speed profile. For a port with a 90 km navigation channel through a pristine marine area of Moreton Bay and with more than 2500 large commercial vessels per year, the total positive impact on emission reduction is consider overwhelmingly positive.

What differs the Green Button approach to other emissions saving methods is that it integrates seamlessly with a tool that already supports the regulator Maritime Safety Queensland mandate to direct vessel transit times and speeds, while at the same time providing an operational tool to make sure that pilots are supported in following the transit plan accordingly. This makes Green Button a potentially very powerful supplementing tool to any Port that is already operating a similar type transit planning system.

Future works will include increasing the number of full trials and improve methods for making sure that pilots are supported and monitored to follow the GB transit profiles. Field trials confirmed that existing measures for supporting pilots in following dynamic speed profiles from GB as opposed to static profiles memorized over time, will require more work with regards to training, profile adjustments and potentially better technology integration into tools that the pilots are already relying on for support such as Portable Pilot Units (PPU).

Once completed successfully the next step could be to roll out the GB tool to support all vessel traffic in Port of Brisbane, followed by potentially all other ports across 5 continents that are also using NCOS ONLINE for safe transit planning including large ports such as Port of Vancouver, Port of Tanger Med and Port of Auckland.

[1] https://www.msq.qld.gov.au/shipping/port-procedures/port-procedures-brisbane
[2] https://ourworldindata.org/co2/country/australia#per-capita-how-much-co2-does-the-average-person-emit
[3] https://www.openco2.net/en/co2-converter

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Best regards,
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Digital operational services for ports