TOQUA

Savings Validation Exercise
Voyage Optimization

Anonymized Template

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Objective

In the scope of a Voyage Optimization project, Shipping Company X, Routing Company Y, and Toqua benefit from being able to calculate and validate the realized savings due to their technology.

Routing Company Y and Toqua both face the same challenge of proving their ROI in an industry where over the past decades other technologies have largely exaggerated their promised savings and have done very little effort to support their claims. To break free from this skepticism it's crucial to prove the ROI in a well-substantiated, scientific study. This document details an approach suggested by Toqua to jointly validate the savings of our technologies, open to suggestions and changes from Routing Company Y's and Shipping Company X's side.

The goal is to be as rigorous as possible, while minimizing the workload for both Routing Company Y, Toqua, and Shipping Company X. The more scientifically substantiated and verifiable the numbers, the stronger the argument.

Challenges

Validating the savings potential of voyage optimization is complex, due to 3 main reasons.

1. **Benefit of hindsight**: re-optimizing routes sailed in the past is usually not considered fair if hindcast data is used. This is because the original optimization made in the past was made based on weather predictions, instead of weather measurements, providing an advantage to hindcast methods.
2. **Re-optimizations during the voyage:** given weather predictions change throughout the voyage, many optimization algorithms re-optimize the route every X hours, adding a high level of complexity to this exercise.
3. **Calculating the cost of hypothetical routes:** the main challenge for every routing ROI exercise is that only 1 route can actually be sailed - for which true data is available - while the cost for all other suggested routes has to be estimated. If the inaccuracy of this estimation is too high, the 'estimated savings' might equally be a result of inaccuracy of the modelling method instead of the savings of the actual optimization.

Given savings due to routing are usually single-digit percentages, it's crucial to account for the caveats above to ensure an accurate 'all other conditions being equal' comparison, to avoid criticism on the claimed savings.

Approach

Toqua suggests the following 4-step approach that counters the 3 challenges above to the extent possible. The numbers currently filled in are **made-up/fictional** and are filled in with the purpose of showing what outcome might be expected. Actual results after undertaking an exercise like this will obviously be different, depending on the case.

1. **Identify the most accurate estimation method for calculating the cost of hypothetical routes**

   Before running different optimizations, there must be agreement on what estimator is most reliable to calculate the cost of the different hypothetical routes. We define hypothetical routes as routes that have been suggested by Routing Company Y's algorithm, but for which the cost needs to be estimated, as not all hypothetical routes can actually be sailed to gather operational data.

   To do so, we compare the accuracy of different models by predicting performance for some actual historical routes sailed by Shipping Company X's vessels, so we have a ground truth to compare with. At first, we do this per point prediction (every 5 minutes - MAPE) to get a general comparison, but more important is the accuracy over a voyage (which will be higher due to averaging out over- and under-estimates over multiple days/weeks). Given sufficiently long voyages, the accuracy of Toqua's model will come fairly close to 100% - being the most accurate estimator to calculate hypothetical routes.

1. **Identify the most accurate estimation method for calculating the cost of hypothetical routes**

MAPE (5min) SOG to Fuel	Sea Trial Curves	Model Z	Toqua Medium Res Table	Toqua Actual Model	Actual Data Ground Truth
Voyage 1	73%	84%	95%	96%	100%
...	...	...	...	...	...
Voyage N	67%	82%	93%	94%	100%
Average	**71%**	**83%**	**93%**	**94%**	**100%**

Voyage Accuracy SOG to Fuel	Sea Trial Curves	Model Z	Toqua Medium Res Table	Toqua Actual Model	Actual Data Ground Truth
Voyage 1	82%	89%	98%	99%	100%
...	...	...	...	...	...
Voyage N	92%	93%	98%	98%	100%
Average	**86%**	**92%**	**98%**	**98.5%**	**100%**

2. **Use different base models to make different optimizations for a single route, all other conditions being equal**

The next step consists of using different 'base models' (=ship performance models) in Routing Company Y's algorithm, using identical routing conditions and constraints. To ensure 'all other conditions being equal', all scenarios have the same departure and arrival times and use the same weather predictions, the only thing that changes is what 'base model' is used to make the optimization by Routing Company Y.

For weather predictions, hindcast data *or* forecast data might be used, as long as the same choice is made over multiple scenarios. The objective is to minimize fuel consumption respecting the departure and arrival times, with the freedom to vary speeds across the route as deemed appropriate. The outcomes are multiple different 'optimal' routes with identical arrival and departure times and with varying Speed-Over-Ground across the route. We think it's a good idea to consider passages that have often been sailed historically, so it reflects realistic conditions and thus realistic savings potential representative for Shipping Company X.

For the base models we consider using:
1. **Sea Trial curve - no corrections**
This is obviously an oversimplification and given it doesn't take weather conditions into account, it will always show the shortest route at a constant speed as the 'optimal' route, regardless. We believe it's useful to include this solution as a lower boundary.

2. Sea Trial curve + empirical correction factor (Model Z, ISO 15016, Kreitners, …)
A sea trial curve with correction factors based on an empirical formula is often used as a'base model' by the industry today. Shipping Company X or Routing Company Y might have their own preferred way of applying these correction factors (that we will call 'Model Z'). If that's the case, we suggest using Model Z as a base model. If there is no model preference or the companies prefer not to share their internal models, we can always default to a version of ISO 15016.

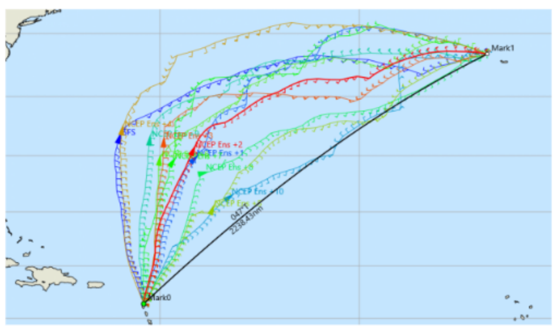
3. Toqua's model
The third base model is Toqua's Ship Kernel. If Routing Company Y's algorithm requires a high throughput (+50.000 predictions/min), the Ship Kernels would be used in a tabular format instead of their original form, leading to a slight drop in modeling accuracy, but making it suitable for the use-case at hand.

Using these 3 'base models' similar optimization scenario's can be run in Routing Company Y's algorithm. These can be historic voyage scenarios using static hindcast data. Alternatively, they can be routes predicted in the present for the future, but under the assumption that today's weather forecasts are true and won't change over time. This keeps things simple enough to assure comparability, while keeping the focus of the exercise on the savings potential of the model, instead of mixing it up with weather forecasting (in)accuracy.

Outcome:
The outcome consists of 3 different routes that each consider themselves to be optimal according to the used base model.

2. Use different base models to make different optimizations for a single route, all other conditions being equal
Design N voyages with a fixed departure time and fixed arrival time - representing realistic options for Shipping company X. Could be historic voyages or simulations.

Voyage 1	Estimated Cost by each model
Sea Trial Curve	790 tons
Model Z	832 tons
Toqua Model	813 tons



3. **Recalculate the estimated cost of the hypothetical routes resulting from the optimizations using the most accurate estimator**
The next step is to compare these 3 different 'optimal' routes according to a single standard. The sea trial curve might for example think it will only consume 790 tons along the voyage at that speed, because it does not take weather factors into account. The actual cost of that route will be higher.

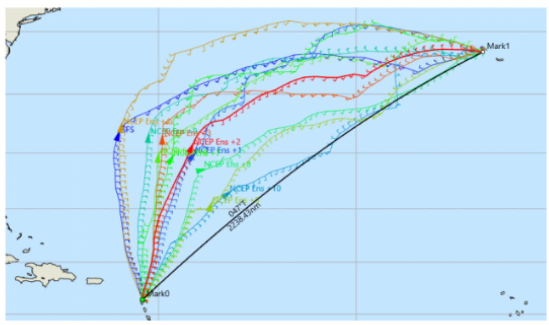
The question then becomes what 'base model' should you use to compare all routes according to the same standard? It would make sense to use the 'base model' that is the best estimator of reality and has the highest accuracy. Following the result of step 1 - that would be Toqua's model with an accuracy of 98.5%. It's not a perfect 100%, but it's the closest to reality we can get considering the accuracy of the available ship performance models.

When recalculating the 3 routes using one single model, the result will be comparable and we can see that the higher the accuracy of the base model, the more 'optimal' the suggested solution. Again, current numbers are made-up, but we expect Routing Company Y's solution with Model Z to show more savings potential than the shortest route. Then we expect the route created using Toqua's model in Routing Company Y's algorithm to provide some % of additional savings on top of the savings using Model Z.

3. Different 'optimal' routes are calculated using different models (Sea Trial, Model Z, Toqua) but using same Routing algorithm. The fuel consumption per route is recalculated using Toqua's model (=best estimator of reality)

Design N voyages with a fixed departure time and fixed arrival time - representing realistic options for Shipping company X. Could be historic voyages or simulations.

Voyage 1	Estimated Cost by each model	Estimated cost by Toqua model	Savings compared to shortest Route
Sea Trial Curve	790 tons	843 tons	0 tons
Model Z	832 tons	822 tons	21 tons
Toqua Model	813 tons	813 tons	30 tons



4. **Over multiple routes, calculate the average savings due to Routing Company Y's routing and Toqua's models**
   We recommend repeating this exercise for multiple routes (5-20) until averaging over routes seems to fairly reflect average operating conditions. The average savings over N routes will then represent the savings possible for Shipping Company X due to Routing Company Y's and Toqua's systems and allow for the calculation of an approximate ROI. Again, the numbers below are made-up and just serve to illustrate the methodology.

4. Over multiple routes, calculate the average savings.
WARNING! These numbers are fictional and just serve to illustrate the methodology.

Fuel Savings compared to shortest route SOG to Fuel	Sea Trial Curves (=shortest route, no optimization required)	Model Z	Toqua Medium Res Table	Toqua Actual Model Ground Truth	Actual Data
Voyage 1	0%	5.2%	4.2%	?	?
...	...	...	...	...	...
Voyage N	0%	2.8%	1.2%	?	?
Average	**0%**	**3.2%**	**5.4%**	**?**	**?**

Results

In this **fictional(!)** example to illustrate our methodology, it is found that the Routing Company Y saves an average of 3.2% fuel consumption per voyage when using ship performance model Z at the base of their optimization algorithm. When they use a Toqua model the average savings jump to 5.4%, roughly a 70% increase in savings. Even though these numbers are fictional, the increase roughly matches the numbers found in an actual study.

At Toqua we believe in numbers above everything else, so just knowing these numbers - even without publishing - would be very valuable to all parties. The industry is sick of 'claimed savings' without proof, so we want to be a breath of fresh air by putting in the effort of proving them as objectively as possible.

For questions or comments, please contact casimir@toqua.ai.