Technical Session Notes
Vessel Encounter Module: Comparing Ship Domains
March 17, 2021

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The following summary notes are not intended to be a transcript but rather a review of the discussion session. Participant questions and comments are shown in bold text followed by Ecology responses. Ecology responses that have been added after the conclusion of the event are preceded by the text "Supplementary answer."

I am unclear whether the model will be hypothetical or if it will use actual vessel traffic data, but if hypothetical it should include the number of vessels that each anchorage area can accommodate. (Lovel Pratt)

JD Leahy: In terms of the number of vessels that can be anchored, the model will simulate vessels arriving to different locations within anchorage areas that can accommodate multiple vessels.

Supplementary answer: The number of vessels that are allowed to anchor in a given anchorage in the model will be capped based on the limit established in the Puget Sound VTS User Guide. There are no Canadian anchorages that can accommodate multiple vessels, so each Canadian anchorage has a capacity of one.

I am curious about the ATB in slide 7 as it is shown anchored in an anchorage that is not ATB-specific. (Lovel Pratt)

JD Leahy: ATBS were used in slide 7 because that happened to be the AIS snapshot in time that was chosen for this example.

I am curious about potential for vessels at anchor to drag anchor in adverse weather. (Lovel Pratt)

Supplementary answer: We plan to model the potential for vessels to drag while at anchor, and the subsequent risk of oil spill that may result.

I have concerns around how ship domains are characterized for vessels at anchor. It would make more sense to include the entire area for the vessel swing. It is important to address the complexities of the anchorage areas and recognize that vessels don't stay in a single place indefinitely. **(Lovel Pratt)**

JD Leahy: You are correct that in your understanding, that as currently laid out, these modeled ship domains for anchored vessels do not move – our rationale in keeping them stationary is that we will be running a large number of scenarios and in each scenario it will be occupying a unique position.

In terms of including the entire area of the vessel swing, these ship domains, even when stationary, are fairly good at representing the total area occupied by the vessel and the anchor gear at a moment in time.

Alex Suchar: We could model the entire swing of the vessel but it may not increase precision or bring anything new to the analysis. Inclusion of the vessel swing might introduce more uncertainty to the modeling results.

Supplementary answer: We remain open to adjusting our approach to how ships are modeled while at anchor, including the consideration of different ways to represent their movements while anchored.

Thank you for the work and contemplation on this model. Swinomish participation has tended to emphasize importance of getting it right on the risk analysis for Anacortes to Cherry Point including Vendovi anchorages. These are not federally designated anchorages but the HSC has a suggested vessel cap. This anchorage will be used more intensely during the most adverse conditions. Ships will want to anchor at safe harbor when there are strong winds etc. Are you doing hypothetical scenarios for the modeling? Suggest modeling anchorage areas both ways. This is one of the most critical locations in the entire study area. Friendly critique is that this webinar format is not conducive to getting it right – we are waiting for a better way to have these discussions. Recommend forming a subcommittee to discuss anchorage risks in this area – talk about range of decision options. Don't find it convincing that the ship domain accurately represents risk at anchor. Not discussed here today is the tribal fishing in this area. (Tom Ehrlichman)

JD Leahy: We will look for alternative ways to have in depth conversations about these topics.

Supplementary answer: We will hold a technical discussion dedicated to the treatment of anchorages in the model.

The supplemental materials mention speeds of 8 to 22 knots. If there was a meeting situation how much weight would speed have? (Fred Felleman)

JD Leahy: The 8-22 knots are listed because those are the min and max speeds on slide 3-4 in the example. The influence, or weight of the ship's speed on the size of the domain is determined by the formulas for ship domain size that we are using.[i]

In terms of encounter probabilities how do we determine inertia if a vessel losses power. If we are looking at a disabled ship how would inertia be accounted for? (Fred Felleman)

JD Leahy: We haven't start that work yet but we will be looking at that as part of the drift model, which we will discuss when we get to the Vessel Accident Module.

How is the width of the ship domain determined? (Ross McDonald)

Alex Suchar: The ship domains are calculated by using the referenced equations (see endnote). The width and length of the shape domain are calculated based on those formulas. The formulas integrate both vessel characteristics and vessel movement information as part of the calculation. As a result, ship domains include dynamic vessel movement components, which is one advantage to this approach.

Does encounter mean an encounter between two ships? (Ross McDonald)

JD Leahy: We count an encounter when two ship domains overlap. This allows us to eliminate all of the moments in the simulation where there is just one ship present and therefore there cannot be a collision there. Areas where ships are closer together will likely have more encounters counted.

So an encounter is not a collision? But enough encounters could be a collision? (Ross McDonald)

JD Leahy: Yes – an encounter is not a collision. Encounters take place daily on the waterway. We are not saying that a certain amount of encounters makes an accident. We are just saying that these are locations in the system that theoretically represent the possibility of a collision.

Will the size of the domain get larger in offshore area or when there are long gaps between AIS signals? (Jeff Pelton)

JD Leahy: No. The size of the domain only changes for a particular vessel based on the speed of the vessel. The domain does not change size for other factors, like for instance a wider waterway.

Are encounters mapping out what happened based on AIS data or are you creating hypotheticals? (Tom Ehrlichman)

JD Leahy: The information in the slides we are looking at today is pulled directly from real, historical AIS messages.

Alex Suchar: As far as the modeling is concerned, we are using AIS data to understand vessel routes and vessel anchor patterns. And we are using that historical AIS data to inform the simulations. When it comes to the risk modeling we will use model simulations based on scenarios we are interested in.

So you will use tracks where vessels actually traveled versus just modeling vessels as following the shipping lanes? (Tom Ehrlichman)

Alex Suchar: Yes, each track will have a unique journey instead of just following the traffic lanes.

What does it mean to distribute accidents to geographic areas? (Tom Ehrlichman)

JD Leahy: Some of how we handle accident rates is a work in progress. If you have an estimate of how many accidents might take place in a given timeframe, you need to then decide where the accidents will likely take place. The encounter model helps decide the geographic distribution of the accidents.

Alex Suchar: The first requirement for a collision is that 2 vessels are in the same place. If there is only 1 vessel there is no collision. What the encounter module is establishing is the regions where vessels often cross paths versus the regions where vessels almost never cross paths. The encounter model tells us the areas where there is potential for a collision. We will have a very large number of simulations – no two simulations will be the same. It will be a balancing act to see how these variations show up and how they inform the risk assessment.

It sounds like the encounter module is a place where you could run different anchorage scenarios (conservative, worst case – swinging on anchor chain, ...). It seems like encounter module could run it both ways to show risk decision-makers a range of risks. (Tom Ehrlichman)

JD Leahy: We are certainly interested in the idea of showing a range of risks.

If you are looking only at historical vessel traffic you may miss risky scenarios that could take place in the future but did not take place in the past. (Christopher Barker)

JD Leahy: When ships in our simulation are moving they are operating on tracks that are real historical data. But as you point out, every day on the waterway is unique, and new situations that have never happened are commonplace. The way that our simulation works is that when vessels are entering the system they are selecting their destinations and routes based on historical distribution and statistical frequency from the past but they are engaging with other vessels in scenarios that are unique and new and did not occur in the past.

It's good that changes in shipping trends will be considered. (Christopher Barker)

JD Leahy: Changing shipping trends are the reason why we are using route segments that allow vessels to make route selections as the move through the model. We want the model to be realistic so we have grounding it in historical data but we also don't just want to replay historical data. The use of route segments is one of the strategies we have put in place to achieve those goals.

I have observed that traffic is not equally distributed across a calendar week due to longshore and other logistical considerations. Has any testing been done on that hypothesis? (Fred Felleman)

Alex Suchar: Based on what we have so far we did not see any trends within the week but we will be working with a larger dataset soon and we may see a different vessel distribution based on the day of the week with the larger dataset. The simulation will allow different scenarios such as increased traffic on certain days of the week.

What years of data are you using right now? (Fred Felleman)

Alex Suchar: Currently we have AIS message for 2015 to 2019.

JD Leahy: Alex is using that AIS messages to build the algorithms for the tools that rely on data. The important part of the work he is doing is building the algorithms. There algorithms will be applied to data (and potentially data from other date ranges) to answer questions and run scenarios. The model will not be tied to a particular baseline year.

2020 was an unusual year – there were more vessels anchored in the Canadian Gulf islands in 2020 than in other years. 2020 may not be representative of a usual year. Seaport Alliance is not seeing a backlog of vessels sitting at anchor but Vancouver is. (Fred Felleman)

Both Pentagonal and Quaternion Ship Domain are great and at the end of the day I think you'll get a rate for the number of accidents per encounter (whatever ship-domain type it might be). Might be of interest that Schultz & Bourne (2019) <https://erdc-library.erdc.dren.mil/jspui/handle/11681/33343> have proposed an approach to encounters, where they take into consideration the difference between course over ground and heading of the vessel (which can be a proxy for wind/currents) to help determine the size of the ship-domain. Might help with drift down the road for you. (Jeff Pelton)

In terms of weather and bunkering, if you are looking at criteria for risk related to weather it is advisable to go to bunker service companies to get their criteria from their Safety Management Systems about when it is safe for them to bunker. It would be good to include this criteria in the model so that you don't model risk that doesn't exist. (Sol Kohlhaas)

Please consider using a different platform that might have less security issues for stakeholders. (Laird Hail)

Supplementary answer: We appreciate this suggestion and are looking into some options. We have recently gained limited access to MS Teams, and are exploring that as an option.

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[i] **Quaternion Ship Domain (QSD) description**

The Quaternion Ship Domain was proposed by (Wang 2010) based, in part, by the work conducted by (Kijima and Furukawa 2003). The QSD is an ellipse with four directional radii:

$$\begin{cases} R_{fore} = \left(1 + 1.34\sqrt{k_{AD}^2 + \left(\frac{k_{DT}}{2}\right)^2}\right)L \\ R_{aft} = \left(1 + 0.67\sqrt{k_{AD}^2 + \left(\frac{k_{DT}}{2}\right)^2}\right)L \\ R_{starb} = (0.2 + k_{DT})L \\ R_{port} = (0.2 + 0.75k_{DT})L \end{cases} \quad (1)$$

Where: L – own ship length; k_{AD} and k_{DT} are gains of the advance A_D and the tactical diameter D_T, and they are given by:

$$\begin{cases} k_{AD} = \frac{A_D}{L} = 10^{0.3591 \lg v_{own} + 0.0952} \\ k_{DT} = \frac{D_T}{L} = 10^{0.5441 \lg v_{own} - 0.0795} \end{cases} \quad (2)$$

The QSD is an ellipse whose shape is characterized by equation (3), where k=2:

$$f_k(x,y) = \left(\frac{2x}{(1+\operatorname{sgn} x)R_{fore}-(1-\operatorname{sgn} x)R_{aft}}\right)^k + \left(\frac{2y}{(1+\operatorname{sgn} y)R_{starb}-(1-\operatorname{sgn} y)R_{port}}\right)^k \quad (3)$$

Pentagonal Ship Domain (PSD) description

(Bakdi et al. 2019) proposed an adjustment to the radii in equation 4 that account for both the length and the breadth of the vessel. They became:

$$\begin{cases} R_{fore} = A + \left(1 + 1.34\sqrt{k_{AD}^2 + \left(\frac{k_{DT}}{2}\right)^2}\right)L + \Delta_{er} \\ R_{aft} = B + \left(1 + 0.67\sqrt{k_{AD}^2 + \left(\frac{k_{DT}}{2}\right)^2}\right)L + \Delta_{er} \\ R_{starb} = C + (0.2 + k_{DT})L + \Delta_{er} \\ R_{port} = D + (0.2 + 0.75k_{DT})L + \Delta_{er} \end{cases} \quad (4)$$

Based on these equations, (Bakdi et al. 2019) parameterized the PSD as follows:

$$\begin{cases} D_1 = 0.9R_{starb} \\ D_2 = 0.9R_{port} \\ D_3 = 0.9R_{aft} \\ D_4 = 1.1R_{fore} \\ D_5 = 0.75R_{fore} - 0.25R_{aft} \end{cases} \quad (5)$$

Bakdi, A., I. K. Glad, E. Vanem, and Ø. Engelhardtsen. 2019. AIS-Based Multiple Vessel Collision and Grounding Risk Identification based on Adaptive Safety Domain. Journal of Marine Science and Engineering 8:5.

Kijima, K., and Y. Furukawa. 2003. Automatic collision avoidance system using the concept of blocking area. IFAC Proceedings Volumes 36:223–228.

Wang, N. 2010. An Intelligent Spatial Collision Risk Based on the Quaternion Ship Domain. Journal of Navigation 63:733–749.