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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 an 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.

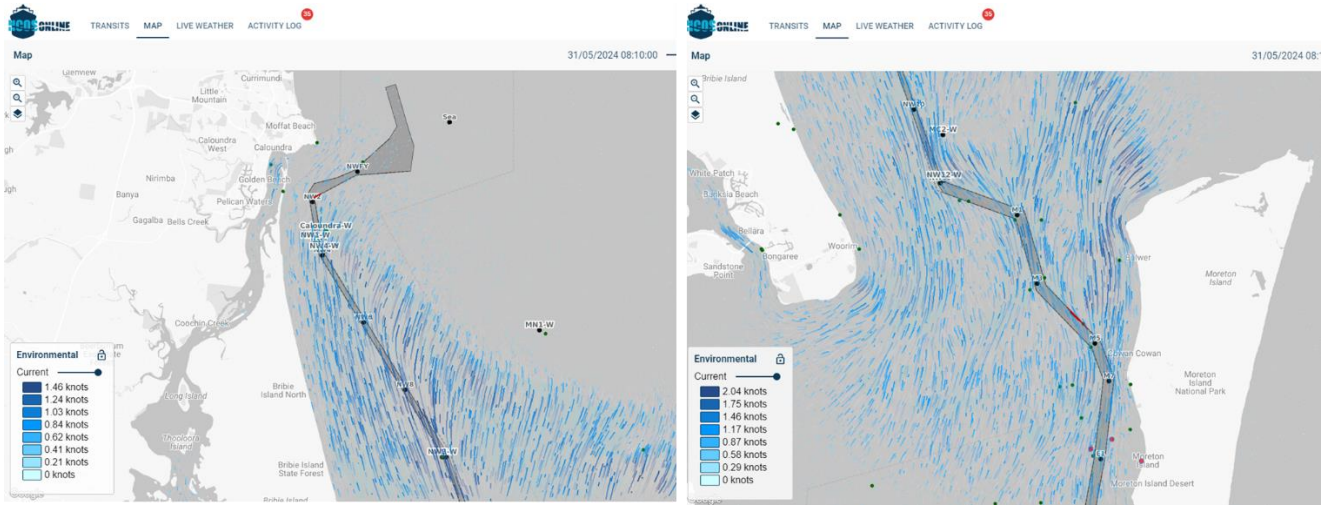

Figure 1 Example of predicted fields in NCOS ONLINE used to calculate safe passage times

As a final input to this calculation the VTS operator has also selected either a Fast or Slow speed profile. In most occurrence 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, the 'Green Button Speed Profile' is selected as below.

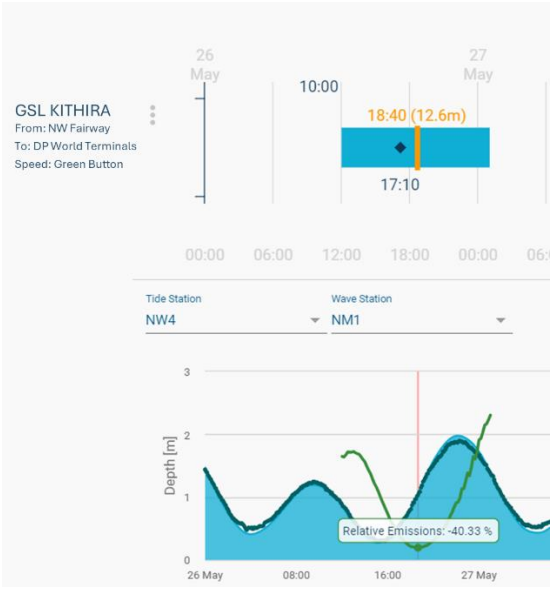

Figure 2 View of Green Button activation in NCOS ONLINE dashboard. Top: Safe passage times using Green Button speed profile shown as blue windows. This keeps the view similar to the existing transit planning, minimising change for VTS. Bottom: The relative emissions savings are shown as a curve (green).

The last step is for VTS to within the safe start window confirm pilot onboard time for the confirm vessel transit. 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
Here for the future

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

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.

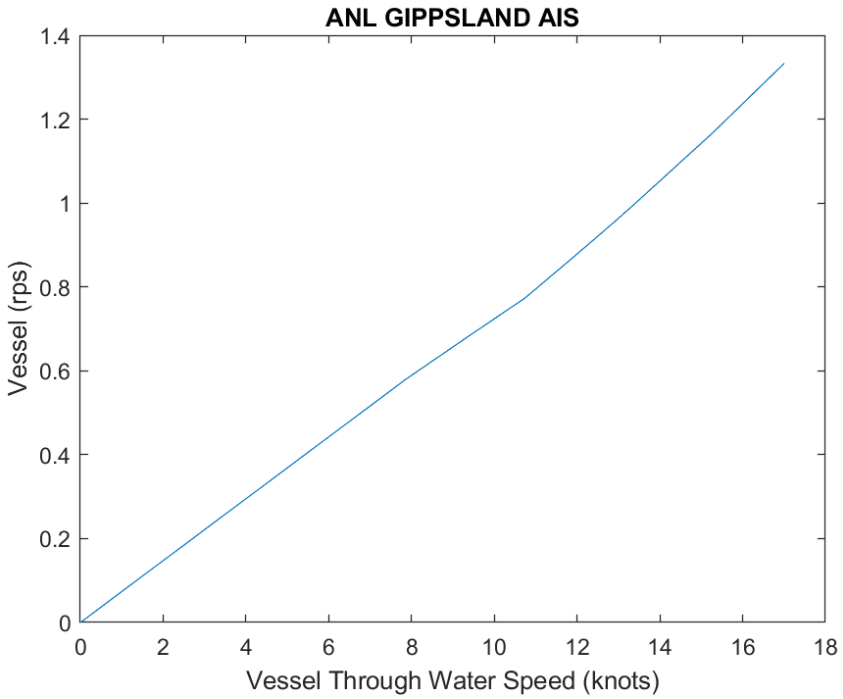

Figure 4 Vertical Through Water Speed for the Green Button transit of the ANL GIPPSLAND

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 deductions of approximately 59%.

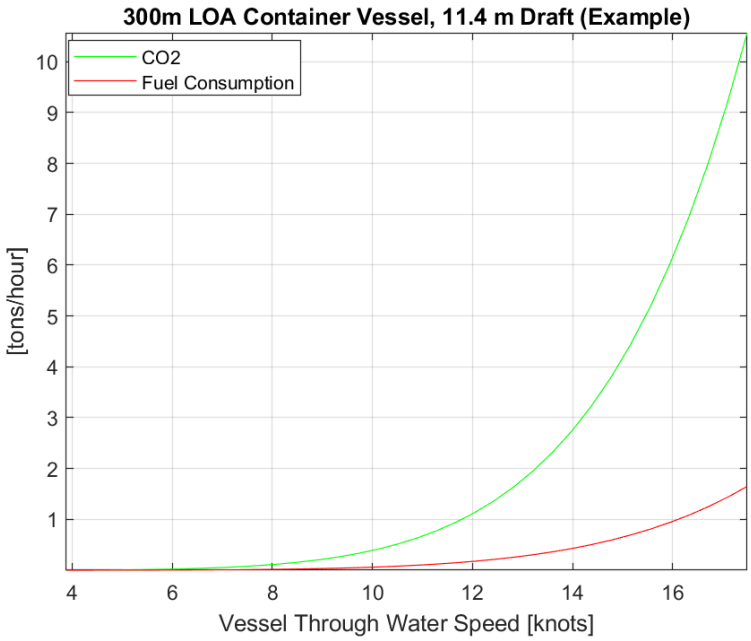

Figure 5 CO2 emissions against Vessel Through Water speeds for a 300m LOA container vessel at 11.4m draft

The Green Button has two ways of providing savings. 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. 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 CO2, NOx, CO, HC, SOx, PM25, PM100 and VOC are all evaluated.

Through the above methodology, the Green Button intents to provide a flexible 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.

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

Full Scale Trials

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

Two container vessel arrivals used so far for validation was ANL GGIPPSLAND and GSL KITHIRA. Specifics for the planned arrival of both vessels is provided in the table below.

	ANL GIPPSLAND	GSL KITHIRA
IMO	9532800	9407885
LOA (m)	320	294
Lpp (m)	304	282
Breadth Moulded (m)	46.0	32.3
Scantling Draft (m)	14.5	13.5
Target Draft (m)	11.4 AP / 11.5 Mid / 12.0 FP	12.4 AP / 12.5 Mid / 12.6 FP
DWT (tons)	56534	56181
Displacement (tons)	89536	78440
Engine MCR (KW)	36,000	41,000
Propeller Diameter (mm)	8500	8500

For both vessel transits it was found that vessel operators would only accept small changes to arrival time at berth of less than 15 minutes due to constraints with allocation of labour. However, being able to commence piloting up to 30-40 minutes earlier than originally planned was accepted.

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.

For ANL GIPPSLAND, final transit start time was shifted by 20 minutes forward and the GB optimised speed transit profile consisted of a transit of mostly 14 knots as illustrated in the green curve in the plot below. The standard transit speed profile is shown as a dashed blue curve.

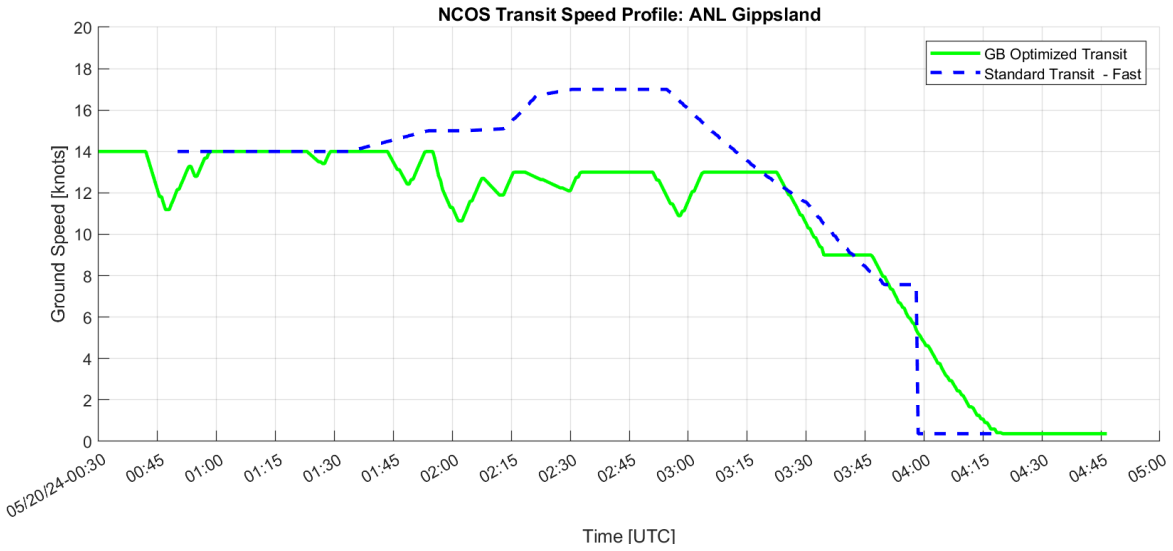

Figure 6 Speed profile for the ANL GIPPSLAND under Standard NCOS transit (Fast) versus Green Button profile

By following the GB Optimized transit profile, the accumulated savings in CO2 was calculated to **50**%.

For GSL KITHIRA, final transit start time was shifted by 45 minutes forward and the GB optimised speed transit profile consisted of a transit of mostly 11 knots as illustrated in the green curve in the plot below. The standard transit speed profile is shown as a dashed blue curve.

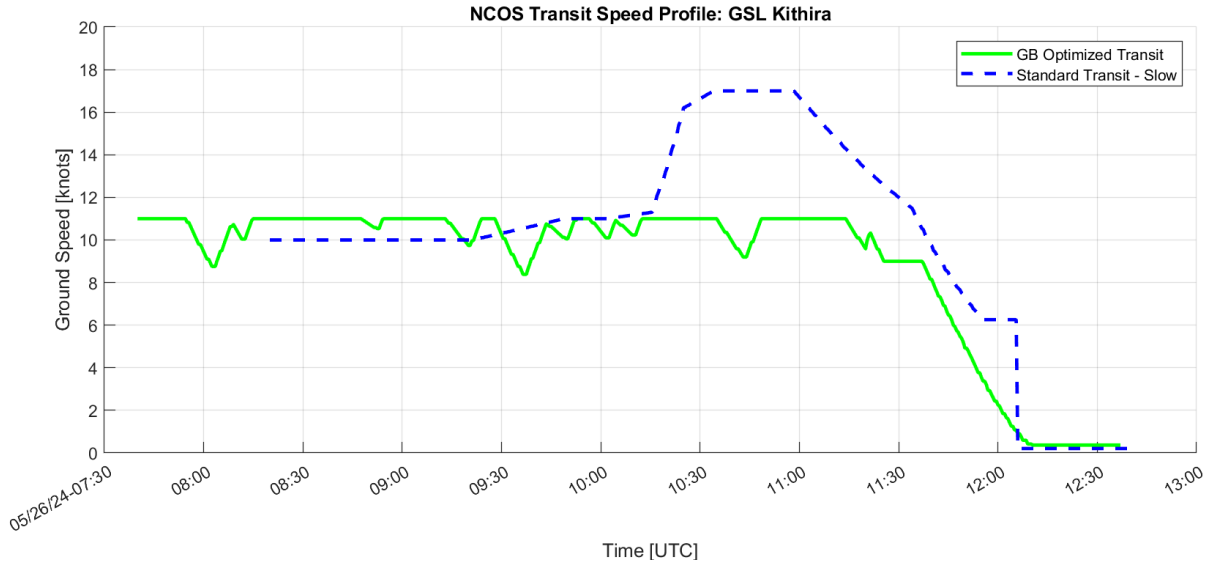

Figure 7 Speed profile for the GSL KITHIRA under Standard NCOS transit (Slow) versus Green Button profile

By following the GB Optimized transit profile, the accumulated savings in CO2 was calculated to **71**%.

The conclusions of the trial to date demonstrated the flexibility for operators to shift start time for inbound transit on the condition that original arrival time alongside the berth was not changed. For container vessels it is assumed that up to at least 1 hour off buffer should be expected in this regard.

Both full scale trial demonstrated the ability for VTS and Pilots to followed the updated transit start time, but some challenges was experienced with pilots remembering to follow the dynamic plans during transit

as opposed to the fixed Slow and Fast profiles that they have memorised and used for several years already.

As a result, actual vessel speed as logged by AIS was faster along some channel segments compared to the GB speed profile and actual savings in emissions would have been much less than it could be.

However, as a positive note the convergence is improving for each trial. For ANL GIPPSLAND the net achieved emissions saving was virtually 0% due to pilot going too fast in the beginning of the transit before converging to the GB speed profile. But for GSL KITHIRA the achieved emission reduction was still 26%. Much less than what could have been achieved but still a significant and encouraging improvement.

Providing better methods to support pilots in following the dynamic GB speed profiles using training and PPU integration will be an emphasis of the next stage of the trials.

Summary and Future Works

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.

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.

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 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.

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Best regards,
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