An Adaptive Planning Tool for Ship Construction Warehouse Capacities

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ABSTRACT

Constructing and overhauling Navy aircraft carriers and submarines is among the most complex work undertaken anywhere in the world. An integral part of these operations is efficient material storage logistics. One of the largest challenges in developing logistical plans for material storage in this environment is the evolving nature of material needs; as ships are built the type of material they require to progress dramatically changes. In this paper, we introduce a simulation model which supports adaptive planning of material storage strategies. This tool utilizes discrete event simulation to adaptively plan warehouse storage layouts and parts turnover across the life of ship construction and overhaul. This tool allows NNS to accurately simulate the massive quantities of parts that arrive at the shipyard every month, route the parts based on optimal paths, and develop efficient storage strategies which are capable of growing and shrinking with program demand.

ABOUT THE AUTHORS

Nick Drucker is a Modeling and Simulation Product Manager at Newport News Shipbuilding. In this role Mr. Drucker is responsible for identifying new application areas for NNS modeling and simulation capabilities. He is also responsible for ensuring product teams develop tools to meet customer needs within these application areas. Previously Mr. Drucker served as a Modeling and Simulation Analyst with NNS, leading project teams during the creation and utilization of modeling and simulation applications for shipyard operations. Prior to joining NNS Mr. Drucker served as an Analyst, Sr. Analyst and later Manager of Product Development for a small modeling and simulation company in Portsmouth, VA. Mr. Drucker possesses a Master's Degree from ODU in International Studies with a concentration and certification in Modeling and Simulation as well as a Bachelor's Degree from CNU in Political Science with a minor in Psychology.

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INTRODUCTION

The construction and overhaul of nuclear powered air craft carriers is one of the most complex tasks undertaken anywhere in the world (Birkler & Chiesa, 2002). The size and complexity of these vessels necessitates a massive amount of material consumption over long periods of time. Newport News Shipbuilding is the only company in the world to design and build these ships, and in addition to the work performed on these vessels the shipyard is also one of only two companies in the United States to design and build nuclear powered submarines. Due to the nature of this work, the shipyard is consistently working to store and manage material for these programs in multiple warehouse locations. However, unlike traditional warehouse logistical challenges relating to ensuring enough material is available, without overstocking or over-holding, the shipyard faces a unique challenge. The constantly changing nature of the work occurring on both the carriers and submarines requires a shifting profile of material storage. As a ship is constructed or overhauled, the type of material required to support the work evolves. Since the material is not static, or even changing in a predictable manner, the shipyard must continually shift its storage plans. In order to support this effort NNS designed, constructed and put in a place a discrete event simulation to assist in balancing warehouse stocking strategies.

The build patterns for carrier construction and overhaul and submarine construction, as well as the general material requirements for a workforce of over 23,000 people presents a material storage challenge uniquely suited for modeling and simulation. While the ship work pattern is planned well in advance and executed to the schedule, the timing of project start dates is often influenced by factors beyond the control of NNS. This prevents NNS from accurately predicting when a set of material will be required far enough in advance of its order date to secure space and plan appropriately for its place in the system. The result is a shifting storage strategy that requires continual tweaking. By implementing modeling and simulation NNS is able to experiment with potential ship build schedules, storage strategies and estimation of warehouse space needs in advance. This allows the company to better predict when space constraints may arise, develop plans to handle material arrivals prior to them becoming known and balance warehouse inventories to maximize space and resources. The shipyard is currently utilizing this tool and has plans to expand its scope to include input from further down the supply chain.

PROBLEM SPACE

Complex nature of shipbuilding

Due to the complex nature of shipbuilding NNS has traditionally had to manage warehouse inventory planning by attempting to handle material as it arrives, planning for the arrival only as ship building contracts begin. Without being able to accurately predict the type and amount of material which will arrive months in advance the shipyard has to manage material based on historical trends and with only the space currently available. As new needs for space arise the shipyard is able to address them only after it becomes clear the space is needed. In addition, managing warehouse inventories is challenging given the number of warehouses the shipyard maintains, their proximity to a given worksite, and the types of material they can hold. The constraints on a warehouse may dictate it store only several types of material which may be far from a workspace where they are needed. Additionally, the changing nature of material requirements on ship builds often requires the company to shift material storage profiles among warehouses to make use of available space, even when these changes may reduce efficiency.

Facility footprint management

NNS must often choose whether to look for additional space or attempt to balance existing facility capacities as construction cycles overlap at peak times. While it is easy to identify the short term tradeoffs from either option, better predicting the long term benefits of one or the other is nearly impossible. The sheer amount of materials associated with shipyard operations, and the seemingly "random" order in which they may arrive requires complex analysis for any tradeoff study, with major assumptions about arrival timelines. Additionally, managing an individual warehouse is often challenging due to the space needs of the entire system. As one warehouse clears space it may need to operate more efficiently an unforeseen change in the material arrival schedule may dictate that the warehouse take on additional stock for some period of time. Managing these pop-up needs, while trying to remain efficient, is further complicated as priorities for material storage and consumption are ultimately dictated by ship build strategies, which may change as conditions in the build process change.

To more efficiently manage facility footprints, and to ensure an optimum amount of space is always available, the shipyard required a tool to experiment with potential material arrival schedules, facility capacities and storage strategies. By testing strategies for storage against current footprints and multiple potential arrival schedules the warehouse management team can better plan for the future material needs. This capability also allows them to predict a space need far enough in advance to perform tradeoff studies between acquiring more space or re-configuring current storage plans. The tradeoff studies are also better able to indicate how either option may impact future warehouse needs and strategies years down the road. By developing several plans in advance the warehouse teams can respond to whichever scenario eventually arises, and have better knowledge of the long term impact of the decision.

THE SOLUTION

Model Structure

With the large amount of material that enters and exits the shipyard, and with the rapid pace at which this happens, it is necessary to model multiple levels of material storage logistics. At a high level the shipyard receives material and then disperses this material to several main warehouses where it is organized and stored. The model focuses on one main receiving warehouse that then disperses material to several high level warehouses where it can be arranged based on storage type and program type. These several warehouses, as well as the lower level warehouses, have a combination of bulk storage space, for larger items, and rack storage space which is more suited for smaller items. These two types of storage space differ from warehouse to warehouse. Each of the several main warehouses either has one type of material storage or both. When a particular warehouse has both types of material storage it is often attributed to the space available in that particular warehouse as well as the layout of that warehouse which the warehouse management team has configured. This matter complicates the model structure because each warehouse differs in both size and layout and must be accounted for accordingly in the model.

Adding to the difficult independent layout of all warehouses in the model, each warehouse has a combination of four types of program material stored within them. These four types are: new carrier construction, overhaul, submarine construction and other. The other category relates to parts that are either received and transferred into company stock or bulk use company items such as paper and printer ink. Again, each warehouse in the model may contain a single type of this program material or contain some combination of all four types. Due to the differing types of program material, each warehouse must be modeled in a fashion that lets them hold any combination of program material or allow one type of program material to be stored there with the expectation that other types of program material come arrive at any time.

The next level of warehouses in the model structure represent smaller, yet separate, warehouses that have their own functions. Unlike the several high level warehouses these smaller warehouses do not receive material distributed from the main receiving warehouse, except in some unique situations. These smaller warehouses instead serve as both overflow locations when the several high tier warehouses become full and when certain materials need to be packaged together for use during the work process. It is essential that these smaller warehouses not only have storage space available for any type of program material that arrives but they must also save space so that when material arrives for packaging, it has sufficient space to both store and work with these materials. Once material has been packaged in one of the smaller warehouses it either leaves the warehouse to be stored somewhere else within the yard awaiting delivery to a specific trade worksite or is delivered to a worksite directly. In order to accurately capture this movement is was important that the model structure look at the real-world examples of material transfers and replicate those transfers.

The transfer codes within the model structure where taken directly from the warehouse management team and replicate the actual movements of the material in the shipyard. There are several types of transfer codes within the model structure, each representing a different transfer within the yard. The first transfer code represents material that enters the shipyard from outside manufacturers or venders. This particular code is only used with the main receiving warehouse and only occurs when that warehouse receives outside material. The second transfer code represents material that is either transferred from the main receiving warehouse to one of the several high tier warehouses or in certain situations when material needs to go directly to one of the smaller warehouses. The next set of movement codes in the model structure can be separated into three different sections. The first of these being a code that sends material from the several high tier warehouses to one of the smaller warehouses for either packaging or for further storage. The second of these codes in one that sends material from one of the high tier warehouses straight to the yard because they do not require packaging and can be used directly by one of the trades within the yard. The final of these codes is one that sends material from one of the high tier warehouses to parts shops in the yard where the material is then either labelled as company stock (paper, printer ink, etc.) or is labelled as stock. When material is labelled as stock, not to be confused with company stock, it represents material that is readily used by the shipyard and can be used for many different projects. This particular type of material is often ordered in bulk and is not ordered on a case by case basis. The final code is one that sends packaged material from one of the smaller warehouses directly to the yard so that it may be worked. Once material is either packaged and sent to the yard or sent to the yard directly it is no longer tracked within the model and thus exits the model structure.

Throughout the structure of the model, from its arrival at the receiving warehouse to its exit to the yard, each piece of material receives and maintains two labels. The first of these labels tracks whether the material can be stored as either rack or bulk. The model logic that decides this also has a specific rule attached to it. If a piece of material is labelled as rack and is not able to fit on the rack at a particular warehouse, most likely because that warehouse has not rack space available, then that piece of rack material can be stored in a bulk location. A piece of rack material that is stored in a bulk location maintains the rack label so that if it is transferred from that warehouse to another is labelled correctly and can be stored in a rack location if the space is available at the warehouse it was transferred to. This rule is one sided and does not carry the same exception for bulk material since bulk material is too big to be stored in rack storage. If a warehouse has no room for bulk material then it must be sent to another warehouse with bulk space available or must be sent to overflow. A screen shot of the final model structure appears in figure 1 and demonstrates how the model represents warehouse capacity for the several high level warehouses and the smaller group of warehouses (the bottom four groups) based on the rules outlined above.

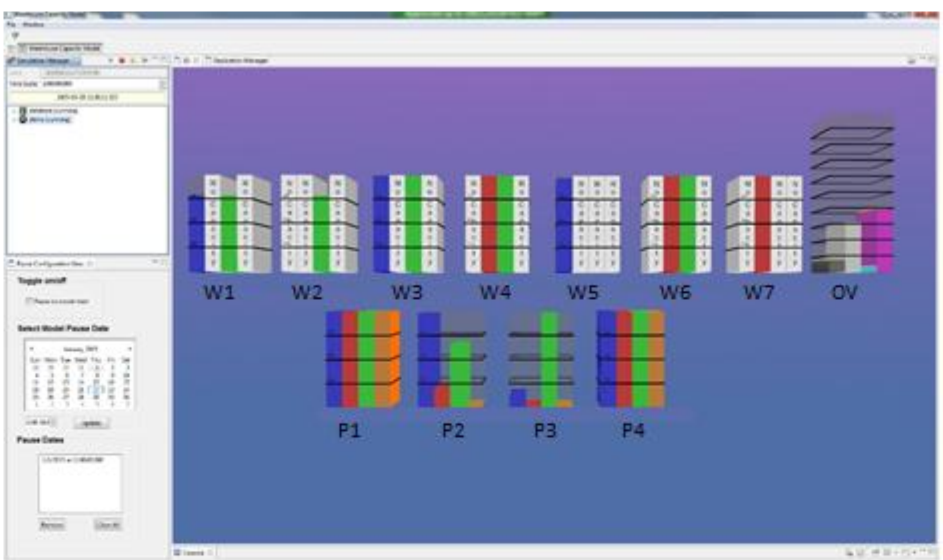

Figure 1: Model Structure

Data Collection and Formatting

Since material flow within the shipyard is not static nor predictable the data collection and formatting for this model required vast amounts of data and extensive analysis. The first step in this process is the collection of raw data. After speaking with many subject matter experts the team determined that trying to get predictions for future incoming material was not feasible and that a different approach was necessary. Historical data was the next logical step. The shipyard maintains a database that contains material from previous years and associates transfer codes with that material. Using that database it was possible to look at all of the material that arrived at the shipyard in the last ten years as well as the transfer codes associated with that material. Due to the size of the data it took several weeks to run all of the reports necessary to obtain this data and once done the data had to be transformed from a historical format to something that could be used to predict future material flow.

After the data collection process the team took the data from its historical form and transform it into distributions so that it could be used in the model logic. The process of transforming the raw data into distributions began with the team collapsing the data into a time scale that would fit the model needs. The model looked at incoming material on a month to month basis while the data showed the material that arrived daily. To solve this problem the team manipulated the data in a spreadsheet so that all daily orders were consolidated into a total number of monthly orders. The daily number of parts entering the shipyard were then added together to reflect a total number of parts for a particular month. With these two data modifications made it is possible to convert the data to distributions.

Using a distribution generator the team entered each month of data the as a single entry for a ten year period. The team did this separately for both the number of orders per month and the quantity of parts per month. Besides dividing the data between number of orders and quantity of parts per month it also had to be manipulated in order to separate each of the four program types from one another. Again the four program types are carrier construction, overhaul, submarine construction and other. Each of these four program types had differing number of orders and parts that entered the shipyard each month and as such they could not be kept together but instead needed to be looked at separately. The final layer of the distribution generation was to look at all of the different transfer codes and generate distributions for how often these codes occurred. Depending on the current projects taking place in the shipyard each transfer code would have a certain number of transfers per month as well as a certain number of parts per transfer. With this being the final level of distribution generation it was possible to input these into the model and allow multiple distributions to work together.

To look at how these data distributions worked within the model it is best to look at a couple of examples. First, for the arrival of material, the model would looks at the order arrival distribution and selects a number from within distribution to determine how many orders arrive at the shipyard each month. Once this is complete the model then look at each one of those monthly orders and uses the quantity of parts distributions to determine how many parts will be contained within each order arriving at the shipyard. The final step in the process is for the model to look at the quantity of parts that arrive at the shipyard every month and use the different program distributions to determine what percentage of those arriving parts will be distributed to the four program types. This type of logic was continued throughout the model for all of the transfer code thus allowing the model to pull from all distributions. It is often seen in the shipyard that certain programs have a cyclical nature of peaks and valleys when it comes to parts arriving for that particular program. Using the historical data to generate distributions allows the model to replicate this cyclical nature thus providing an accurate picture of the number of orders and parts that would arrive at the shipyard each month.

Model Use

Following the completion of the model the team began utilization to support the analysis of warehouse storage strategies. Utilizing the historical data and incorporating current data outlining material on hand the team validated that the model accurately captured the material movement process. To assist in the validation and to support use of the model as an analysis tool the system produces several reports outlining material storage over time. Figures 2, 3, and 4 demonstrate some of those reports. Figure 2 shows a high level view of how much material flows through the system following a batch of runs. To produce the chart the system averages material on hand by program over the life of the runs. It then generates a line chart to help the user identify which programs may exceed capacity. The user is then able to experiment with different storage strategies to alleviate any potential over runs, long before the lack of space would occur.

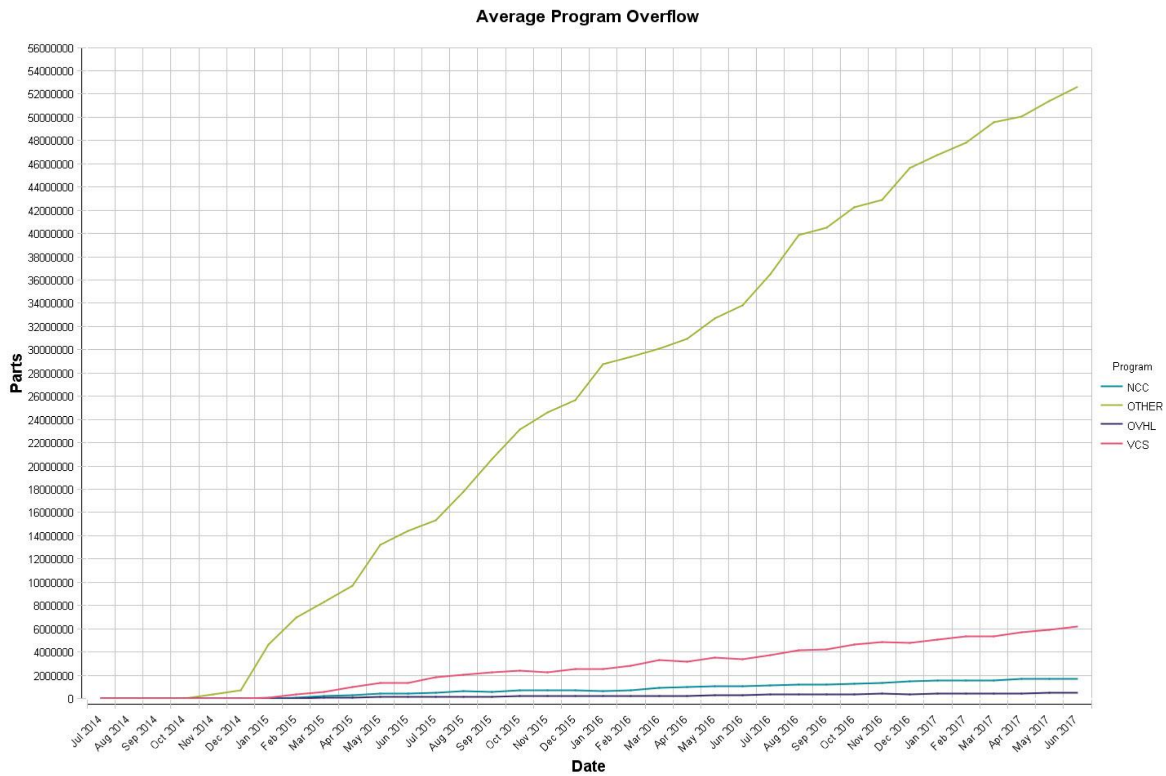

Figure 2: Average Quantities Over Time

Figure 3 shows a similar view, but from a specific warehouse level. The user is able to filter the data by selecting which warehouse to view and then examining the quantity of parts in those warehouses. The report generates a sandchart, as opposed to a line chart, to allow a user to see how several warehouses, or all warehouses, may store material over time. As the lines hit peak capacity the line will level off, indicating the maximum space in that warehouse was reached. This further allows a user to identify which warehouses may be filling up, augmenting the view provided by the program chart shown in figure 2.

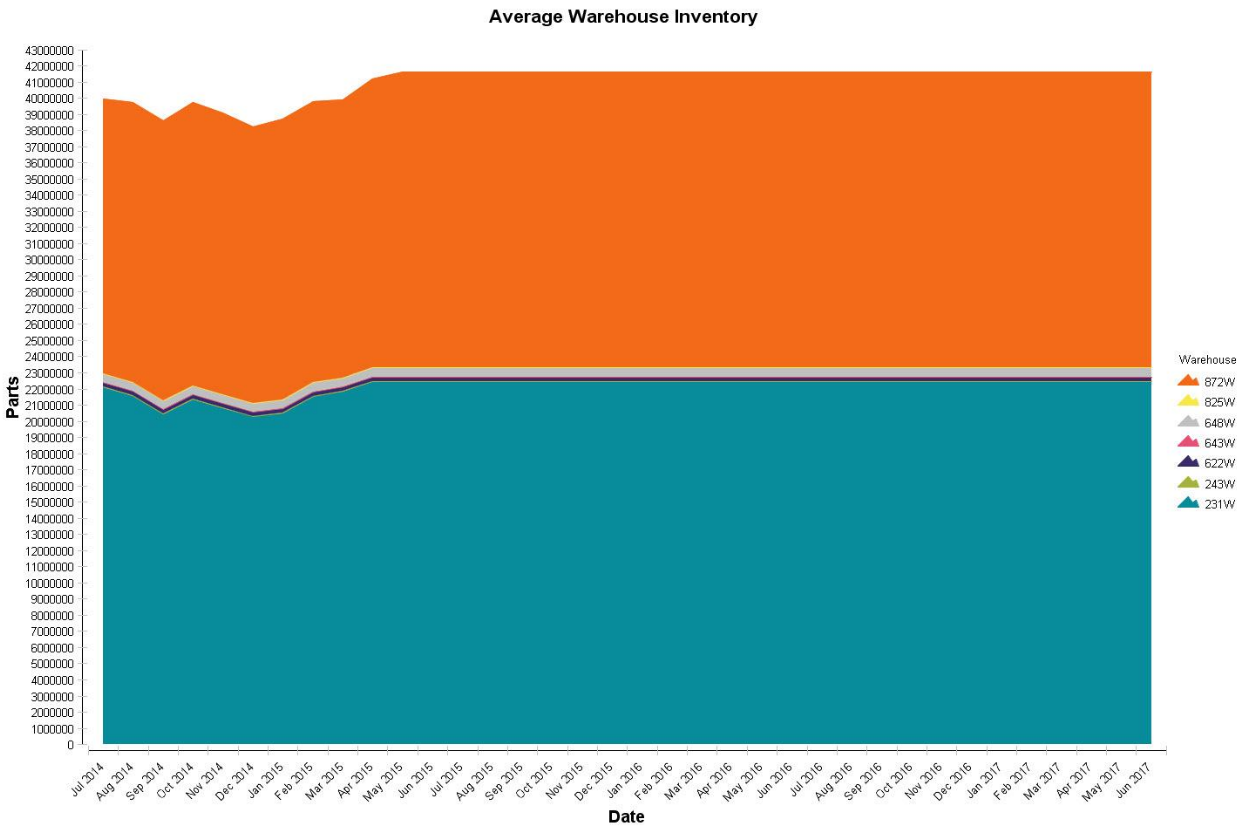

Figure 3: Average Inventory In Warehouses

Figure 4 provides a sandchart showing all warehouses material filtered by program and storage type. The user is able to select a specific storage type or program and view how the material looks across the entire model. For instance, a user may choose to view all new carrier construction material stored in racks across the model runs. They will then be presented with a sandchart showing how, over time, the rack NCC material accumulates and leaves the warehouses. Figure 4 shows all programs and all material types. Where the chart becomes square the material exceeds the total capacity of the warehouses, indicating to the user the need to evaluate re-organizing warehouse layouts or acquiring additional space.

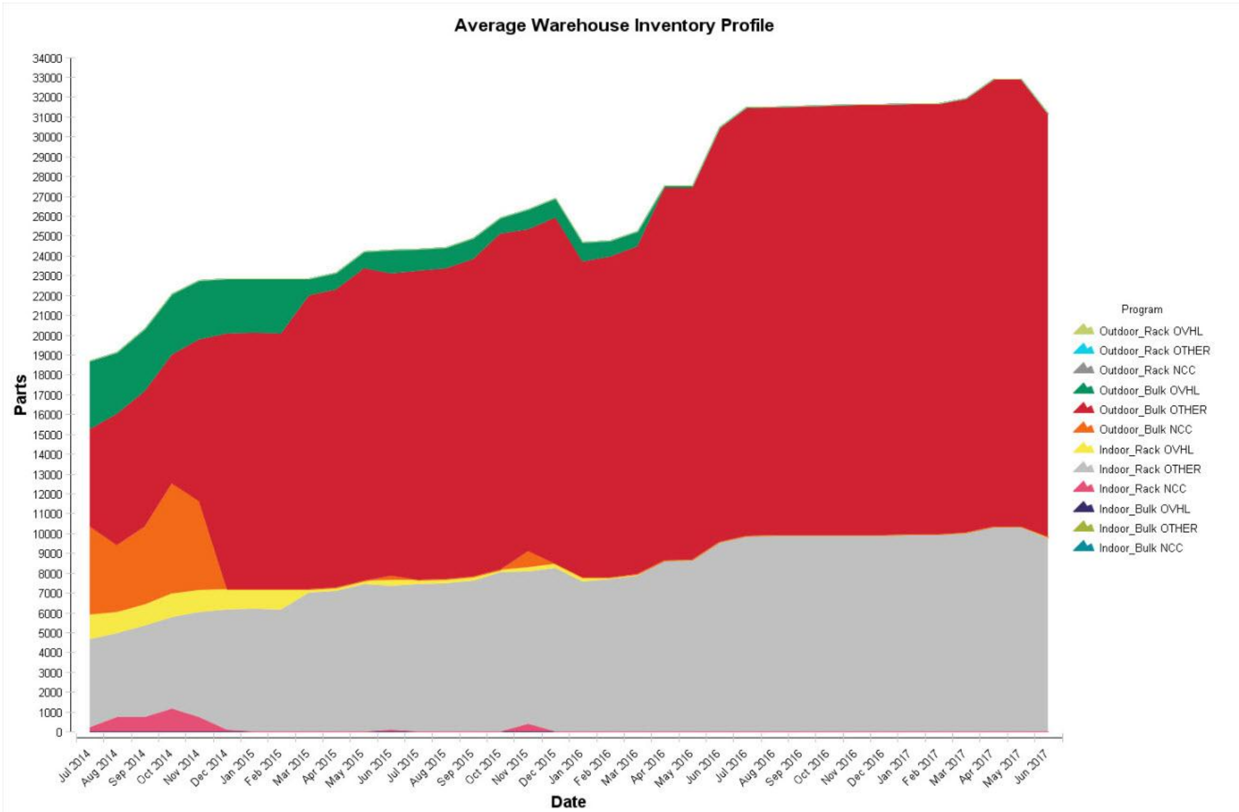

Figure 4: Average Inventory By Program and Storage Type

The use of the model and the charts shown above allowed the warehouse team to validate a proposed new plan for warehouse storage strategy. The team used the model to baseline the current process and confirm that the current strategy would not support new build plans, dictated by the current Navy shipbuilding schedule. As a result the team developed a new strategy to store material, and using the model, confirmed that the new strategy would alleviate space constraints, simplify the storage and transfer process, and support the shipyard over the next 10 years as the build schedules begin to solidify.

Future Use

To further support the warehouse team the model will continue to provide on demand analysis of storage profiles based on build schedules. If a build schedule changes or more construction projects begin, the model will also support the team in assessing their impact on the plan for material storage. If such an incident occurs, and the model identifies the need to modify the storage strategy the model will support the experimentation to perfect a new strategy. Additionally, the team is expanding the model to include work performed on or near the actual ships. Where the model currently stops tracking material when it is delivered for trade usage, the expanded model will track material to the trades, allow the material handlers and trades workers to experiment with where to stage the material, and allow them to visualize how the material will fit within the construction footprint. The increased fidelity of material demand will increase the accuracy of the warehouse model, and likewise the warehouse model storage plan will help the material handlers and trades workers better plan how to stage their work. The visual component of the expanded model will also highlight where potential staging overlaps occur, and may be expanded back to the warehouse model to help warehouse manager's experiment with individual warehouse layouts.

SUMMARY

To handle the complex nature of material storage in a shipbuilding environment NNS developed an adaptive planning tool for warehouse management. The tool allows the warehouse team to analyze potential material arrival schedules against current capacities to identify ideal storage strategies. The tool also allows them to response rapidly to any unpredicted changes to a ships build strategy, as well as determining which buying strategies fit within the current warehouse capacities. The tool has already supported the team in examining a new storage strategy which is currently being implemented. The tool confirmed that the new strategy was feasible, and would allow NNS to allocate enough space within each facility to support its current plan and potential flex needs. In the future the tool will grow to include the movement of material to job sites and its eventual incorporation into a ship during the build or overhaul process. The greater fidelity to follow material from its receipt to consumption will further improve the warehouse teams ability to plan and manage their facilities by seeing further down the supply chain.

REFERENCES

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