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A SIMULATION MODEL TO EVALUATE NAVAL FORCE FLEET MIX

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ABSTRACT

The Defence Research & Development Canada – Centre for Operational Research and Analysis created a Discrete-Event Simulation model, called the Platform Capacity Tool (PCT), to answer questions regarding the suitability of fleet mixes (numbers and types of naval platforms) required by the Royal Canadian Navy to meet its desired operational output and to fulfill its mandate. The PCT, implemented in Arena® Software, is a detailed scheduling tool that assigns platforms to random and scheduled events as they occur in the simulation. The assignment is based on event prioritization and on basic scheduling rules. The tool is flexible, allowing the user to analyze various fleet mixes and to help in answering "what if" type questions. This paper describes the PCT (inputs, outputs and assumptions) and presents a notional scenario involving the transition from one class of ship to two classes to demonstrate how the tool can be applied.

1 INTRODUCTION

1.1 Background

The primary role of the Defence Research & Development Canada (DRDC) Centre for Operational Research and Analysis (CORA) is to provide operational research and analysis support to the Department of National Defence and the Canadian Armed Forces (CAF). DRDC CORA often has to conduct analysis related to force structure and force development in support of the future Navy and, more specifically, provide objective analysis of proposed mixes of naval platforms to ensure the Royal Canadian Navy (RCN) can meet its desired operational output. While the term platform can often include vehicles, equipment or persons that perform a mission, in the context of this paper, it refers specifically to ships. Since the RCN is in the midst of modernizing its fleet by replacing existing classes of ship, requests for studies on the right numbers and mixes of platforms have come frequently in recent years to DRDC CORA.

DRDC CORA continuously develops and maintains tools to provide timely and scientifically sound advice on this subject to the RCN, when requested. A Discrete-Event Simulation (DES), called the Platform Capacity Tool (PCT), was developed in Arena® Software (Rockwell Automation 2021) to provide insight into the number of platforms required to meet desired operational output. In essence, the PCT is a detailed scheduling tool that assigns platforms to events as they arise in the simulation. It is flexible, allowing the user to quickly analyze various fleet mixes and answer "what if" type questions.

Since its creation, the PCT has been used to assess the operational effectiveness of an RCN Force Structure with and without the Kingston-Class Maritime Coastal Defence Vessel (MCDV) and to quantify the impact of a potential divestment (Fee and Caron 2018). It was also used to quantify the operational effectiveness of various fleets by a North Atlantic Treaty Organization (NATO) Specialist Team that conducted a cost-benefit analysis comparing traditional and mission modular naval forces (Logtmeijer et al. 2020).

1.2 Overview

This paper serves two main purposes. First, it describes the PCT, including the main inputs required to run the simulation, the outputs it produces, some of the assumptions behind the tool and its limitations. Second, the paper demonstrates how the tool can be utilized by applying the model to a notional scenario which involves the transition from one class of ship to two new classes of ship. The example used is fictitious and for illustration purpose only. Note that technical details and a guide on how to use the PCT were previously published in an internal DRDC Scientific Report (Valois et al. 2019).

2 RELATED WORK

2.1 Problem

Fundamentally, most fleet size problems boil down to a question of *supply* and *demand*: how well does a supply of assets (in this case ships) meet an operational demand? The problem itself is similar to other classes of problems and is not specific to the RCN. In recent years, a number of comprehensive surveys and overviews of these families of problems and approaches have been published in the literature, including: Wojtaszek and Wesolkowski (2012) on fleet mix problems, and Pantuso et al. (2014) on maritime fleet size and mix problems. The following discussion focuses on the studies carried out by DRDC CORA scientists to inform the RCN (and other services of the CAF) on fleet mix and fleet structure related questions and highlights how the modeling of supply and demand concepts were handled.

2.2 Past Studies

2.2.1 Demand

Studies have modeled operational demand as being either deterministic or stochastic in nature. For instance, Bourque and Mirshak (2015) used a fixed operational demand expressed as ambition levels (set by Senior Leadership) which involved setting a required operational output from the fleet, in terms of readiness states (i.e. different status of a ship dictating the kinds of missions it can accomplish) and number of platforms in each state at any given time. Conversely, other studies (Allen et al. (2005), Bourque and Eisler (2010), SPA (2016), Fong and Caron (2018), and Caron et al. (2019)) have used stochastically driven approaches to establish operational demand for ships. This is accomplished through the use of a list of hypothetical scenarios, or vignettes, capturing the activities that the RCN should be prepared to act on.

2.2.2 Supply

There are different approaches to determining whether the supply matches the demand, each with strengths and drawbacks. Simple and straightforward analytical models have been employed by DRDC CORA in the past (Bourque and Mirshak (2015), and Fong and Caron (2018)). Based on factors like maintenance cycles, these models assume that a steady flow of ships is available at all times in different ship readiness states. The models then verify if and how much of the demand signal can be satisfied with the number of ships available. Although such approaches are easy to set up and run quickly, scheduling conflicts are ignored because of the simplified problem which yields optimistic results. This approach is also more tailored for cases when one class of ship is considered.

Simulation tools to explore alternative fleet mixes have been successfully used in the past when a "whole-of-navy" look (i.e. multiple classes of ship) was needed (Bourque and Eisler (2010), and SPA (2016)). For example, Bourque and Eisler (2010) proposed a detailed scheduling tool, called Tyche, which captures many scheduling rules and constraints that exists in reality. In this case, special assignment logic was implemented to handle such things as capability matching, deconfliction rules, pre-emption and re-tasking. The results it generates are largely dependent on the algorithms implemented, which may or may not reflect current and future real world fleet planning. This approach is prone to being particularly input intensive.

2.3 Current Approach

The PCT, described in the next section, builds upon concepts found in Tyche (Bourque and Eisler 2010). The operational demand for ships is first generated stochastically using a Monte Carlo simulation. Then, to evaluate whether the operational demand can be satisfied, it follows a detailed scheduling algorithm. The PCT is a simpler alternative to tools like Tyche, requiring fewer input parameters and without built-in metrics, but its detailed outputs provide the opportunity to generate more flexible evaluations of the fleet performance in post-processing.

3 PLATFORM CAPACITY TOOL

3.1 Overview

A high-level view of the PCT is presented in Figure 1. Implemented in Arena® Software, it simulates ship assignment to events as they occur in a scheduled or random fashion. It is intended as a means to quantify the capacity of a given fleet mix under specific platform availability conditions (i.e. a supply of ships) to meet that operational demand. The main components of the PCT are discussed below.

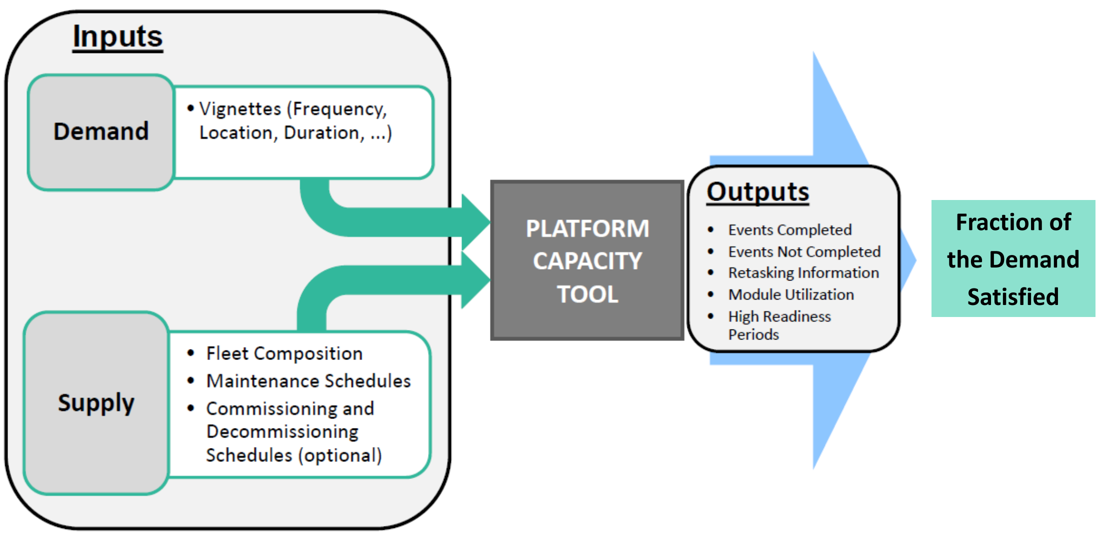

Figure 1: High-level view of the Platform Capacity Tool.

The general flow of the PCT is presented in pseudocode form in Figure 2. After the input parameters are read, a large number of replications have to be executed in order to generate statistically valid results.

At the beginning of each replication, a new operational demand is generated. Each demand represents a potential future that the RCN may face. It is generated stochastically using maritime vignettes, which are a set of hypothetical scenarios that aim to capture the spectrum of activities that the RCN is prepared to respond to (Fong and Caron 2018). The list of RCN vignettes was originally created in 2008 (Bourque and Eisler 2008) and was revisited in 2018 (Greenwood et al. 2018). The current list is composed of 60 vignettes.

In Figure 3, an example of a vignette is provided which describes the demand on the RCN to respond to requested humanitarian assistance and re-establishment of infrastructure as the result of a natural disaster occurring in North America. Operation UNISON, the assistance provided by Canada following Hurricane

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Algorithm: PLATFORM CAPACITY TOOL
Read Input Parameters
for Each replication do
    Generate Operational Demand
    for Each day do
        Check for ships availability
        Prioritize active events in queue
        for Each Event do
            Check for response from available ships
            if Response available then
                Assign resources
            else
                Check for Responses with rerolled ship
                if Rerolled response available then
                    Assign resources; ongoing event assigned "Partially Completed"
                else
                    if Event Response Time expires on next day then
                        Reassign event to queue for next day
                    else
                        Event assigned "Not Completed"
        Manage model resources
```

Figure 2: General flow of the Platform Capacity Tool in pseudocode form.

Katrina in 2005 (DND 2007), falls in this category. Each vignette is primarily characterized by the same information: “Type”, “Frequency”, “Duration” and “Impact”. These fields are used to establish the likelihood of occurrence of the vignette. For the example in Figure 3, based on historical data and projection, the RCN is expected to be involved in such a scenario once every ten years, and the anticipated duration ranges between three and six weeks. An impact category or consequence of failure (“Very Low”, “Low”, “Medium”, “High” or “Very High”) is assigned to each vignette.

Provide Disaster Relief in North America

This vignette takes place within the coastal areas of Canada and those of Continental United States. It involves the RCN in a humanitarian assistance disaster relief role providing support from the sea to coastal communities affected by disasters (e.g. hurricane and earthquake)

Type	:	Random
Frequency	:	1 every 10 years
Duration	:	3 to 6 weeks
Impact	:	Medium

Figure 3: Example of a maritime vignette – Provide disaster relief in North America.

For each replication, a list of events (an event is a specific instance of a vignette) is generated with the number, location, duration and timing of each event being generated stochastically by the PCT. Note that the number of events of a particular random vignette is generated using a Poisson distribution while the start and the duration are drawn from uniform and triangular distributions, respectively.

For each simulated active day, the PCT carries out the following operations. First, the ships’ availability is updated based on the following: (1) ship(s) going to or coming back from maintenance; (2) ships(s) being commissioned or decommissioned; and (3) ships(s) returning from a mission. Once a ship returns from the mission, the associated event is marked as "Completed".

The list of events is then prioritized based primarily on the impact category of the vignettes and how long the events have been in the queue. Once the list of events is sorted, the events are dealt with one-by-one, in the order they rank in the list. The model determines if there are ships available that can be assigned to the event. A ship is deemed available if it is not currently performing, traveling to or preparing for another ongoing event, is not in maintenance and would have sufficient time to conduct the event and return before the start of its next maintenance period. If many combinations of available ships can be matched to the event, the ships closest to their next maintenance period are given priority. If no appropriate combination of ships is available, the PCT then performs a second check to verify if any ship currently deployed on missions can be re-assigned to the event according to rules set by the user. In the PCT, this mechanism is referred to as *re-rolling*. Allowing re-rolling of ships is optional in the PCT and the rules are set by the user. An example of a rule could be that a ship deployed on an event of Impact Category "Very Low" has the potential to be re-rolled to another one of Impact Category "Very High". Re-rolling is limited to a single ship, so that only an already available partial response that is short one ship can be completed by re-rolling. An event that has one of its ships re-rolled is marked as "Partially Completed".

At the end of the day, there are events in the queue that are removed if they have not been assigned a response and have reached their response time threshold. These events are marked as "Not Completed". For example, in order for the navy to be relevant and have an impact in a search and rescue event, the response has to occur within a few days. On the other hand, a non-combatant evacuation operation, for instance, needs planning and therefore can stay longer in the queue because a response is not required immediately when the event pops-up.

Once the simulation is completed, detailed lists of "Completed", "Not Completed" and "Partially Completed" events are generated. From this, a schedule of assets can be constructed for each replication, such as the one included in Figure 4. The example shows the allocation a 12-ship fleet with two classes

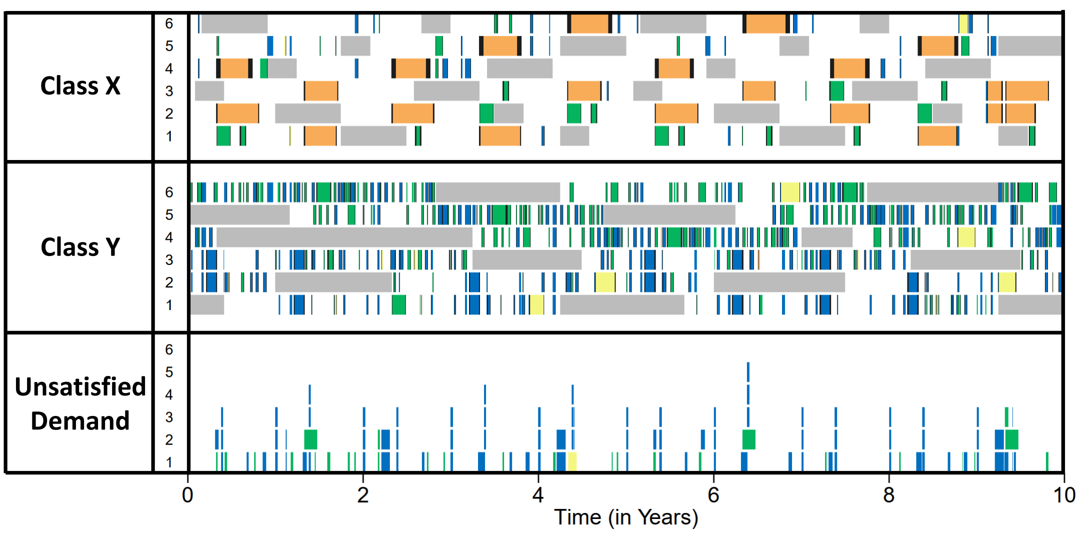

Figure 4: Example of a schedule generated from a single replication with the PCT.

of ship (Classes X and Y) over the course of 10 years of operations. Each colored block corresponds to a period of time where the ship is assigned to respond to an event. White periods describe time when the ship is unassigned and remains at a home port. Each ship in the class has fixed maintenance periods, represented by the gray blocks, and a smattering of events, colored according to the impact category of each event. Travel to and from the event location is depicted in black where applicable. The leftover demand that could not be assigned a timely response is visualized at the bottom of the diagram. Each block corresponds to a demand of a single ship (excluding travel) for the duration shown. Such visualization gives a quick indication of how busy each ship is and allows the user to identify any trends arising from insufficient supply.

3.2 Input

The input parameters for the PCT are captured through worksheets in a Microsoft Excel Workbook. The inputs include, but are not limited to, the following:

- **Vignettes**: The of list vignettes driving the operational demand, including type (random, scheduled or follow-on), frequency, duration, potential location(s) of the generated event, preparation time, response time and impact category. Potential responses for each vignette are also required (up to three). They vary depending on the ships considered in the analysis.
- **Rerolling Rules**: Vignette rerolling rules allow the model to determine if an ongoing event can be interrupted in order to complete an event of greater importance occurring simultaneously. Note that the PCT limits to one the number of ships that can be rerolled from one event to another.
- **Ship Availability**: For each ship, in order to determine when it can respond to an event, a home port has to be specified as well as its maintenance schedule. It is also possible to account for changes in ship availability due to commissioning and decommissioning of vessels.
- **Locations and Travel**: The simulation can be run in its simplest form without any rerolling. While it is possible to include direct event-to-event rerolling, when a ship is re-tasked, it must return to its home port before continuing to the new event. The model may also implement travel restrictions to prioritize responses from ships that are nearby. Additionally, travel is assumed to be at a constant speed.
- **Other General Input**: The PCT operates by generating a set of events over the course of a designated time span and then assigning ships in response. The number of replications that the simulation is run is specified in the general input. Typically, a minimum of 100 replications are performed.

3.3 Output

By design, the PCT does not compute any predetermined Measures of Effectiveness. Instead, a lot of data are collected as the simulation in Arena® Software runs. At the end, the PCT outputs a range of raw data that can be analyzed depending on the study's requirements. These include: lists of events completed, partially completed and not completed, as well as information about ship utilization and equipment (if applicable). The output data can be processed in Microsoft Excel or other software such as R (R Core Team 2013) based on the analytical needs of the current project.

4 NOTIONAL EXAMPLE

Many navies around the world are currently going through fleet transitions: replacement of one or more older classes of ship with one or more newer ones. While a successful transition depends on more factors than those presented here, having a sense of the impact of ship availability changes over time on the likely operational efficiency of the class of ship or fleet can be insightful in contextualizing transitioning schemes.

The example below illustrates how the PCT can be used to evaluate two fleet configurations through a notional example involving the transition from one class of ship to two. The first class, Class A, has six highly capable ships. The new classes of ship, Classes B and C, are expected to fulfill the same roles as the incumbent, but with varying degrees of capability. Class B will be composed of four less capable ships and will respond primarily the low impact vignettes. Class C's capability will be comparable to that of the incumbent class, but will have only four ships.

4.1 Assumptions and Inputs

Both scenarios present fleet transitions under the same operational conditions (i.e. generated from the same random seed) over a period of 40 years. Ten vignettes were used to describe the operational demand. The vignettes' details and parameters are presented in Tables 1 and 2. For each scenario, 100 replications were performed and the results presented below exclude two year warm-up and cool-down periods. Note that, in the simulation, both periods (i.e. warm-up and cool-down) are not fixed and can be set by the user. The remaining timeline (38 years) is divided into periods of two years and the operational effectiveness metric used in this paper represents the percent of events, which began in each period, that were completed. To simplify the simulation, no re-rolling rules were applied, no maintenance periods were included and no travel restrictions were implemented. The fleet operates out of a single home port that it must return to when awaiting assignment.

Table 1: Vignettes considered with their input parameters.

Vignette	**Random (R) or**	**Impact**	**Frequency**	**Duration (in days)**		
ID	**Scheduled (S)**	**Category**	**(per year)**	**Min**	**Mode**	**Max**
1	S	Low	3	30	–	30
2	R	Low	30	14	21	28
3	R	Low	8	14	20	45
4	R	Low	8	5	10	15
5	R	Low	5	14	–	75
6	R	High	3	20	25	40
7	R	High	5	30	–	60
8	R	High	2	150	–	250
9	R	High	0.75	120	–	1,000
10	R	High	1.25	30	60	272

Table 2: The three possible responses for each vignette presented in order of preference. The values correspond to the number of ships per class (A, B and C) required for an appropriate response.

Vignette	**Response 1**			**Response 2**			**Response 3**		
ID	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
1	1	0	0	0	1	0	0	0	1
2	1	0	0	0	1	0	0	0	1
3	1	0	0	0	2	0	0	0	1
4	1	0	0	0	1	0	0	0	1
5	2	0	0	0	3	0	0	0	2
6	2	0	0	1	1	0	0	0	2
7	2	0	0	1	1	0	0	0	2
8	3	0	0	2	1	0	0	0	3
9	3	0	0	2	1	0	0	0	3
10	2	0	0	1	1	0	0	0	2

4.2 Baseline Case

The baseline scenario describes the expected ideal scenario. The transition plan is as follows:

- Class A ships are decommissioned at one year intervals, starting at the beginning of Year 15.
- Class B and Class C ships are delivered each time a Class A ship is decommissioned in an alternating schedule, i.e. where the first decommissioned Class A ship is replaced by a Class B ship, the second, a Class C ship and so on.

This transition scheme ensures the number of active ships to be constant throughout the transition and then increased at the end. This is represented graphically in the top graph of Figure 5.

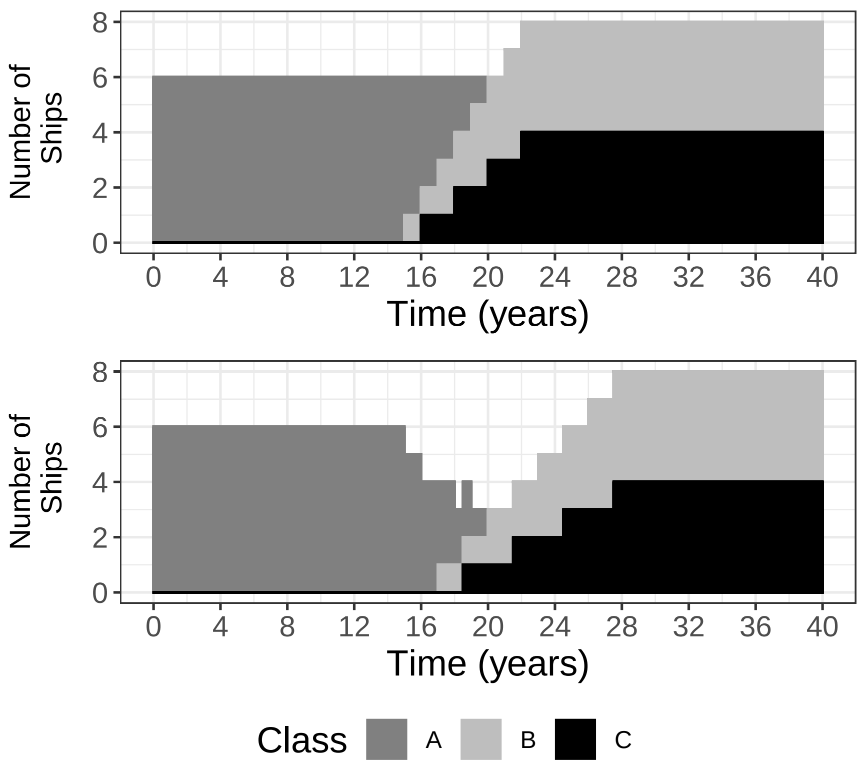

Figure 5: Transition schedules for baseline and excursion scenarios.

Figure 6 describe the percent of events completed over two-year periods with a ribbon showing the 25% and 75% quantiles. The percent of events completed is shown for the whole demand (top) and then split into high impact vignettes (2nd) and low impact vignettes (3rd).

First, the figure highlights how poorly the initial fleet configuration is at providing timely responses to high impact vignettes. These vignettes are less frequent, but since they often require multi-ship responses, less than 30% of the demand is met despite having priority in the assignment algorithm. This trend is not improved with the change in fleet composition: even with eight ships, the fleet continues to struggle to respond to high impact vignettes. With the change in fleet composition, the percentage of low impact vignettes completed improves, accounting for the majority of change observed in the overall fleet performance since these represent the most frequent vignettes.

This transition scheme results in a relatively smooth transition. In the initial state, with six Class A ships, all vignettes have only one response. As the transition begins, an increase in performance is observed in low impact vignettes as more responses become available. Once all Class A ships have been decommissioned, there is a dip in performance for all vignettes as the first response (and for high impact vignettes, the second response as well) becomes inaccessible. As the final two ships are added to the fleet, more of the low impact demand is met with the final larger fleet.

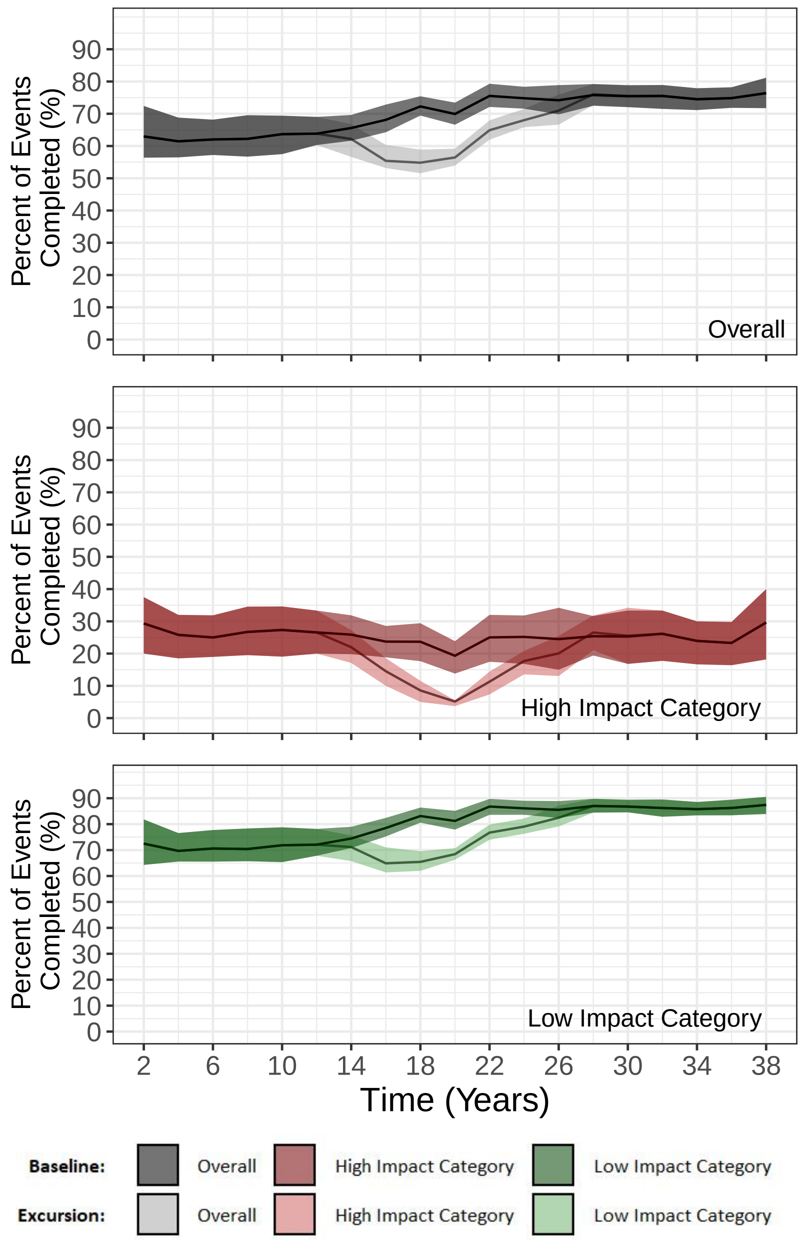

Figure 6: Results for the baseline and excursion scenarios from 100 replications with the PCT.

4.3 Excursion

This excursion was devised to highlight the impact that changes to the commissioning schedule would have on the operational efficiency of the fleet. The transition plan is as follows:

- Class A ships are decommissioned at one year intervals, starting at the beginning of Year 15.
- Class B and Class C ships delivery schedule is shifted by two years. They still follow an alternating schedule, but the intervals between each new ship is extended to 18 months.

The number of active ships changes over time as illustrated in the bottom graph in Figure 5. Figure 6 show the impact of this change on the percentage of events completed.

The initial state of the fleet is similar to that of the baseline case. Since there is a decrease in the number of active ships before any new vignette responses become available, the fleet experiences a large dip in performance as the transition begins. In particular, with the high impact category vignettes which typically require two or three highly capable ships, the fleet loses the ability to perform concurrent activities for several years. Starting around Year 19 of the simulation, and for a period of nearly two years, the fleet loses the ability to respond to any high impact vignettes when it is reduced to only one highly capable ship (either Class A or Class C). This impact could likely be mitigated by first commissioning a Class C ship rather than starting with Class B.

4.4 Summary of Findings

The analysis conducted above was able to identify the following behaviors:

- The analysis identified that the initial number of Class A ships was inappropriate given the high impact vignette demand.
- Fleet performance in the example is sensitive to delays in scheduling, particularly in the high impact vignettes.
- Decreases in operational effectiveness can be observed due to both a decrease in the number of ships and a reduction in the flexibility of responses available.
- Being able to program only three responses limits the ability to define multiple responses for the initial fleet, transient fleet and final fleet.

5 CONCLUSION

This paper presented a flexible DES tool developed by DRDC CORA to address fleet mix and force structure questions for the RCN. The engine of the PCT was developed in Arena® Software and the inputs and outputs are managed through a Microsoft Excel Workbook. The tool uses a stochastically generated demand and, with a detailed scheduling approach, determines how well a supply of ships can fulfill the expected demand. It provides insight into the number of platforms required and allows the user to quickly answer "what if" type questions. An example of how the PCT can be used was also demonstrated in the paper through two scenarios where a navy transitions from a single class of ship to two classes of ship. The resulting analysis highlighted deficiencies in the mismatch of fleet configurations to operational demand as well as quantifying the impact of modifying transition schedules on the performance of the fleet.

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DISCLAIMER

The reported results, their interpretation, and any opinions expressed therein remain those of the authors and do not represent, or otherwise reflect, any official opinion or position of the Department of National Defence or the Government of Canada.

REFERENCES

Allen, D., D. Blakeney, B. Burton, and D. Purcell. 2005. "Fleet Mix Study: Determining the Capacity and Capability of the Future Naval Force Structure". Technical Report, DRDC CORA TR 2005-38, Defence Research and Development Canada Centre for Operational Research and Analysis.

Bourque, A., and C. Eisler. 2008. "Fleet Mix Study: Establishing the Historical and Policy Basis for the Maritime Vignettes". Technical Memorandum, DRDC CORA TM 2008-038, Defence Research and Development Canada Centre for Operational Research and Analysis.

Bourque, A., and C. Eisler. 2010. "Fleet Mix Study Iteration II Making the Case for the Capacity of the Navy After Next". Technical Report, DRDC CORA TR 2010-159, Defence Research and Development Canada Centre for Operational Research and Analysis.

Bourque, A., and R. Mirshak. 2015. "Impact of Canadian Surface Combatant Fleet Size on Delivering Naval Ambitions". Scientific Report, DRDC-RDDC-2015-R244, Defence Research and Development Canada.

Caron, J.-D., V. Fong, and V. Brion. 2019. "On the Use of Simulation and Optimization for Mission Modules Selection in a Maritime Context". *Military Operations Research Journal* 24(1):41–56.

Department of National Defence (DND) 2007. "Operation UNISON 2005 — National Defence and the Canadian Forces". http://www.forces.gc.ca/en/operations-abroad-past/op-hestia.page. Accessed: 5th March 2021.

Fee, M., and J.-D. Caron. 2018. "Impact of the Maritime Coastal Defence Vessels on the Royal Canadian Navy's Operational Output". Scientific Letter, DRDC-RDDC-2018-L082, Defence Research and Development Canada.

Fong, V., and J.-D. Caron. 2018. "Analyzing Independent Fleet Output for the Canadian Surface Combatants – Methodology and Results". Scientific Report, DRDC-RDDC-2017-R149, Defence Research and Development.

Greenwood, N., J.-Y. Forcier, and H. Fitzpatrick. 2018. "Maritime Vignette Analysis – Rationalization and Response Development". By International Safety Research, CORA Task 038 Final Report, DRDC-RDDC-2018-C153, Defence Research and Development.

Logtmeijer, R., J.-D. Caron, M. Fee, M. Rudius, S. Otten, D. Manley, M. Clarke, and J. Lin. 2020. "NATO Mission Modularity Cost-Benefit Analysis". In *Proceedings of the 2020 International Naval Engineering Conference*. Institute of Marine Engineering, Science and Technology Institute.

Pantuso, G., K. Fagerholt, and L. Hvattum. 2014. "A Survey on Maritime Fleet Size and Mix Problems". *European Journal of Operational Research* 235(2):341–349.

R Core Team 2013. "R: A Language and Environment for Statistical Computing". http://www.R-project.org. Accessed: 3rd March 2021.

Rockwell Automation 2021. "Arena Simulation Software for Manufacturing from Rockwell". https://www.arenasimulation.com. Accessed: 1st March 2021.

System Planning and Analysis (SPA) Inc. 2016. "CSC Fleet Capacity Assessment Final Outbrief (Presented by J. V. Quigley)". 25-Aug-2016.

Valois, S., M. Fee, and J.-D. Caron. 2019. "Platform Capacity Tool (PCT) – Description of the Model and a Simple Application to Mission Modularity". Scientific Report, DRDC-RDDC-2019-R097, Defence Research and Development Canada.

Wojtaszek, D., and S. Wesolkowski. 2012. "Military Fleet Mix Computation and Analysis". *IEEE Computational Intelligence Magazine* 7(3):53–61.

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