Berth to berth voyage schedule optimisation – a Torres Strait case study

Gregory Hibbert[1] and David O'Brien[2]
[1] OMC International, Melbourne Australia; g.hibbert@omcinternational.com
[2] Tidal Shipping, Australia

Abstract
This paper presents a case study on the potential operational and commercial efficiency gains available from an under-keel clearance (UKC) based scheduling approach to voyage planning via the Torres Strait.

The Torres Strait shipping lane imposes operational UKC constraints on vessels that utilise the waterway when drawing drafts over 8 meters. This constraint affects not only the maximum drafts that operators can expect per vessel (and hence cargo throughput), but also makes timing an important consideration. By the nature of the tidal cycles in the region, these timing and draft constraints vary daily to seasonally in an operationally impactful manner.

To fully utilise the waterway's throughput capacity on a per-vessel basis, a schedule planning tool has been developed that can find optimised opportunities to maximise voyage profitability for vessel operators. This is achieved by modelling the voyage from origin berth to destination. This optimisation considers; freight rates & vessel cargo tonnage, time charter rates, fuel consumption and bunker costs, and the effect of wind, wave & ocean currents on vessel steaming times. Where the origin and destinations are also UKC constrained, these are also taken into account.

This case study finds that the complexity of the timing and UKC constraint interactions provides opportunities where fuel costs, time costs and freight yields may be balanced to reveal unexpected optimal strategies. These are particularly likely during the mid-year months where the daily high-water levels tend to be lower.
An analysis has been performed for just such a trade route, where the estimated savings by following optimised results are up to USD55,000 for specific voyages and an average of USD11,000, depending on the constraints modelled and the time of year.

Keywords: under-keel clearance, shipping, planning, efficiency, integration

1. Introduction

The profitability of shipping voyages can be optimised by the consideration of voyage duration, fuel consumption and cargo in financial terms. While the cargo carried can affect the fuel consumption and speed characteristics of a given vessel, from an under-keel clearance (UKC) perspective the laden draft also interacts with the availability of sailing opportunities (and risk profiles) through depth-constrained waterways. One such waterway is the Torres Strait between Australia and Papua New Guinea, which is regulated by the Australian Maritime Safety Authority (AMSA) [4]. OMC International's Under keel clearance management (UKCM) system [1], a dynamic UKC (DUKC®) decision support platform [7], is used by AMSA to manage deep draft (8+ meters) traffic.

Recognising the interactions between time, speed, draft & sailing windows through Torres Strait provides the opportunity for considering alternative strategies to schedule selection. The schedules can be selected to maximise cargo shipped, minimise fuel consumption, manage arrival time at a destination or maximise overall efficiency. The effect of coastal winds, currents and waves are also considered, which can have a marked impact on time and fuel considerations [3]. To explore the possibilities, OMC International has developed a prototype system dubbed the "Berth to Berth UKC-based schedule optimisation" (or Berth to Berth for short). This paper details the potential benefits and limitations of the integrated "Berth to Berth" scheduling system.

2. Coastal voyage scheduling

To provide optimised voyage schedule advice, operational constraints from the origin berth to the destination need to be taken into account. This analysis is based on a coastal voyage from the Gulf of Carpentaria to the South East Queensland coast, per Figure 1. Vessel availability, cargo loading times and required arrival windows are considered on a voyage-by-voyage basis. Where UKC and other sailing restrictions apply at the load port and/or discharge port, these are also considered in the optimization to avoid or minimise unnecessary waiting time.

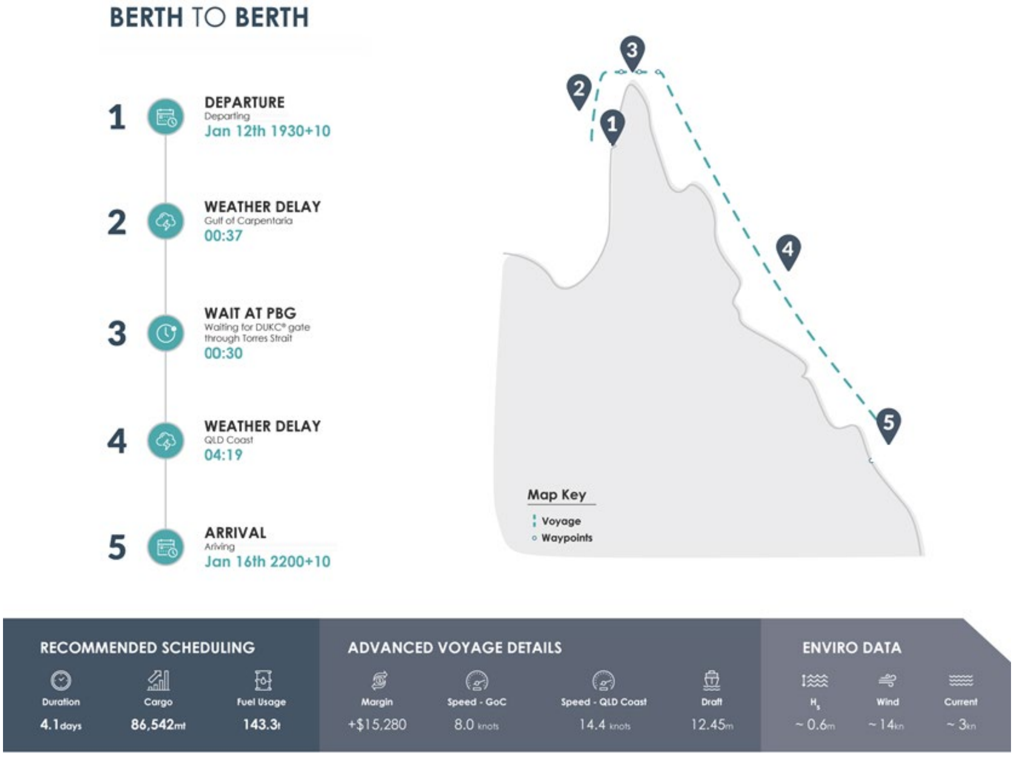

Figure 1 – An example of Berth to Berth voyage schedule advice displayed as an infographic; the overall advice is visible at a glance with details available in the bottom bar; this user experience provides ease of use for schedulers

2.1 Demand-driven scheduling

The straightforward method for scheduling voyages from load port to the discharge port is to focus on forecast stock requirements and to queue vessel availability at the load port accordingly. With simple assumptions about the cargo tonnage and voyage time expectations, this can be an effective method to provide continuity of stock shipments. With the uncertainties inherent in large scale shipping operations, this approach reduces the potential for complex analysis and the risk of disruptive changes due to revised information.

A downside to the straightforward approach is that it precludes the opportunity to take advantage of synergistic opportunities such as deep-draft DUKC® windows "lining up" along the voyage, or conversely to avoid foreseeable problems such as adverse weather conspiring to delay ideal passage.

2.2 Constraints on schedule optimisation

Re-introducing some complexity into the problem can make the best of these opportunities. A decision support system such as Berth to Berth can ingest the operational uncertainties together with scheduling constraints to find novel or atypical schedule strategies. This approach allows the operators to be largely freed of the burden of considering the complexities and financial impacts of their decisions, while the Berth to Berth system is tasked with finding the best set of outcomes and proposing them to the users. The system protects from disruptive changes due to operational uncertainties by considering dynamic forecasts stochastically, reducing the impact of forecast revisions.

To optimise this logistical problem, several constraints need to be considered. These include under-keel clearance requirements at locations along the coastal route (including Torres Strait), weather events, time charter rates, fuel costs and freight rates. The Berth to Berth system adopts optimisation algorithms to provide shippers with optimal vessel loading and sailing schedules by balancing logistical constraints relating to vessel draft and passage duration.

The process of choosing an optimised schedule using the system begins with entering the schedule constraints into the system. Depending on the availability of seasonally variable deeper draft access for the region in question via the use of UKCM, these constraints can be key to identifying the most cost-effective schedule option. These constraints include:

- Vessel (for specific draft vs. displacement characteristics, fuel vs. speed curves)
- Vessel speed range (through-water)
- Load port & berth
- Discharge port / terminal / anchorage
- Departure time options (typically near high-water at origin port, also dependant on other port traffic)
- Minimum cargo tonnage

- Destination arrival window
- Maximum UKCM draft [4][5][6]

Some constraints can be bypassed and ignored where this is desirable, for instance the minimum cargo can often be ignored since the system will automatically optimise for maximum cargo to increase revenue to the owner/operator.

During the "summer" months from December to April, tides in the region tend to peak at levels that allow the Torres Strait draft limits to provide many sailing windows. The opportunities to optimise when this is the case tend to be focused on fuel use minimisation, with minimum steaming speeds to suit conditions and avoid adverse currents (or to catch assisting currents) and minimise impeding wind and wave conditions. Optimisation will minimise the waiting times for a suitable window through Varzin / Prince of Wales Channel (Torres Strait).

However in the "winter" months the available drafts through the UKCM are much more restricted, resulting in the opportunity to balance cargo revenue (extra centimetres of draft) against the risk of delayed access through Torres Strait; simply loading a vessel to the draft cap would in some instances delay passage by weeks or even months. Vessels have on occasion been diverted to avoid excessive delays.

2.3 Environmental & Operational uncertainty

When planning on the timescales required for voyage scheduling, operational forecast products for tide anomaly, coastal currents, winds and (spectral) waves are all needed to reduce the range of uncertainty inherent in multi-day ahead planning [8]. The forecast guidance' are statistically evaluated and adaptively integrated into the system to provide stochastic estimations of the range of conditions likely to be encountered, with prognostic value out to around 7 days and beyond. Coupled with port and vessel particulars, this dynamic approach to UKC (DUKC®) management may be applied at the load port and discharge port in addition to the UKCM which provides the greatest opportunity for optimisation in a volatile environment.

Similarly freight rates, time charter rates and fuel costs can be volatile and vary in dynamic markets. Hence the "optimal" trade-offs will vary such that the most financially optimised schedule for one ship and time may differ widely from another (for instance based on differing fuel consumption curves or tonnes per centimetre immersion figures). A range of values for these can therefore be entered into the system; where the prices are known the range is simply set to the known value.

In the event of changes to the shipping requirements, such as stockpile issues or cargo grade variances, the Berth to Berth system may be called on to adjust scheduling advice according to the revised operational requirements. To make any meaningful optimisations under these circumstances, there must be sufficient flexibility in the operations to act on the proposed changes such as delayed sailing at the load port (to load more product), or vice versa to "short-load" and catch an earlier sailing opportunity.

To reduce the cognitive load on operational users, the impact of the estimations and allowances made by the system are routinely summarised using pre-selected risk profiles. Only in extreme circumstances are the details brought to the user's attention, or if the user specifically queries them.

2.4 User Experience

A prototype system was developed to seek feedback from shippers, delivered via a cloud hosted web interface. As a result of this feedback, where possible the planning inputs were pre-loaded from external data sources to minimise the burden on the users. Users can correct these inputs when appropriate, which are saved with the specific vessel and schedule planning data set, which can be re-loaded later on for revised calculations or as a starting point for new calculations. A screen shot of the prototype is shown in Figure 2.

Time-varying ship-specific information such as fuel versus speed curves are editable and stored when updated information is available (e.g. after drydocking when hull and propeller performance is improved due to the removal of fouling [2]). Other time-invariant particulars such as summer draft, displacement and tonnes per centimetre (TPC) can be loaded from a ship database, given the vessel's IMO number. These details can be viewed, modified and saved from the browser-based user interface as shown in Figure 3.

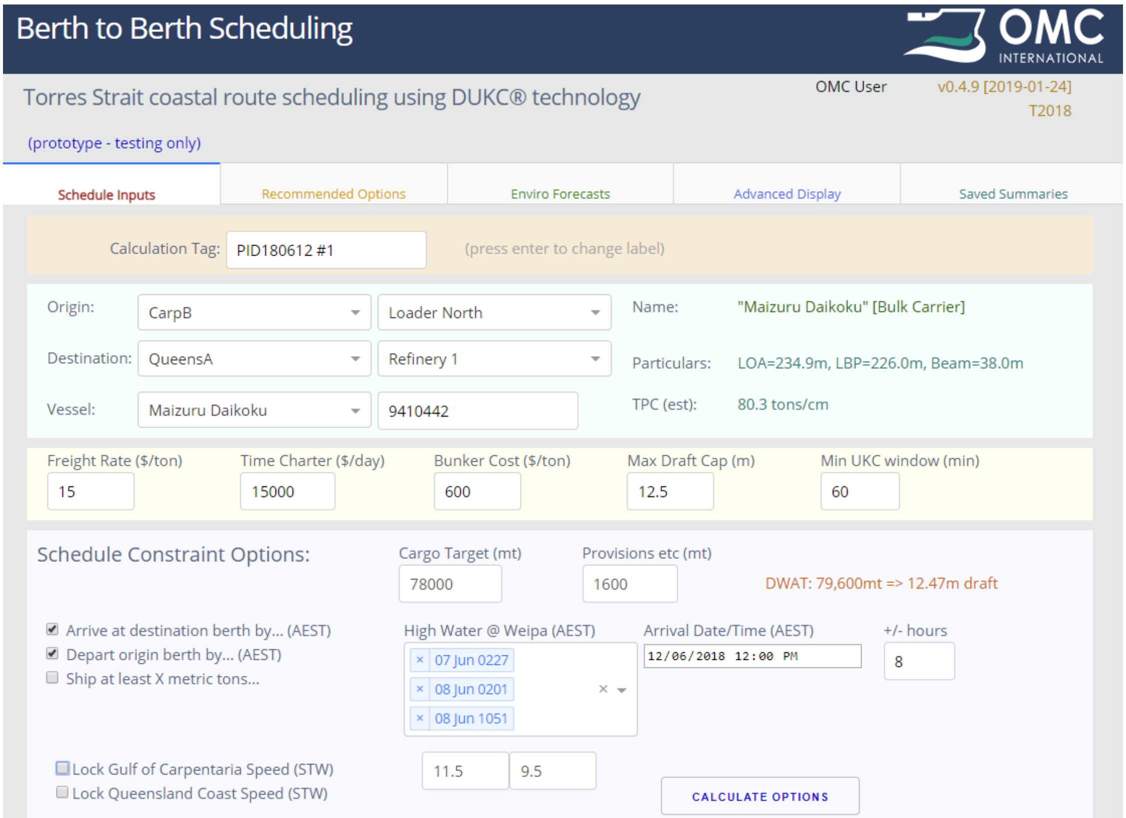

Figure 2 – Screenshot of the constraints page for the prototype Berth to Berth system; details are remembered or automatically loaded where possible to minimise manual entry; users specify constraints to suit various scenarios

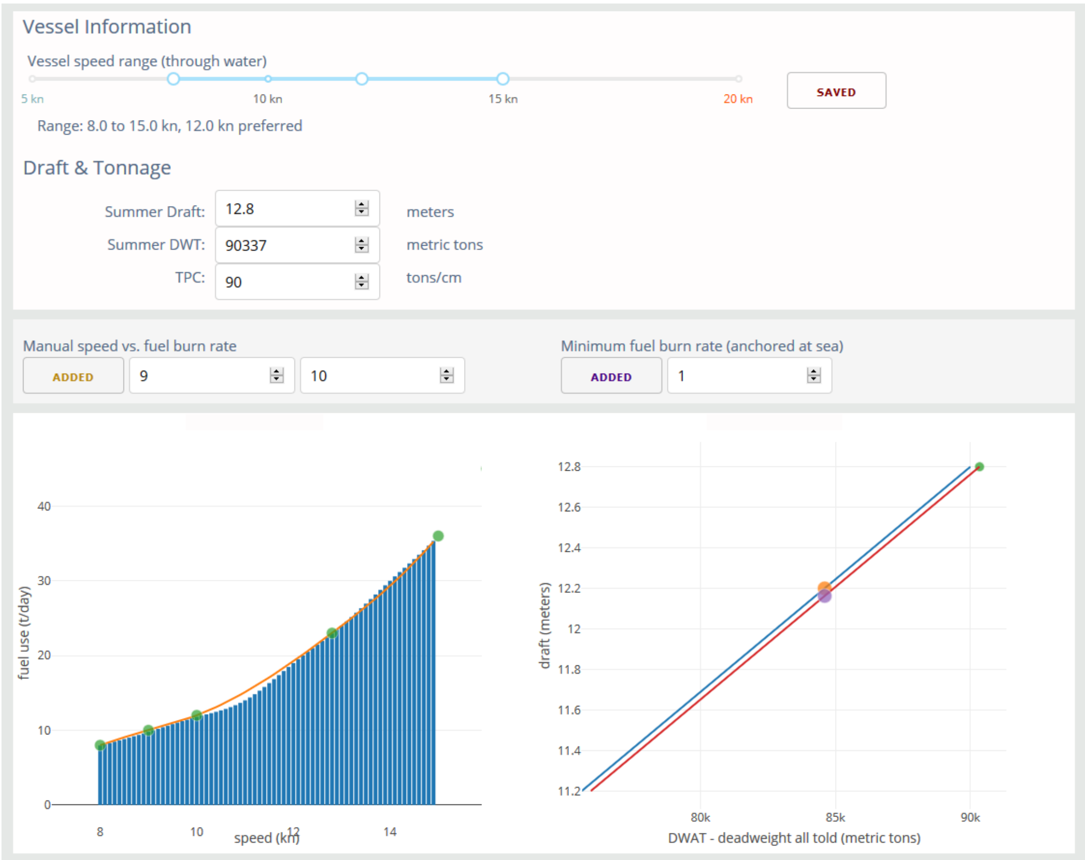

Figure 3 – Screenshot of prototype system vessel particulars input & display; fuel consumption curves can be inferred from few data points or fully entered, and draft-tonnage characteristics are loaded from a database; these ship characteristics can be vital in determining optimal strategies since these characteristics determine the financial outcomes

The latest forecast weather is automatically used in the selection of optimised schedules, with expected voyage weather information and routing advice available. This can then be shared with other stakeholders such as the master, pilots and port operators via a web URL. The information provided to specific users can be tailored to suit their requirements.

The schedule advice is delivered using an infographic-style presentation to highlight the results of the optimisation, and the pertinent differences between competing strategies such as the difference in timelines along the horizontal plane, per Figure 4. Producing the results in the prototype takes several seconds to a few minutes depending on the range of options available, however calculation optimisations are expected to dramatically reduce this waiting period.

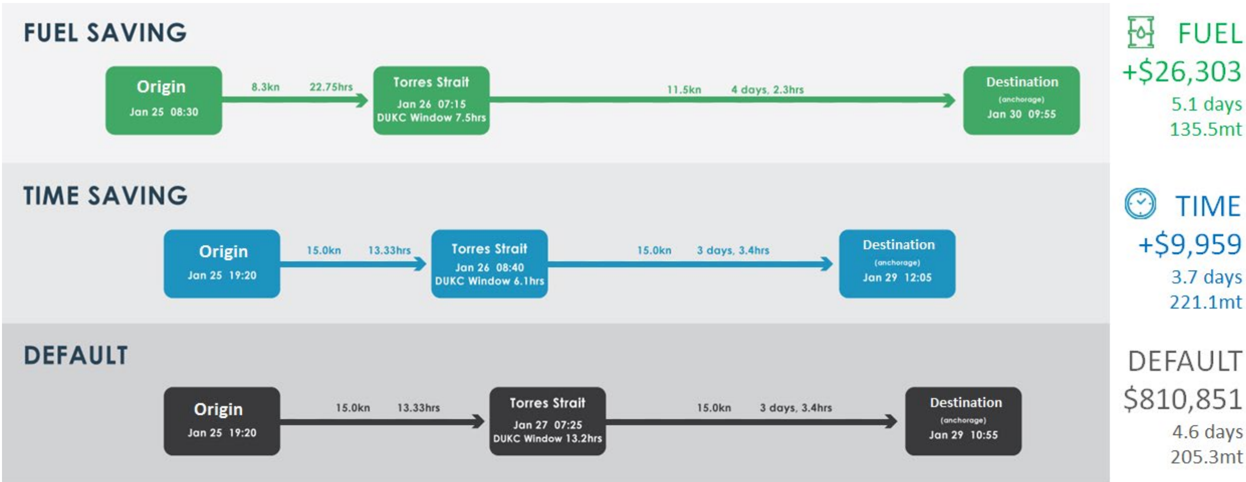

Figure 4 – Presentation of Berth to Berth alternate suggestions for voyage scheduling for a specific draft target; the schedule timing alternatives for a given draft are visually contrasted in time and financial terms; fuel and time are balanced in financial terms (cargo versus draft can also be balanced)

2.5 Impact of Torres Strait draft cap

In accordance with Marine Order 54 [4] the allowable maximum vessel draft through Torres Strait is capped at 12.2 metres. Weather and traffic conditions permitting, vessels with drafts of 12.2m or less are generally able to navigate through the Torres Strait on most days of the year when considering dynamic under-keel clearance factors and minimum under-keel clearance requirements of 1 metre (or 10% of draft). As outlined in this paper, seasonal variations in water levels result in greater under-keel clearance being available during the period November to March and occasionally less in the remaining months.

For the duration of the Torres Strait UKCM deep draft trials, under the Navigation Act 2012, AMSA issued temporary regulatory exemptions to the Torres Strait UKCM provisions as set out in Marine Order 54 (Coastal Pilotage) for a handful of dedicated RTM vessels [5]. Each exemption was issued under strict conditions to ensure that vessel navigational safety is maintained.

The draft cap through Torres Strait on throughput imposes a constraint on the range of schedule options. A less restrictive draft cap provides more schedule options, which enable the selection strategies to increase overall efficiency, reducing the number of vessels required to ship the same volume over time or increasing the overall cargo shipped. This is particularly valuable in the "summer" months where UKC requirements for deeper drafts are more frequently met.

3. Key Findings

By varying departure and arrival times within one or two tides (12 to 24 hours), the profitability of voyages could be increased by US11,000 per voyage (averaged) depending on the relative fuel, charter and freight values. This is a significant improvement on a relatively short four-day transit. The benefits ranged up to USD55,000 for specific voyages where the Torres Strait system provided narrow windows of opportunity for optimal utilisation.

The optimisations balance the cost and revenue factors on a financial basis, such that sometimes delaying arrival or departure times could increase draft (and therefore cargo revenue), by utilising alternate Torres Strait sailing windows, saving fuel or avoiding adverse weather conditions as in Figure 5. Through the study period of 2018 sailings, no single strategy of minimising speeds or maximising drafts provided the overall optimal outcomes. Indeed, the mix of optimisations varied with season and the relative phasing of the tidal levels for the DUKC® systems. These optimisations can also be sensitive to the relative freight values, fuel costs and time charter rates so the optimal solution for a given schedule can differ depending on specific ship characteristics and market rates.

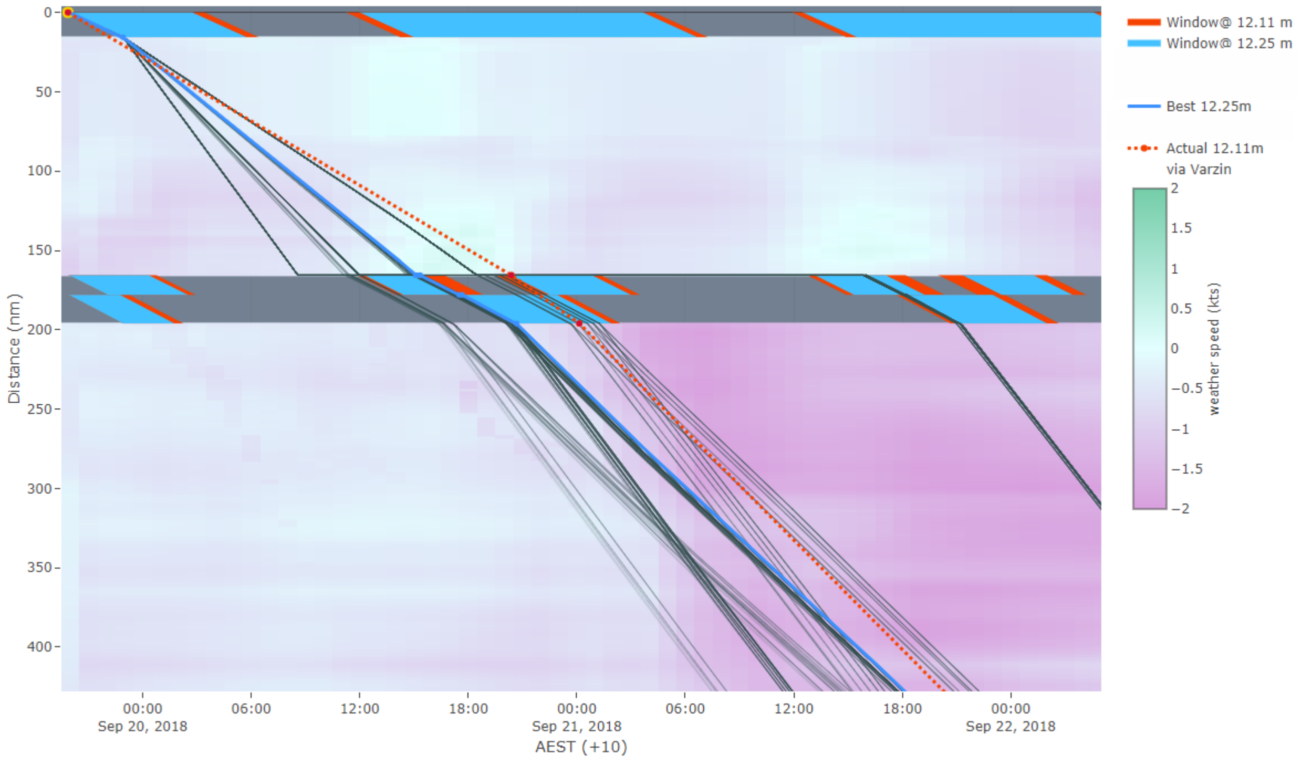

Figure 5 – A prototype system screenshot where alternate scenarios are compared taking DUKC(R) windows; vessel speed characteristics and forecast weather into account; the weather impact on speed and fuel efficiency over the south-bound leg can result in divergent strategies for optimal outcomes

The overall savings included a mix of fuel savings, revenue increases through draft uplift and a potential increase in vessel utilisation with shorter laden voyages. No one strategy was always optimal, though seasonal trends could be estimated well in advance using astronomical tide and current predictions.

4. Future Directions

Realising the value of the Berth to Berth approach to voyage schedule optimisation depends on the ability of shippers to action the advice provided. This can be challenging in an environment where various parties have contractual obligations and operational objectives that may not always align with the overall efficiency of shipping.

On the modelling side, the accuracy of fuel consumption characteristics and the reliability of weather forecasts are also important considerations which need verification to ensure that advice is issued based on a sound basis.

To best utilise the schedule optimisation advice, the operating framework of the shipping operations must be considered in producing the constraints and modelling. In essence, wherever possible there should be a range of timing options within the scheduling options for the model to find optimal results for cargo uplift, fuel saving and weather routing.

This may be assisted by the addition of risk profiling for schedule options, where uncertainties in weather (water levels, currents, waves etc), availability and readiness timings, and dollar rates can be summarised with the results. The recommended results can then be selected to provide users with options that satisfy their needs for reliability and comfort.

5. References

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