MOTT MACDONALD

Port of Wilmington Planning Services for Container Yard Improvements

Final Yard Planning Report
August 2018

North Carolina State Ports Authority

NORTH CAROLINA PORTS

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Port of Wilmington Planning Services for Container Yard Improvements

Contents

Executive Summary

Port of Wilmington Yard Improvement

Background

Following the sustained success and significant container volume growth experienced at the Port of Wilmington, the North Carolina State Ports Authority (NCSPA) commissioned Mott MacDonald in 2017 to undertake a Container Terminal Yard Improvement Planning Study with the key objective of expanding the current terminal throughput capacity to accommodate a minimum 750,000 twenty foot equivalent units (TEUs) annually, by 2025.

With recent investments in infrastructure improvement projects including the procurement of three new neo-panamax cranes, berth renovations and vessel navigation improvements, the work to enhance the Port's operational and commercial resilience is already underway with the container berth's potential capacity set to increase to 1,000,000 TEUs annually.

However, in order to achieve the forecasted annual throughput volume of 750,000 TEUs, it has been identified that existing key port infrastructure directly behind the berth such as the main terminal gate complex and container storage yard will require further improvements and upgrades so that the capacity of the rest of the terminal can match or exceed the targeted 750,000 TEU annual throughput.

The prevailing capacity of the three main container box exchange nodes at the terminal are shown on the right of the page. The perceived capacity bottleneck at the terminal is situated at the main gate complex. With a 340,000 TEUs/annual capacity the gate requires urgent investment to rectify the capacity deficit. The storage yard capacity is also considered to be at a critical level standing at 389,000 TEUs/annum. The storage yard capacity is mainly limited by the current paving quality and terminal spatial constraints.

The final terminal yard improvement plan has therefore concentrated on the enhancements of the above bottlenecks identified with the addition of integrating other vital infrastructure developments such as a new dedicated container intermodal yard and improved reefer cargo storage facilities to further facilitate the port's expansion outlook.

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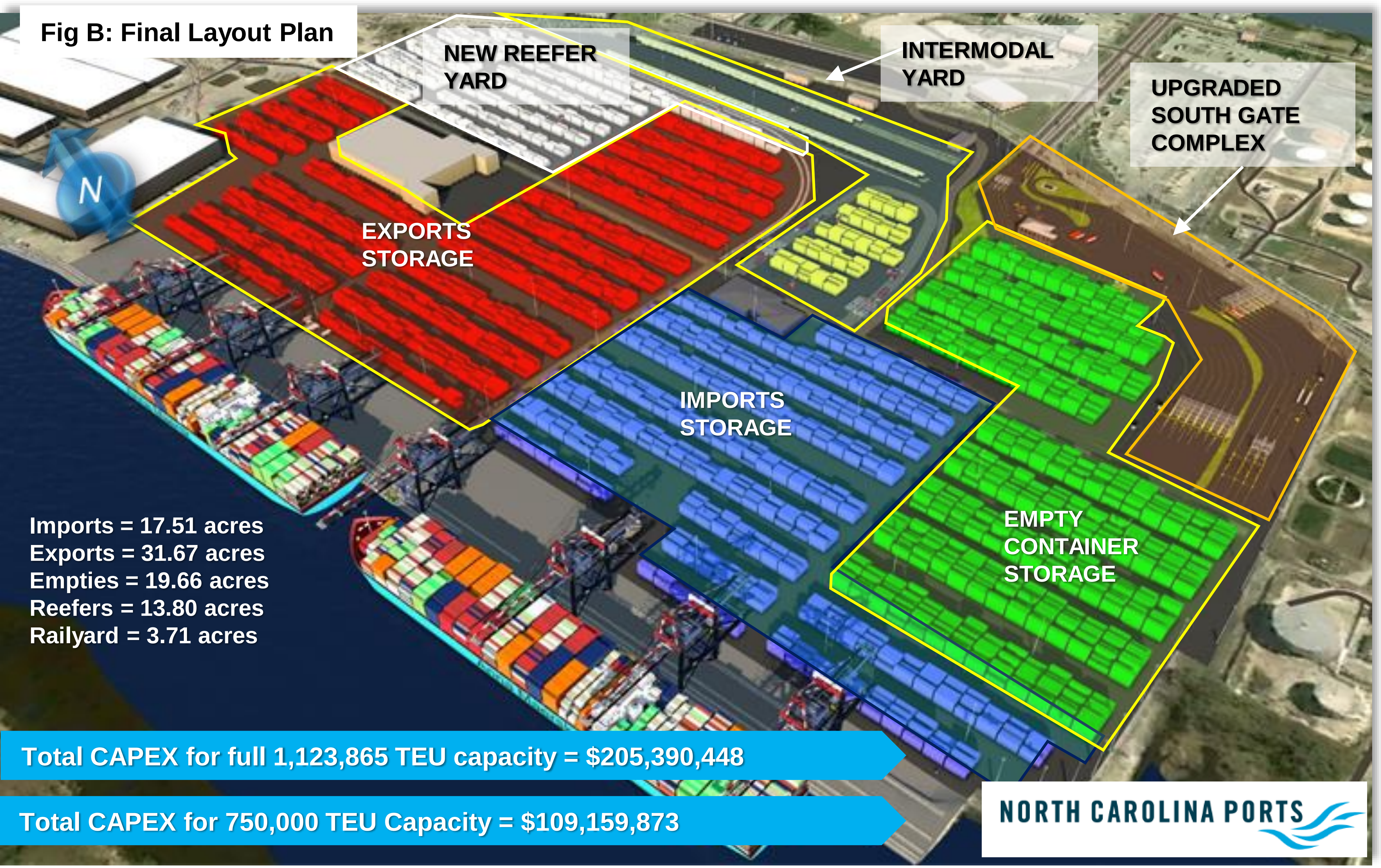
Yard Improvement Plan

Multiple yard improvement options which satisfied the future requirements of the port were derived and scrutinized, and as a result of a detailed selection process, the final layout determined for further development and implementation is shown in Fig B, with the key proposed projects and terminal reconfiguration highlighted.

Table 1: Container Ground Slots and Throughput

	TEU Ground Slots	TGS %	Yard Capacity (TEUS/yr)	Throughput %
Imports	1,865	21%	441,428	39%
Exports	3,221	37%	455,563	41%
Empties	2,236	26%	112,905	10%
Reefers (Laden)	576	7%	72,867	6%
Reefers (Empties)	814	9%	41,102	4%
	8,982		1,123,865	

Fig B: Final Layout Plan



The final yard layout shown in Fig B presents the final phase of the development whereby all available terminal space has been reassigned for container storage and stacking such as the T7 warehouse, the dolomite bulk storage and steel billet storage areas towards the north of the container terminal, and the log export leased land. All terminal paving will be upgraded to allow for a maximum stacking height of five high laden boxes, five high empty boxes and a maximum stack utilisation of 70%. The paving upgrade proposed requires the most significant investment and is considered to be the most critical for improving yard storage capacity. The individual storage capacities and ground slots for each container type are shown in the Table 1. The terminal is to remain reach stacker operated in the future.

The total throughput capacity for this layout is estimated at 1,123,865 TEUs per year. However, to match the annual throughput target of 750,000 TEUs, areas 'J', T7 warehouse, the dolomite storage and steel billet storage areas do not need to be upgraded in the immediate future, and can be phased-in when the demand arises.

The terminal gates are expanded and rebuilt over the existing terminal area 'L'. The gate will be upgraded with seven 'In' gates and six 'Out' gates, utilizing modern technology.

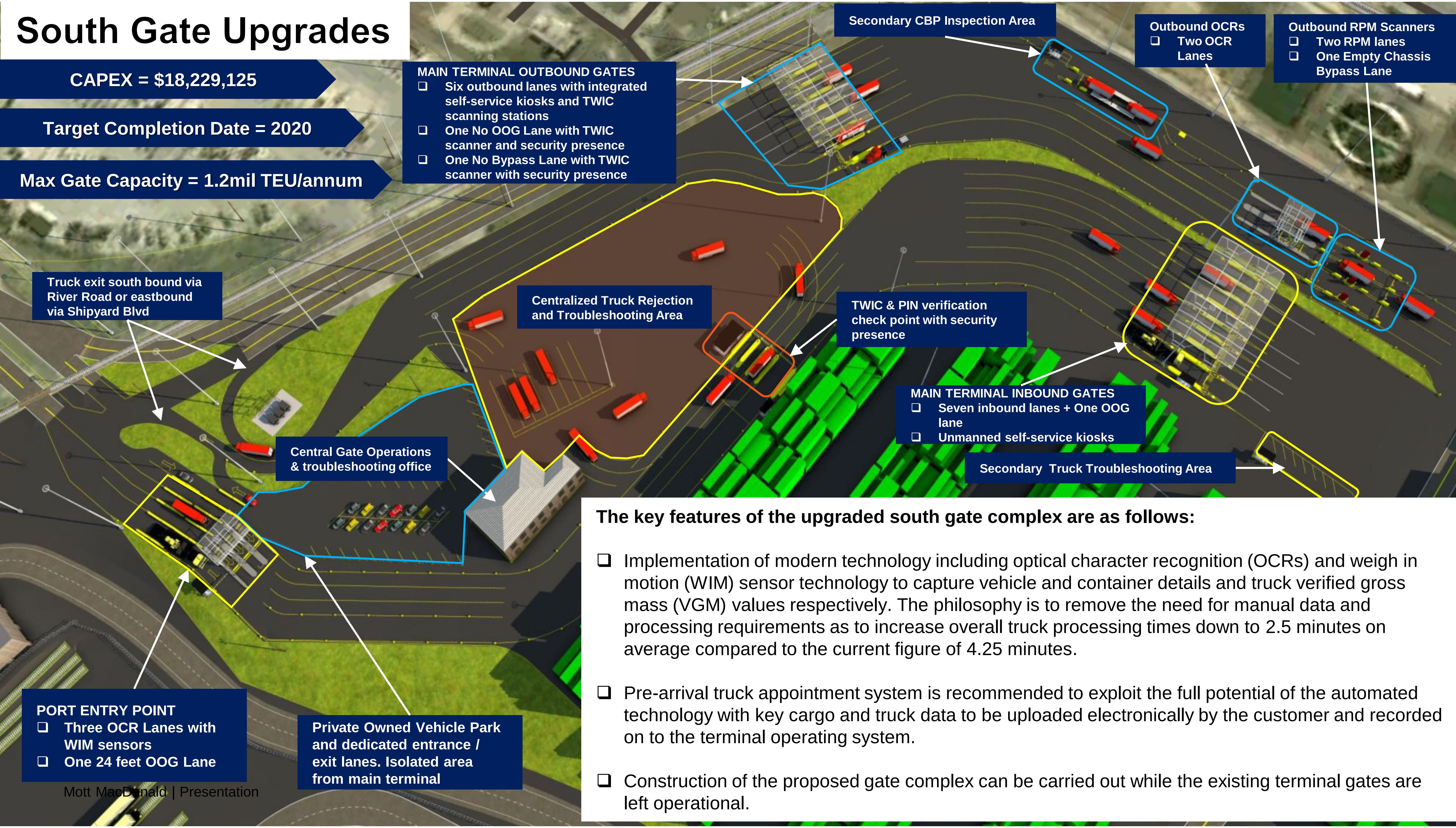
A new intermodal yard dedicated for containers is proposed for handling a minimum of 8% of the targeted container throughput. A new reefer yard storage area is proposed to expand the stacking density of refrigerated cargo boxes in the future, allowing laden reefers to be stacked three high in a dedicated location of the terminal.

South Gate Upgrades

CAPEX = $18,229,125

Target Completion Date = 2020

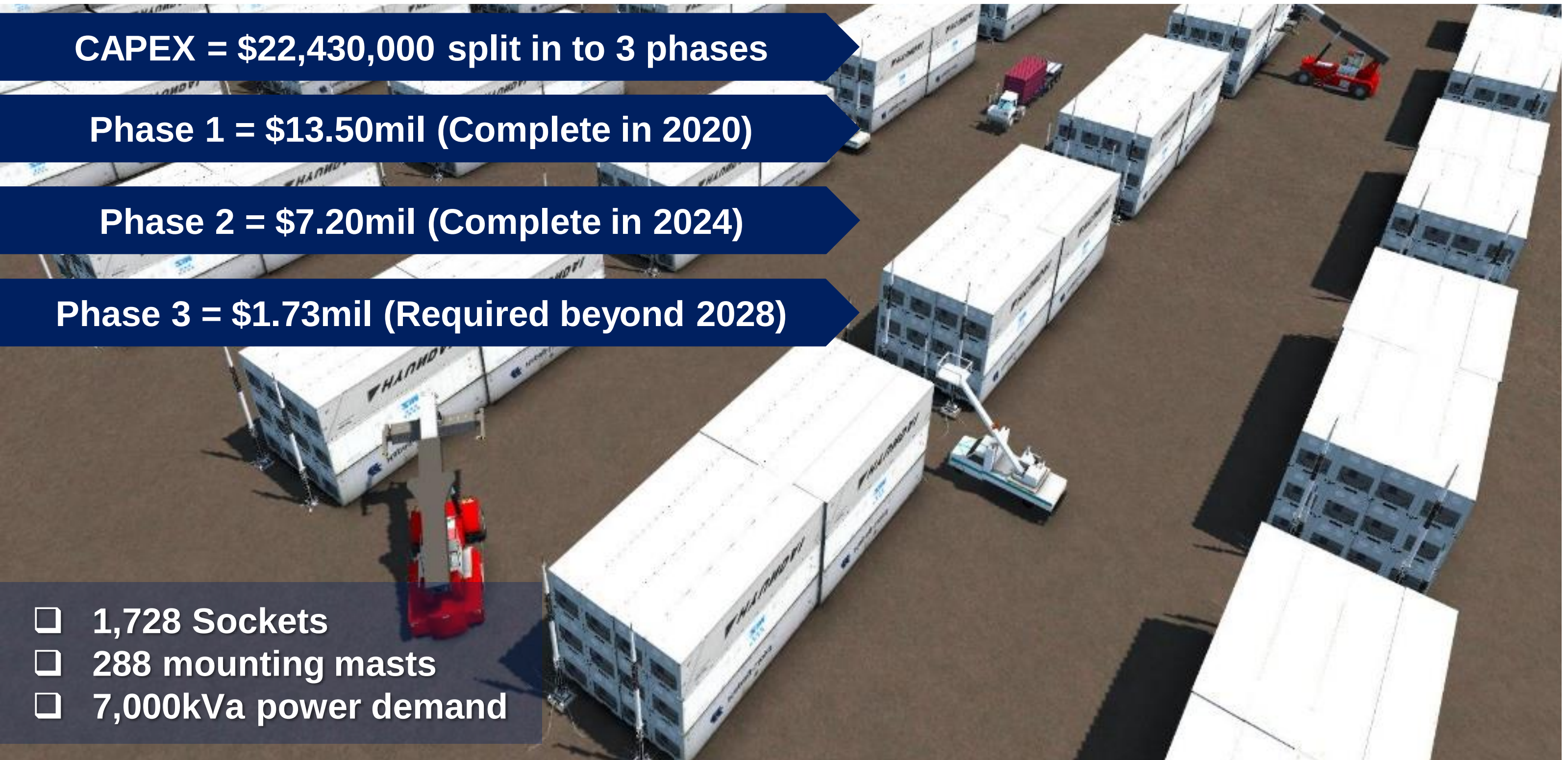
Max Gate Capacity = 1.2mil TEU/annum



The key features of the upgraded south gate complex are as follows:

- ❑ Implementation of modern technology including optical character recognition (OCRs) and weigh in motion (WIM) sensor technology to capture vehicle and container details and truck verified gross mass (VGM) values respectively. The philosophy is to remove the need for manual data and processing requirements as to increase overall truck processing times down to 2.5 minutes on average compared to the current figure of 4.25 minutes.
- ❑ Pre-arrival truck appointment system is recommended to exploit the full potential of the automated technology with key cargo and truck data to be uploaded electronically by the customer and recorded on to the terminal operating system.
- ❑ Construction of the proposed gate complex can be carried out while the existing terminal gates are left operational.

New Reefer Yard



NEW REEFER YARD

By installing reefer sockets on 30 foot steel masts, laden reefer boxes can be stacked three high and four deep in two rows. This increase the reefer storage capacity without having to install reefer racks. The reefer yard will be operated by reach stackers while the sockets and plugs will be reached using cherry pickers.

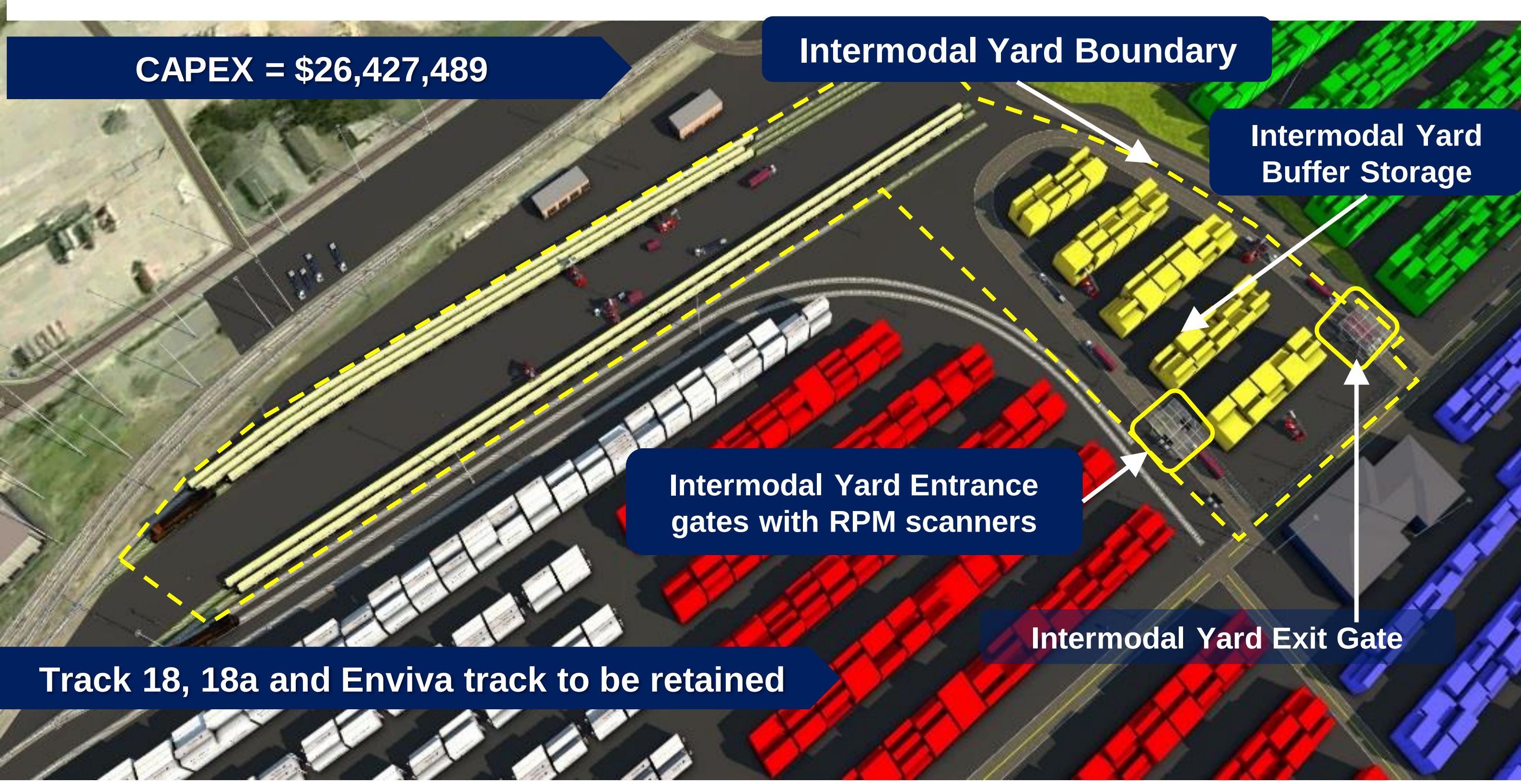
INTERMODAL YARD

With an additional 4 dedicated rail sidings, each 1,250 feet in length, the new intermodal yard is able to form and service 5,000 foot long trains. Reach stackers will be deployed to load/unloaded the rail cars while TICO trucks will be utilized to transfer the boxes the boxes in and out of the intermodal yard. Four dedicated reach stackers will be required to serve the intermodal yard in order to turn the train around within eight hours.

UPGRADED CONTAINER YARD PAVING

All container stacking areas within the terminal are proposed to be upgraded to allow for a maximum stacking height of five high laden boxes, five high empty boxes and a maximum stack utilisation of seventy percent. Asphalt paving has been considered for all of the container stacking areas and the majority of the terminal improvement plan except in areas of high wheel braking and accelerating such as the main gate lanes where concrete is used. Cconcrete paving in the stacking yard is currently considered as an optional solution which requires further investment if required.

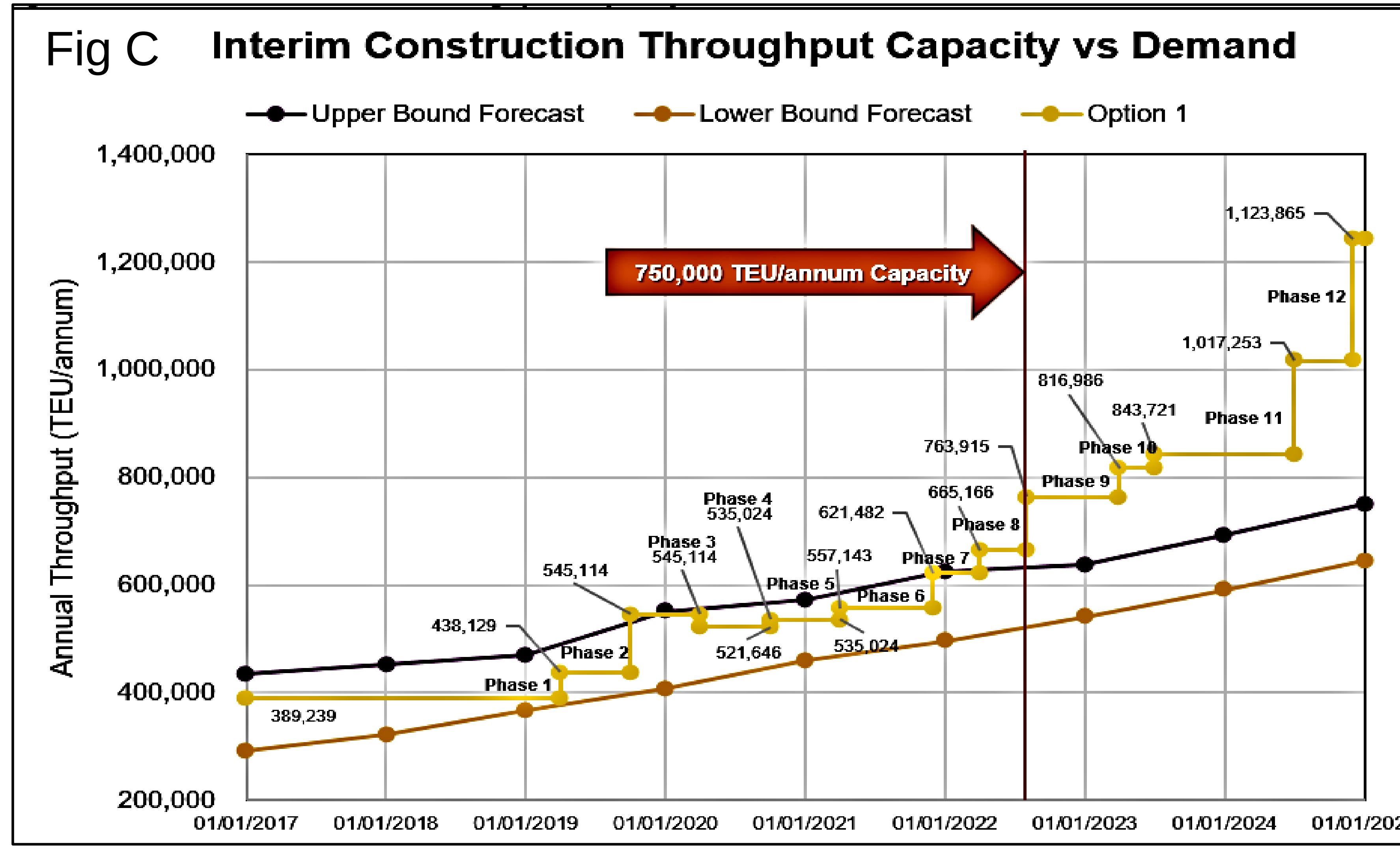
Intermodal Yard



Upgraded Container Yard Paving

Project Implementation and Construction Phasing

A high level project implementation schedule, from FY2019 to FY2025 has been developed, comprising twelve phases to fully develop the full terminal yard improvement plan with a maximum terminal capacity of 1,123,865 TEUs per year. These phases are shown against the NCSPA container throughput forecasts in Fig C. However, in order to achieve the targeted annual throughput of 750,000 TEUs, the project does not need to extend beyond Phase 8, as indicated. In the preparation of the project construction phasing plan, the aim was to ensure that the interim terminal capacity during construction remains above the lower bound forecasted throughput volumes. This ensures that the terminal can operate during the construction with a minimal amount of disruption. This has been achieved by dividing up the terminal upgrade project into small packages of work, so that large areas of container storage will not be decommissioned at any one time. Each step in the capacity graph shown in Fig C indicates an areas of terminal paving being completed.



The terminal yard improvement plan can be sub divided into 4 main projects. These are shown with their indicative start and completion dates:

Project Cost Estimates

The total estimated CAPEX for implementing and constructing the terminal yard improvement plan is $205,390,448*. This assumes the full build out costs to achieve the maximum terminal capacity of 1,123,865 TEUs per year. The breakdown of the individual project components are shown in Table 2 below.

Table 2: Yard Improvement CAPEX Breakdown

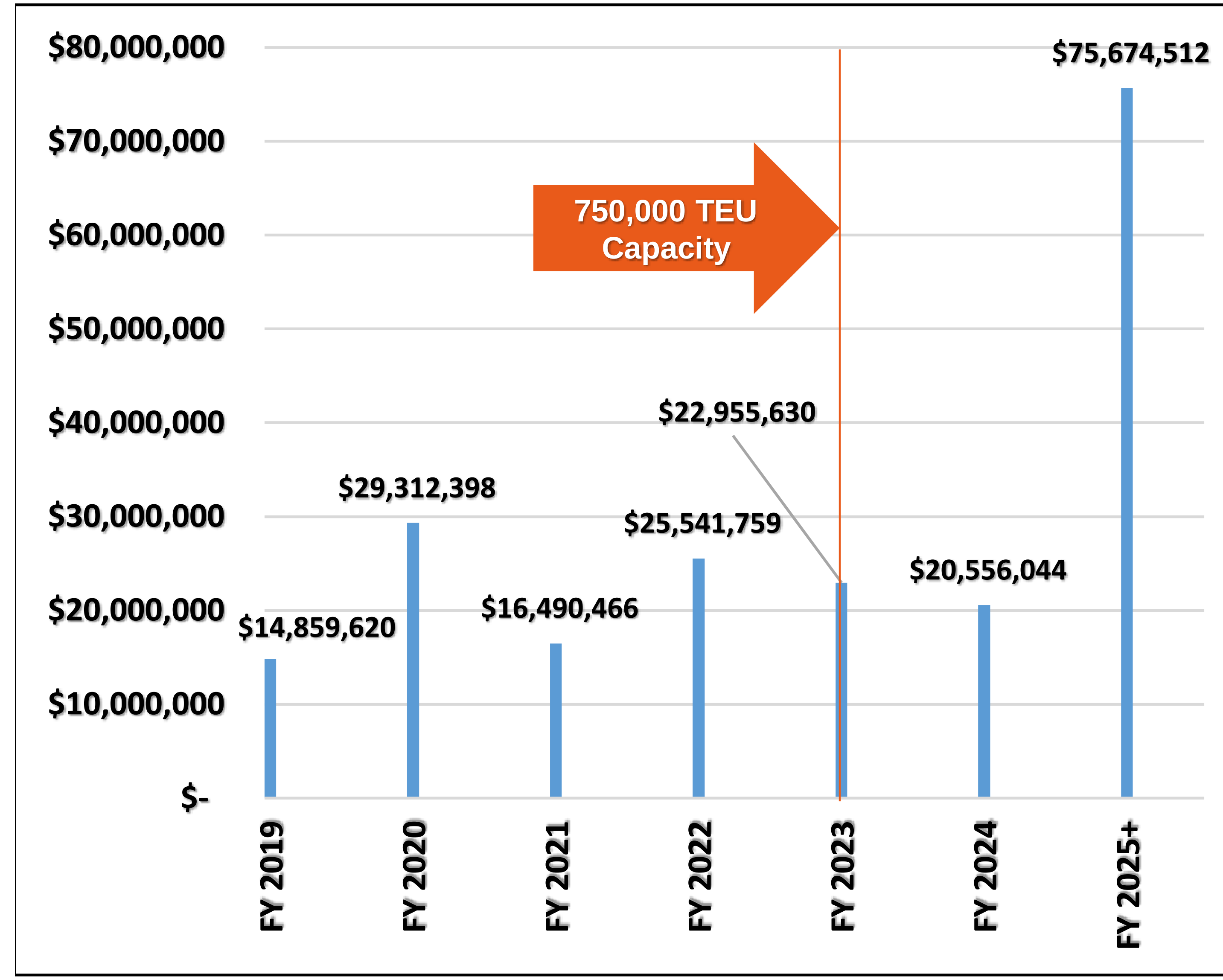
Yard Improvement Project	Costs (US$) (Full Capacity)
Container Yard	126,240,553*
Reefer Yard	22,433,281
South Gate Upgrade	18,229,125
Intermodal Yard	26,427,489
Equipment	12,060,000
TOTAL	**205,390,448**

The project schedule is proposed to span across eight years and assumed to commence in 2019. The CAPEX therefore is envisioned to be invested across the same duration. The estimated Capex is projected against the construction phasing and project schedule to produce the theoretical investment profile for each fiscal year as shown in Fig D.

The CAPEX estimate for providing exactly 750,000 TEU terminal capacity is $109,159,873 which includes the necessary repaving of container stacking yard areas with asphalt only, the south gate upgrades and phase 1 of the reefer yard upgrades. This cost excludes repaving areas J, T7 warehouse, bulk storage areas north of the container terminal and the construction of the intermodal yard.

** CAPEX is for asphalt paved container stacking yards only. Please see Section 8 – p172 for further details*

Fig D: Project Investment Profile



Budget Priorities

From the list of projects required to implement the yard improvement plan the following projects are considered to be priority investments and shown in Table 3.

- **Reefer Yard Phase 1**
    - CAPEX = $13,526,073.
    - Work spread over FY2019 and 2020.
    - 5.5 acres of re-paving work including all associated earthwork.
    - Five hundred reefer sockets and eighty four reefer masts.
    - All civil infrastructure services including drainage, electrical and lighting etc.
    - One time substation upgrade cost to DUKE energy.
    - All design and supervision costs.

- **South Gate Upgrade**
    - CAPEX = $18,229,125.
    - Work spread across FY2019 – FY2021.
    - Port gate structures and associated equipment.
    - OCR portals and barn structures only (GOS excluded).
    - Radiation scanner infrastructure.
    - WIM sensors.
    - TWIC gat kiosks and rising barrier arms.
    - Associated buildings and security booths etc.
    - Road surfacing, repaving and associated earthworks.
    - Civil infrastructure services including drainage, power and lighting.
    - Line marking and signage.
    - Traffic management systems.
    - Design and supervision.

- **Area F east repaving works**
    - CAPEX = $10,204,464.
    - Work spread across FY2019 – FY2020.
    - 5.5 acres of terminal asphalt paving.
    - Associated earthwork.
    - Associated civil infrastructure services such as drainage, power and lighting.
    - Design and supervision costs.

Table 3: Priority Project Budgetary Requirements per Fiscal Year

Project	FY 2019	FY 2020	FY 2021	
Reefer Yard (Phase 1)	$7,765,849	$5,760,224		Reefer Yard Ph 1 Total $13,526,073
South Gate Upgrade	$1,222,317	$12,856,966	$4,149,842	South Gate Upgrade Total $18,229,125
Area F East (5.5 Acres)	$5,558,392	$4,646,072		F East Paving Total $10,204,464
TOTAL FISCAL YEAR BUDGET	$14,546,558	$23,263,262	$4,149,842	Combined Total $41,959,662

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1. Introduction

Project background

1.1 Project Background

The Port of Wilmington is located on the United States East Coast in the State of North Carolina. It is situated thirty miles from the mouth of the Cape Fear River. The Port is publicly owned and operated by North Carolina State Ports Authority (NCSPA). At present the Port offers the following facilities and services:

- ❑ *Bulk cargo handling and storage.*
- ❑ *Break bulk cargo handling and storage.*
- ❑ *Container cargo handling and storage.*
- ❑ *Rail yard.*
- ❑ *Military cargo facilities.*
- ❑ *Open and covered storage warehouses and transit sheds and;*
- ❑ *Cold store facilities.*

The Port of Wilmington has steadily increased its cargo throughput over the last ten years especially with the containerized cargo volumes. With the trend in container cargo throughput set to potentially rise to 750,000 twenty foot equivalent units (TEUs) by 2025, NCSPA have commissioned Mott MacDonald Inc (MMI) to carry out a Container Terminal Yard Improvement Planning Study to achieve the following core objectives:

- ❑ Assess the current throughput capacity of the Port of Wilmington Container Terminal,
- ❑ Assess the short fall in capacity to achieve the targeted throughput of 750,000 TEUs per annum by 2025,
- ❑ Propose terminal yard improvements to increase the capacity to accommodate 750,000 TEUs per annum by 2025,
- ❑ Define the short and long-term development schedule and phasing plans to achieve the terminal yard improvement works,
- ❑ Develop an investment strategy with the anticipated spending profile in accordance with proposed yard improvements.

In addition to the above core project objectives listed above, the following sub objectives were required to be integrated within the final Yard Improvement Plan:

- ❑ Incorporation of a new Intermodal Rail Yard capable of handling 5,000 foot long trains and a capacity to accommodate up to 8% container throughput,

- ❑ Identify current issues with the port civil infrastructure and propose future upgrade and improvements within the yard improvement plans,

- ❑ All yard improvement plans are to consider Ports of Wilmington's Strategic Seaport and the associated Port Planning Order requirements laid out by the U.S. Department of Transportation's Maritime Administration.

1.2 Project Summary

The Container Yard Improvement Project for Port of Wilmington was carried out over a thirty week duration and consisted of five unique stages of work.

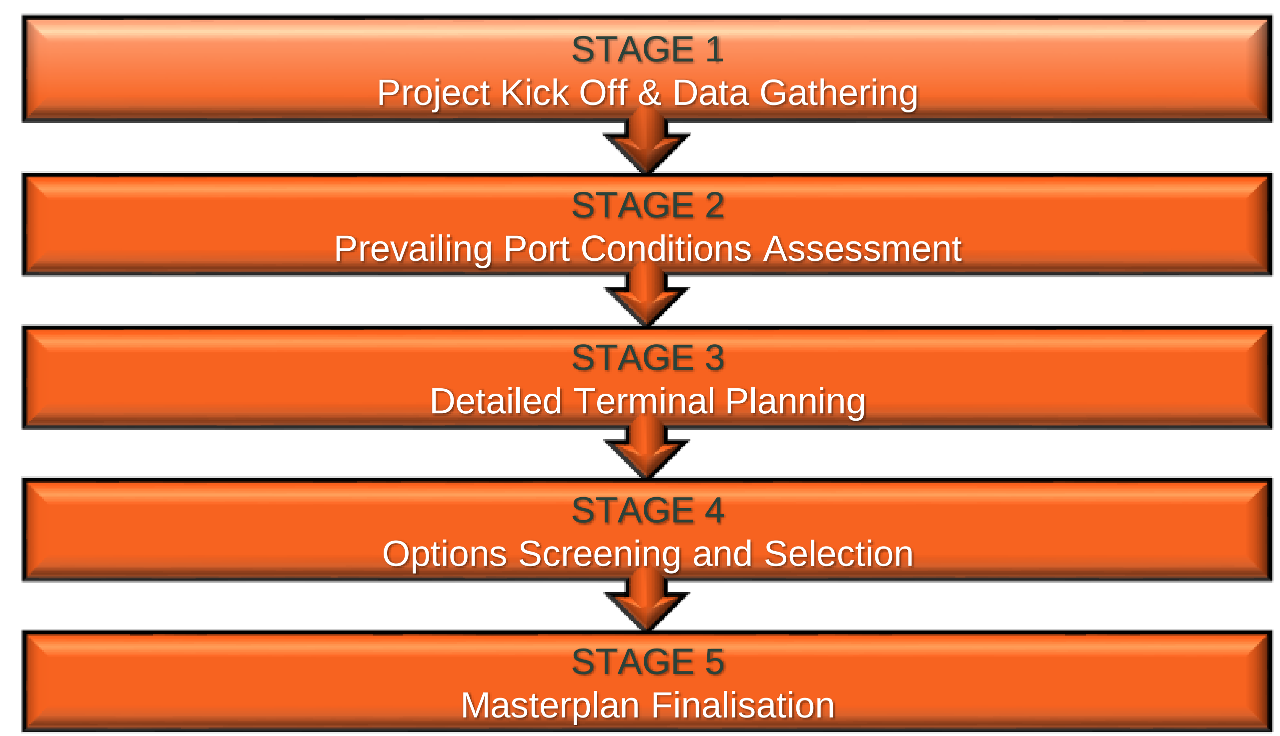
STAGE 1 & 2: The first two stages of the project consisted of the collection and assessment of the port's operations, container throughput statistics, prevailing port conditions and current civil infrastructure limitations. The list of data collected and obtained to data can be found in Annex C of the Inception and basis of Planning Report, January 2018. The concise list of port operational parameters used for the yard planning is recorded and presented in Chapter 6 of the Inception and Basis of Planning Report, January 2018.

With the obtained data, the container terminal's existing capacity was assessed for each of the internal container transfer nodes such as the main gates and yard storage area. The perceived terminal capacity was then compared to the future container throughput volumes targeted. The deficit between the two values was assessed along with the contributory factors leading to the shortfall noted and recorded for the concept yard planning process. This process has been documented in the latest Inception and Basis of Planning Report.

STAGE 3: Once the details of the basis for planning were confirmed and agreed with NCSPA, detailed terminal planning was carried out using the data and results from the initial assessment work produced in stages 1 and 2. During the detailed planning stage, solutions and terminal yard layout options were derived to overcome the throughput and operation shortfalls identified. Apart from ensuring each option was able to accommodate the target container throughput volume, each layout option also considers future expansion possibilities and the integration of new infrastructure such as a new intermodal yard and ongoing terminal projects.

STAGE 4: From the collection of layout option produced at Stage 3, the four most feasible base options were selected to take forward for further screening. Each option was critiqued for their advantage and disadvantages along with their estimated CAPEX costs. A multi-criteria analysis was used to score and rank the options in order to differentiate between the options and to aid select the preferred option to take forward. Criterion such as overall cost, security and operational performance was used during the screening exercise along with agreed weighting for each scoring criteria applied to reflect the importance to NCSPA of each layout option quality assesses. The scoring and weighting was performed and agreed with NCSPA.

STAGE 5: From the options screening exercise performed at Stage 4, a preferred layout option was selected to take forward for further refinements and construction phasing. A the cost estimate for the preferred option was then summarised into a spending and investment profile by breakdown the individual development projects in phases and time frame as to when the projects will need to be funded, time for design, procurement and construction.



1.3 Basis for Terminal Upgrade Planning

The basis for planning has been documented and set out in MMI's report titled "Port of Wilmington Planning Services for Container Yard Improvements – Inception and Basis of Planning Report" January 2018 document reference 386768-01-A. From time to time in this report, the Inception and Basis of Planning document will be referred to since this document contains the port operational parameters and capacity constraints form which the concept yard improvement layouts have been derived. It is therefore recommended that this Report is read in conjunction with the Inception and Basis of Panning Document. The objective for this project is to ensure the Container Terminal at Port of Wilmington will be able to accommodate a future container throughput capacity of 750,000 TEUs per annum by 2025. In physical terms, the ability for the port to accommodate this volume of containers manifests into three main internal box transfer nodes which all have to either match or exceed the targeted throughout volume. The node with the lowest capacity that is also below the target throughput will be considered as the 'bottleneck' of the terminal. The three main terminal container transfer nodes are as follows:

A. Berth/Quayside Container Handling Capacity

Although the berth and quay side capacity is not strictly within the remit of this Yard Planning Study, it is worth mentioning that the berth and quay side handling capacity plays a vital role to enable sufficient number of container ship calls of the correct parcel and vessel size to accommodate the future 750,000 TEU/annum volumes as well as ensuring that there are sufficient quay length and ship to shore (STS) crane numbers to physically handle the volume of boxes on and off the vessels at the Port. As stated in the Inception and Basis of Planning Report, with the current ongoing quay upgrade works at berth eight, the berth capacity has been estimated at 938,963 TEUs per annum spread over seven STS cranes.

B. Container Terminal Yard Storage Capacity

Should the berth and quay capacity be sufficient to handle the required volume of boxes on and off the ship, the next terminal node that will require to match the 750,00 TEU capacity will be the internal terminal container storage capacity. The estimated yard storage capacity has been estimated to be a maximum of 389,239 TEUs per annum. This takes into account the current quality of the terminal paving, maximum potential stack utilisation, terminal yard areas available for container stacking and average stacking heights achievable. Further details on the perceived current yard storage capacity is presented later in this Report.

C. Terminal Gate Capacity

The final terminal node which needs to match or exceed the target throughput capacity is the entrance and exit gates of the terminal. The capacity of the main terminal gates ensure that sufficient container trucks can enter and exit the terminal to either pick up or drop off container boxes. Even if the terminal yard and quay are able to accommodate the future targeted throughput of 750,000 TEUs per annum, it is futile if the gates cannot allow sufficient truck flows to flow in and out of the terminal to physically deliver and pick up the stored boxes inside the terminal. In fact, both yard and the quay side will not be able to fulfil their potential maximum capacities without the gate capacity first matching the yard and quay. This is because without the correct turnover of containers in the yard which requires trucks to enter the terminal, new boxes cannot be stored since there will not be enough free container slots available. Further details on the current perceived terminal gate capacity is presented later in this Report.

1.4 Container Throughput Forecast

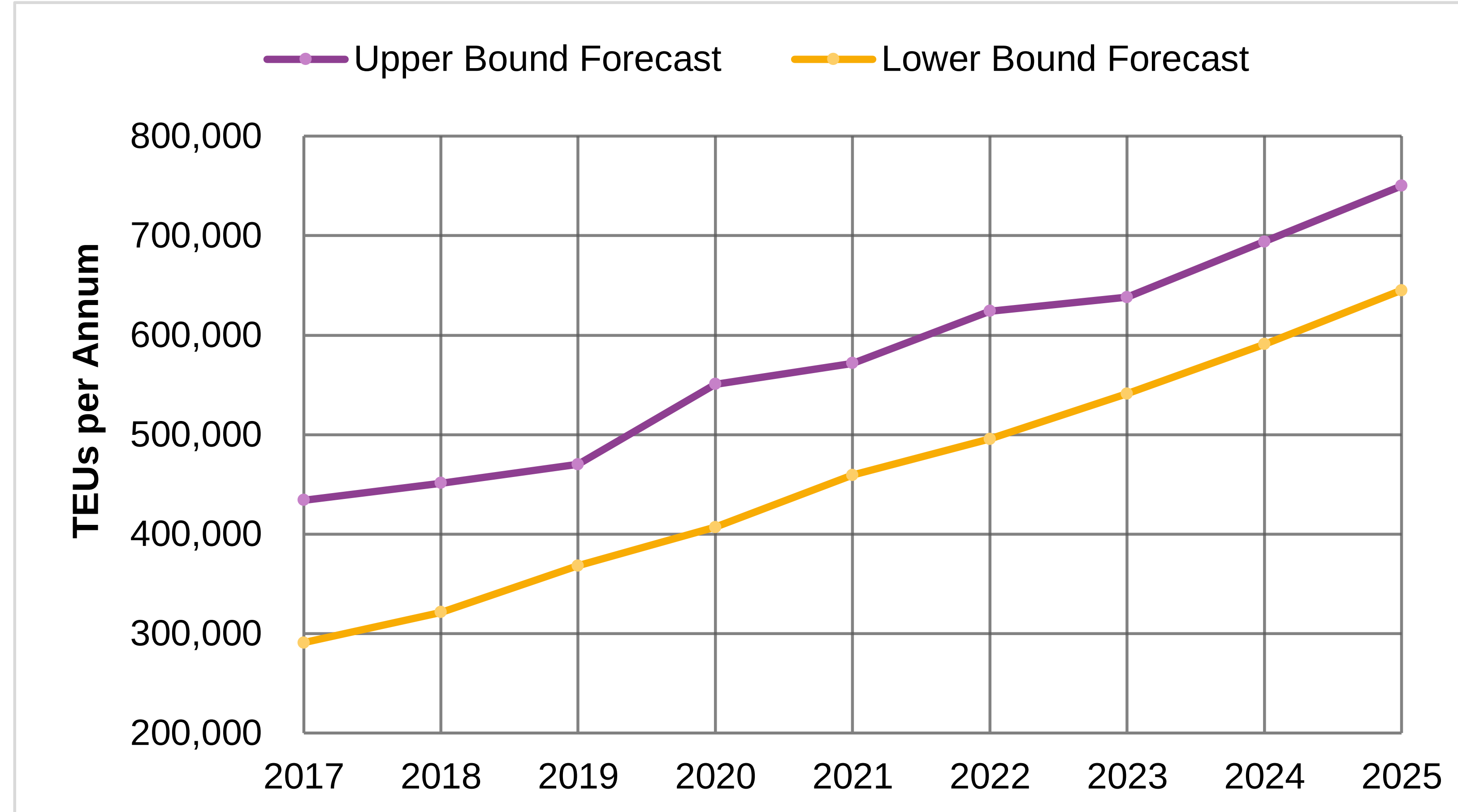
Having established the main project objective of ensuring that the terminal is able to accommodate a throughput volume of 750,000 TEUS per annum by 2025, it is important to understand the rate at which the throughput volumes will increase from the present day throughput figures to the targeted container volumes in the future as this will enable better understanding to plan for the construction and implementation phasing, making sure the interim terminal capacity during the construction stage will match or exceed the capacity growth rate.

Market forecast figures were received from NCSPA as shown on Figure 1. Two sets of forecast figures were provided by NCSPA, these are presented by the two lines shown with the purple line representing the upper bound forecast whilst the lower yellow line indicates the lower bound TEU volumes forecasted to 2025.

The upper bound forecast figures are considered to be the most positive potential container throughput volumes predicted by NCSPA and include the target throughput volume of 750,000 TEUS by 2025. For the Port to fulfil the upper bound volumes it is anticipated that local commercial and transportation economical drivers would have to materialise such as the new development of the CSX rail terminal upgrades and change in shipping volumes. The rate of growth projected for the upper bound estimate is approximately 316,070 TEUs over eight years or close to 39,509 TEUS every year until 2025. It is noted that the upper bound forecast figures for fiscal year 2017 were not achieved and instead, the actual container volumes handled were closer to the lower bound predictions.

The lower bound set of container throughput predictions starts off with the actual containers handled at the port for 2017 and is believed to have been projected forwards using an average growth rate of approximately 10% year on year.

Figure 1: Container Terminal Throughput Forecast



Although actual container volumes handled at the Port still lags behind the upper bound forecast, it is believed that the Port is still optimistic that the upper bound forecast figures are still attainable in the future and therefore, the object for planning a yard layout to accommodate 750,000 TEUs per annum by 2025 still holds.

However, for construction phasing purposes. NCSPA has instructed MMI to ensure that the interim construction capacity of the terminal will remain above the lower bound forecast figures.

1.5 Container Split

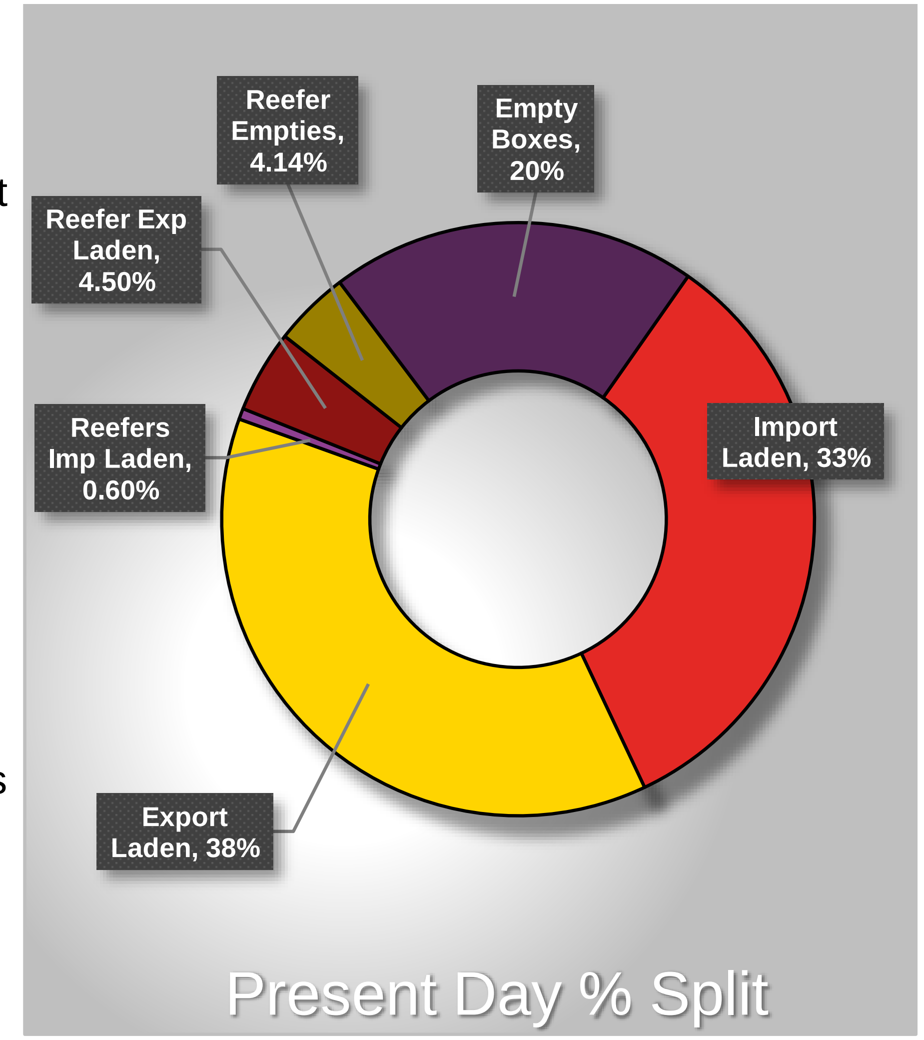
Another important planning parameter considered for the yard improvement works is the percentage split in container types to be handled at the port at present and also NCSPA's future prediction's on how container types will develop over time. The pie charts shown opposite present the current and future target container percentage splits. The key changes are as follows:

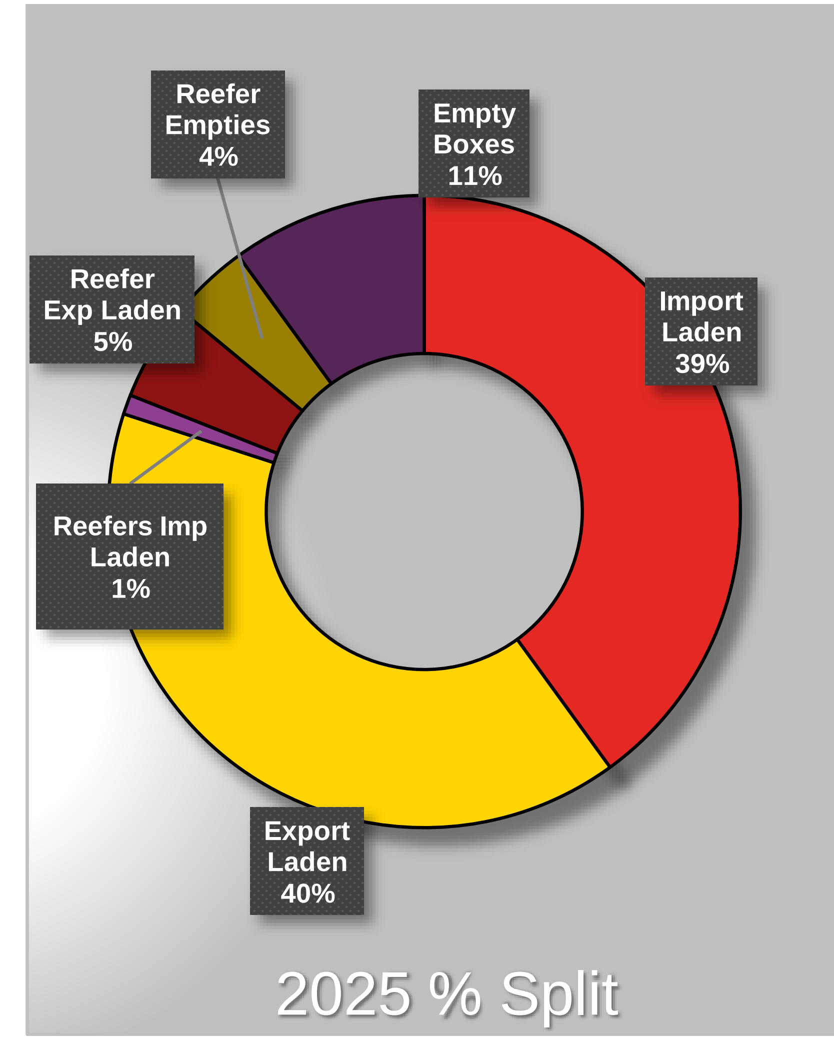
1.5.1 Empty Boxes

Empty boxes currently account for 20% of all containers handled at the Port. A large percentage of empty boxes coupled with a long dwell time of approximately 25 days lead to large spatial storage requirements at the terminal which limit the overall throughput capacity in the yard. NCSPA has indicted that the large percentage of empty containers at the time of assessment is due to Maersk using two trade lanes to position empty boxes and double load them at the Port to get them back to Asia on the outbound leg which in turn created a false high number of empties in the terminal. This practice is a short term with NCSPA indicating that this will cease in the future leading to lower empty box numbers in the future. In 2025, the forecasted empty container percentage of overall throughput will be 10-11%.

1.5.2 Laden Boxes

The current laden container import and export percentages handled at the Port are 33% and 38% respectively. By 2025, NCSPA are expecting to balance import and export laden boxes at the terminal so that its closer to a 50:50 split. The future export and import laden box percentages will be 39% and 40% respective of the overall containers handled. A more balanced import and export percentage for laden boxes will contribute towards the lowering of empty container numbers required to be stored at the repositioning of empty boxes can be achieved in the hinterland with less empty boxes required to be brought into the terminal to balance off the import deficit.



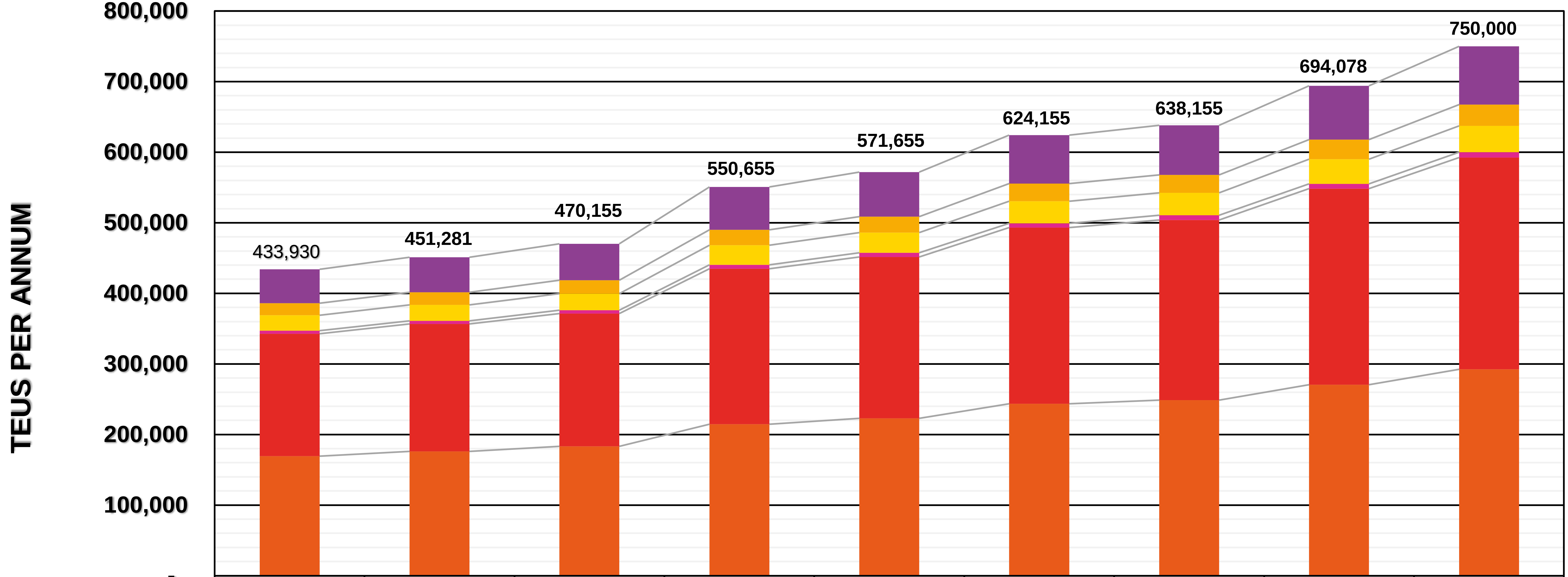


1.5.3 Laden Reefers

All laden reefers are set to grow in numbers in the future from the current 4.5% in exported laden reefers to 5% and current 0.6% Imported reefers to 1% by 2025. A total of 6% laden reefers has been considered for the overall yard improvement layouts derived.

Applying the container split figures above, the actual container numbers in TEUs has been plotted on the graph on the next page. See Figure 2.

Figure 2: Future Container Throughput and Container Split



	2017	2018	2019	2020	2021	2022	2023	2024	2025
Empties	47,732	49,642	51,717	60,572	62,882	68,657	70,197	76,349	82,500
Reefer Empties	17,357	18,051	18,806	22,026	22,866	24,966	25,526	27,763	30,000
Reefer Laden Exp'	21,697	22,564	23,508	27,533	28,583	31,208	31,908	34,704	37,500
Reefer Laden Imp'	4,339	4,513	4,702	5,507	5,717	6,242	6,382	6,941	7,500
Export Laden	173,572	180,515	188,062	220,262	228,662	249,662	255,262	277,631	300,000
Import Laden	169,233	176,002	183,360	214,755	222,945	243,420	248,880	270,690	292,500

2. Prevailing Port Conditions

Existing Port Capacity

2.1 Introduction

As part of the initial Stage 2 prevailing port conditions assessment work carried out, the existing perceived gate, berth and yard capacities were calculated and presented in Chapter 3 of Mott MacDonald's Inception and Basis of Planning Report dated January 2018. The capacities derived for each of the terminal box interchange nodes were based on theoretical static formulae and best practice bench mark guidance for container terminals.

During stage 3 of the detailed planning work, the existing port capacities were further verified and refined through more developed port operational parameters and through stochastic discrete event simulation of the port.

Although traditional static hand calculations are suitable for high level estimates on port capacity, the formulae utilised are very sensitive to empirical factors which are included to compensate against random events which occur during day to day port operations such as the peaking factor and 'shape factor' of the terminal area etc.

The main terminal gate, main yard and berth have all been modelled and simulated using the most up to date port operational parameters at each of these nodes. The following section of this report provides an explanation into the methodology of the port simulation utilised.

2.2 Port Simulation

2.2.1 Introduction

The port was modelled using Rockwell Automation ARENA software rather than just using standalone calculations. ARENA is a discrete event modelling software which can assess large dynamic processes making it an ideal tool for assessing the operation of port operations.

Discrete Event Modelling

Discrete event modelling provides better accuracy of results to calculate capacities by:

- Introducing distributions to the inputs and processes in the system allowing peaks and troughs to be calculated to obtain both average and extreme values, by running the model multiple times.
- Assessing "knock-on" effects of changes to be discovered easily as the whole system is modelled, compared to stand alone calculations, e.g. how the number of reach stackers in the yard can affects the out gate queue length.
- Capturing dynamic aspect of the port facility rather than looking at a simplified snapshot of the terminal.

Port of Wilmington

For the Port of Wilmington Container Yard, a global model of the whole port was established to assess global variables such as truck turn time & yard utilisation. This allowed the interferences and linkages between process to be assessed and designed. To check the operation of the simulation simple arithmetic calculations were used to compare the results to the existing data obtained from the NCSPA. This created the baseline model which was found to have the same characteristics as the Port and therefore this baseline model can then be adapted to test the various layout options.

For key aspects, that require more detailed assessment such as the gate and the intermodal yard small bespoke models were developed. These were calibrated from the global model and allowed easier testing and assessment of options that could then be reintroduced into the global model if required.

2.2 Port Simulation

2.2.2 Simulation Methodology

Terminal Operation

The port is currently operated exclusively using Reach Stackers and Trucks. To model this the system is split into two main processes:

1. Ship Import & Export Operation [Shown as purple arrows].
2. Hinterland Delivery & Receipt Operation [Shown as red arrows].

To develop a representative simulation model, key simulation parameters have been devised for the main nodes in the model. These parameters have been derived, using data provided, and in liaison with the NCSPA. The following operations are the main nodes to the model that are used to allow the ARENA model to simulate reality:

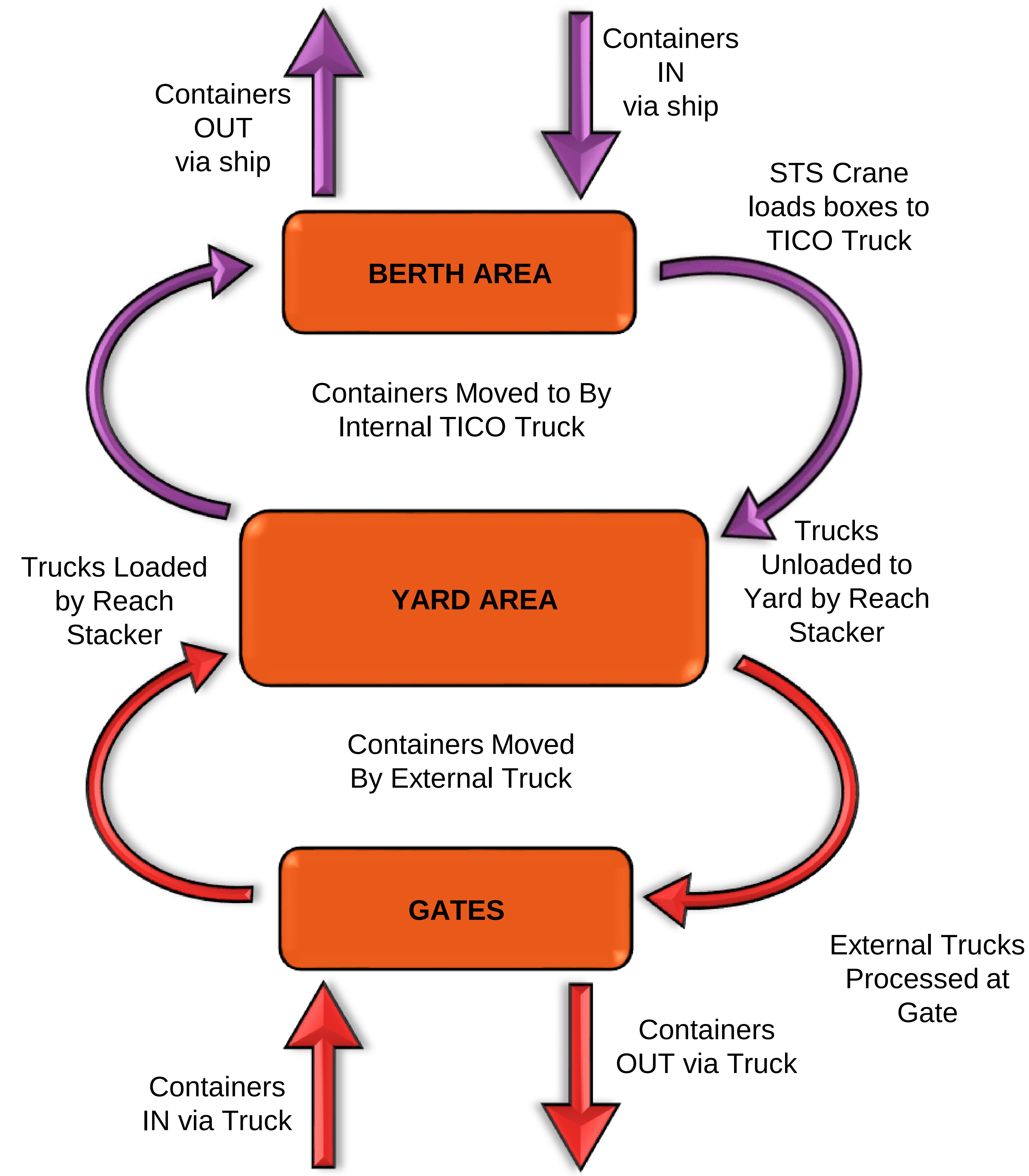
Ship Import & Export Operation

- Crane offloading .
- Internal truck transportation.
- Reach stacker processing in yard.

Hinterland Delivery & Receipt Operation

- Gate Process.
- External truck transportation.
- Reach stacker processing in yard.

The baseline parameters were decided using existing data and was used to model the existing systems, different parameters were devised for the future scenarios based on the improvement of technology and processes.



2.2 Port Simulation

2.2.2 Simulation Methodology

2.2.2.1 Berth Area

There are currently three berths, Berth 7 (700'), Berth 8 (1050') and Berth 9 (900'). This provides a total Berth length of 2650'.

An industry benchmark, given in PIANC Report 158, 2014, equates to 305 – 427 TEU/ linear foot of quay. This shows that the berths at the Port of Wilmington have the potential to increase capacity to between, **823,000 and 1,152,200 TEU/annum** as required to increase the terminal throughput.

This shows that the berth is not likely to be the critical node in the improvement of the terminal throughput. As these are only averages, it is possible that the berth would be able to operate a higher throughput than these averages.

The current utilization of the berths is approximately 28%. To maintain a suitable waiting time it is suggested that the utilization of the berth does not increase over 50%.

STS Cranes

There are currently six STS cranes along the three berths:

- Four post-panamax STS cranes numbered 12, 14, 15 & 16 (commissioned 2007),
- Two older Liebherr cranes, Cranes 9 & 10, (to be demolished).

Two new super post panamax cranes (22 box wide) have been ordered and are expected in 2018, with a third expected Jan 2019 and there is a potential for a forth. This would lead to seven or eight STS cranes for the future scenarios along the three berths.

Using average values from literature this would equate to an average of 880,000TEU/year passing through the cranes. This is based on the average moves per hour which is given as 25 moves therefore this was proportioned by the average moves at the Port of Wilmington (40 moves/hour) which would give an approximation of **1.4 million TEU/year.**

If required there is sufficient space along the berth for additional cranes if required, therefore the amount of cranes available will not be the limiting factor in the increase in terminal throughput and has not been considered further.

.

2.2 Port Simulation

2.2.2 Simulation Methodology

2.2.2.1 Berth Area

The governing input into the global terminal model is the number of import containers arriving and the terminal and export containers leaving the terminal via ship. The shipping schedule for FY2018 was taken from data received from the NCSPA (October 2017), and the averages for each vessel call were calculated from 17 weeks of data in FY2018.

Using the averages taken, the annual container throughput from this schedule is 156,936. Using the given TEU Ration of 1.75, the TEU Throughput is taken as 274,638. It is assumed that all vessels have the same import-export split as given in the data (49.9% Import/51.1% Export).

To assess the baseline capacity the current shipping schedule was multiplied by a factor within the ARENA software. As the berth operation was considered adequate this is considered a suitable methodology even though the number of containers arriving on each vessel increases, and the baseline value is within 25%. For modelling the future options new shipping schedules are developed to provide a more representative view of the berth usage.

Figure 3: Container Ship Alongside Berth 8 – Port of Wilmington

2.2 Port Simulation

2.2.2 Simulation Methodology

2.2.2.1 Berth Area

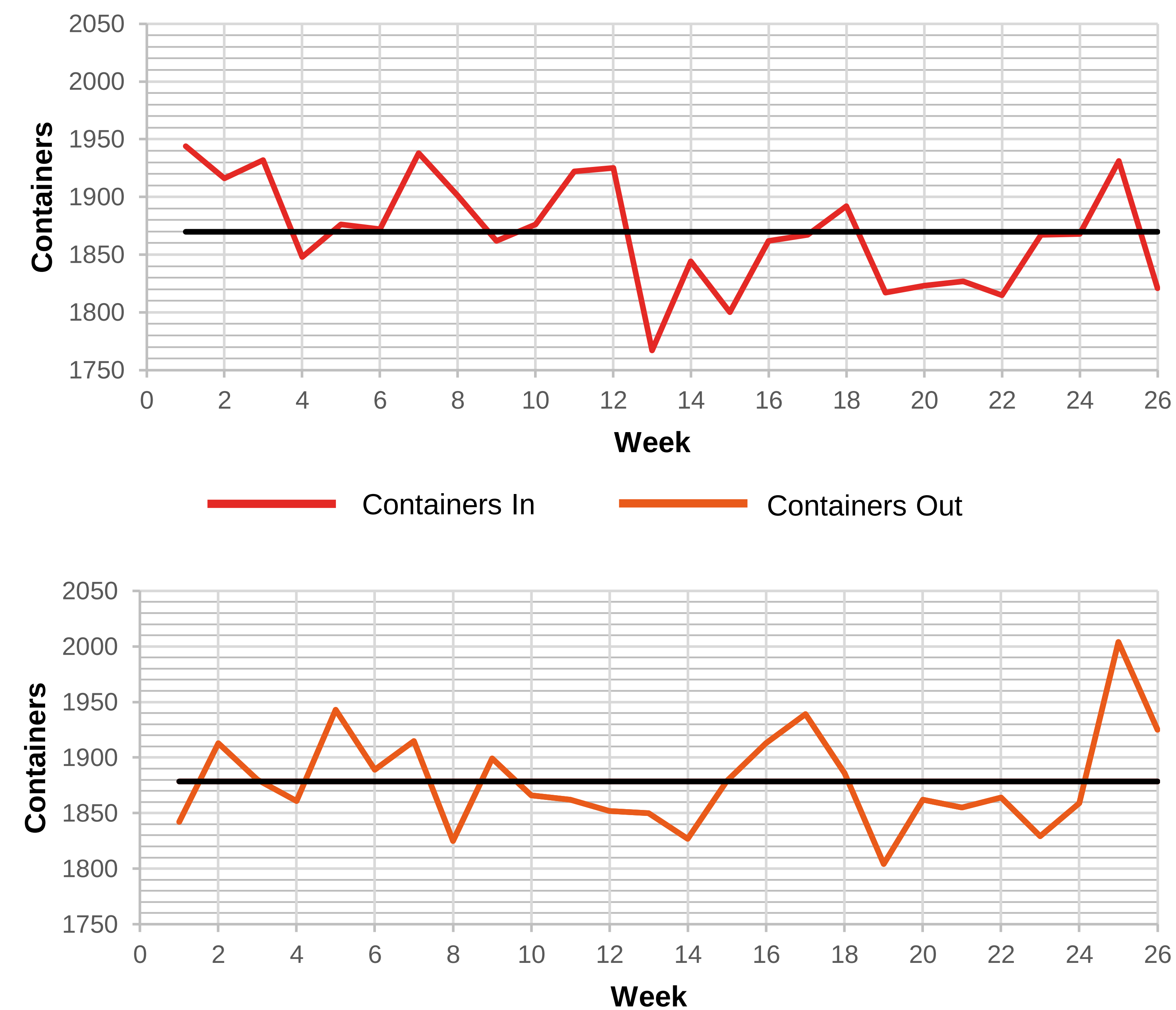
The ARENA model is stochastic model and has a randomness allocated to the input schedules, the values used in the schedule are equal the mean of the exponential function.

The graph in Figure 4 shows the number of containers arriving and leaving by ship for the baseline global terminal model. The descriptive statistics are:

	In	Out
Mean	1,870	1,879
Median	1,868	1,865
Minimum	1,767	1,804
Maximum	1,944	2,004

Due to the randomness in the model the number of containers arriving and leaving by ship, the number of containers arriving and leaving via truck/rail are linked to the number of containers entering and leaving by ship. This reflects the reality that if 250 containers are delivered by ship, only the sufficient trucks required to deliver these to the hinterland will arrive at the terminal, not a random amount. Therefore the “hinterland container demand” is not an independent input.

Figure 4: Graph showing the number of containers arriving and leaving by ship per week for the baseline model running with a throughput of 340,000 TEU/annum for 26 weeks (6 months).



2.2 Port Simulation

2.2.2 Simulation Methodology

2.2.2.2 Yard Area

Terminal Equipment used for simulation

The stacks are worked exclusively by Reach Stackers, using both internal and external trucks to transport the containers between stacks.

There are currently seventeen operational Reach Stackers in the container yard:

- 3 No 2017 Kone SMV 4535 TC6
- 3 No 2016 Kone SMV 4535 TC6
- 3 No 2015 Kone SMV 4535 TC6
- 8 No 2005 SMV SC 4527 TB6

The process times for the unloading and loading of containers was devised from, experience at the NCSPA, reach stacker specifications and videos made at the kick off meeting.

The internal trucks transport containers from the berths to the yard. These are operated by a subcontractor, TICO. They operate around forty to fifty internal tractor trailers. The number of TICOs operating for a boat to unload depends of the number of cranes being used, as the crane speed of unloading can only be maintained if there are sufficient TICO trucks. Reach stackers are considered to operate all over the terminal and it is considered that there is sufficient that the time for them to move between areas is considered negligible and will be mitigated by terminal planning.

Chassis Changes

There is currently a chassis yard on the east side of River Road . This is used for the parking of truck chassis which are not owned or operated by NCSPA. For dual move operations, i.e. when a truck enters the terminal to drop off a box and then immediately takes on another mission to pick up a box as well, the chassis yard and its close proximity to the terminal plays an important role to enable dual moves to be executed.

When a dual move truck enters the terminal to drop off a 20 foot box and is then required to pick up a 40 foot box, the truck driver must leave the terminal and enter the chassis yard to change the chassis before re-entering the terminal to complete the dual move operation. Since NCSPA have indicated that the trucking companies do not own any adjustable chassis frames and only operate single length chassis, truckers which have been assigned a dual move must leave and enter the terminal, NCSPA have stated that dual moves account for 30% of all box exchanges.

Having trucks leave the terminal and renter again just to pick up a different box causes unnecessary truck volumes at the gate and will only slow down the gate processing of trucks at peak times as this will add to the queueing at the gates. This process for dual moves has been considered and simulated in the port model.

2.2 Port Simulation

2.2.2 Simulation Methodology

2.2.2.2 Yard Area

The container stacking yard is split into the following areas in the baseline model based on the yard planning information received from NCSPA. The following table shows the number of TEU ground slots in each area.

Area	Use	TEU Ground Slots
A1	Imports	450 TGS
A2	Empties	
C	Empties	410 TGS
F1	Empties	1,112 TGS
F2	Imports	
F3	Exports	
H	Imports	444 TGS
J1	Empties	1,152 TGS
J2	Exports	
K1	Reefer Exports	894 TGS
K2	Imports	
K3	Reefer Empties	
L1	Empties	1,299 TGS
L2	Reefer Imports	

2.2.2 Simulation Methodology

2.2.2.2 Yard Area

Traffic Routing

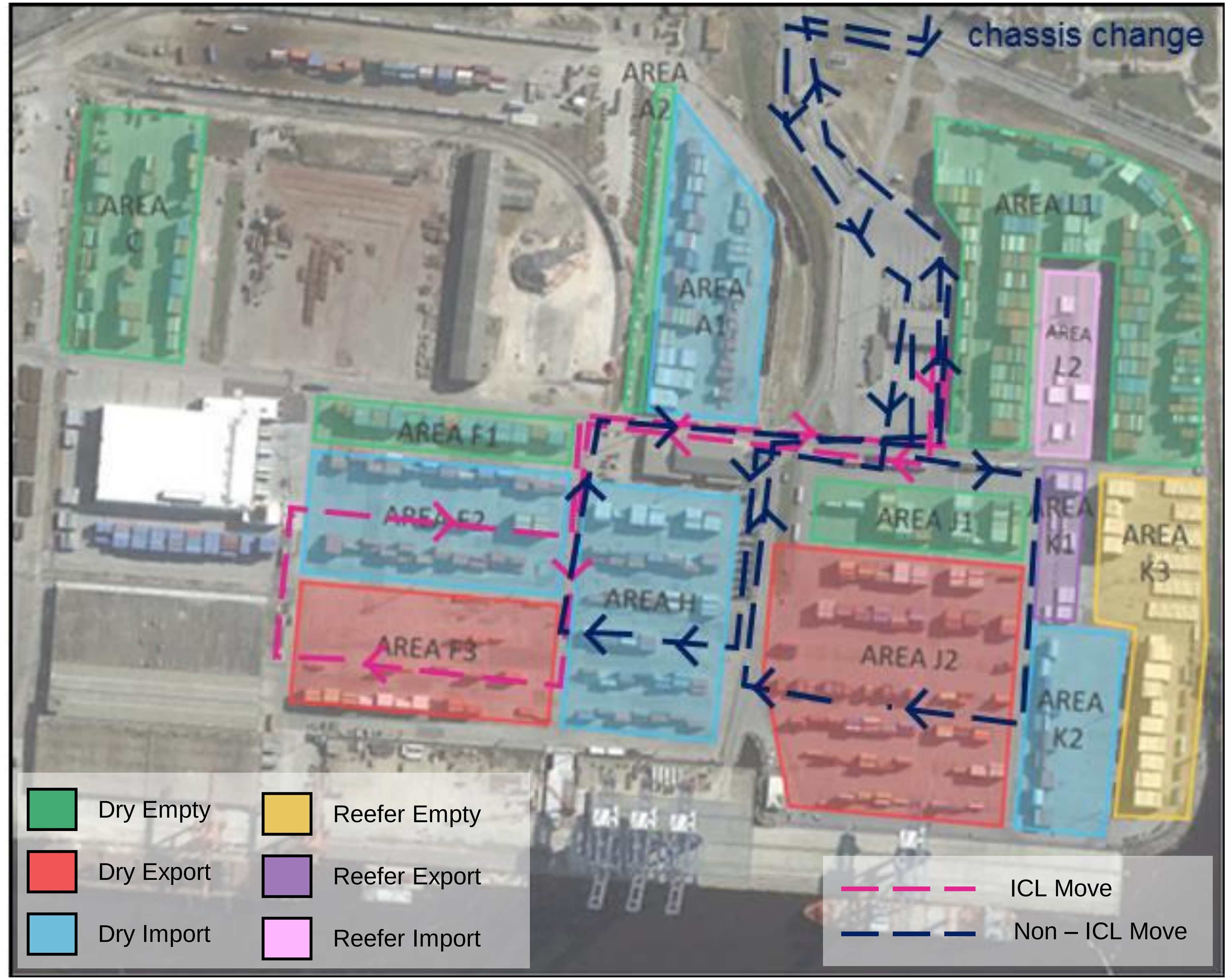
All trucks arrive through the South gate, and the route they take within the terminal depends on the container type. The majority of trucks arrive to drop off one type of box and then collect another box to deliver to the hinterland in move. This causes many different truck routing options due to many different combinations.

Figure 5 shows the different areas within the current port operation. The two routes show a dual move truck entering the terminal, dropping off a box at the export stack and then moving to the import stack to pick up a box.

Currently the ICL containers are all held in area F, so the drop off and pick up occur close to each other. For the Non ICL move the truck completes a chassis change between drop off and pick up of the box. This occurs of 30% of the dual move trucks, who have to leave the terminal and then re-enter through the gate increasing traffic on the port internal roads.

There are multiple combinations of truck movements in the yard, because there are many small areas for different container types. This will increase the variety of the time for each struck spent inside the terminal, and will increase the amount of trucks on the roads as there is not one clear route.

Figure 5: Truck Routing in the Port of Wilmington



2.2.2 Simulation Methodology

2.2.2.2 Yard Area

Further Model Assumptions

- The model is assumed that all areas are equally preferable and is split on arrival between the different areas based on the total number of ground slots.
- The use of the ICL imports/export & empties in area F are simulated and the percentage of import trucks is considered by chance. An example of this is shown on the next page.
- The model operates in number of containers and the difference between containers and TEU throughput is calculated using the TEU ratio of 1.75.
- Only one container is considered to be moved at any given time by both the internal & external trucks (no twin moves).
- No miscellaneous cargo is considered e.g. tanks that would require different processes.

Table A: Baseline Case Parameters using within the ARENA model for the Yard & Berth Area Operations.

No.	Operation	Baseline Case
1	Number of TICO Trucks	40
2	Number of Yard Reach Stackers	17
3	Reach Stacker Unloading from Stack	Exponential Distribution: Mean (3min)
4	Reach Stacker Loading to Stack	Triangular Distribution: Min (1min) Mean (2min) Max (4min)
5	Speed of Internal Trucks in Terminal	20mph
6	Crane moves per hour	Triangular Distribution from berth data: Min (30nmph), Mean (35nmph), Max (40nmph)
7	Average Number of Cranes / Vessel	1.7
8	Percentage Chassis Changes	30% of dry dual move trucks
9	Percentage Intermodal	0%

2.2 Port Simulation

2.2.2 Simulation Methodology

2.2.2.3 Gate Area

Truck Input

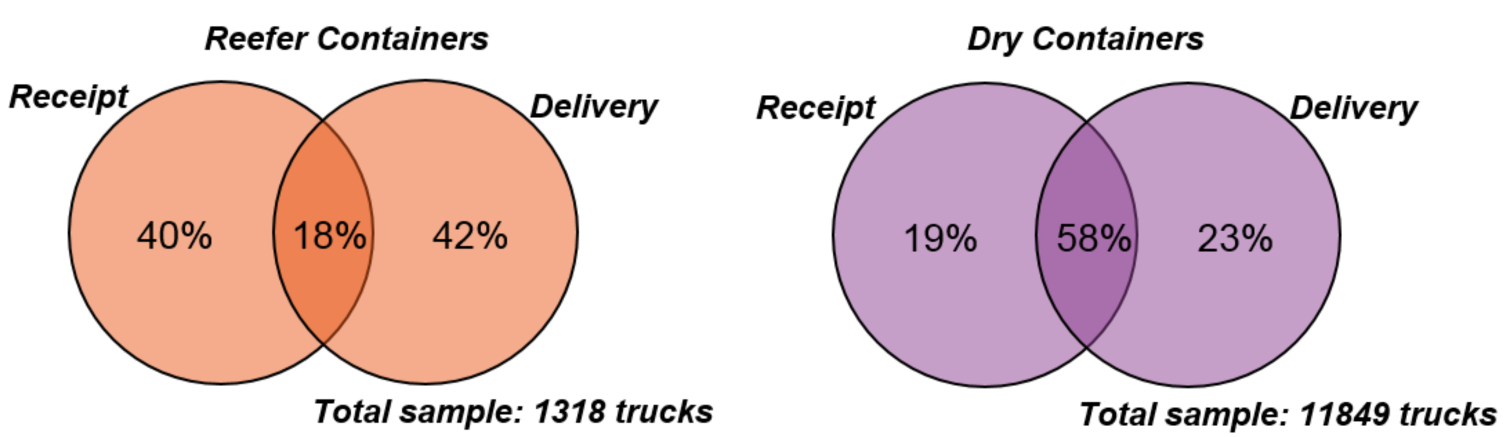
Only two container types are specified within this model, 'Dry'/'Standard' and 'Reefer'. Other containers such as tanks etc. are not included as they make up such a small percentage of the throughput.

'External Trucks' arrive at the port to drop off or pick up containers. At the Port of Wilmington some trucks perform both these roles and are so names 'dual moves'. Therefore the external trucks are one of:

- **Receipt/Export Move Truck** – Truck arrives bringing container to terminal.
- **Delivery/Import Move Truck** - Truck arrives to collect container from terminal.
- **Dual Move Truck** - Truck arrives to bring container to terminal & collect container from terminal.

From the gate data available the number of each of these trucks can be calculated:

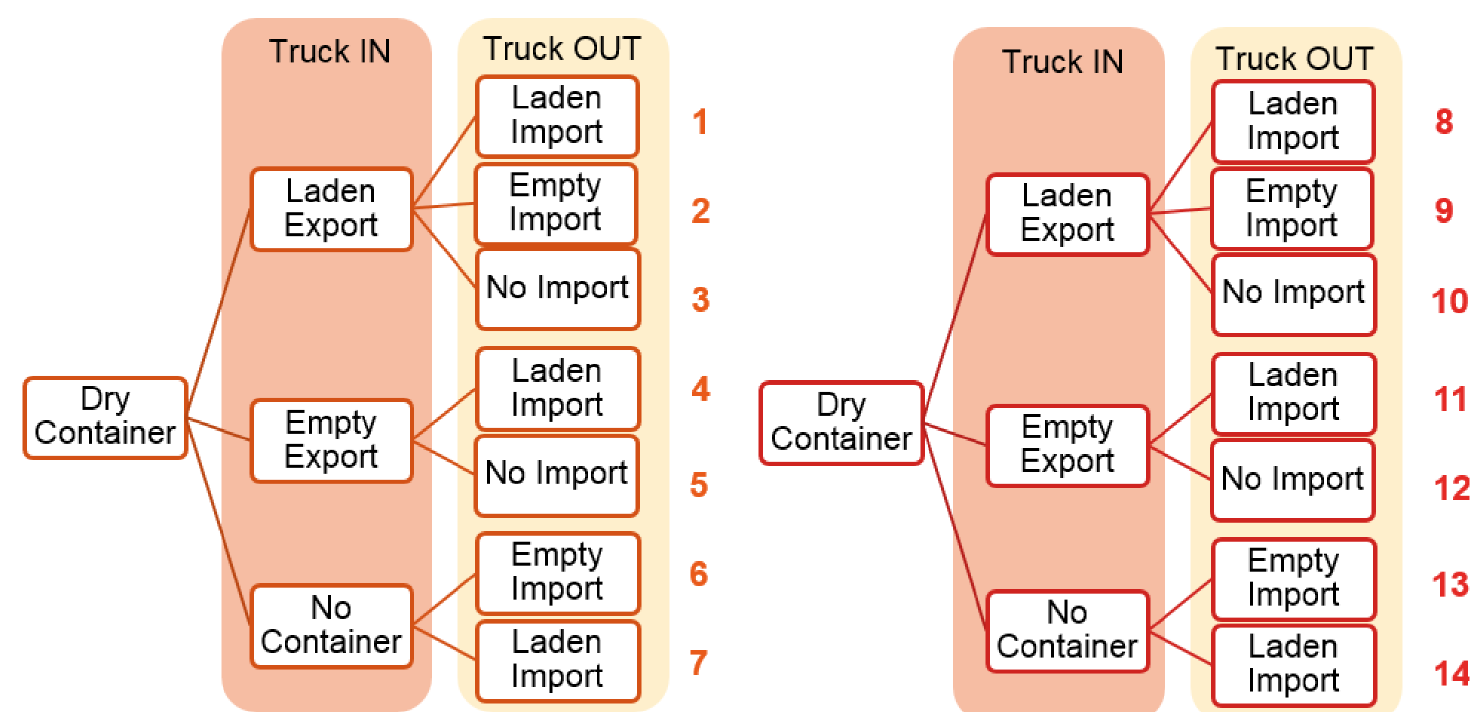
Figure 6: Percentage of Dual Moves



The reefer containers are managed by a separate haulage company and therefore an external truck cannot service both reefers and dry containers so the processes are considered completely separate.

Therefore fourteen different combinations of truck are available as shown in Figure 7. It is assumed that a truck will not enter the port with an empty container and leave with an empty container as this interchange would be completed outside of the terminal, equally a truck will not enter and leave with no container.

Figure 7: Truck Definitions



2.2 Port Simulation

2.2.2 Simulation Methodology

2.2.2.3 Gate Area

Truck Input
As previously mentioned, the number of containers arriving and leaving the terminal via road and rail is linked to the number arriving and leaving by ship, as it would be in reality. The delay between the two is based on a triangular distribution using the mean as the dwell time.

Due to the varying amounts of dual moves, and the large number of possible combinations, the number of trucks passing through the gate each day is not specified directly in the model. Instead the number of containers is specified, This corresponds to either one container per truck for a single move (receipt or delivery) and two for a dual move.

Therefore as the number of trucks in not directly specified in the input this leads to a wide variety of actual truck numbers at the gate, predominantly due to the number of dual moves which varies due to probability. These values are shown in Figure 8. To ensure that the numbers passing through the gate are suitable, the output has been compared with the October 2017 gate data.

The actual number of trucks is shown for four weeks when running the model at 340,000 TEU throughput is shown in Figure 9. It can be seen that large peaks and troughs can be seen in the data but on average the values are much lower. This is expected to follow reality, and is taken into consideration in the design when considering the critical parameters defined.

Figure 8: Baseline Container Input. This is the number of containers that are can pass through the gate per hour. (A dual move truck counts as 2 containers

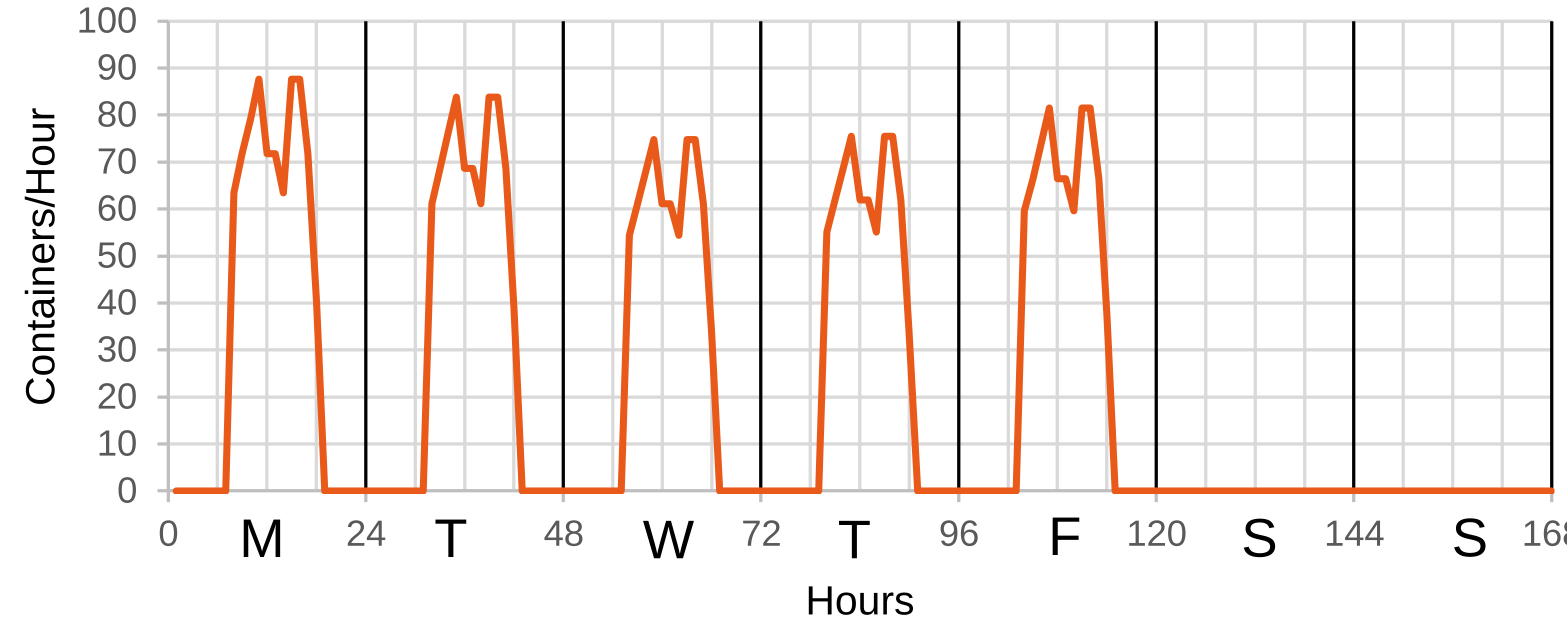
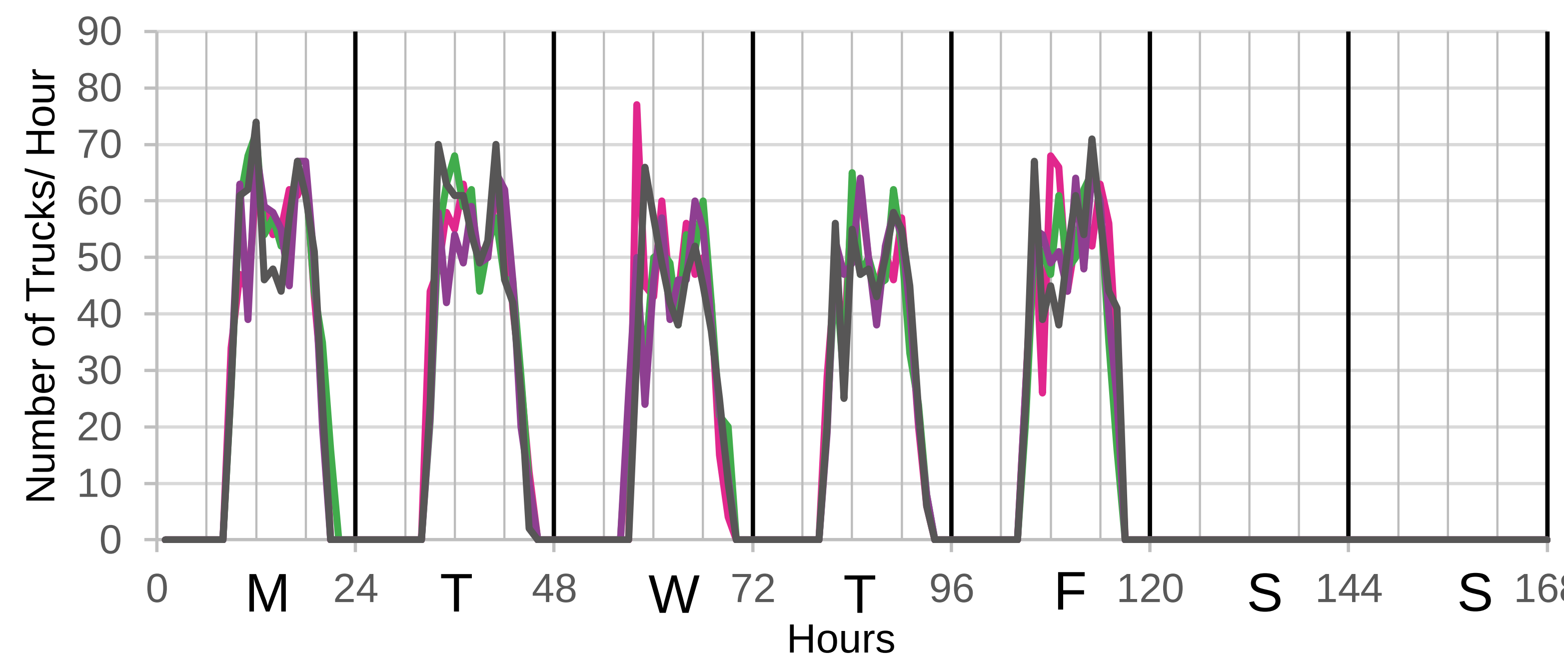


Figure 9: Baseline Trucks/Hour through gate for four different weeks. The variation is predominantly due to the number of dual moves.



2.2 Port Simulation

2.2.2 Simulation Methodology

2.2.2.3 Gate Area

<u>Gate Operating Times</u>
Access to the container terminal at the Port of Wilmington is through the South Gate. The existing container gate operation times are taken from the NCSPA as:
Monday – Friday 07:00 to 18:00.

This provides fifty five hours of gate operation in a given week. (eleven hours per day). However it is noted that there is existing out of hours gate usage for additional cost, but this is not included within the baseline model, used to calculate gate capacity.

<u>Gate Operating Procedures</u>
The terminal has four in gates [Numbers 1,2,3,4] and three out gate [Numbers 5,6,7]. All truck entering or re-entering the terminal must pass through the main gate complex.

The following two slides outline the current entrance and exit gate procedures, and demonstrate how this has been converted to logic models within the ARENA software.

Figure 10: Current Gates

2.2 Port Simulation

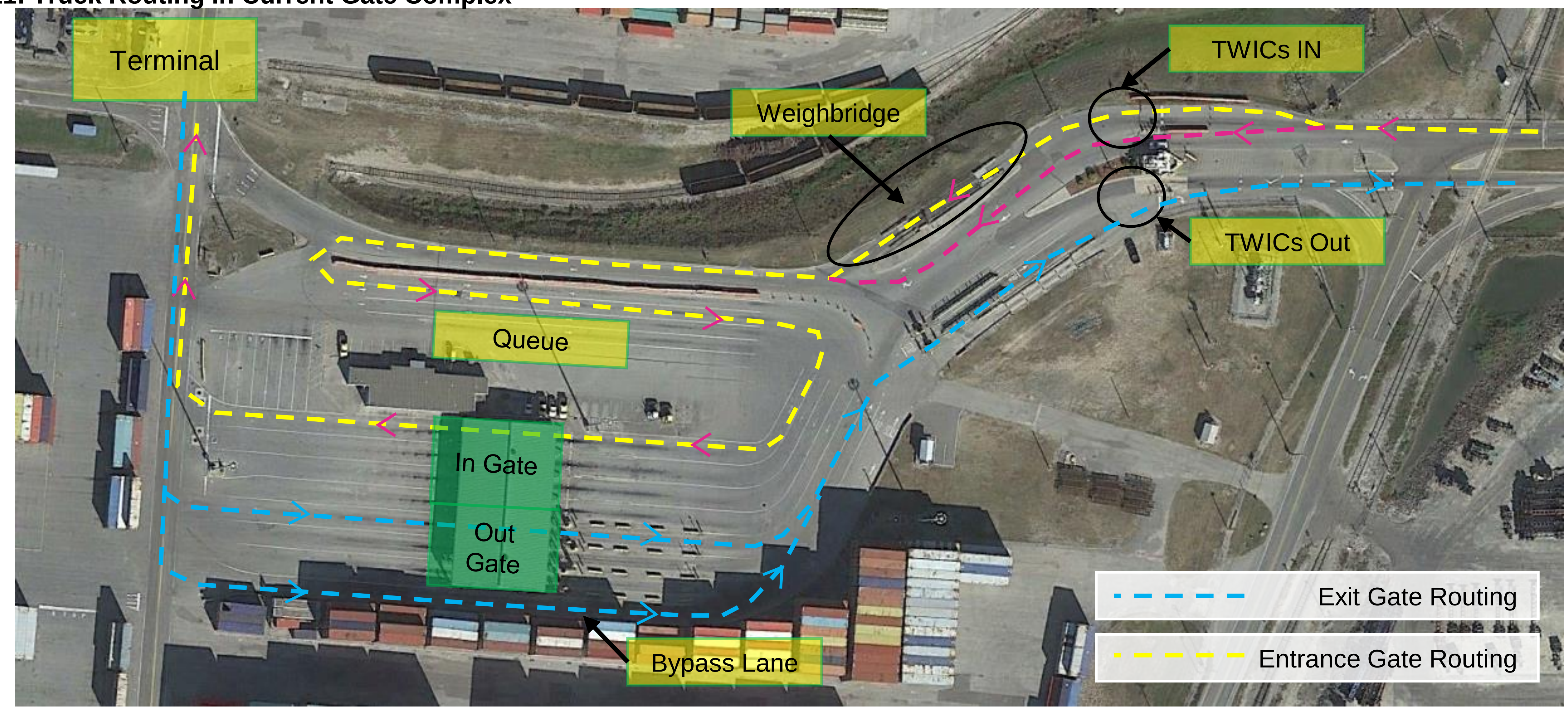
2.2.2 Simulation Methodology

2.2.2.3 Gate Area

Gate Routing

The current truck routing around the gate complex is shown in the figure below. The detailed process is shown on the following section of this report.

Figure 11: Truck Routing in Current Gate Complex



2.2 Port Simulation

2.2.2 Simulation Methodology

2.2.2.3 Gate Area

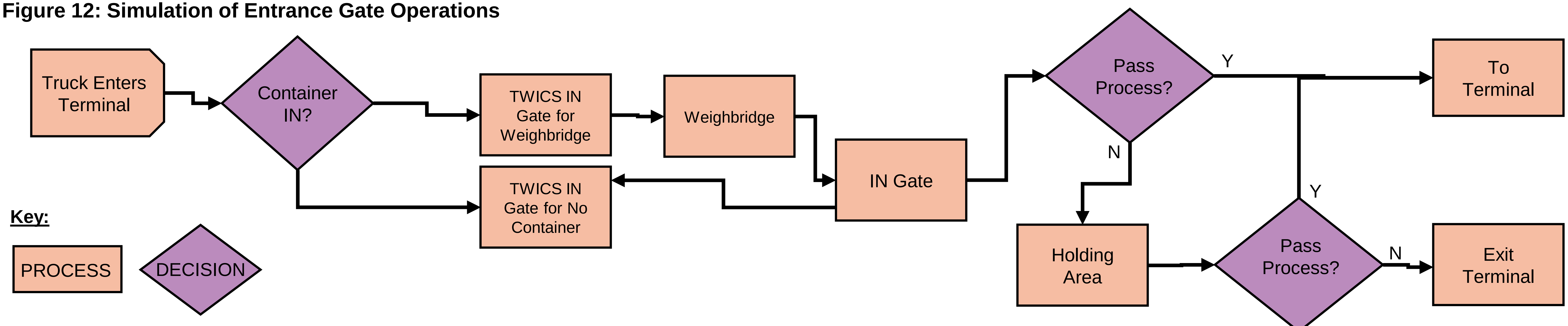
Entrance Gate Operating Procedures
The diagram shown is an representation of the modelling of the current entrance gate at the Port, as processed by the simulation modelling.

Currently there are two TWICs gates, one which leads to the weighbridge. All loaded containers entering the port must be weighed. The driver takes the reading and reports it to the operator at the in gate. Empty containers and chassis can bypass this.

At the gate all of the data from the containers has to manually be transferred to the system. The gate operator manually requests gate pass number, booking reference inbound details, and then uses manually operated cameras to locate the chassis number, container number, license number and seal checking and then manually inputs the details into the system. Gate and TOS then compares this to the Port's data base before issuing the mission ticket. This can be a long process, and can lead to errors.

If there is something wrong with the container it is pulled over into the holding area for manual inspection. If this fails the truck is routed out of the terminal and not allowed to continue into the terminal.

Figure 12: Simulation of Entrance Gate Operations



2.2 Port Simulation

2.2.2 Simulation Methodology

2.2.2.3 Gate Area

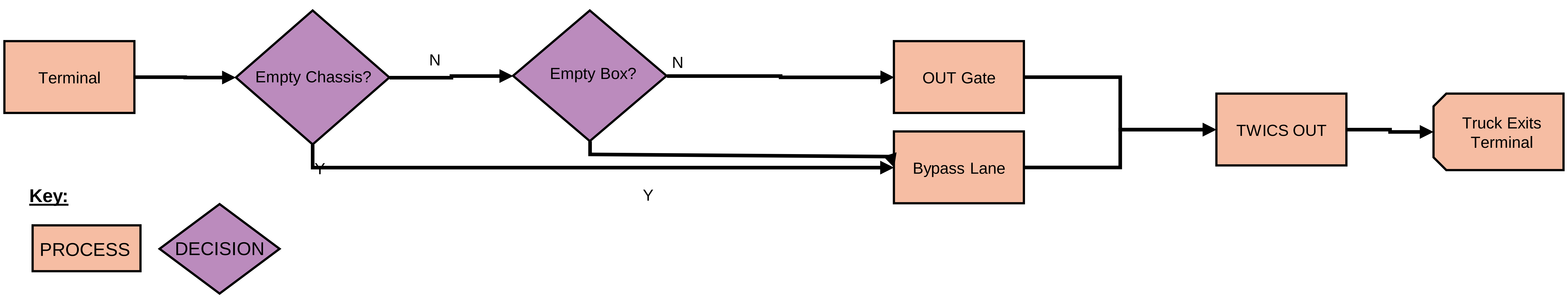
Exit Gate Operating Procedures

The diagram shown is an representation of the modelling of the current exit gate at the Port, as processed by the simulation modelling.

There are currently three exit gates. Only trucks with loaded containers must pass through the gates, where there is some manual processing of the outward container including, chassis number, container number, license number and seal checking and radiation scanning of the box which is a mandatory requirement by homeland security. If the truck has an empty chassis (no container) or the container is empty then the trucks can bypass the gates via a bypass lane, so a large percentage of the trucks do not pass through the out gate. The chassis yard is located outside the terminal and the trucks that need to change chassis will need to use the bypass lane.

The trucks then pass through the gate and to the TWICs out gates where the driver scans the pass to leave the terminal and enter the highway.

Figure 13: Simulation of Exit Gate Operations



2.2 Port Simulation

2.2.2 Simulation Methodology

2.2.2.3 Gate Area

Parameters for the Gate Aspects

The parameters given in Table B, show the processing times that are included within the ARENA model. The time have either been defined by the NCSPA or data provided, or have been assumed.

The key aspect of the model was to identify a failure criterion. For the gates this is taken as:

"Queue length exceed the maximum queueing capacity more than 50 times per year".

When the queue exceeds the allowable space this will interfere with other aspects, for example clogging up roads within the terminal if the exit gate queue is exceed or queuing onto the highway if the entrance gates are exceeded.

Table B: Current Baseline Gate Input Parameters

	Operation	Baseline Case
1	TWICs IN processing time	15 seconds
2	Weighbridge processing time	30 seconds
3	In Gates Number	4
4	In gate Processing Time	Triangular Distribution from gate data: Min (3.25min), Mean (4.25min), Max (5.25min)
5	In gate Max Queue Capacity	40 trucks
6	Out gate Processing Time	Triangular Distribution from gate data: Min (3.25min), Mean (4.25min), Max (5.25min)
7	Out Gates Number	3
8	Out gate Max Queue Capacity	15 trucks
10	TWICs OUT Processing time	15 seconds
11	Failure Capacity of System	Queue length exceeds the given capacity 50 times per year.
12	Percentage failure of In gates	0.06%

2.2 Port Simulation

2.2.2 Simulation Methodology

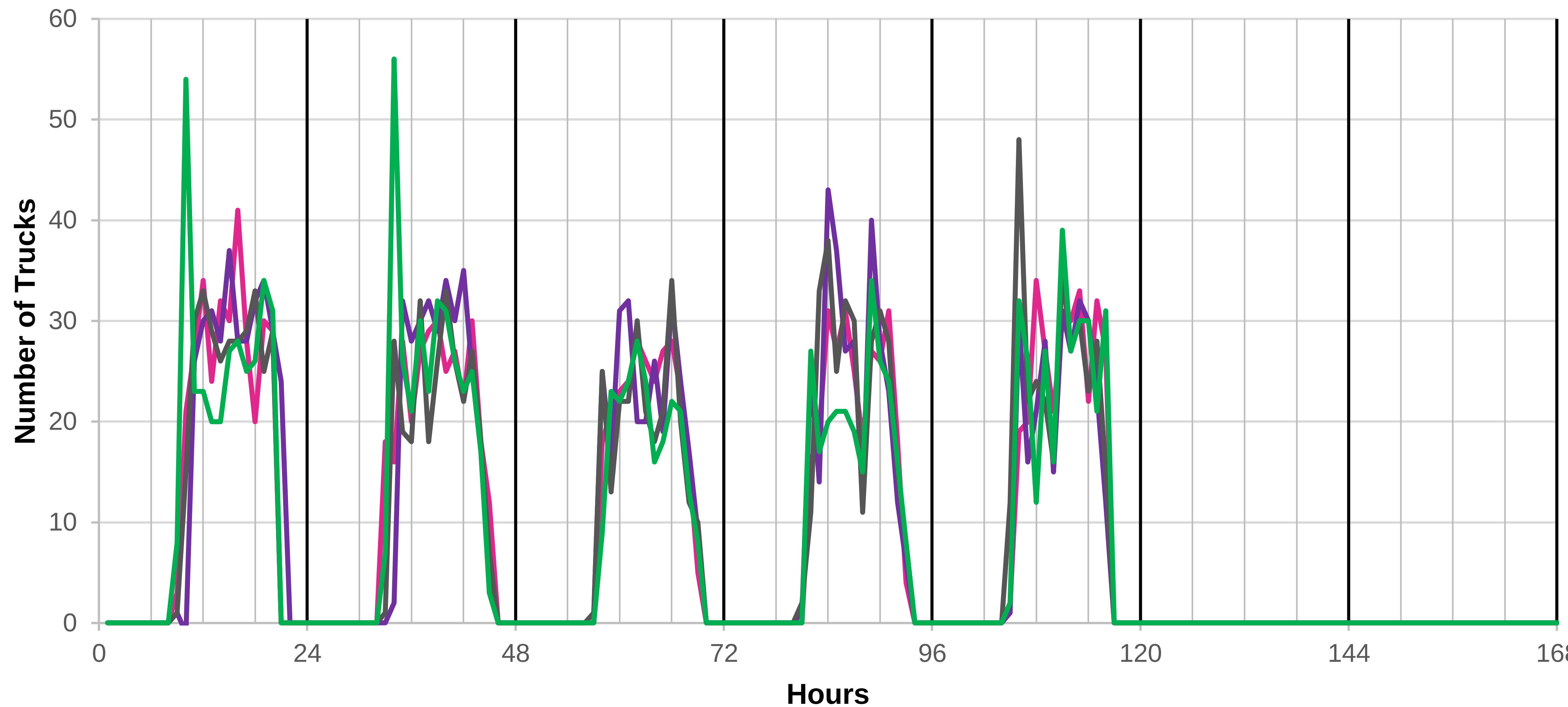
2.2.2.3 Gate Area

Exit Gate

Due to the bypass lane approximately only 44% of trucks pass through the exit gates.

In comparison to the entrance gates the results are more peaky, this is due to the increased variation of the truck entities before they reach this point in the simulation, with trucks travelling to different areas and having different processing times, which can combine to form the large peaks and troughs.

Figure 14: Baseline Trucks/Hour through exit gate for four different weeks. It can be seen that there are large peaks and toughs due to model randomness and variation in processing times.



2.2 Port Simulation

2.2.3 Existing Gate Capacity

Introduction

From the initial discussions with the NCSPA during the kick off meeting and the tour of the port, it was noted that the gates looked like the limiting factor in the system.

The system is mainly manual and currently it has been reported that there are periods where the trucks have to be marshalled into area A within the port boundary because the queue has exceeded the capacity. This is not ideal and therefore it was expected that the gates were unlikely to be able to operate at much higher throughput than existing without improvements.

Current Gate Limitations

The current gate is limited by the process, and the infrastructure that is available. The gate currently relies on the skill and speed of experienced operators to process the trucks. The data from the containers has to manually be transferred to the system, either taking data from the driver or using manually operated cameras to locate items such as the chassis and container number. This process can lead to mistakes, and rework that take time.

It is also reported that the system is slow which is likely to be as a result of slow hardware which is slowing the terminal operating system down. The data input by the gate operators has to be compared with the system and before mission tickets can be generated. Sometimes this can take a long time causing frustration on to the driver and operator. Both these factors lead to long processing times, shown in Table C.

Table C: Gate processing Times – Baseline Case

Processing Times	IN Gates	OUT Gates
Distribution	TRIA	TRIA
Min (minutes)	3.25	3.25
Mean (minutes)	4.25	4.25
Max (minutes)	5.25	5.25

The current asphalt paving around the gate complex is heavily rutted and it will be necessary to improve the pavement at this location. As the traffic flow increases through the compound as the throughput increases the number of trucks passing will increased and therefore it is suggested that concrete paving is adopted with any improvements.

The length of the queuing areas is defined by the geometry at the gates, for this model a value of 40 was taken as the maximum queue length for the entrance gates and 15 for the exit gates. Queuing at the gates is only a problem if:

1. The queue line extends outside the allowed space impacting other processes or road network.
2. The time spend queuing becomes a significant problem for users so other shipping routes may be considered.

2.2 Port Simulation

2.2.3 Existing Gate Capacity

Methodology

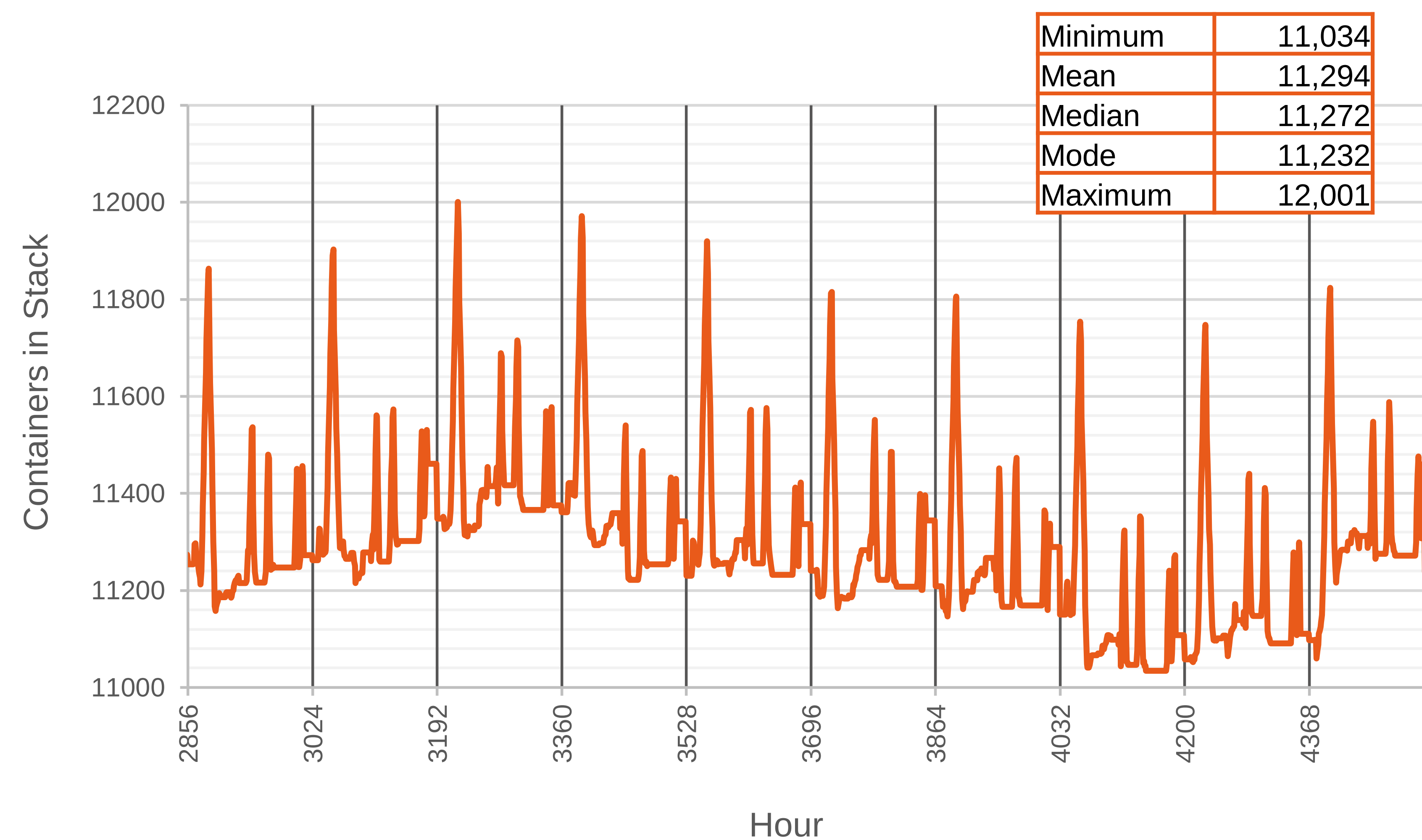
To define the baseline capacity of the gates, the ARENA global baseline model was used, with all of the baseline parameters discussed in “2.2.2 Simulation Methodology”. The aim was to assess the maximum TEU throughput that could be sustained before the failure criterion of the gates is met.

Failure is taken to have occurred when the queue length exceed the maximum queueing capacity of the gates more than 50 times per year. The system would be considered to fail if either the entrance or exit gates failed.

The model is set up to model a full week (168 hours) and the model run for 52 weeks concurrently so the containers and trucks remain in the system and any knock on effects of busy or slow weeks can be seen. The weekly averages and maximum and minimum reading can be taken from the models to paint a picture of the system as a whole. An example of this is shown in Figure C, showing the number of containers stored in the terminal.

The model was run for from the initial throughput of 274,638 TEU or 156,936 containers; taken from the indicative shipping schedule devised, and was then increased incrementally until the failure of either the entrance of exit gates occurred.

Figure 15 : *Number of Containers stored within the terminal for the baseline case of 340,000TEU for 10 weeks of the simulation.* *The randomness caused by the input distributions can be seen. The peaks shown every week represent a large input of boxes from the EC2 vessel arriving Monday evening/Tuesday morning when no trucks are operating. As the import-export slit is not that large, there is not a large spike for the weekend when no trucks are operating as the ships are roughly exporting the same number as what they import.*



2.2 Port Simulation

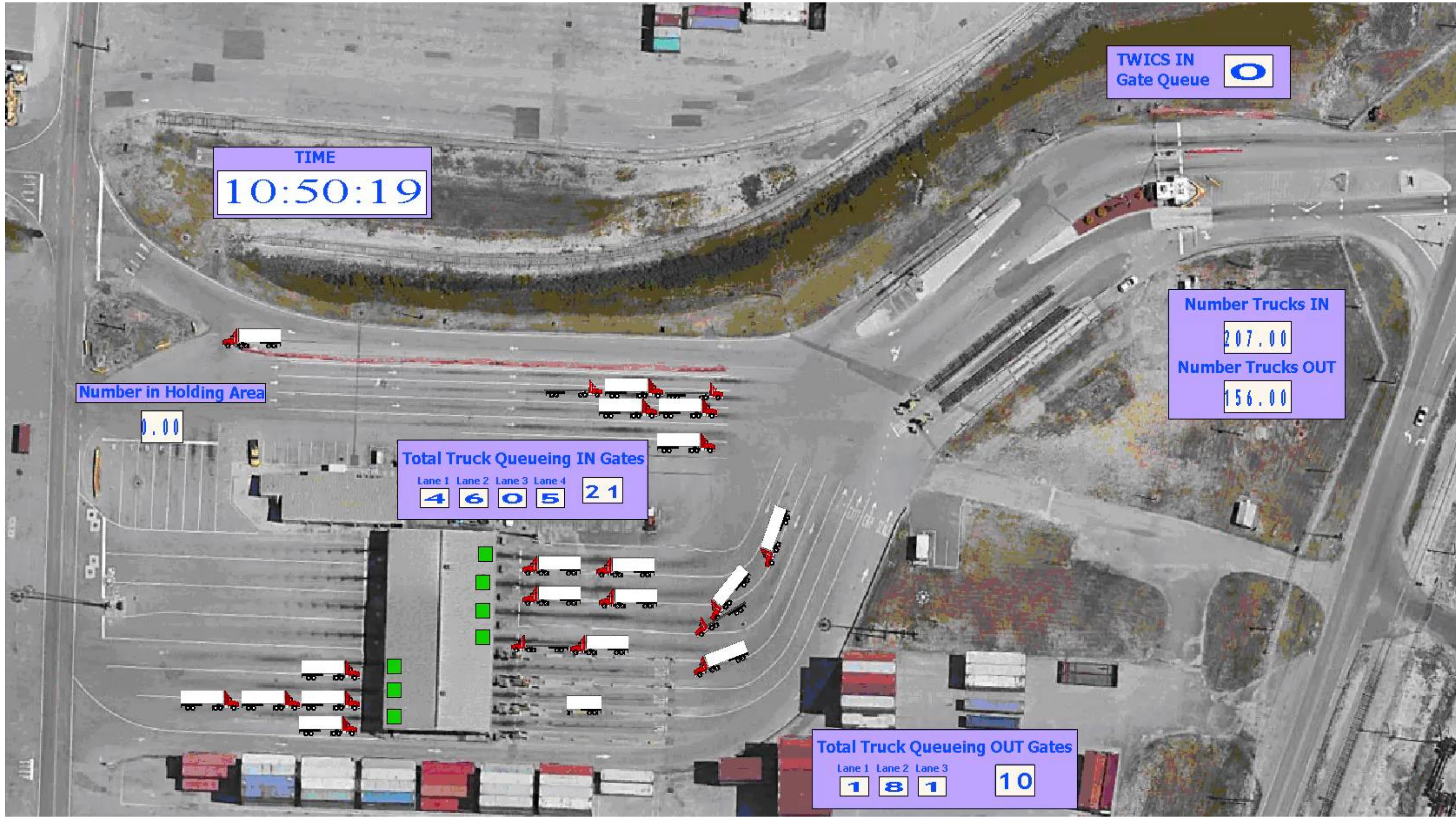
2.2.3 Existing Gate Capacity

<u>*Gate Operation – Baseline Condition*</u>

The following animation shows the baseline gate model running, showing the queuing at the entrance and exit gates.

It is clear that the gates are running close to capacity. The queuing capacity defined for the gates is close to being met during this run and therefore if this was to be happening regularly, this would be considered the failure of the system.

A video of the simulation is provide opposite.



2.2 Port Simulation

2.2.3 Existing Gate Capacity

Results

The basic statistics for the baseline gate are shown in Table D.
The gate throughput is equal to the terminal throughput and although there are currently a small percentage of containers which are transported by rail, these still go through the main gates at present.

The number of trucks used to transport the containers equates to an average of 2,527 trucks per week. Including the number of chassis change trucks that are processed by the entrance gates twice, the average number of trucks processed per lane, per week on the entrance gates is 720. This is compared to the out gates where only 475 are processed by each lane.

The chassis changes have a significant impact on the gate, as they comprise of just over 12% of the total number of the entrance gate processes. These are trucks that have already been though the gate system once to bring in a container, and now are having to do it again to take one out. This process will be adding to the overall truck turn time as well as the gate capacity and without these the baseline gate throughput would be increased. The requirement for chassis changes may be addressed in the future to increase the gate capacity further if required.

The entrance gates are limiting the system and cause the failure, with 51 times the queue exceeded over 40 trucks waiting. This is taken as the point the system would fail and marshalling would be required.

Even though the system failed the average waiting time is 0.21 hours (12 minutes 36 seconds) for the entrance gates and 0.0223 hours (1 minute 21 seconds) so on average both sets of gates work successfully but fail due to peaks.

Table D: Current Baseline Gate Output Results

	TEU	Containers
Gate Throughput (per annum):	341,096	194,912
% Intermodal:	0%	
Terminal Throughput (per annum):	341,096	194,912

Container IN Via Truck	97,686	**Container OUT by Truck**	97,226
Container IN Via Ship	97,226	**Container OUT by Ship**	97,686

IN GATE (4 Number)	**Average**	**Max**
IN Gate Processing Total	149,730	
Number Chassis Changes	18,294	
Total Trucks IN	131,436	
IN Gate Queue Time (hours)	0.21	1.06
IN Gate Queue Number	3.55	60
Times Exceed Capacity / Year [40Nr]	51	

OUT GATE (3 Number)	**Average**	**Max**
OUT Gate Processing Total	74,228	
% Total Trucks	56%	
OUT Gate Queue Time (hours)	0.0223	0.484
OUT Gate Queue Number	0.19	21
Times Exceed Capacity / Year [15Nr]	30	

2.2 Port Simulation

2.2.3 Existing Gate Capacity

Results

For a random week during the 52 week simulation, the following queue lengths were recorded for both the entrance and exit data. The data shows the larges queue recorded per hour.

For the entrance gates, Figure 16 shows that once a queue is generated it takes many hours for the queue to subside, due to the number of trucks per hour being close to the actual amount so there is not much spare capacity. It can also be seen that the entrance queue is nearly reaching the queue capacity most days and had exceed once.

The exit gates show a more peaky distribution and the average queue is low. There appears to be a peak most days but the magnitude is more variable due to the increased number of process occurring within the terminal before the exit gates. The random week chosen happens to be one where the queue exceeds the maximum, but it can be seen that the entrance gates are critical in this baseline case.

Using the processing times, each lane should be able to process between 11.5 – 18.4 truck per hour for either the entrance of exit. Using the mean the trucks that can be processed per week (55hours), per lane equals 776.5 which is larger than the actual average of 720. Therefore a steady system would cope however the gate fails due to peaks in traffic during the week and the day and also during busier weeks. This can easily be seen in the ARENA outputs, which shows the benefit of discrete event simulation modelling.

Figure 16: Queue Length at Entrance Gates – Baseline Case 340,000TEU

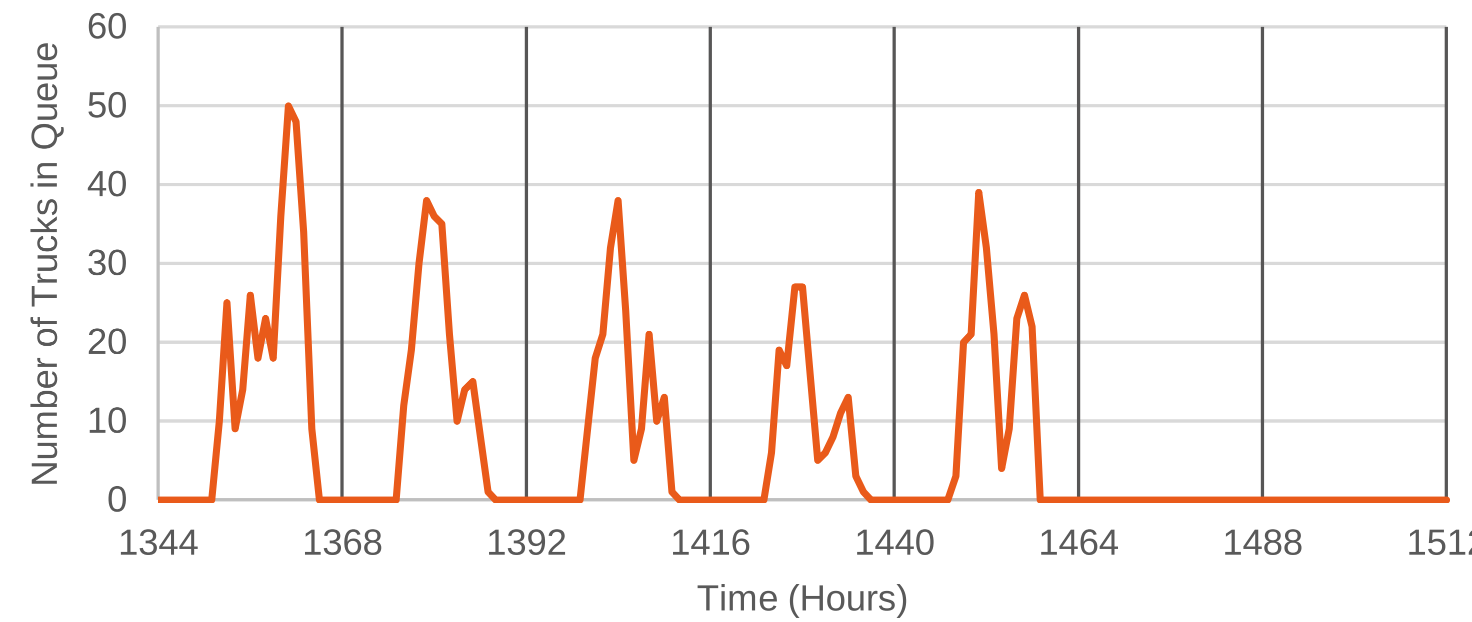
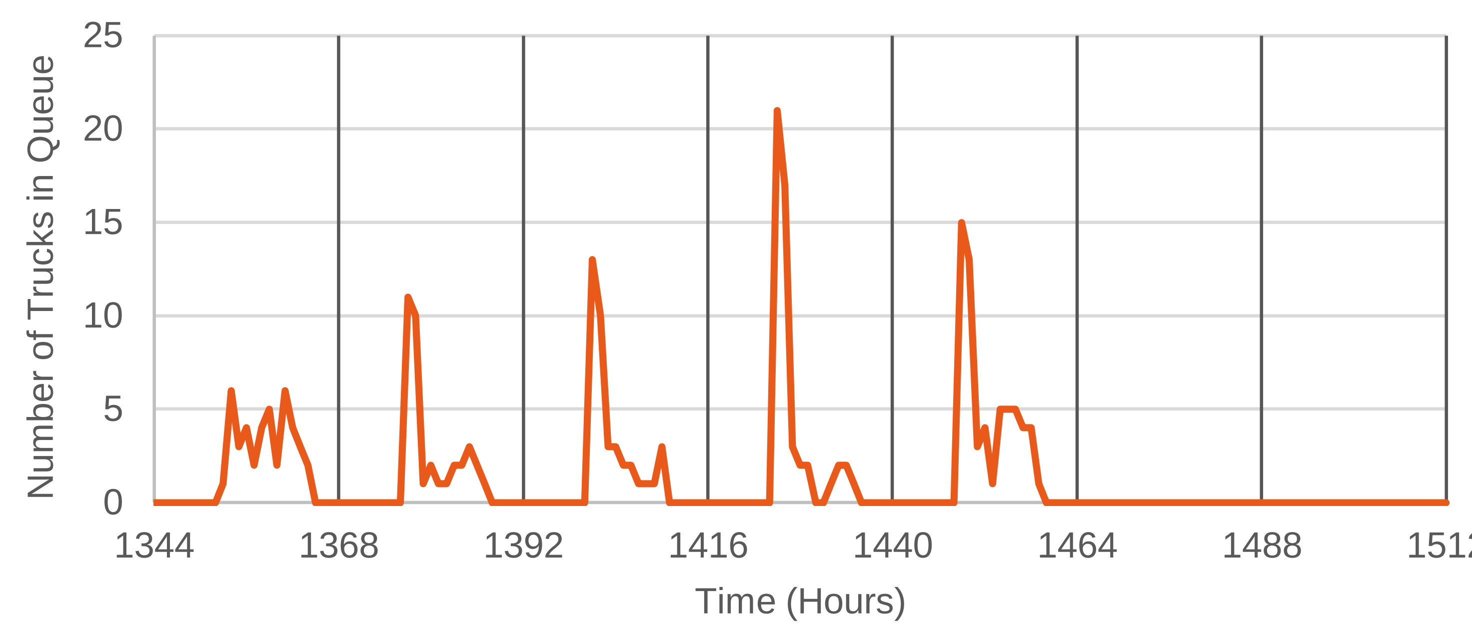


Figure G: Queue Length at Exit Gates – Baseline Case 340,000TEU



2.2 Port Simulation

2.2.3 Existing Gate Capacity

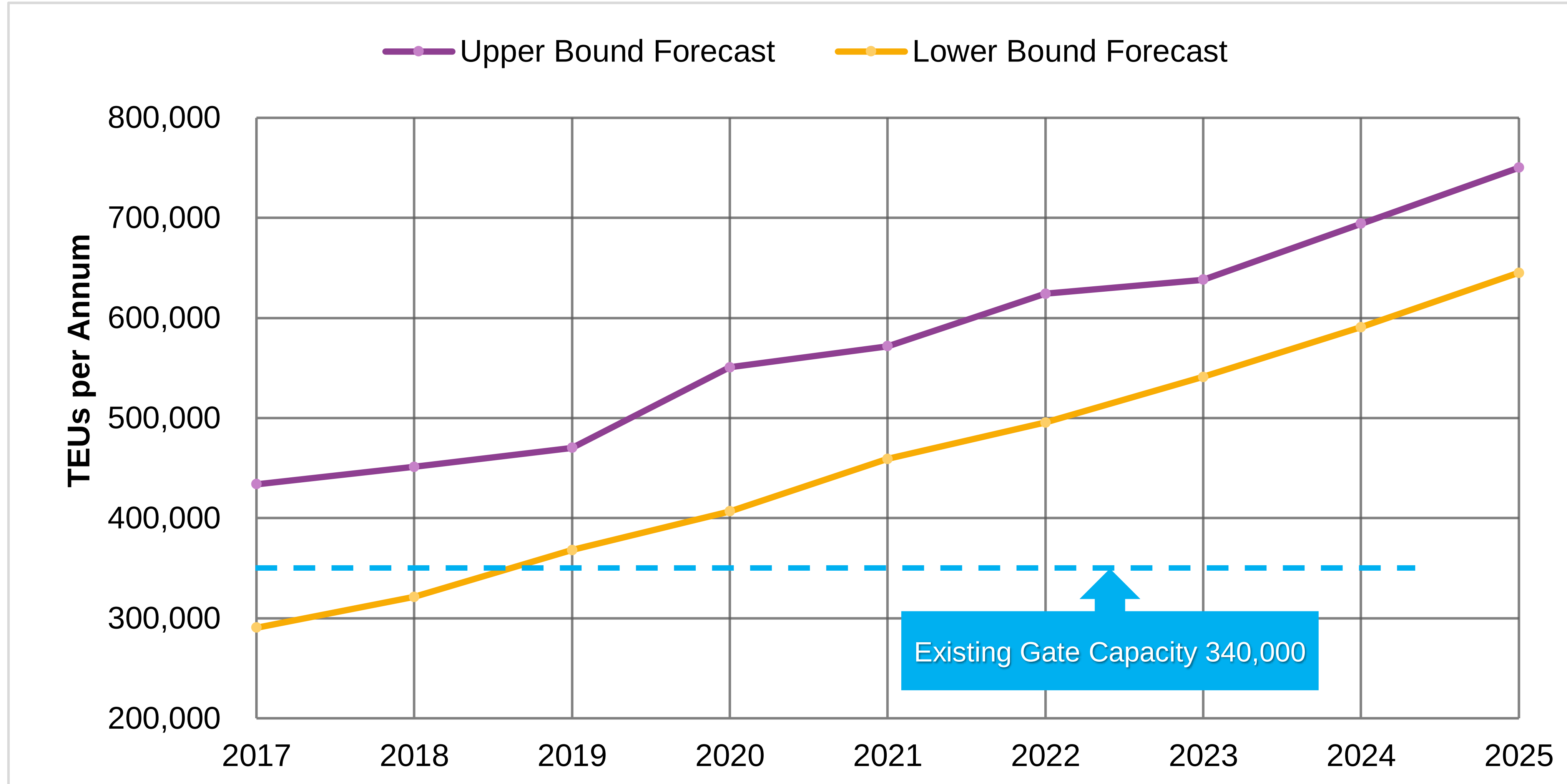
Comparison with Market Forecast

Figure 17 shows the gate capacity for the baseline condition of the gates against the future forecast for the terminal throughput. This shows that the current gate capacity is not sufficient for the terminal expansion.

Currently the gates are failing at some points, with trucks having to be marshalled into area A. The NCSPA are expecting to reach the lower bound throughput for financial year 2018 of 321,251 TEU. This is only slightly below the calculated gate capacity so to be able to meet the requirement to grow in 2019 and beyond, upgrades to the south gate will be required.

Gate Capacity Improvements

Figure 17: Existing Gate Capacity shown against the market forecast



To improve the terminal throughput there are a variety of options:

1. Reduce the processing time of the gates.
2. Increase the operational hours at the gate and the terminal.
3. Add more gates to the entrance/exit.
4. Increase rail modal split and reducing trucks on the road and taking pressure off the gates.
5. Reduce the number of chassis changes, reducing truck passes though entrance gates.

The relative benefit of these individual options is explained in Chapter 3 – Proposed Port Improvements.

2.2.4 Existing Yard Storage Capacity

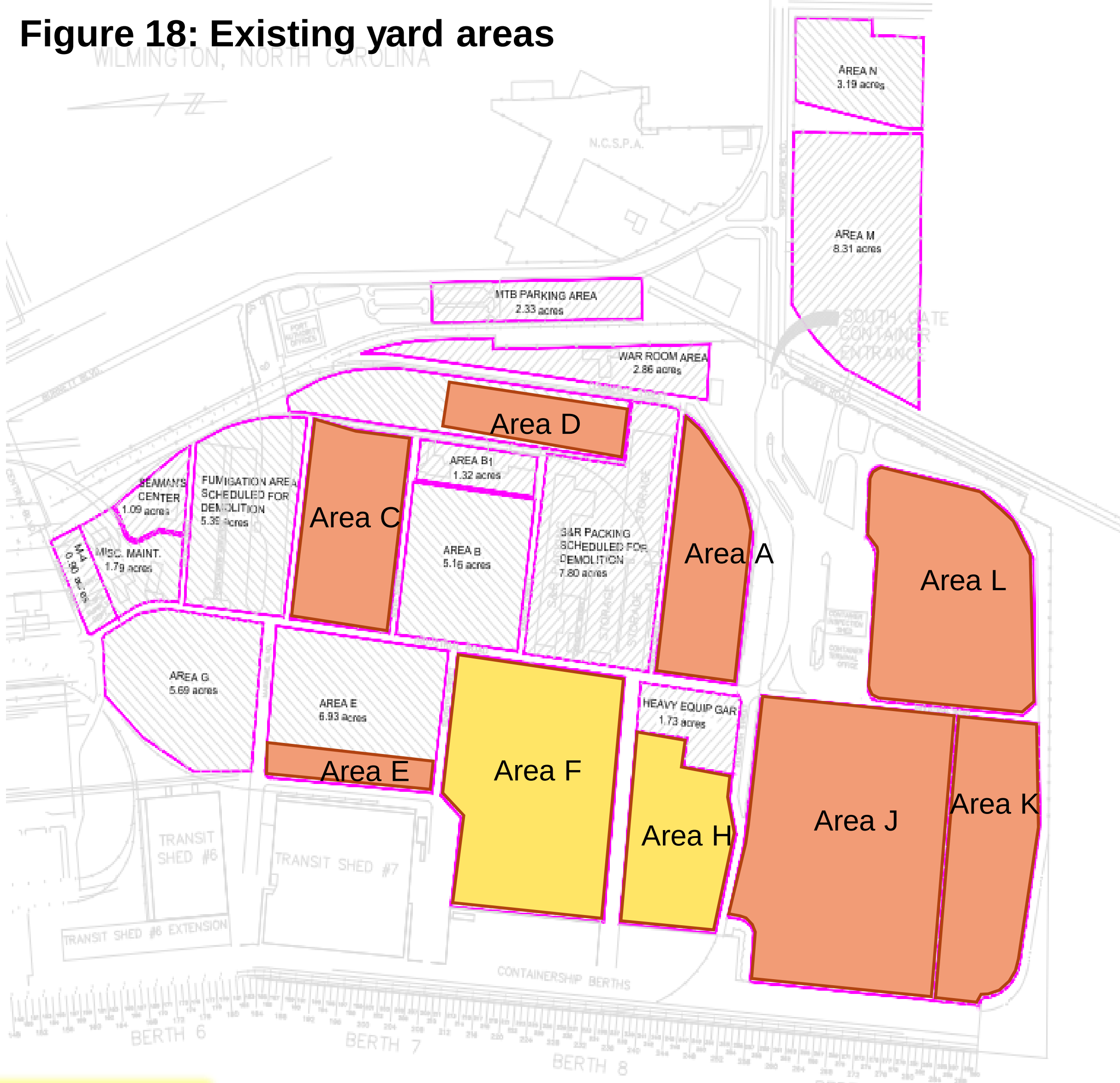
2.2.4.1 Current Storage Areas

Figure 18 shows the present yard areas. The present-day usage, number of TEU ground slots (TGS), and average stack height for each of the yard areas are given in the Table below.

The pavement is designed with the intention to have an average stack height of four-high for laden boxes and five-high for empties five-high, with laden reefers being unstacked so as they can be plugged into the ground-based reefer sockets. The average stack heights in area F and area H (both highlighted in yellow) are significantly below four-high for laden boxes. The stack heights in these areas are limited by the quality of the pavement which is in poor condition, most likely because these are the busiest areas in the container yard with the higher wheel load repetitions causing more severe wear and the more frequent container moves causing rutting in the stack areas. The average stack height of area K is also low, but this is because of unstacked laden reefers.

The stack heights limit the terminal capacity as significantly fewer boxes can be stored.

Figure 18: Existing yard areas



	Area A	Area C	Area D	Area E	Area F	Area H	Area J	Area K	Area L
Usage	Empties Imports	Railyard (Empties)	Empties	Empties	ICL Shipping (Import, Exports)	Imports	Exports	Reefers Imports	Empties Reefers
TGS	450	410	256	154	1,112	444	1,153	894	1,299
Average Stack Height	3.86	4.88	5.00	5.00	3.16	2.93	3.98	2.93	4.27

2.2.4 Existing Yard Storage Capacity

2.2.4.2 Yard Capacity and Utilization

Given the number of TGS, the average stack height, and dwell times of each container type (see table, top right), the annual expected throughput can be estimated by:

$$Throughput = \frac{No\ of\ TGS \times\ Stack\ Height \times Utilization}{Peaking\ factor \times \frac{Dwell\ time}{365}}$$

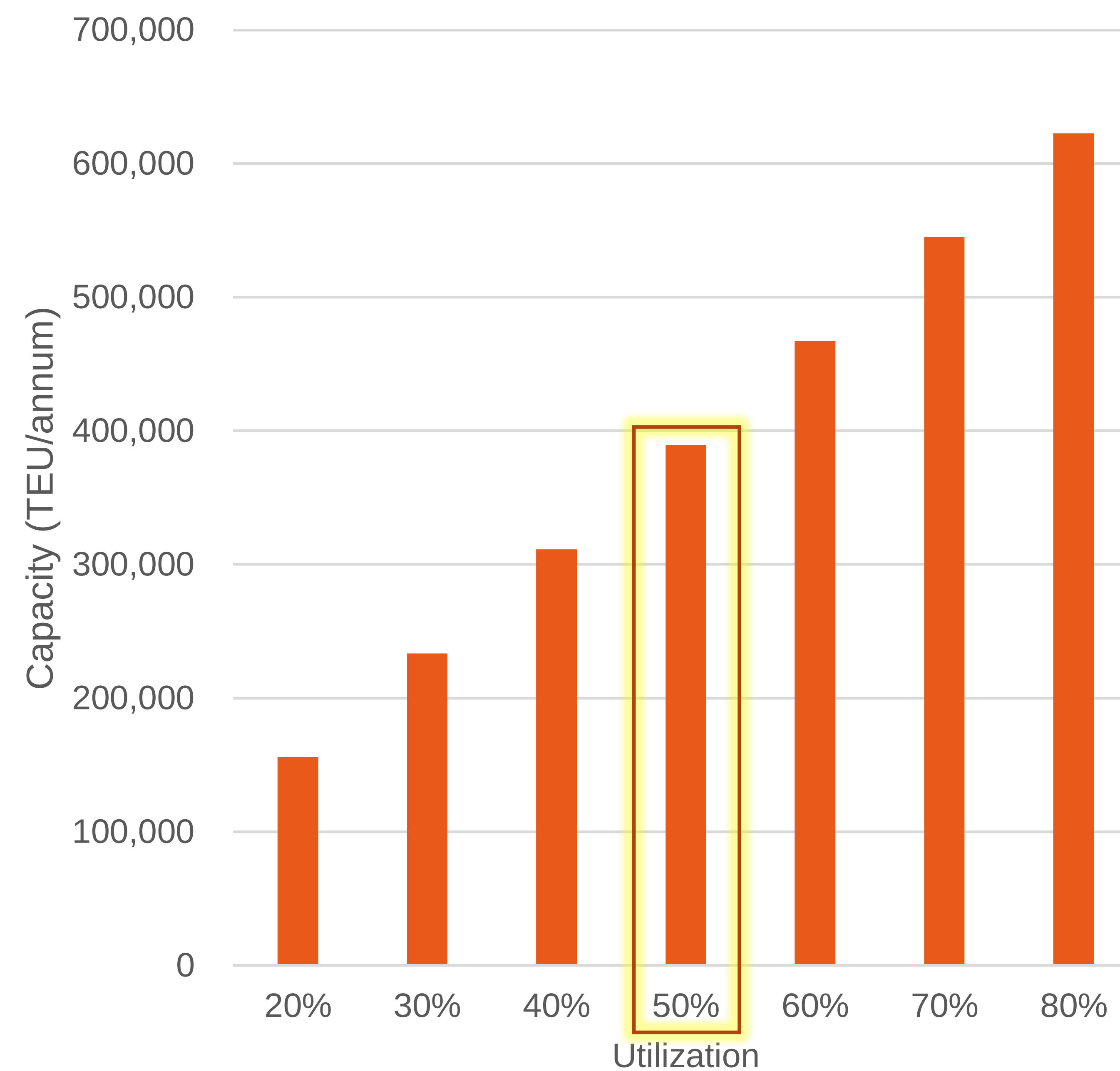
Where the peaking factor is 1.10.

Varying the utilization gives the throughput values shown in Figure 19. Due to the quality of the paving, the current stack utilization limit at the terminal is around 50%, and this will be assumed for the base theoretical yard capacity.

The dwell time for empty containers has now been reduced to 23 days from the 38 days as utilized in the Inception and Basis of Planning Report January 2018.

	Imports	Exports	Empties	Reefers (laden)	Reefers (empty)
Dwell Time	4 days	7 days	23 days	7 days	23 days

Figure 19: Current yard capacity based on utilization



2.2.4 Existing Yard Storage Capacity

2.2.4.3 Pavement Quality

The current container yard paving is composed of asphalt over a crushed limestone subbase. It is heavily patched and repaired and is noted to be limiting the stack height of the containers in certain areas. It is noted that paving area F in particular is in a critical condition. Images to the right show the general state of the pavement in Area F.

Although it appears that the pavement sub-base and subgrade material has been designed to withstand both static and dynamic loading, the asphalt layer does not appear to have been designed to withstand the high concentrated container corner casting loads. The very high point loads imposed at the container corners locally overstress the pavement resulting in distinct shallow depressions in the asphalt layer. It is evident that the asphalt has been allowed to fail locally under high container corner loads with a view of accepting frequent maintenance and repair to the top layers of asphalt over the course of the pavement’s service life.

At the present throughput handled by the port, the storage area is approximately 30% utilized due to the poor quality of the pavement limiting the stack height; an area of 5-10 acres is taken out from the container yard for repair every 2-3 years, further reducing the terminal’s capacity. The frequency of maintenance is only expected to increase as utilization of the storage facility increases to meet the target of 750,000 TEU/annum. The increased frequency of maintenance would mean more of the yard storage area will be unavailable to the port, reducing the port’s capacity on a permanent basis.

Figure 20: Pavement rutting in Area F

Figure 21: Ponding in Area F

2.2.4 Existing Yard Storage Capacity

2.2.4.4 Typical Wheel Load Repetitions

PIANC WG165 on the 'Design and Maintenance of Container Terminal Pavements' gives guidance on number of passes expected between container stacks. The number of Truck Road Repetitions are dependent on the length and width of the stacks, while the passes by reach stackers, the Side/Top Pick Load Repetitions, are dependent on the width of the stacks.

Trucks pass along the length of the stack. The number of truck passes expected in a year is determined by:

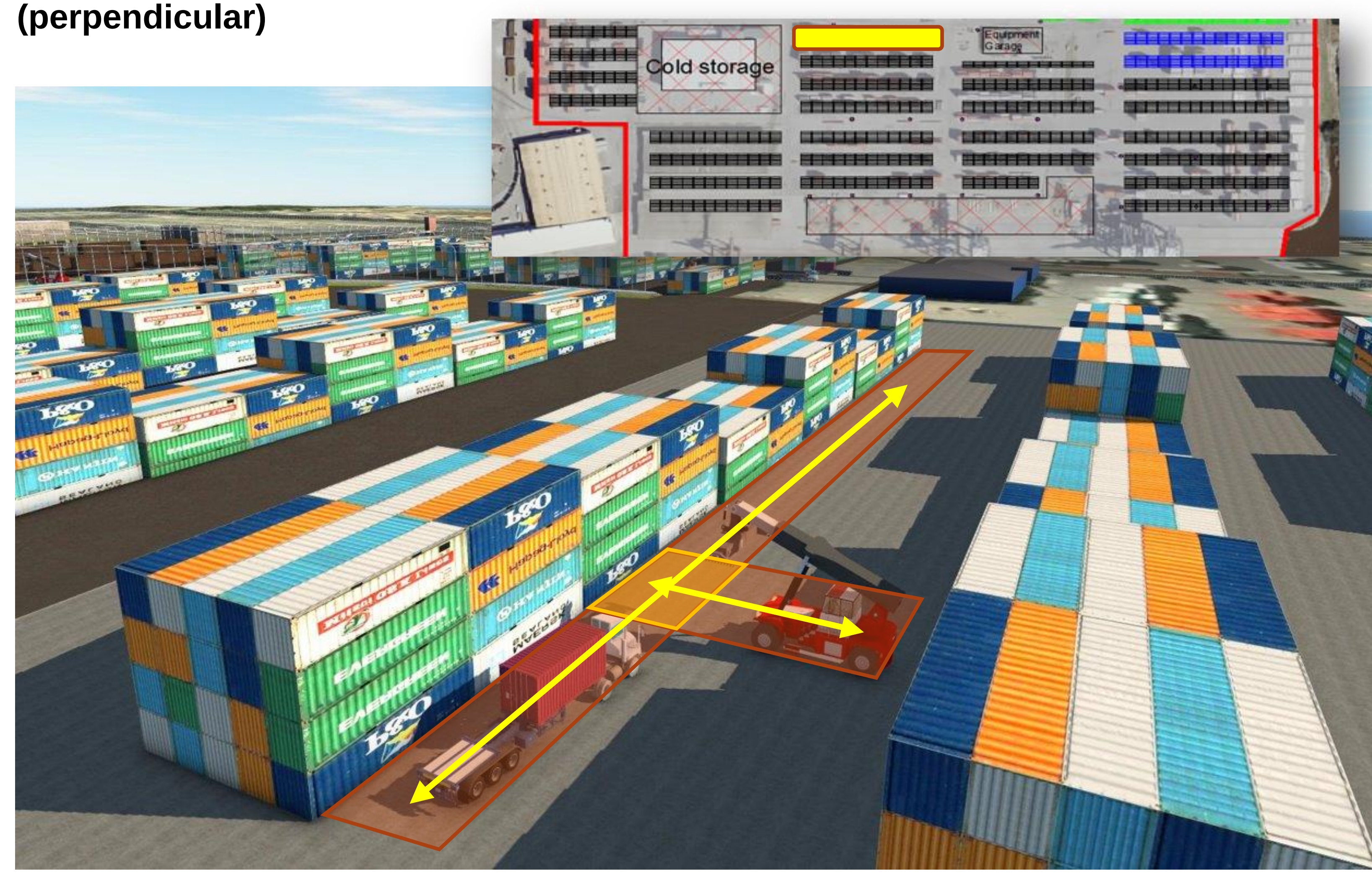
Truck Load Repetitions = $C_5 \times C_6 \times (365 / DW) \times SU \times L \times H \times W / C_4 / C_7$

Reach stackers move perpendicular to the stacks to perform their top and side pick motions. The number of reach stacker passes along a particular patch of concrete is given by:

Side/Top Pick Load Repetitions = $C_5 \times C_6 \times (365 / DW) \times SU \times H \times W / C_7$

The variables in the above formulations are defined as:
- SU is the estimated ground slot utilization in the stack
- DW is the average dwell time of the containers in the stack
- L is the length of the stack (in TEUs)
- W is the width of the stack (in TEUs)
- H is the height of the stack (in TEUs)
- C_4 is the average TEU's per lift/box
- C_5 is the trips per box (typically 2)
- C_6 is the moves per trip
- C_7 is the number of accessible sides to the stack

Figure 22: Typical wheel load paths for trucks (parallel) and reach stackers (perpendicular)



A typical stack in Area F has the following values:
- Dwell time for import boxes DW = 4 days;
- Length of the stack L = 26 TEUs (or 13 forty-foot boxes);
- Width of the stack W = 6 TEUs;
- Height of the stack H = 5 TEUs (max);
- Number of accessible sides C_7 = 2.

The moves per trip for a reach stackers is C_6 = 2 for moving towards and away from the stack for side/top picking, and trucks have a single move per trip (C_6 = 1) travelling along the length of the stack.

2.2.4 Existing Yard Storage Capacity

2.2.4.5 Effects of Increasing Wheel Load Passes

The graphic on the right presents the number of truck and reach stacker passes at a typical container stack in area F, for varying stack utilizations between 20% and 80%.

In order to meet the target of 750,000 TEU/annum with the current yard layout, stack utilization will need to increase from the present 30% to 80%, with the number of truck and reach stacker passes increasing by 170%; this is nearly three times the current number of passes. Even if the port were to only meet the lower end target of 645,000 TEU/annum, stack utilization will need to increase to 70%, which leads to ~130% increase in passes.

The net result is a busier terminal with higher static loads and more frequent wheel loads.

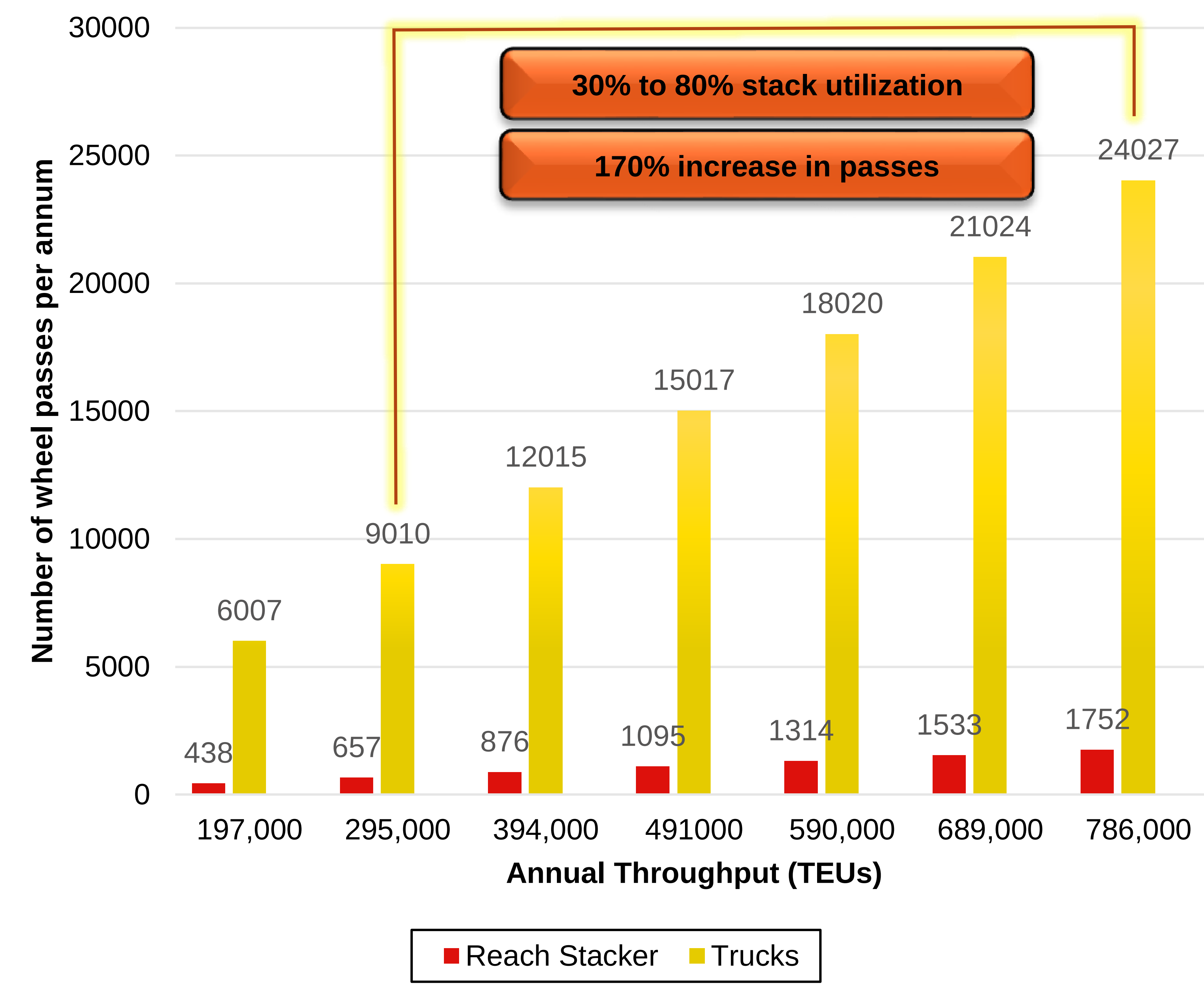


Figure 23: Container Handling Equipment Wheel Passes vs Throughput

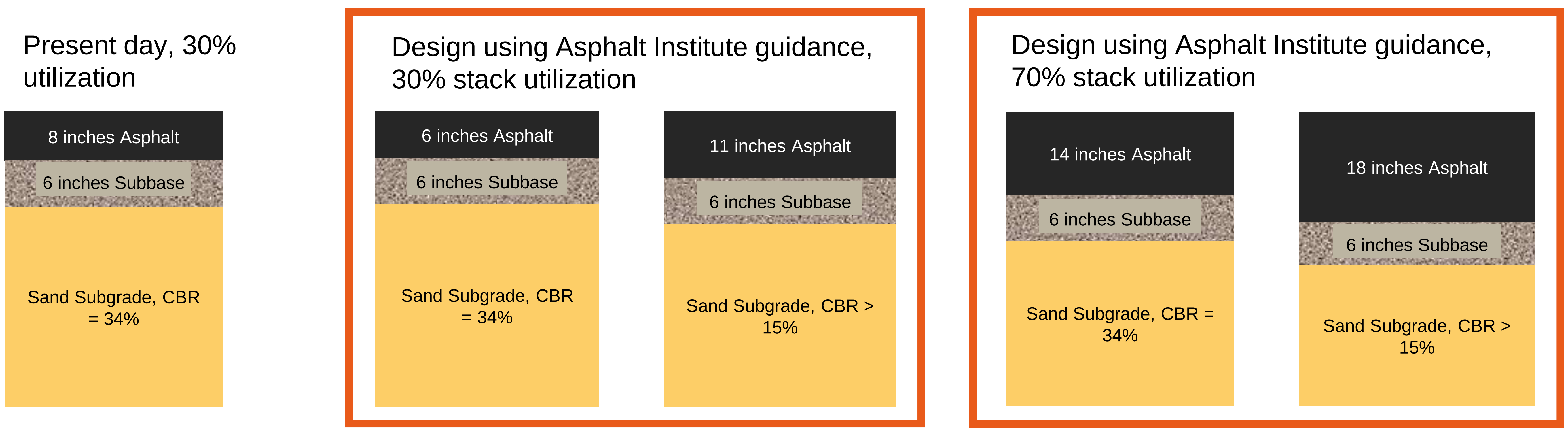
2.2.4 Existing Yard Storage Capacity

2.2.4.6 Design of Present Paving

The pavement was designed with reference to Asphalt Institute guidance, MS-23: “Thickness Design Asphalt Pavements for Heavy Wheel Loads”. As the title suggests, the guidance focuses on wheel loads from port vehicles (i.e. trucks and reach stackers) and does not consider static loads which include high concentrated corner casting loads. Also, the guidance does not factor the dynamic loads from trucks and reach stackers, such as braking, acceleration, and turning.

In area F, the present pavement has an 8-inch asphalt layer over a 6-inch subbase and a subgrade with CBR of 34%. The current design satisfies the Asphalt Institute guidance for 30% utilization if pavement thicknesses are designed to this 34% CBR subgrade; the guidance treats all subgrades greater than 15% CBR in the same way and does not recommend extrapolating for higher values.

To meet future demand, stacks will need to be utilized at least 70% with the present yard layout. This will require a much thicker 14-inch asphalt layer if a higher CBR of 34% is considered for the subgrade, or 18-inch asphalt layer if the Asphalt Institute guidance is followed. These new designs still only consider wheel loads with factoring for dynamic loads, and are still far from adequate for high static loading of the containers.



2.2.4 Existing Yard Storage Capacity

2.2.4.7 Conclusion

Comparison with Market Forecast

Figure 24 shows the yard capacity for the baseline condition of the terminal against the future forecast for the terminal throughput. This shows that the current yard capacity is not sufficient for the terminal expansion beyond 2018.

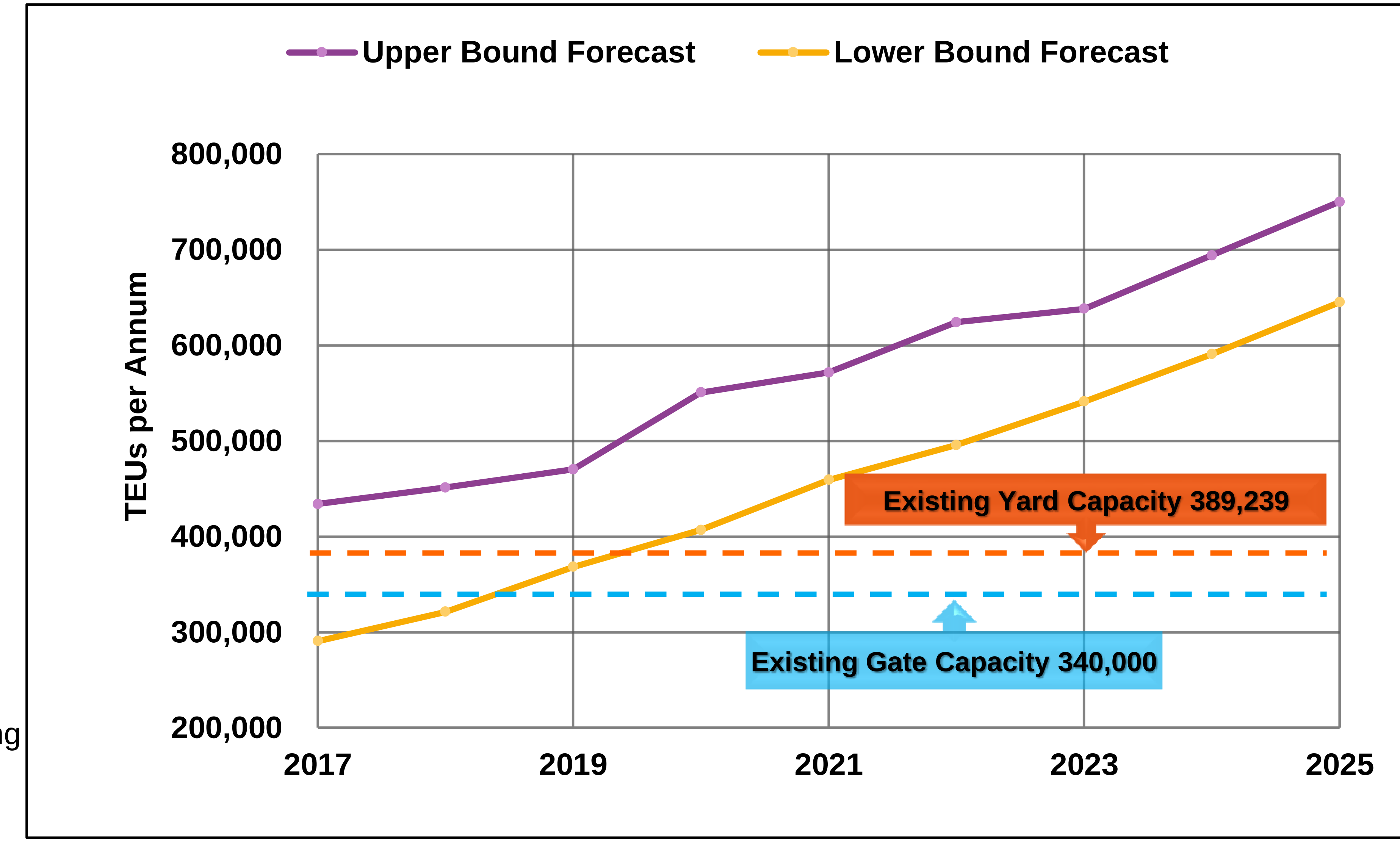
The yard is limited primarily by the quality of the pavement, which limits the possible stack height and density of the stacks. The terminal is also limited by the stack arrangements. The NCSPA are expecting to reach the lower bound throughput for financial year 2018 of 321,251 TEU. This is only slightly below the assumed yard capacity so to be able to meet the requirement to grow in 2019 and beyond, upgrades will be required.

Yard Improvements

To increase the yard capacity there are a variety of options:

1. Repave storage areas with stronger, more durable pavements able to withstand five high laden stacking corner loads.
2. Rearrange the stacks to optimise space.
3. Take over more terminal space for container storage.
4. Install RTG operation at the terminal.

Figure 24: Existing Yard and Gate Capacity vs Market Forecast Projections



2.2 Prevailing Conditions

2.2.5 Existing Rail Yard Capacity

A detailed explanation of the existing rail operations at the port can be found in Section 4.4.2 of Mott MacDonald's Inception and Basis of Planning Report dated January 2018.

It is currently assumed that the rail yard utilizes Container Tracks 1 and 2 for the unloading operations which can hold a potential length 4,200ft of well cars. The Main Track is therefore used as a storage line for the remaining length of well cars that cannot fit on to Container Tracks 1 and 2. These tracks are presented in the Figure below.

Figure 25: Existing Container Terminal Rail Yard

It has been reported that a maximum train length of 9,000ft can be accommodated with the existing rail road track setup shown in Figure 49 above. However, for a 9,000ft train to be serviced, a total of three separate train switches and reformations would be required since the service tracks 1 and 2 can only accommodate a train length of approximately 4,200 feet at any one time. The total time to turnaround the 9,000 feet train to and from CSXT in May 11, 2017 had been reported to be 7 hours.

A 9,000 feet train could potentially hold up to 173 number 52ft long well cars. If each well car can accommodate 4no TEUs the total number of Twenty Foot Equivalent units that can be transported by a 9,000 feet long train is approximately 692 TEUs.

Should the entire inventory of rail tracks in the port be utilized it may be possible to accommodate a larger volume of containers i.e. the utilization of rail tracks 0, Wood Siding and Classification tracks 2, 3, 4, 5, 6, 10, 11, 12, 13, 14, 15 and 18A. Although this is possible in theory, in reality, the logistics of switching and shunting of well cars from other areas of the port which is not directly within the vicinity of the rail yard may lead to inefficient container movements and is likely to increase the train turnaround times. Although the current rail yard set up appears to have capacity to accommodate and turnover a 9,000 feet train in 7 hours, the current method in which the trains are handled appears not to be the most efficient since multiple train and well car switches are required in order to turn around a 9,000 feet train. Over a prolonged period of service time with more frequent train arrivals and longer train formations, the operational efficiency may deteriorate due to this frequent switching and reforming of well cars.

However, given that the target intermodal % in 2025 is set at 8%, a 9,000ft train will be more than what is required since a 692 TEUs per train formation capacity will give rise to an annual container throughput by train of 126,290 TEUs per annum which is approximately 16% of the 750,000 TEU throughput targeted. Therefore a smaller yet more efficient intermodal yard is required as considered in Mott MacDonald's Report, "*Wilmington Rail Improvements – Landside Rail Improvements Serving the Port and Moving Trains Safely through the Community, 2017, September 6th.*"

2.2 Prevailing Conditions

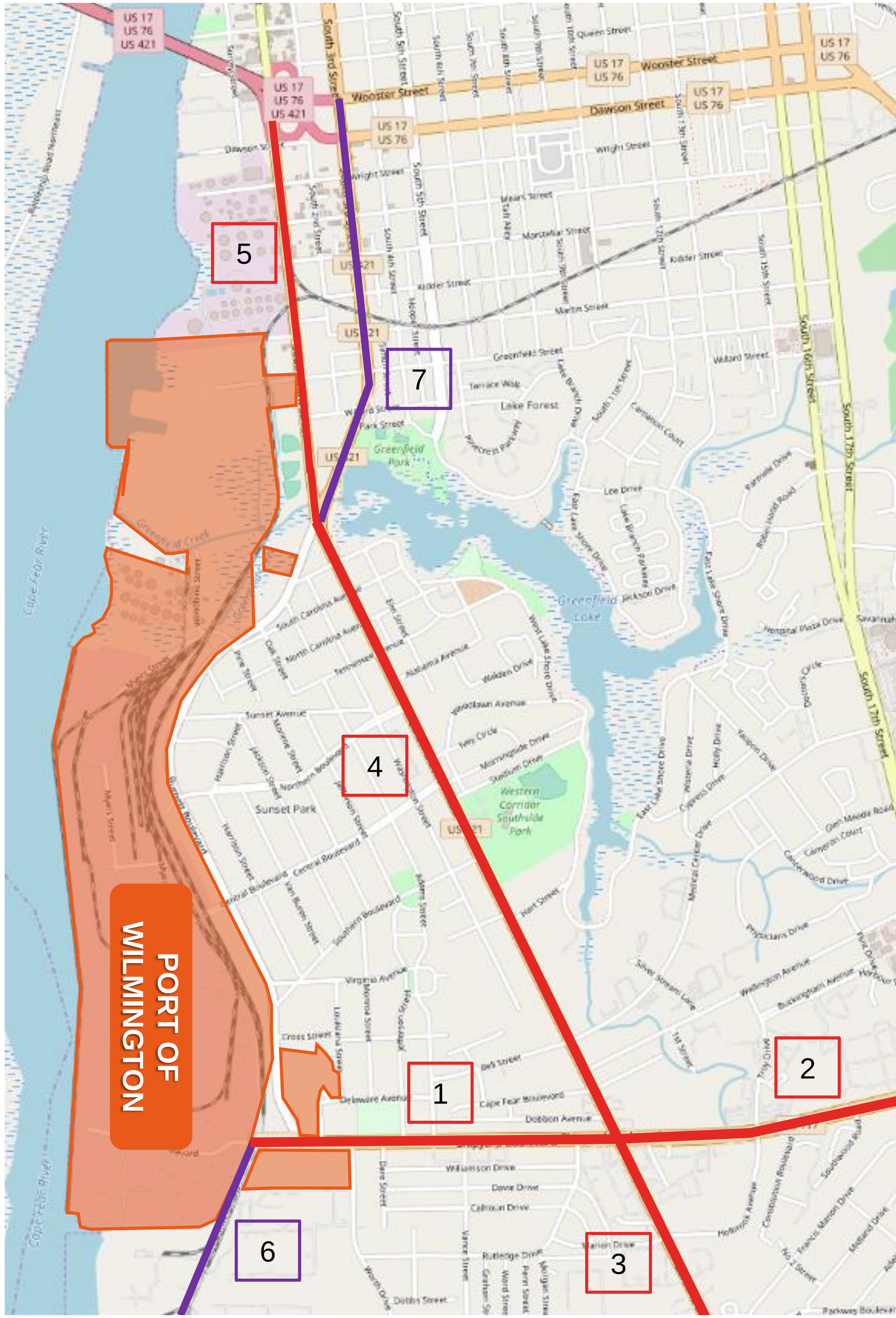
2.2.6 Existing Hinterland Capacity

The North Carolina Department of Transport (NCDOT) has made available traffic data for North Carolina's road network. The data provides the Annual Average Daily Traffic (AADT) in Passenger Car Units (PCUs), which can be translated to peak-hour traffic using guidance from the Highway Capacity Manual (2010).

The table below shows the operational peak-hour volume and the peak-hour capacity for a Level of Service classification 'D' (LOS D) for each of the main roads leading to the port. The roads are labelled numerically in the figure to the right, with the current truck routes in red.
It is evident that links from the northern approach are highly stressed; in particular, Front St and Carolina Beach Rd northern approach suffers from utilization of 166% and 110% respectively at present. These will only increase with increased port traffic.

Refer to Section 3.3.3 of the Inception and Basis of Planning report for further information on the hinterland capacity calculations presented in the table below.

Nr ID	Road	No. of lanes	Speed limit (mph)	AADT Demand / Capacity (PCU)	Peak-hour Demand / Capacity (PCU)	% Utilization of LOS D
1	Shipyard Blvd West	4	35	1,942	1,029 / 1,942	53 %
2	Shipyard Blvd East	5	35	2,552	1,194 / 2,552	47 %
3	Carolina Beach Rd South	4	45	2,020	1,547 / 2,020	77 %
4	Carolina Beach Rd North	4	40	1,945	2,148 / 1,945	110 %
5	Front St	2	35	929	1,544 / 929	166 %
6	River Rd	2	30	828	505 / 828	61 %
7	3rd St	4	35	1,942	1,135 / 1,942	58 %



2.2.6 Existing Hinterland Capacity

Future plans for the Cape Fear Crossing will potentially change the truck routing in the hinterland. The new crossing is intended to alleviate pressure from the Cape Fear Memorial Bridge. As of the end of last year, options for the new crossing have been reduced to three, one of which connects at River Road and continues onto Independence Boulevard (labelled Option 3 on the right).

Option 3 will cause all port traffic destined for the south gate that presently use Carolina Beach Road northern approach to be diverted around to River Road or to take the Carolina Beach Road southern approach. If the change were made immediately, either utilization of River Road would increase to 79% or utilization of Carolina Beach Road south would increase to 84% depending in the routing.

In meeting the future port requirement of 750,000 TEU/annum, utilization of River Road could increase beyond full capacity to 122%. It is advisable to consider upgrading River Road to a two-lane two-way road should River Road be used for port traffic in the future.

The Cape Fear Crossing project is currently in progress and a final option is yet to be confirmed. However, from the initial options proposed to date, the future Port of Wilmington Yard Layout and the upgraded south gate will be designed to accommodate the future Cape Fear Crossing and associated traffic flow implications.

River Road (post-diversion)	Operation – Peak-hour (PCU)	% Utilization (LOS D)
Present day traffic	653	79 %
750,000 TEU (without intermodal yard)	1,010	122 %
750,000 TEU (with intermodal yard)	976	118 %

Carolina Beach Road, southern approach (post-diversion)	Operation – Peak-hour (PCU)	% Utilization (LOS D)
Present day traffic	1,696	84 %
750,000 TEU (without intermodal yard)	2,130	105 %
750,000 TEU (with intermodal yard)	2,081	103 %

Options for Cape Fear Crossing (Star News Online, 2016)

3. Proposed Port Improvements

Port Upgrade Options

3. Proposed Port Improvements

3.1 Introduction

Having established the existing Port capacity at each of the box exchange nodes for the container terminal, these being the terminal gate, stacking yard, container berth and intermodal yard, the shortfall in capacity at each of these nodes has been established based on the target throughput of 750,000 TEUs per annum. This Chapter of the report will detail the options that have been considered in overcoming the capacity deficit at each of the terminal nodes.

In summary the following capacities and capacity deficits are as follows:

South Terminal Gate

- ❑ Perceived existing gate capacity of 340,000 TEUs per annum.
- ❑ A short fall of 410,000 TEUs per annum in gate capacity is calculated.
- ❑ Truck processing time being the main contributory factor in low gate capacity.
- ❑ Gate queueing issues are currently being experienced during peak operational times.

Container Stacking Yard

- ❑ Perceived existing yard capacity of 389,000 TEUs per annum.
- ❑ A shortfall of 361,000 TEUs per annum in the yard has been calculated.
- ❑ Yard capacity limited by paving quality and availability of space.

Container-Berth

- ❑ With future seven STS cranes in operation and over 2600ft of quay length the perceived berth capacity will be close to 1 million TEUs per annum.
- ❑ The capacity is not considered to have any shortfalls in achieving the targeted 750,000 TEUs per annum.
- ❑ However, once the yard and gates have been upgrades, the berth may become the bottleneck, i.e. once the potential yard and gate capacities overtake that of the berth.

Intermodal Yard

- ❑ Although it is technically possible to form 9,000ft trains by utilising all of the rail track inventory at the port and potentially serve a 16% modal split in 2025, the operations and well car manipulation required to do so is not considered to be efficient.
- ❑ The current rail yard at the terminal does allow for a 4,200ft train to be formed over tracks 1 and 2, which has a potential capacity of 323 TEUs. However the layout of the tracks and security arrangements for box exchanges in place at present do not comply with the requirements for a frequent intermodal service operation.

In summary, the area which needs the most urgent attention are the main entrance and exit gates which can be considered as being at capacity already.

3. Proposed Port Improvements

3.2 Proposed Gate Improvements

The baseline maximum TEU throughput for the current gate complex is 340,000 TEU. This is below the 2019 lower bound estimate for the Port of Wilmington throughput of 368,170 TEU. Therefore improvements to the gates will be necessary in the short term and in the design of a new gate complex in the future options.

The options that were considers as improvements are listed below and discussed in more detail in the following slides:

1. Add more gates to the entrance/exit.
2. Increase the gate hours.
3. Increase modal split.
4. Reduce the processing time of the gates.
5. Reduce the number of chassis changes.

The options have been assessed using the ARENA global port model that was developed in the baseline modelling described in Section 2. All of the parameters remained constant apart from the items that are being assessed.

Further work to assess the integration of technology such as OCR and automated gates, within the gate complex has also been investigated and have been modelled using a calibrated gate mode in ARENA used to look in more detail at the gate areas specifically.

Potential Options for Increasing Gate Capacity

- **INCREASE NUMBER OF GATES**
- **INCREASE GATE HOURS WORKED**
- **INCREASE MODAL SPLIT**
- **REDUCE PROCESSING TIME**
- **REDUCE CHASSIS CHANGES**

3.2 Proposed Gate Improvements

3.2.1 Additional Gates

Adding additional gates will increase the capacity of both the entrance and exit gates. As this has an effect of diluting the queue lengths of the trucks. The graph in Figure 26 shows the increase for the various number of gates. As explained in the simulation methodology, the following was assumed for the existing gates:

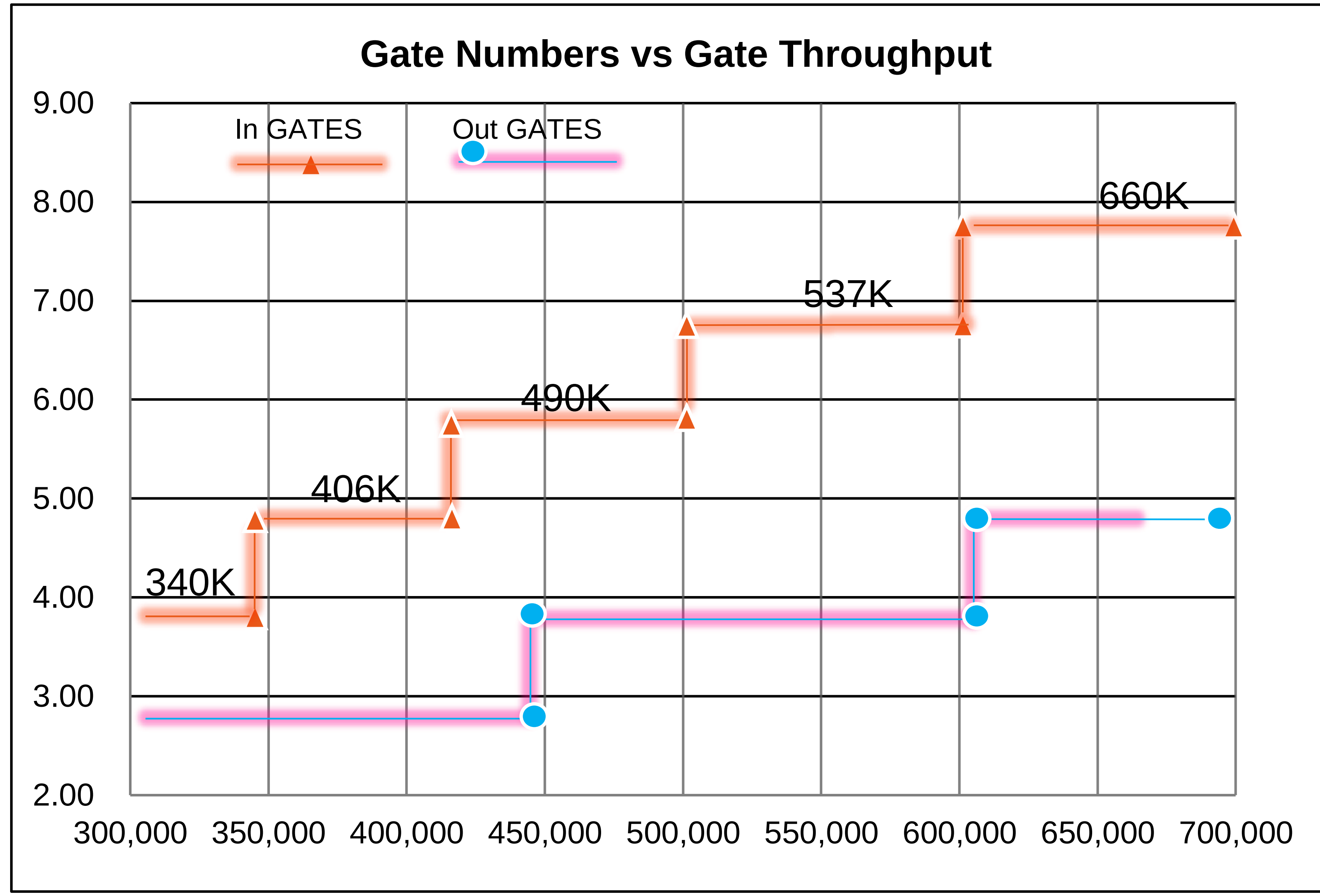
- ❑ Average weekly schedule developed from October 2017 gate data.
- ❑ Capacity of IN gate queue : 40 trucks.
- ❑ Capacity of OUT gate queue: 15 trucks.
- ❑ Failure of model is taken when the queue length exceeds the given capacity 50 times per year.

- ❑ Every time the gate simulation model indicated that truck queueing capacity was exceeded for more than 50 times a year an additional gate lane was added and re-ran.

Increasing the entrance gates but not the exit gates was investigated and found that due to the increase in trucks entering the terminals, the queue for the exit gates caused the model to fail so the gates numbers needed to be increase together.

For the gate upgrade options it was decided that due to space constraints the maximum gates that should be used are 7 entrance gates and 6 exit gates. This can hold a maximum of 537, 000 TEU throughput which will only sustain the gate to 2020 for the higher market forecast or 2023 for the lower bound estimate. This would need to be combined with some of the other improvement options to keep pace with the yard improvements.

Figure 26: Terminal Throughput for different numbers of gates.



3.2 Proposed Gate Improvements

3.2.2 Increase Gate Hours

The current gate operational hours equate to fifty five hours, eleven hours (7am – 6pm) Monday to Friday. Therefore there is sufficient availability to increase the working hours to allow more truck to enter the port to drop off and collect containers.

Increasing the working hours from eleven to twelve hours each day was tested using the baseline global port model, using the distributions through the model. The difference in the container volume throughput is shown in Figure 27. As the percentage is split over a longer time the magnitude of container throughput and therefore truck arrivals can be increased.

The results of the model are shown in Table E. The percentage increase in the gate processing are:

The percentage increase in operating time	**9.1%**
The percentage increase in throughput	**8.4%**

An additional hour does not increase the terminal throughput linearly as the model is governed by randomised peaks in the arrival patterns, but does give an approximation to the throughput increase, that could be used as an approximation for the assessment of the model.

Figure 27: Percentage of daily container throughput for 11 and 12 hour days.

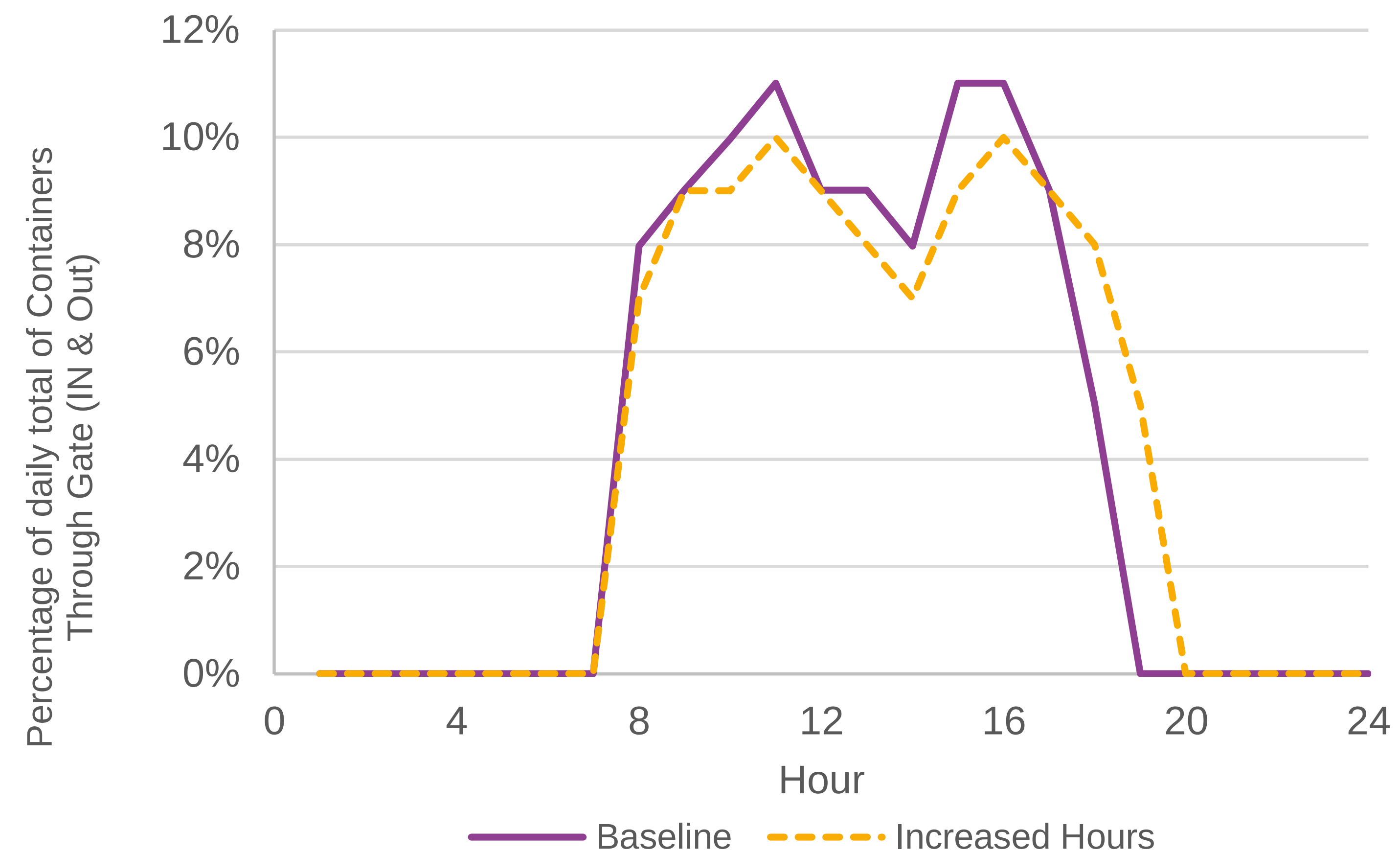


Table E: Gate Output Results

Hours of Operation	11 hours/day (55 hours per week)	12 hours/day (60 hours per week)
Terminal Throughput (TEU)	341,096	369,926
Terminal Throughput (Containers)	194,912	211,386
Average Trucks per Day	504	550

3.2 Proposed Gate Improvements

3.2.2 Increase Gate Hours

The assessment was also compared when the additional five hours of gate processing time were on a separate day (Saturday). As with the previous investigation, adding the hour on each day, the percentage split was altered and can be seen in Figure 28.

The global baseline port model was run using this new schedule, and the results are shown in Table F.

The percentage increase in operating time	**9.1%**
The percentage increase in throughput	**9.2%**

The percentage increase is more equal to the percentage increase in time as the trucks arriving on the Saturday are not contributing to the existing queues within the terminal unlike adding the hours on each day, as the additional trucks will join the back of the queue. Therefor a full additional day on a Saturday would increase the terminal capacity by 20% (11 additional hours) to 409,315 TEU.

As the gate is a manual process it will be necessary to include longer or additional shifts for the operators or may require the need for additional employees. However this will be the only cost as all the infrastructure is as existing and therefore this is a useful to increase the gate capacity in the short term.

Figure 28: Percentage of daily container throughput the baseline and increased hours

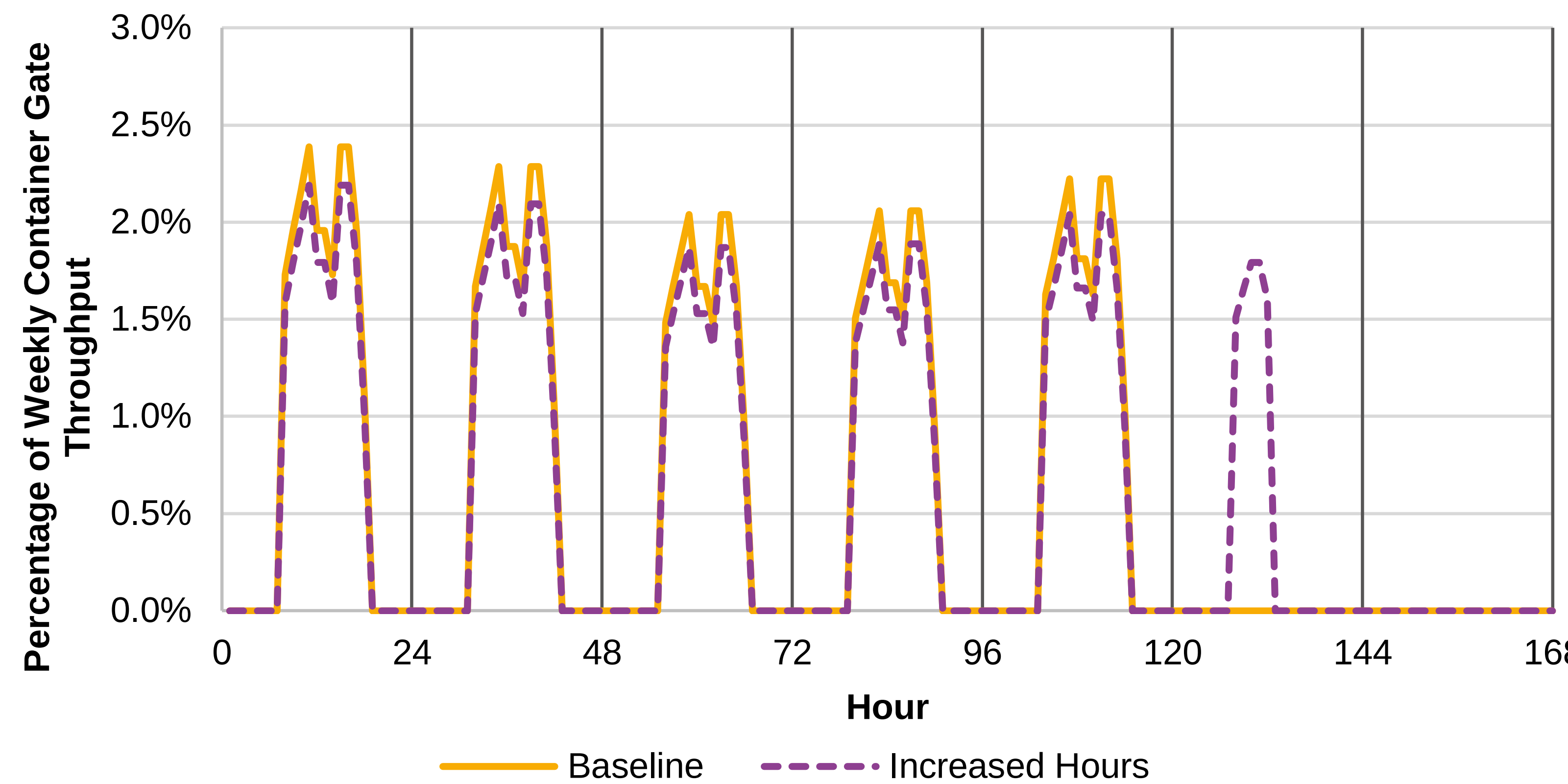


Table F: Gate Output Results

Hours of Operation	5 days (55 hours per week)	6 days (60 hours per week)
Terminal Throughput (TEU)	341,096	372,518
Terminal Throughput (Containers)	194,912	212,867
Average Trucks per Hour	45.8	46.4

3.2 Proposed Gate Improvements

3.2.3 Increase Model Split

All of the containers in the baseline model interact with the hinterland via trucks. Although there are currently a small percentage of containers which are transported via rail, this percentage is considered insignificant but this is expected to increase with the introduction of the upgraded intermodal yard.

The baseline model was tested with the intermodal split of 5% and 8%. The gate throughput remains the same as the failure of the gate will occur at the same throughput. As there is now containers transported by rail the overall terminal throughput with increase.

The percentage that can be transported by rail is dependent on the development of the new railyard that will occur later in the development time frame, and also the availability of the facility to offload the containers at a facility inland.

The new railyard is not expected to be implemented prior to 2025 and therefore the modal split that can be achieved prior to this is minimal and other methods are likely to be required to increase the capacity in the short term.

Table G: Increased Modal Split Output Results

	Baseline 0% Model Split	5% Modal Split	8% Modal Split
Gate Throughput (TEU)	341,096	341,096	341,096
Throughput (Containers)	194,912	194,912	194,912
Intermodal Throughput (TEU)	0	17,952	29,660
Intermodal Throughput (Containers)	0	10,258	16,949
Terminal Throughput (TEU)	341,096	359,048	370,756
Terminal Throughput (Containers)	194,912	205,170	211,861
Percentage Increase	-	5.2%	8.7%

3.2 Proposed Gate Improvements

3.2.4 Reduce Processing Time of Gates

The processing times of the gate are held up by the manual processing of the container and chassis data and the infrastructure and hardware operating the terminal operating system. Without understanding the intricacies of the current system any assessment is an arbitrary value, which was taken as an improvement of 1 minute with all other parameters remaining constant. The updated times are shown in Table H.

	IN Gates		OUT Gates	
	Baseline	Improved	Baseline	Improved
Distribution	Triangular		Triangular	
Min (mins)	3.25	2.25	3.25	2.25
Mean (mins)	4.25	3.25	4.25	3.25
Max (mins)	5.25	4.25	5.25	4.25

The exit gates become critical causing the model to fail, caused by an increased number of trucks within the terminal as the entrance gate processing time has reduced. The overall average waiting times have reduced for both gates. However, sharp peaks still cause the model to fail albeit at a higher annual throughput.

The overall percentage increase is **20.1%** which is a large improvement. In order to reduce the processing time, improved hardware or reduction in the number of manual processes would be required which may take time to introduce.

Table H: Reduced Processing Output

	Baseline	Reduced Processing Time
Throughput (TEU)	341,096	409,711
Throughput (Containers)	194,912	234,121
Avg. Waiting Time Entrance Gate	0.21 hours	0.14 hours
Max. Waiting Time Entrance Gate	1.06 hours	0.62 hours
Avg. Waiting Time Exit Gate	0.022 hours	0.018 hours
Max. Waiting Time Exit Gate	0.484 hours	0.37 hours
Avg Queue Entrance Gate	3.174	2.02
Max. Queue Entrance Gate	62	66
Avg. Queue Exit Gate	0.19	0.17
Max. Queue Exit Gate	23	22
Failure	IN Gate	Out Gate

3.2 Proposed Gate Improvements

3.2.5 Reduce the Number of Chassis Changes

The baseline model has 18,294 chassis changes out of a 149,730 processes thorough the gate, which equates to 12%. If these were removed the entrance gate capacity would increase.

The ARENA model was used to assess this change using the same baseline parameters. If all the chassis changes were removed the gate capacity would increase by 18%, and if 50% of the chassis changes were removed the capacity would increase by 5.6%. The valises are shown in Table I, and it shows that although the throughput has increased the waiting times remain constant.

The gates are still governed by the IN gates, as these still fail first even with a reduction of trucks passing through the gates when the chassis changes are reduced.

The other benefit of reducing the chassis changes is that the area now used for that process on the opposite side of River Road would then become available for other operations, such as maintenance activities or container stacking.

To remove all the chassis changes it would be necessary to remove the need for the chassis to be switched by moving to adjustable chassis. However this is not likely to be possible as the chassis are not owned by the NCSPA but by haulage companies, and therefore they do not have any authority to instigate this change.

Therefore the chassis changes are considered to remain for this study and if some of these were ever to be removed in the future this would lead to an improved operation of the gates.

Table I: ARENA Model Results for reducing chassis changes.

	Baseline	50% Chassis Changes Removed	100% Chassis Changes Removed
Throughput (TEU)	341,096	360,195	401,893
Throughput (Containers)	194,912	205,826	229,653
Avg. Waiting Time Entrance Gate	0.21 hours	0.19 hours	0.19 hours
Max. Waiting Time Entrance Gate	1.06 hours	1.18 hours	0.87 hours
Avg. Waiting Time Exit Gate	0.022 hours	0.027 hours	0.034 hours
Max. Waiting Time Exit Gate	0.484 hours	0.52 hours	0.41 hours
% Increase Gate Throughput	**N/A**	**5.6%**	**18%**

3.2 Proposed Gate Improvements

3.2.6 Do Minimum – Temporary Gate Improvements

In the short term it is likely that the gate capacity will need to be improved to maintain the expected forecast.

The lower bound forecast is 368,170 in 2019 which is a 14.6% increase over the 2018 value. In this timeframe large infrastructure improvements cannot be considered, therefore temporary measures will need to be considered.

It is deemed impossible to reduce the chassis changes in the short term since NCSPA do not own or have control over how the trucking companies run their business and even though this would increase the throughput so this is excluded from the temporary gate improvement option.

The simplest solution that requires minimal additional cost is to increase the gate hours of operation. Table J shows the requirements for hours for the time up to financial year 2020. This gives the terminal time to introduce alternative methods to increase the throughput.

The introduction and increase in the use of intermodal transport of containers would increase the throughput further but would be limited for a few percent until the new intermodal yard is introduced.

Increasing the processing time will require significant cost attached to a new TOS system and the associated infrastructure improvements and will take time to introduce.

Table J: Hours of Gate Operation required to achieve the lower bound throughput for between financial years 2018 and 2020.

Year	Estimated TEU Throughput	Hours Required	Notes
2018	321,251	55 hours	Current Gates
2019	368,170	60 hours	Half Saturday
2020	406,845	66 hours	Full Saturday

The quickest the south gate upgrade works can be constructed is anticipated to be the end of 2020.

As the gate complex is currently close to capacity, there may be the need to introduce additional hours for the current gates prior to the new gates if the throughput rapidly increases. However, given the urgency with the current gate capacity, it is deemed essential for the south gate upgrade works to commence as soon as possible.

Since the new south gate complex upgrades are identified as an urgent project, any additional or temporary gate construction is not deemed cost effective since these are not permeant solutions and any investment and construction executed will end up as abortive works. The following temporary gate solutions are for information only and provides NCSPA an indication as to how lanes numbers assist with the current gate capacity.

3.2 Proposed Gate Improvements

3.2.7 Do Minimum – Temporary Gate Improvements

Additional Lanes

As proven in Section 3.2.1, adding additional lanes to the existing gate complex will have the effect of increasing truck capacity. In the interim phases and before any new gate complex is considered, it may be possible to introduce two more gate lanes in the existing gate complex as shown in Figure 29. This is described as follows:

- ❑ Remove all boxes south of the gate complex to make way for two additional exit gate lanes- this can be formed with line markings and or traffic bollards and barriers.
- ❑ Boxes that have been removed will need to be relocated to other newly repaved areas of the terminal such as the DRI building area.
- ❑ The existing bypass lane and one of the newly formed exit lanes will required a temporary shelter or demountable covering installed over them.
- ❑ The outer most exit lane will become the new by-pass lane.
- ❑ Existing exit lane number '5' will need to be reversed in direction and converted into an entry lane.
- ❑ This set up will provide five IN gates and four plus one exit lanes.
- ❑ The capacity of this set up can give a temporary capacity increase of approximately 19.5% taking the gate truck capacity to 406,000 TEUs per annum.
- ❑ However, a point to note is that the RPMs will need to be repositioned and procurement of one additional set of RPM scanners will be required.

Figure 29: Interim gate upgrade works

Although the provision of additional lanes at the existing gate complex will theoretically increase terminal capacity, this solution is considered to be a limited temporary measure which does not provide sufficient capacity to satisfy the target throughput of 750,000 TEUs per annum by 2025. For a more long term solution to the terminal capacity bottleneck issue, NCSPA will require a complete redesign of the terminal gate arrangement. Therefore, NCSPA should prioritise the design and implementation of a new gate complex instead of carrying out abortive temporary solutions. The temporary gate capacity improvement options presented in this report demonstrates that in critical circumstances, there are relatively quick 'fix solutions' available to NCSPA's deployment.

3.2 Proposed Gate Improvements

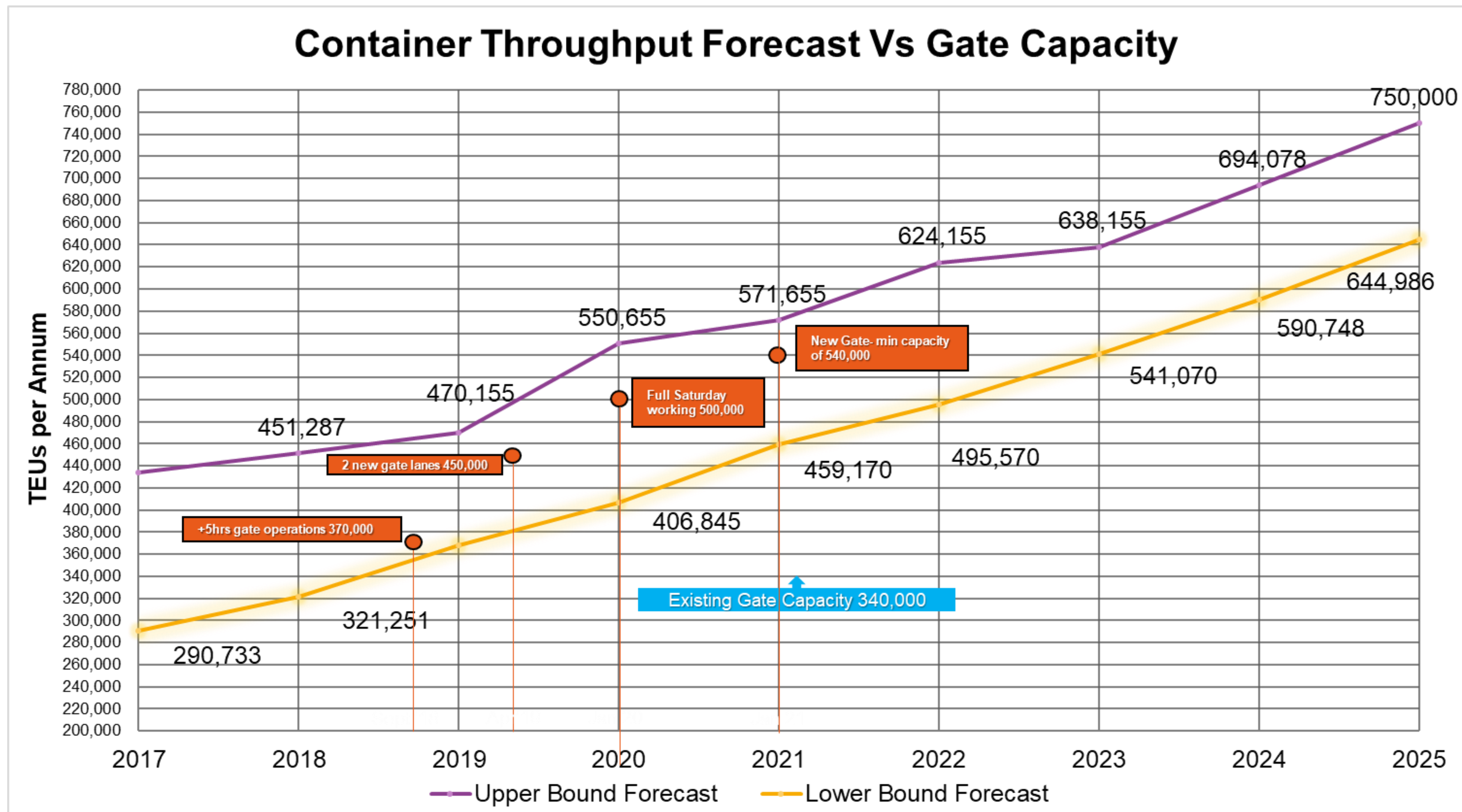
3.2.8 Do Minimum – Temporary Gate Improvements

The sequencing of the Do-Minimum Option is shown in Table K and is represented in Figure 30 as the blue line. In this case additional hours would be required in the time until the final new gate complex is required, even with an updated terminal operating system. This is just an indicative option that matched the lower bound forecast, and can be easily adapted dependent on the integration of the intermodal yard and the new gate complex.

Table K: Do Minimum Option

Year	Improvement	TEU Throughput	% Increase
2018	Baseline Gate	340,000	
2018	5 Additional gate hours (60hrs per week)	369,748	8.4%
2019	Two new gates (5 In & 4 OUT)	451,093	22%
2020	Saturday Working (66 hours per week)	499,585	10.75%
2020 Sep	New gate with 7 IN and 6 Out Lanes	540,000	8.1%

Figure 30: Percentage of daily container throughput for 11 and 12 hour days.



3.2 Proposed Gate Improvements

3.2.9 Gate Improvement Summary

In summary, the five gate capacity upgrade options and their relative efficacy is summarised below. As can be observed, by far the most effective and efficient option to increase gate capacity is by reducing the time taken to process a truck at the gates.

1. Increase Gate Numbers	Average of 9% Increase in capacity per gate
2. Reduce Truck Processing Time	20% Increase in capacity per minute reduced
3. Remove 50% Chassis Changes	6% Increase (18% for all chassis changes removed)
4. Working an Extra Shift on Saturday	20% Increase in throughput per extra 11 hours shift
5. Utilisation of Intermodal Yard	7% Increase in throughput for 8% modal Split

3.2 Proposed Gate Improvements

3.2.10 Truck Processing Time

As explained, one of the most effective methods to increase gate capacity at the port is to reduce the truck processing time at the gate. However, before a solution can be applied the root cause for the longer waiting times experienced by the trucks at the existing gate complex must be investigated. On average a truck would need to wait up to 4.25 minutes before they clear all checks and paper work at the interchange before being issued a mission ticket to proceed.

Through observations of the gate operations, the following points are believed to be the main contributory factors in the slower than industry standard truck processing times.

- When an inbound truck enters the terminal gates, a gate pass number and booking reference is manually requested, this can take longer if a TWIC was not available as additional paper work from the day pass centre would need to be confirmed. This process of manually cross checking paper documents relies on ‘human interactions’ which can lead to the risk of human error as well as time wasted on ‘small talk’.

- When a truck pulls into an entry gate lane, a manually operated camera is utilised to locate the following:
    - Truck license plate number,
    - Container Number
    - Seal Presence and damage
    - ISO number
    - Chassis Number

The camera position is not fixed and as truck positioning at the gate varies, the camera position must be adjusted every time a truck pulls into the lane. This manual adjustment of the camera to capture multiple pieces of information is time consuming and relies heavily on the skill and dexterity of operators.

- Once the camera has been locked on to desired subject, data is manually recorded onto the terminal operating system. The data is usually a long string of alpha –numerical combinations, the manual capturing of this data is open to human error and the speed in which the data can be inserted via a keyboard interface is down to an operator’s skill and dexterity and may be influenced by fatigue over the working day.

- Once all the data has been inputted into the terminals operating system (TOS), it appears that the verification process is less than optimum since there is a noticeable ‘lag’ between the data input and the final issuance of the mission ticket. Intermittently, the TOS will not be able to determine a ‘slot’ for a container. In this situation, the information is transferred to an ‘ad-hoc’ yard planning station before a mission ticket could be issued. This would further increase the truck processing time.

Summary

In summary, given that the gate truck processing is predominantly manually operated, the current gate operations are considered to be highly efficient. However, there is a limit on how quickly manual-labour can capture and process the information required at the gate. If truck processing times are to be reduced, the manual operational side of the truck processing procedure must be targeted, eliminated future gate upgrades.

3.2 Proposed Gate Improvements

3.2.11 Introduction of Technology – Optical Character Recognition

Technology and automation should be considered when replacing manual labour at the gates in order to speed up the truck processing times. Optical Camera Recognition (OCR) technology has been steadily deployed in ports across the world in the last 10 years and as OCR technology has matured, its effectiveness and benefits have been an attractive proposition for many ports.

OCR is essentially the automated process of reading numbers and letters through a digital camera and is usually integrated to the terminal operating system. Special cameras are mounted on a gantry or OCR portal and when a truck drives though the cameras are strategically located to automatically read and record the licences plate number, chassis number and container box number.

Apart from picking up the numbers and letters from the truck and container, the cameras are also able to record pictures of the container and truck as they pass through the portal. This information is usually kept on record as proof of damage and condition of the containers entering the terminal.

Modern OCR systems now offer high speed processing without the need for trucks to slow down as they drive through the portals. Most modern OCRs can record the data required at truck speeds up to 22mph and therefore a single camera can potentially process up to 500 trucks per hour.

On average, it stakes 3 seconds to capture all the data required as compared to the 4.25 minutes needed on average at the manual gates currently utilized at the Port of Wilmington. The highest OCR accuracy rate in the market is currently >98% and has now lead to greater utilization and adoption of OCR technology in many ports around the world.

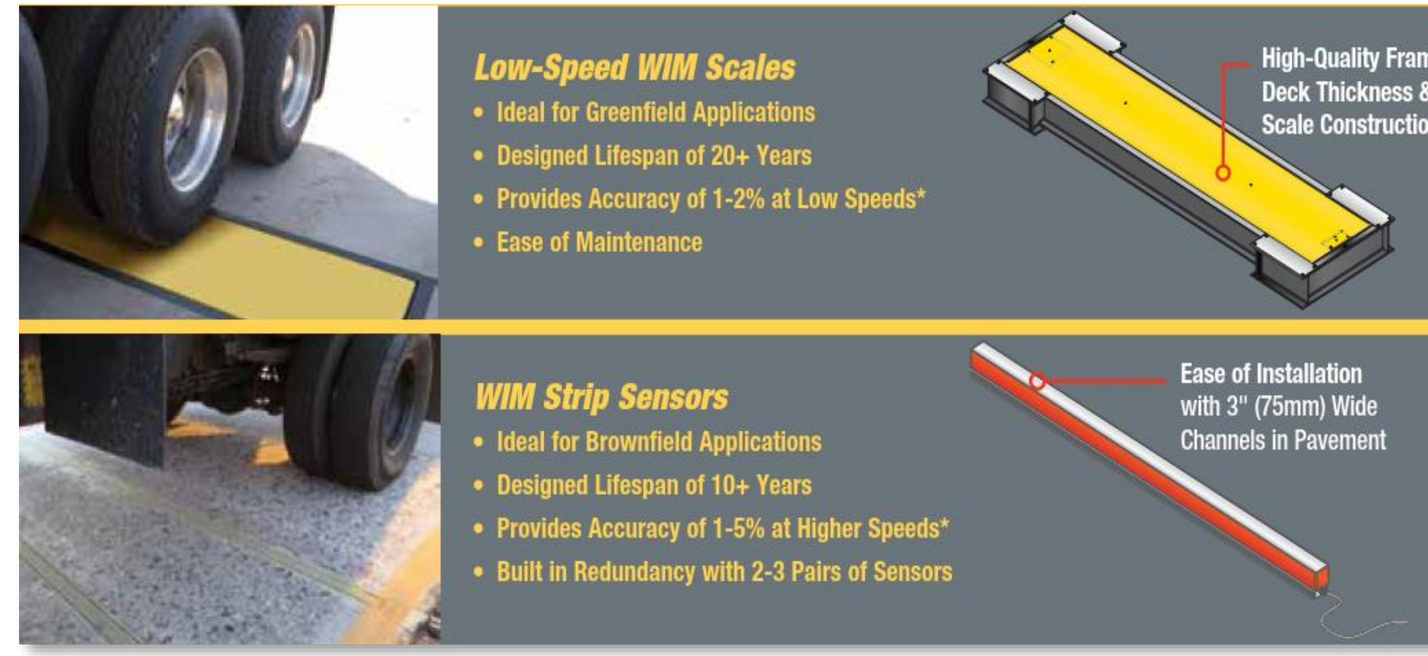
It is envisaged that the use of OCRs would eliminate the requirement for manual data capture at the main gate interchange. However, the requirement of TWICs verification and the cross verification of the data captured at the OCR with the data stored in the Terminal Operating System is still required. This means a separate check point for TWICs and a separate station for cross check data from the OCR/GOS and the TOS will be required. These can all be automated with the minimal of human interaction using self-service kiosks.

3.2 Proposed Gate Improvements

3.2.12 Introduction of Technology – Weigh in Motion Sensors

Although not part of the main gate process, the Port of Wilmington requires laden trucks to be weighed before entering and exiting the terminal. This is to cross check the Verified Gross Mass (VGM) which is now a SOLAS regulation requirement for shippers to declare. The current equipment used at the port are static weigh scales which need the truck driver to park the truck on the scale and stop whilst the weight reading is taking place. The weight is usually displayed and the truck driver is asked to manually record this and report to the gate operator. This, again, is highly dependent on human interaction and it takes time to process which adds precious seconds to the overall truck turnaround time.

It is proposed that the port consider the use of weigh in motion (WIM) sensors in all terminal upgrade plans for the future. Should NCSPA wish to continue the process of verifying the VGM of containers, WIM sensors can aid in speeding up the rate at which this can be carried out. WIM sensors are essentially a load cells consisting of quartz crystals and unlike static scales, WIM systems are capable of measuring vehicles traveling at a reduced or normal traffic speed and do not require the vehicle to come to a stop. This makes the weighing process more efficient.



The WIM sensors are usually installed within the paving and can be categorised into two main types. These being strip sensors or Low Speed WIM (LS-WIM) scales. The LS WIM scales are preferred for container terminals due to their accuracy which is rate at 2% at 10mph. Many LS-WIM scales are IMO SOLAS compliant as well as being approved by the OIML 134-1 and ASTM E1318-09

An example of WIM sensor use is at the West basin Container Terminal L.A. where WIM sensors has been integrated into their gate system since 2011

3.2 Proposed Gate Improvements

3.2.13 Introduction of Technology – OCR Positioning

Should OCR technology be deployed at the Port, the location of the OCR portals was assessed along the entrance gate route, either at a location separate from the main gates (Option A) or immediately adjacent to the gates (Option B).

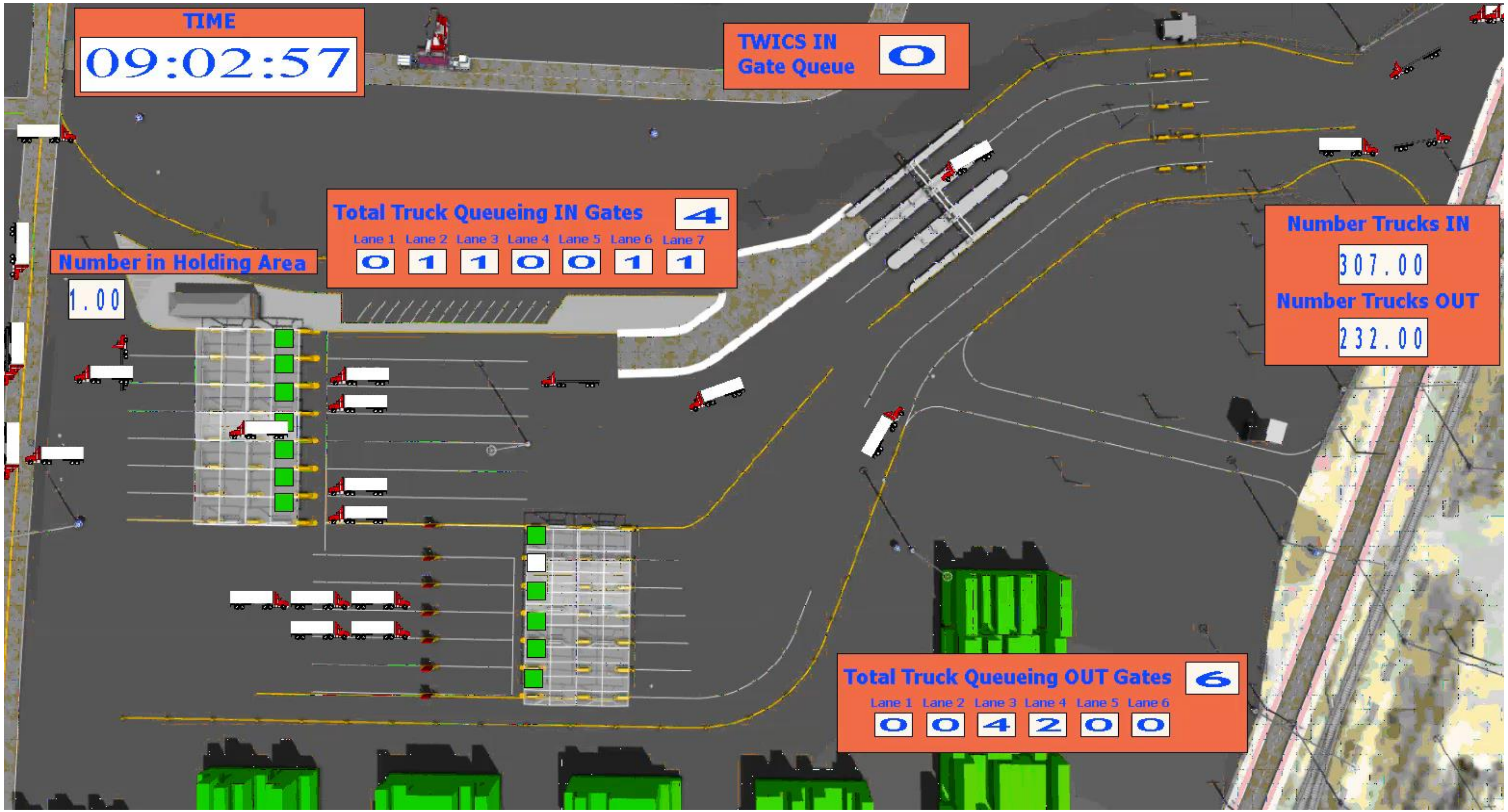
The OCRs have no processing time as they can capture the information with speeds of 25mph. Indicative layout options are shown in Figure 31 which is drawn up for one of the four proposed options. The timings and results of this assessment will be applicable to all of the gate layout options.

The assessment was conducted using the calibrated gate model developed in the simulation work. Both scenarios were modelled with a flow of 1520 trucks per day which equates to a terminal throughput of 965,000 TEU assuming chassis changes have not been reduced and 8% of containers transported by rail. The future gate numbers have also been increase to seven IN and six OUT as explained earlier in this Report.

Figure 31: Indicative Diagrams of the Location of OCRs within the Entrance Gate Complex.

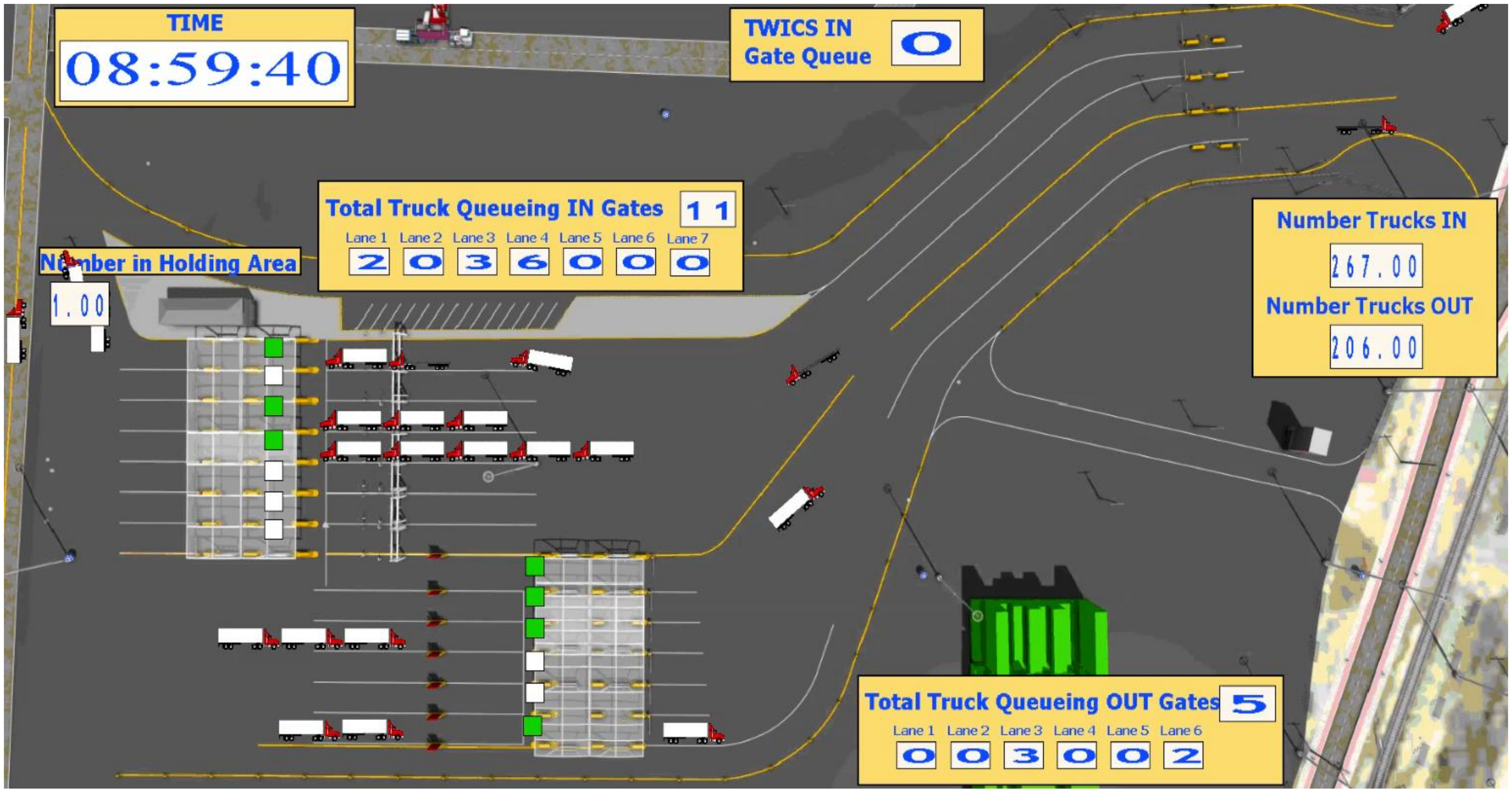
3.2 Proposed Gate Improvements

3.2.13.1 Location of OCRs *Animation – OCRs Separated from Gate Lanes OPTION A*



3.2 Proposed Gate Improvements

3.2.13.2 Location of OCRs *Animation – OCRs Located With Gate OPTION B*



3.2 Proposed Gate Improvements

3.2.13.3 Location of OCRs

Results and Comparison

The results of the two models are shown in the animations and the results shown in Table L. From the models, Option A with the OCR gates separate to the gates results in less queuing at the main gates, and the pressure transfers to the TWICS entrance gates, which were assumed with a conservative processing time of 25 seconds.

The sensitivity of a lane failure (one out of the three) is located in Appendix E and demonstrates that although greater peaks may be developed within the model, the averages are considered suitable and enough redundancy is captured within the entrance gates lanes.

Another benefit of Option A is that only three OCR portals are required rather than the 7 for Option B which will be a significant cost saving both in the equipment and the infrastructure required. Even though the overall time for the process is similar reducing the wait at the main gate will make the system appear to the user that the system is more efficient and lead to less frustration by the drivers.

As can be seen the overall time for a truck to enter the terminal and be issued with a mission ticket is on average 2.5 minutes which is a significant improvement from the 4.25 minutes currently experienced by truckers at the port.

Table L: ARENA Model Results for different OCR locations.

IN Gates	**Option A**	**Option B**
Queue Length (*Average/Maximum)*	0.84/15	2.68/ 34
Waiting Time (*Average/Maximum)*	46s/12min	1.56min/20min

OUT Gates	**Option A**	**Option B**
Queue Length (*Average/Maximum)*	0.24/6	0.37/ 9
Waiting Time (*Average/Maximum)*	26sec/11.2min	21s/10.5min

TWICs IN Gates	**Option A**	**Option B**
Queue Length (*Average/Maximum)*	0.12/5*	0.17/8*
Waiting Time (*Average/Maximum)*	10s/2.9min	13s/3.6min

TWICs OUT Gates	**Option A**	**Option B**
Queue Length (*Average/Maximum)*	0.044/5	0.030/5
Waiting Time (*Average/Maximum)*	2.5s/1min	3s/56s

**** 99.5 percentile value = 3.2 trucks for Option A & Option 2B***

3.2 Proposed Gate Improvements

3.2.13.4 Development of RPM Scanners

RPM Scanner Investigation

The RPM scanners are preferred to be located before the exit gates as required by Customs Border Protection (CBP) using new upgraded scanners that can on average scan 175 trucks per hour as reported by Pacific Northwest National Laboratory (PNNL).

The impact of this is investigated using the calibrated independent gate models to identify the potential impact this has on the whole port system. As with the introduction of the OCRs, separating the RPM scanners will mean fewer scanners are required, and the gate process will be improved.

The varying parameters of the testing of the two gates are shown in Table M. There is no change to the entrance gate process and minimal change to the overall gate process time. These parameters were tested within the calibrated gate model, with the same terminal throughput of 1,152,000 TEU (assume 8% by rail). This equates to approximately 1,830 trucks per day.

It was decided that a minimum of two RPM gates, and a secondary container inspection area to test the scan failures. This is to ensure there would be an RPM scanner in the event of a failure and incorporate some redundancy into the system.

Table M: Simulation Model parameters for the RPM locations within the gate complex.

	RPM integrated with Gate	RPM separate to Gate
TWICs IN Gate	25 seconds	25 seconds
OCR	Drive-Through	Drive-Through
IN Gate	Triangular Distribution Min: 1.5min/Mean 1.75min/Max: 2min	Triangular Distribution Min: 1.2min/Mean 1.5min/Max: 1.8min
RPM Numbers	6 (RPM on each exit lane)	3
RPM	Triangular Distribution Min: 1.5min/Mean 1.75min/Max: 2min	25 seconds
Out Gate		Triangular Distribution Min: 1.25min/Mean 1.5min/Max: 1.75min
TWICs Out	15 Seconds	15 Seconds

3.2 Proposed Gate Improvements

3.2.13.5 Development of RPM Scanners

RPM Scanner Investigation

The output statistics from the model with the RPM located at the gate and separately are shown in Table N. There is no effect on the entrance gate process.

The queue for the exit gates has been reduced as the queue is likely to be spread between the gates and the RPM scanners. The queue capacity was taken from the indicative drawings for the options, and all the queues all fit within the queue capacity so there are no expected times where the terminal will be affected.

The assessment of a failure of a RPM scanners was undertaken and the system has sufficient redundancy that the gate would still be in operation.

The introduction of the RPM is not a significant influence on the gates system. As the gate system for the new layout is limited by the out gates, introduction of the RPMs separate to the gates will increase the overall capacity of the gates.

Table N: ARENA Model results for RPM scanner locations.

	RPM integrated with Gate		RPM separate to Gate		Limit
	Average	Max	Average	Max	
Wait Time In Gate	1.3 min	29 min	1.3 min	29 min	-
Queue In Gate	1.70	26	1.70	26	45
Wait Time Out Gate	0.6 min	13.8 min	0.4 min	7.8 min	-
Queue Out Gate	0.4	11	0.26	8	25
Queue TWICs In Gate	0.067	6	0.067	6	6
Queue TWICs Out Gate	0.069	6	0.079	7	6
Wait Time RPM	**Not Available**		3 sec	1.8 min	-
Queue RPM			0.03	5	6

3.2 Proposed Gate Improvements

3.2.14 Future Gate Parameters

The future gate complex selected will contain seven entrance gates and 6 exit gates. This has been selected as a compromise between the amount of space required for a gate complex and the ability to increase capacity in the gate by other means shown in chapter 3.2. Reducing the gate processing time is considered the most effective way to increase the overall capacity of the gate complex and therefore the terminal.

The parameters in Table O have been used for the modelling of the final option to assess the overall capacity of the gate complex. The overall capacities have been obtained for the future model and compared with the yard capacities.

The following slides highlight the final gate processes and parameters used for the inputs to the optioneering models and the assessment of the maximum final gate capacity. These parameters are applicable to all of the different options layouts that will be covered in Section 4. The space for the integration of the OCRs is required for the maximum gate capacity.

Table O: Parameters for Final Gate Complex Model

	Operation	**Baseline Case**
1	TWICs IN processing time	25 seconds
2	TWICs IN Max Capacity	7 trucks
3	Weigh-in-motion time	0 seconds
4	OCRs	5 seconds
5	In Gates Number	7
6	In gate Processing Time	Triangular Distribution from gate data: Min (1.2min), Mean (1.5min), Max (1.8min)
7	In gate Max Queue Capacity	40 trucks
8	Out gate Processing Time	Triangular Distribution from gate data: Min (1.2min), Mean (1.5min), Max (1.8min)
10	Out Gates Number	3
11	Out gate Max Queue Capacity	22 trucks
12	TWICs OUT Processing time	15 seconds
	TWICs OUT Max Queue Capacity	7
13	Failure Capacity of System	Queue length exceeds the given capacity 50 times per year.

3.2 Proposed Gate Improvements

3.2.14.1 Future Gate Parameters

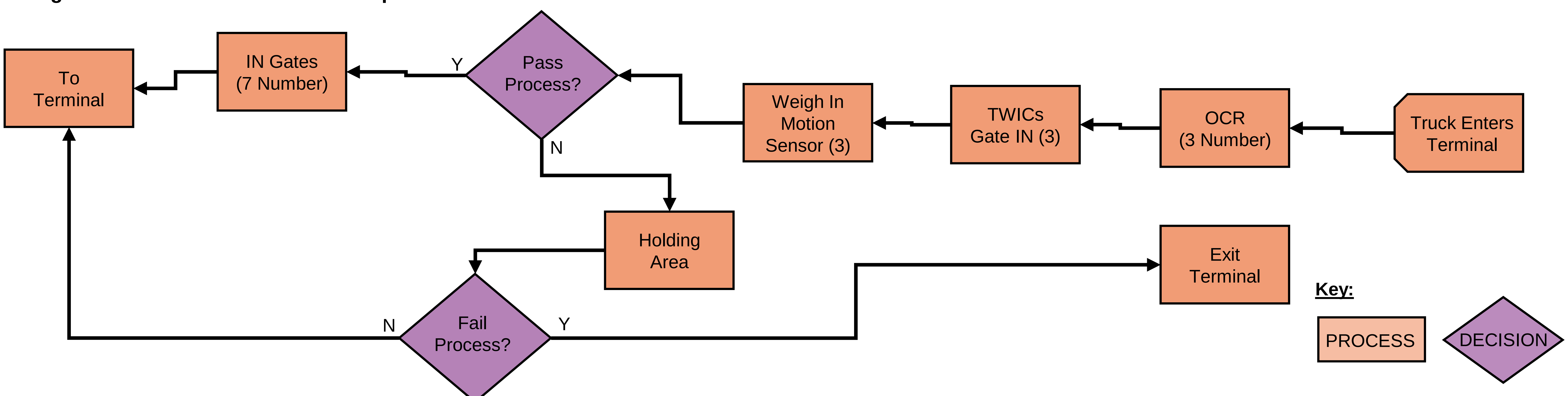
Entrance Gate Operating Procedures

The diagram shown is an representation of the modelling of the future Entrance Gate at the Port, as processed by the simulation modelling in ARENA.

The current two TWICs gates are replaced with 3 entrance lanes each containing the TWICs gate, OCR and weigh-in-motion sensors. This then splits to 7 entrance queuing lanes for the automated entrance gates. If there is a problem noted by the OCR scanners the trucks can be pulled over immediately after the TWICs gate for inspection or manual data entry. Therefore this truck does not have to wait until after the gate process and add the queue. The truck can then be re-routed to the exit gate if required without having to enter the port.

The automated gates use the data that is captured in the OCR gates and looks up the required containers in the terminal operating system (TOS) and then print the mission ticket for the driver. The speed of the TOS is the most important part to this process and the faster the information can be retrieved the faster the process will be.

Figure 32: Simulation of Exit Gate Operations



3.2 Proposed Gate Improvements

3.2.14.2 Future Gate Parameters

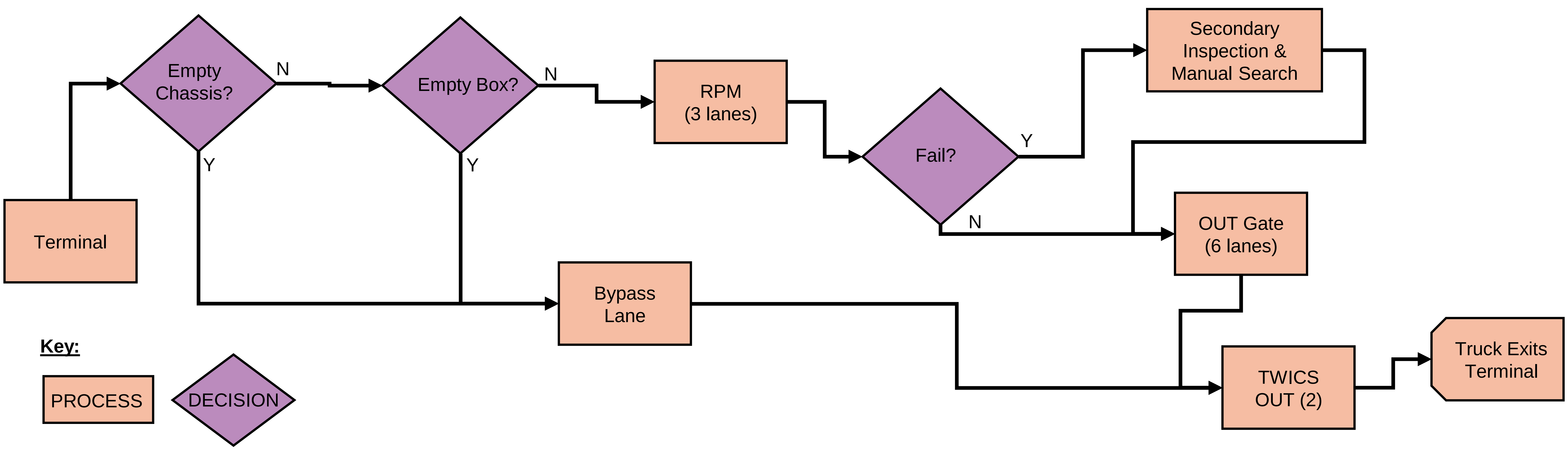
Exit Gate Operating Procedures

The diagram shown is an representation of the modelling of the future planned Exit Gate at the Port, as processed by the simulation modelling.

For the assessment in Section 2.7, the RPMs being located within the terminal and not integrated within the exit gate was preferable as the queue for the exit of the terminal was split, so this was integrated into the final option. The trucks pass through one of three RPM scanners and if they fail can be rescanned prior to the exit gate. This then splits to six exit gates before the truck leaves via the TWICs gate.

The bypass lane is for empty chassis and containers that do not need to be passes through the RPM scanner or the exit lane processing.

Figure 33: Simulation of Exit Gate Operations



3.2 Proposed Gate Improvements

3.2.14.3 Future Gate Parameters

The shipping schedule for the future condition was taken from the existing schedule and then adding additional vessels with varying parcel sizes to the schedule. It has been assumed that the parcel size will not increase for each vessel but that the number of vessel services will increase.

Using the averages taken, the annual container throughput from this schedule is 571,480. Using the given TEU ratio of 1.75, the TEU Throughput is taken as 1,000,090 TEU. It is assumed that all vessels have the same import-export split as given in the data (49.9% Import/51.1% Export).

To assess the capacity of the terminal this schedule is multiplied by a factor within the ARENA software. As the berth operation was not of concern, this is considered a suitable methodology as this schedule is above the target forecast even though the number of containers arriving on each vessel will vary.

Figure 34: Existing Port of Wilmington Sough Gate complex

3.2 Proposed Gate Improvements

3.2.15 Future Gate Capacity

Results

The basic statistics for the baseline gate are shown in Table P. The gate throughput is less than the terminal throughput due to the percentage of containers that are transported in and out of the terminal via rail.

The intermodal percentage is set at 8%. This is the maximum considered as part of the study. If an increased amount of intermodal transit was increased, the overall terminal throughput would increase. The failure characteristic of a queue exceeding the capacity times per year. The gates are limited by the entrance gates as the introduction of RPM scanners reduce the queues at the exit gates. The overall increase in the processing times has allowed the average queuing times to be minimal, ensuring a good service for users.

The average number of trucks arriving at the entrance gate per hour of operation is 171.2. Using the average processing time of 1.5 minutes, each lane can process 40 trucks per hour and therefor the gates on average would be suitable for the flow however peaks in the data are what cause the model to fail. Even with the introduction of a booking system there will still be peaks and troughs naturally in the day and week, so this is still maintained within the model.

The number of chassis changes has not been reduced and there is a large number of chassis changes that impact on the entrance gates, and reduce the overall terminal capacity.

Table P: Current Future Gate Output Results

	TEU	Containers
Gate Throughput (per annum):	1,104,845	631,340
% Intermodal:	8%	
Terminal Throughput (per annum):	**1,190,094**	680,054

Container IN Via Truck	297,166	**Container OUT by Truck**	323,769
Container IN Via Ship	357,446	**Container OUT by Ship**	322,608
Container IN Via Rail	24,038	**Container OUT by Rail**	24,676

IN GATE (7 Number)	**Average**	**Max**
IN Gate Processing Total	489,492	
Number Chassis Changes	58,302	
Total Trucks IN	431,190	
IN Gate Queue Time (hours)	0.015	0.2
IN Gate Queue Number	0.85	56
Times Exceed Capacity / Year [40Nr]	49	

OUT GATE (6 Number)	**Average**	**Max**
OUT Gate Processing Total	246,165	
% Total Trucks	57%	
OUT Gate Queue Time (hours)	0.0008	0.057
OUT Gate Queue Number	0.024	17
Times Exceed Capacity / Year [15Nr]	4	

3.2 Proposed Gate Improvements

3.2.15.1 *Truck Arrivals Output*

The number of containers arriving and leaving the terminal via road and rail is linked to the number arriving and leaving by ship. Due to the varying amounts of dual moves, and the large number of possible combinations, the number of trucks passing through the gate each day is not specified directly in the model, leads to a wide variety of actual truck numbers at the gate.

The output of the number of trucks passing through the entrance and exit gates of the final model, running at terminal throughput of 1,190,094 TEU with an 8% modal split can be seen in Figures 35 and 36. As seen before the out gate remains more peaky than the entrance gates.

Figure 35: Number of Trucks per hour though entrance TWICs gate.

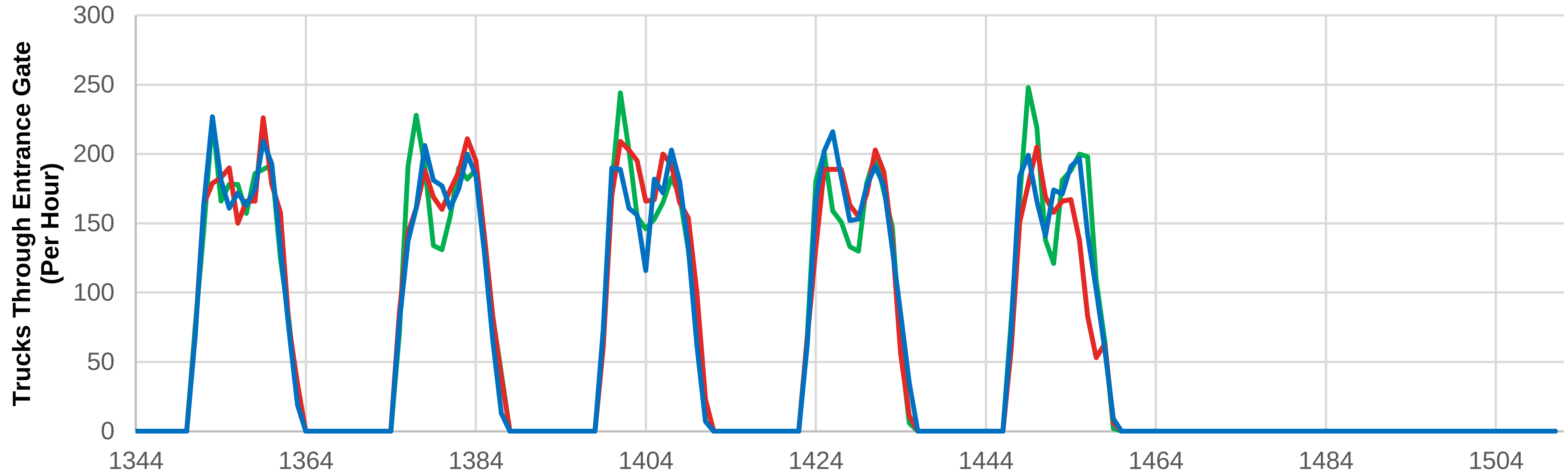
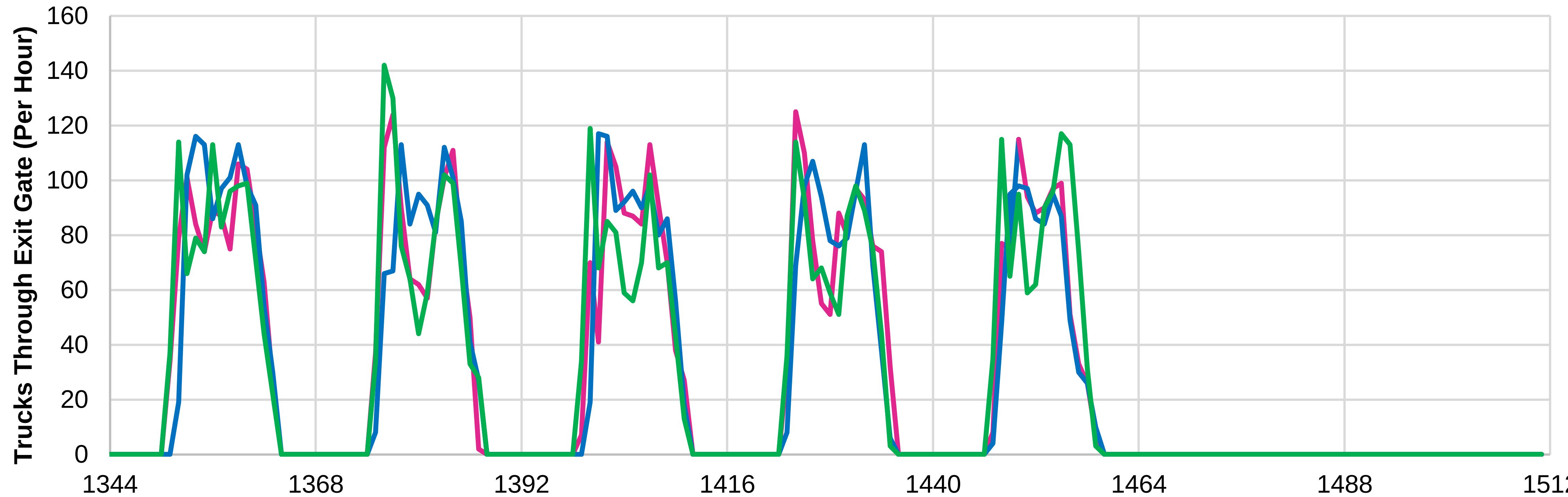


Figure 36: Number of Trucks per hour through RPM scanners on Exit gate.



3.2 Proposed Gate Improvements

3.2.15.2 Future Gate Capacity <u>*Results*</u>

For a random week during the 52 week simulation, the following queue lengths were recorded for both the entrance and exit data. The data shows the largest queue recorded in every hour in the given week. The gate is only operational for eleven hours per day, Monday to Friday.

For the entrance gates, Figure 37 shows that the queue exceeds the capacity once during the week but that the average queue is much lower. The entrance gates more regularly have a queue than the exit gates, which have a very peaky distribution with the maximum queues only occurring for a small period of time, and there is occasionally no queue at all. This peaky distribution is a result of the combination of processes within the terminal all with different durations combining to appear at the exit gates at the same time. This is easily discovered within the discrete simulation modelling and would be difficult to capture in static calculations.

Figure 37: Queue Length at Entrance Gates – Future Case TEU

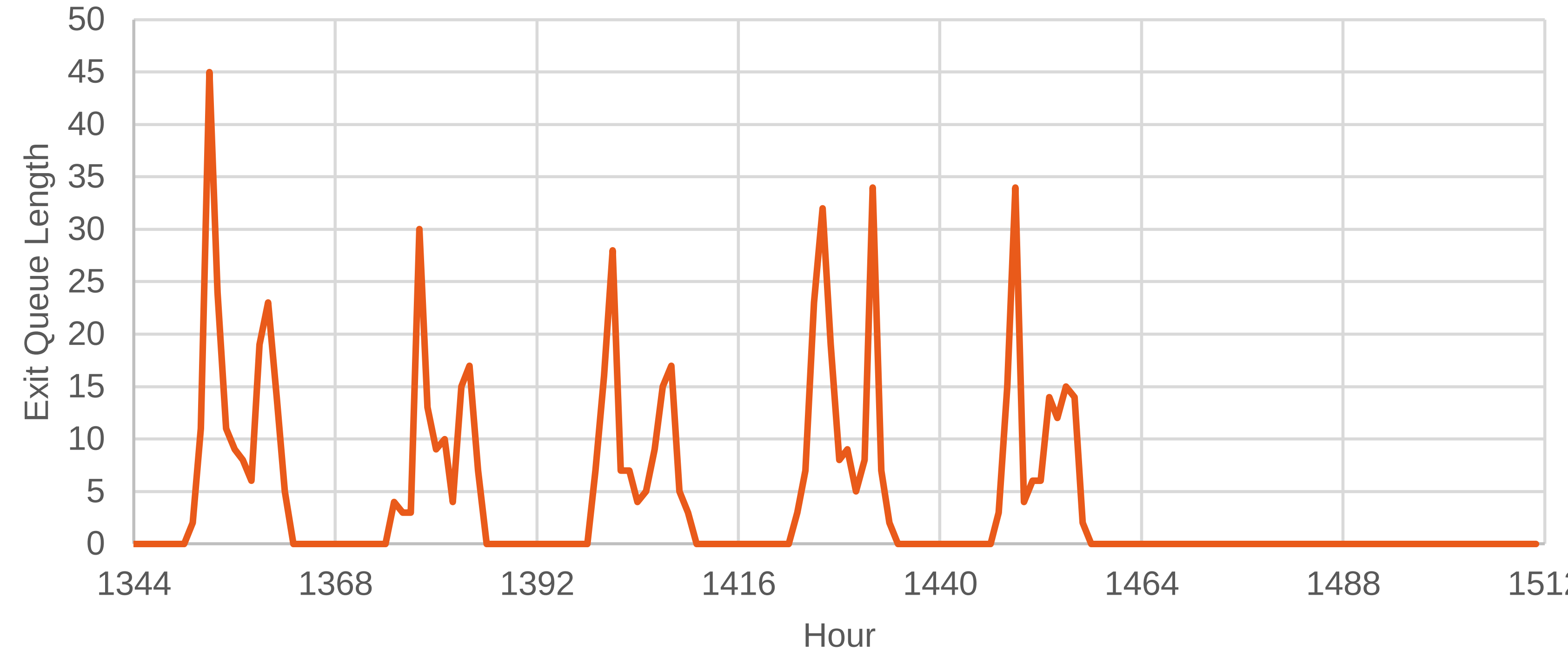
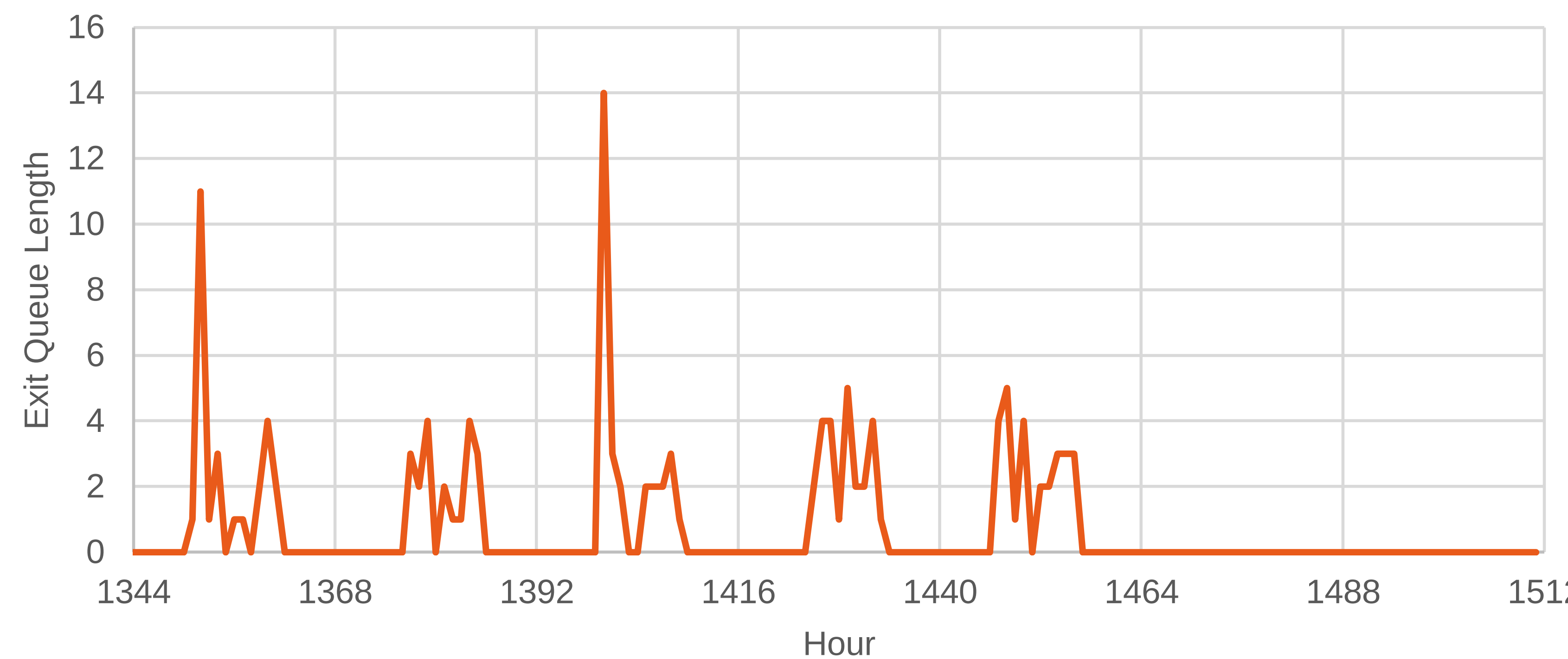


Figure 38: Queue Length at Exit Gates – Future Case TEU



3.3 Yard Upgrades

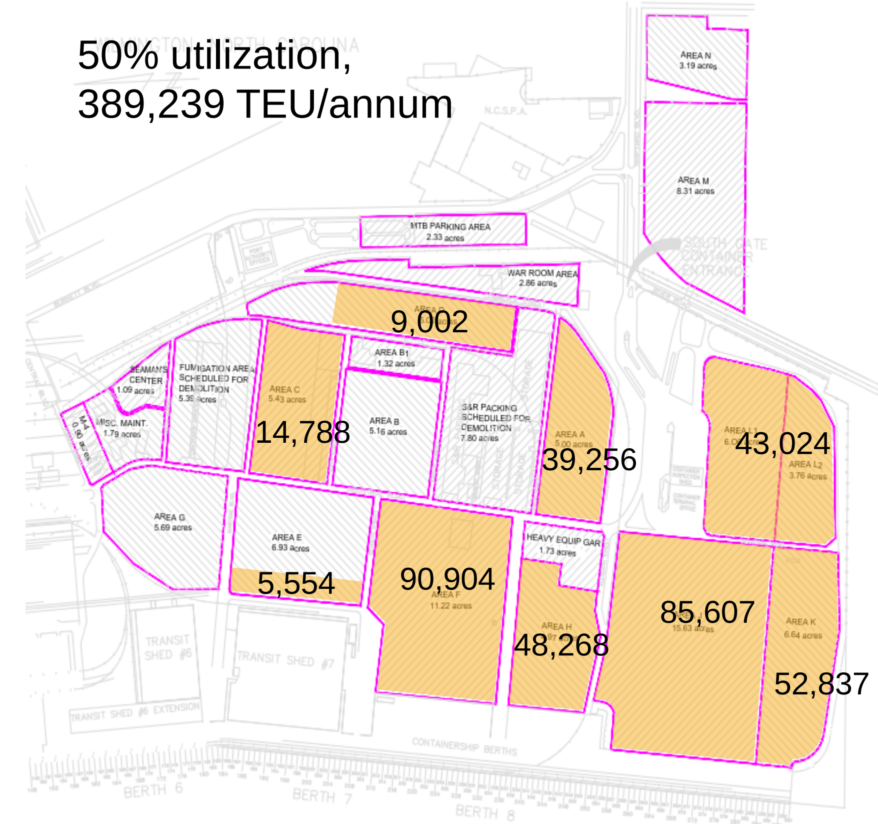
3.3.1 Paving Improvement Requirement

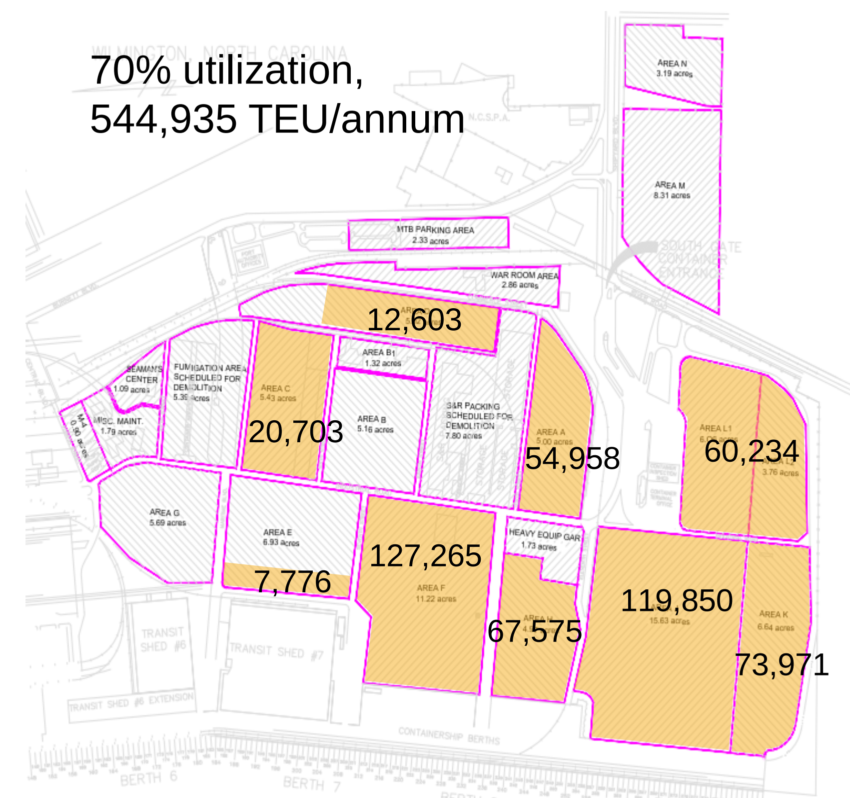
As noted in Section 2.2.1.4, the quality of paving is a critical factor limiting the capacity of the terminal. This has a direct effect on the stacking height and the density of stacks that can be achieved. If 50% stack utilization is achievable with the current paving using the current ground slots, the capacity of the terminal is 389,239 TEU/annum. Simply by increasing the utilization to 70% a capacity of 544,935 TEU/annum is possible. To achieve this, it is necessary to upgrade the paving for the following reasons:

- Though the subgrade is significantly strong in bearing the container loads, it is the asphalt layer that is a cause for concern, particularly because of local rutting caused by the container corner casting;
- With increased terminal throughput in the future, increased wheel load repetitions also become a concern;
- When maintenance work is required to address pavement disrepair, areas of the yard are made unavailable, reducing the overall capacity of the terminal and preventing the port to achieve even the 50% utilization figure of the terminal.

The pavement was designed with reference to Asphalt Institute guidance, MS-23. Because of the limitations of the Asphalt Institute guidance with regards its treatment of static loads and dynamic factors on wheel loads, or lack thereof, it is not recommended that the Asphalt Institute guidance be used for the design of container yard pavements; PIANC WG165 does not deem the Asphalt Institute method as valid for the design of container terminal pavement.

The British Port Association (BPA) manual for 'The Structural Design of Heavy Duty Pavements for Ports and other industries' presents a method for design that is well-known and has been used worldwide since the late 1970s. The BPA method is among those presented by PIANC WG165 as valid for the design of container terminal pavements. The BPA manual discourages the sole use of asphalt paving in container terminals. The designs that follow in the next section utilize the BPA method and are designed for operations in the 11.22-acre Area F as an example. It should be noted, however, that the designs are based on assumptions and high-level estimates and should not be taken as the final design. Further detailed design is required.





3.3 Yard Upgrades

3.3.2 Preliminary Paving Design Methodology

Two load cases must be considered in the design of container terminal pavement: dynamic wheel loads, and static container corner casting loads.

3.3.2.1 Dynamic Wheel Loading

Section 2.2.4.4 outlines the method of estimating the number of truck passes and reach stacker passes in the stacking area. In order to design a pavement for these conditions, a maximum design wheel load and number of equivalent wheel load passes needs to be defined for a 20-year design life (BPA guidance).

Individual wheel loads are determined from dividing each axle load by the number of wheels on that axle. The influence of neighbouring wheels is also considered through the geometry of the vehicle. The largest of these wheel loads is taken as the maximum design wheel load.

The number of equivalent wheel load passes over the design life is determined by summing the passes from each wheel, with the number of passes for each wheel scaled in relation to the maximum wheel load.

The design truck considered has a tractor with wheelbase of 9 feet and a trailer with distance of 33 feet between trailer axle and hook up point, and a total unladen weight 16,500 kg. The design reach stacker considered is a Kone Cranes SMV 4535 TB5. The design container of weight 22,000 kg is assumed.

The BPA manual recommends applying Dynamic Factors to the wheel loads to account for manoeuvring of the vehicle. These are listed in Table P.

After applying these dynamic factors, the maximum design wheel load achieved is 23 tonnes (or 225 kN), and the total equivalent wheel load passes over the design life is 2,250,000.

The design wheel load and total number of passes can be related to Figure 39 which indicates that 300 mm, or around 12 inches, of load-bearing C8/10 CBGM (cement bound granular material) is required for the design.

TABLE P: Braking and accelerating factors

Dynamic Factors	Truck	Reach Stacker
Braking	10%	30%
Cornering	0%	40%
Acceleration	10%	10%
Uneven paving surface	20%	20%

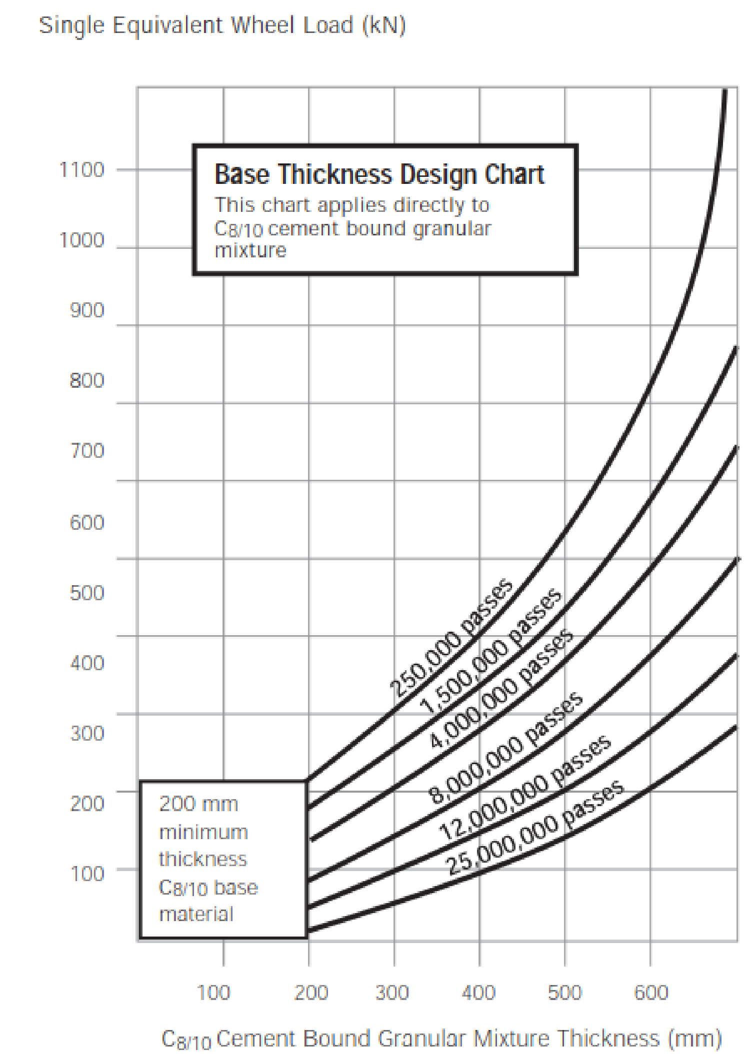


Figure 39: Paving base thickness design Chart BPA Manual

3.3 Yard Upgrades

Two load cases must be considered in the design of container terminal pavement: dynamic wheel loads, and static container corner casting loads.

3.3.2.2 Static Container Loads

The BPA manual contains guidance on pavement design for static container corner casting loads. For five high stacking, arranged in rows six containers wide, the load on the pavement is estimated as 914.4 kN (Table Q). Relating this to the curve in Figure 40 gives a required load-bearing pavement thickness of 585 mm, or 23.5 inches, C8/10 CBGM.

From the design calculations, it is evident that the loads from the corner castings are critical and so these are used in the design of the pavement.

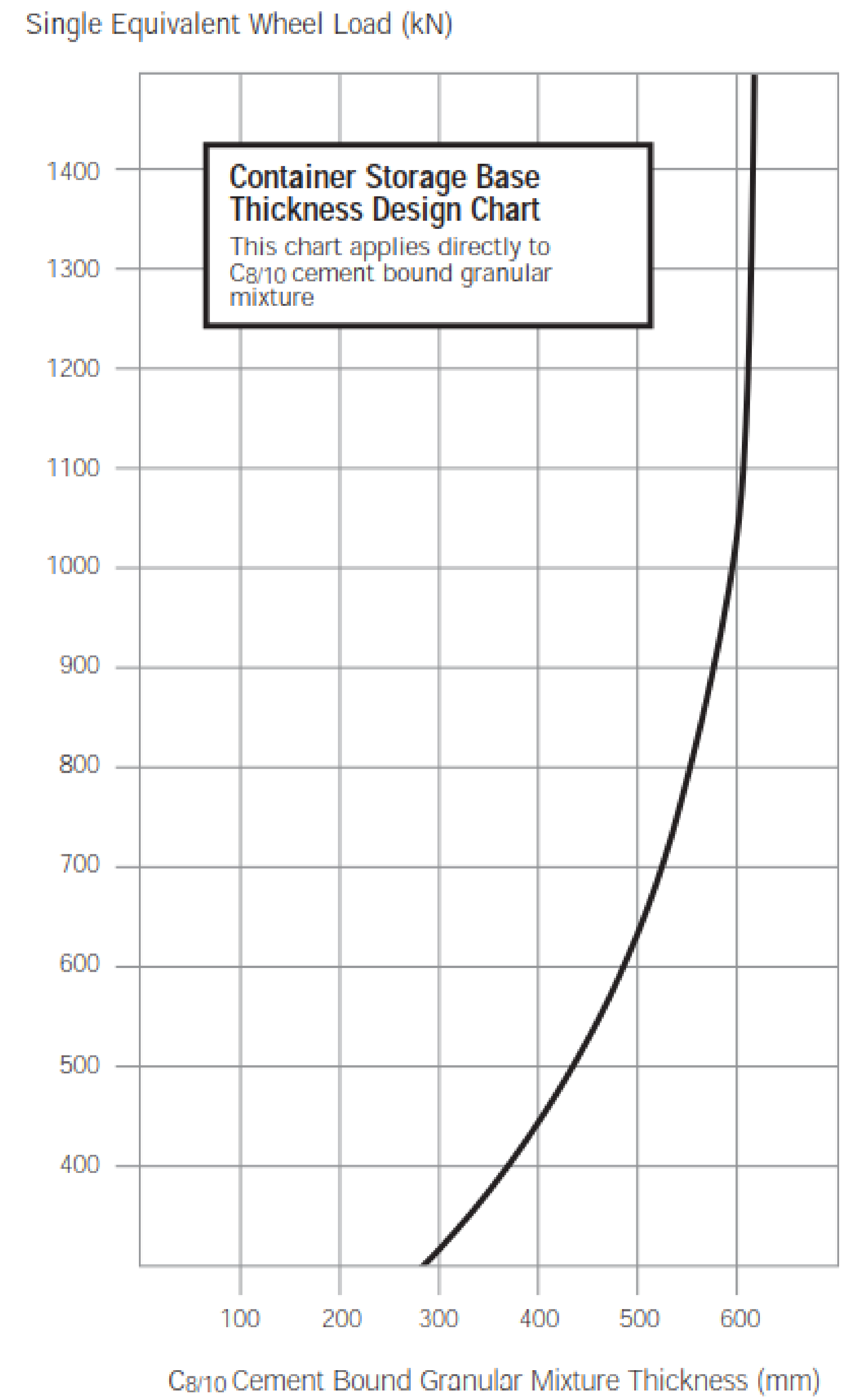
To ensure the structural integrity of the paving over the design life, and in order to spread the point load from corner castings into a distributed load, the load-bearing section is overlaid by a surface course that is allowed to wear.

Options for surface courses are: concrete block paving; reinforced concrete slab; and asphalt. Each of these options is explored in the next section.

Table Q: BPA Container Load of Pavements

Stacking Height	Reduction in Gross Weight	Contact Stress (N/mm^2)	Load on Pavement (kN) for each stacking arrangement		
			Singly	Rows	Blocks
1	0	2.59	76.2	152.4	304.8
2	10%	4.67	137.2	274.3	548.6
3	20%	6.23	182.9	365.8	731.5
4	30%	7.27	213.4	426.7	853.4
5	40%	7.78	228.6	457.2	914.4
6	40%	9.33	274.3	548.6	1097
7	40%	10.9	320.0	640.0	1280
8	40%	12.5	365.8	731.6	1463

Figure 40: BPA design chart for CBGM thickness



3.3 Yard Upgrades

3.3.3 Pavement Improvement Options

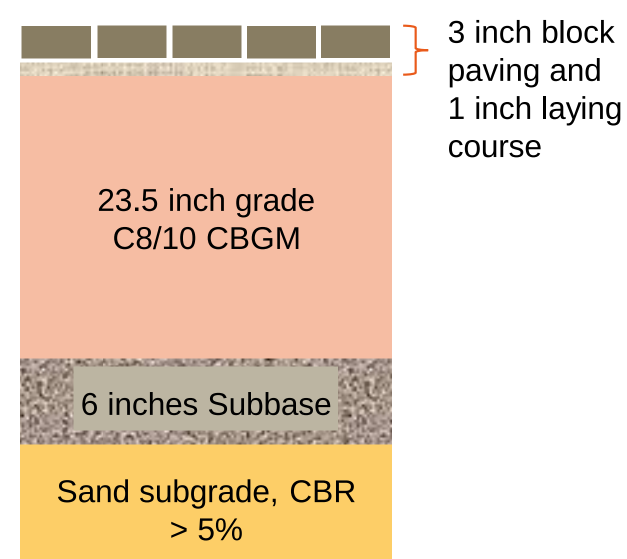
CBGM with Concrete Block Paving - This section uses concrete block paving as a surface course that transfers the loads through a 1-inch laying course to a load-bearing 23.5-inch grade C8/10 CBGM (cementitious bound granular mixture) base course. Block paving can be laid at a relatively fast pace and performs well in container terminals, requiring little to no maintenance over the design life. There may be limited availability locally in terms of material and expertise. Over a 11.22-acre Area F, a CAPEX of around $7.92 million can be expected for construction.

CBGM with Reinforced Concrete Slab - The surface course for this section is a reinforced concrete slab that transfers the loads to a 17.5-inch CBGM base course. The base course is a reduced depth as the overlying slab can bear some of the load. This section requires little to no maintenance over the design life. Over a 11.22-acre Area F, a CAPEX of around $8.80 million can be expected for construction.

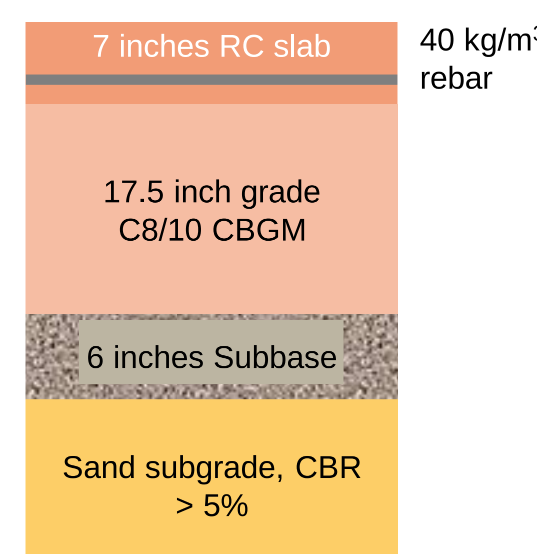
CBGM with Asphalt surface course – A surface course of 2.5-inch asphalt and a 2.5-inch binding course transfer the loads to a 23.5-inch CBGM base course. Asphalt is relatively inexpensive locally and is quick in construction. Though the paving is of adequate strength, there is expected to be local wearing of the surface course, and so will require maintenance over the design life. Over a 11.22-acre Area F, a CAPEX of around $6.70 million can be expected for construction. At present, with 30% utilization, areas of the terminal are taken out of commission every 2-3 years for pavement repair. The frequency of repairs will increase with utilization, with 70% utilization needing repairs possibly every 10-15 months. Over the 25-year design life, the OPEX can be around $2.59-6.62 million, giving a whole life cost of around $9.29-13.32 million.

Area F (11.22 acres)	CAPEX ($ millions)	25-yr OPEX ($ millions)	TOTAL ($ millions)
Block Paving	7.92	-	7.92
RC Slab	8.80	-	8.80
Asphalt	6.70	2.59-6.62	9.29-13.32

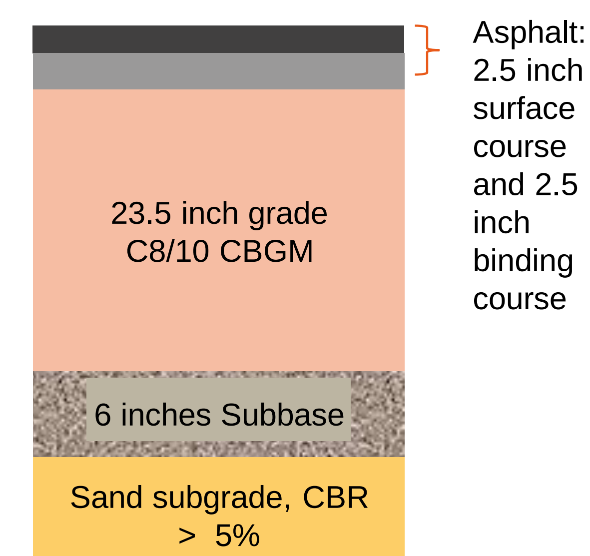
Concrete section w/ block paving



Concrete section w/ RC slab



Concrete section w/ Asphalt overlay

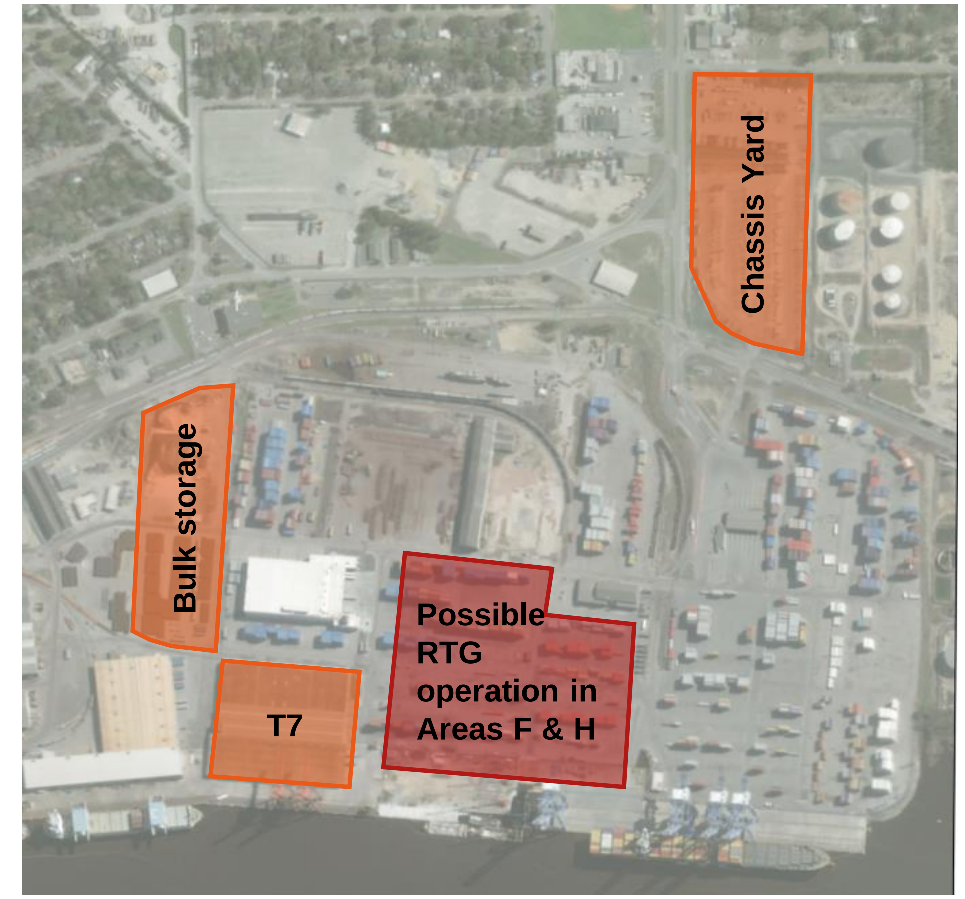


3.3 Proposed Port Improvements

3.3.4 Additional Yard Areas

Future potential container storage areas have been identified within the current terminal boundary these include the bulk storage areas north of the terminal and warehouse T7 once demolished. The bulk storage areas currently used for dolomite and steel billet storage can both provide an additional 8 acres of land whilst warehouse T7 will provide up to 3.9 acres of useable land for container stacking. Taking back these areas increases the capacity of the terminal by around 115,000 TEU/annum.

In addition, If the chassis yard is repurposed for container storage, it is possible to increase the capacity of the terminal by a further 185,000 TEU/annum. This will, however, require either the relocation of the chassis or the loss of capability to store chassis at the port.



3.3.5 Rubber Tyred Gantry Cranes

The repaving of Area F and Area H provides an opportunity to implement rubber tyred gantry (RTG) cranes at the terminal. Stacks can be packed denser with each stack 8 containers wide, and RTGs can stack higher, with an average stack height of 5 and a maximum possible stack height of 6 boxes. Implementing RTG operation in Area F and Area H increases the terminal capacity by around 100,000 TEU/annum.

To implement RTG operation, the pavement needs to be designed for 6-high stacking. Also, the channelization of the RTG wheel loads will also need to be considered in the design.

3.3 Yard Upgrades

3.3.6 New Reefer Yard

The laden reefers which are currently stored in areas K and L are not stacked. As established in Section 1.5, the Port is set to experience an increase in reefer cargo volumes in the near future and it is not ideal for the terminal to continue leaving laden reefers unstacked especially if non-refrigerated cargo volumes are also increasing in parallel. Stacking of containers as high as possible in the future is an important requirement in the future in order to maximise the land available within the terminal if the targeted 750,000 TEUs per annum yard capacity is to be achieved.

Large container terminals with a large portion of reefer container throughput volumes will traditionally be stacked four to five high with the reefer sockets mounted on a steel frame structure at one end of the stack known as a ‘reefer rack’ as shown in Figure 41 opposite. Terminal operation staff will have safe and easy access to the reefer plugs and sockets. However, this method of storing reefers is expensive to install and operate since it is normal for reefer container stack in this manner to be handled via RTGs or rubber rail mounted gantry cranes (RMGs).

For smaller scale reefer operations and volumes, more economical solutions for stacking refrigerated containers are available. One such solution is implemented at the Maher terminal in New York where by the reefers are stacked three high in single rows for straddle carrier operations as shown in Figure 42 opposite. Instead of installing a reefer rack to provide reefer sockets and access to the containers, the Maher refer terminal has installed steel masts alongside the stacked reefers where the sockets are attached. Access to the reefer plugs and sockets are carried out using cherry pickers or mobile elevated platforms.

The Maher reefer yard solution has been considered in the planning process for the new refer yard arrangements for the Port of Wilmington. However, adjustments have been made to accommodate reach stacker operations.

Figure 41: Reefer Racks

Figure 42: Reefer Yard at Maher Terminal N.Y.

3. Proposed Port Improvements

3.4 Intermodal Yard Improvements

3.4.1 Introduction

In July 2017, after a 30-year absence, intermodal rail service returned to the Port through the Queen City Express (QCE), which connects to CSXT intermodal's facility in Charlotte. In addition, with the construction and opening of the Carolina Connector (CCX) intermodal terminal in Rocky Mount in the future, new intermodal service will be introduced to feed into what will be an East Coast rail hub for CSXT. Based on these significant rail developments within the region, Port of Wilmington are set to capitalise on the potential to transport containers in and out of the new intermodal facilities and in order to do so, upgrades to the current rail infrastructure in the container terminal is required. Depending on how quickly the new intermodal services can be constructed the Port of Wilmington is set to potentially switch up to 25% of all container throughput volume to rail. However, it appears that the implementation plan for CCX may take longer than anticipated and therefore, the remit for the intermodal yard planning is reduced down to 8% with a view for expansion in the future.

As stated in Section 2.2.5 of this Report, the current layout of the rail tracks which serve the container terminal are is not suitable for future intermodal use, these factors being as follows:

- ❑ Container track being on a bend is not ideal for loading or unloading of boxes.
- ❑ Total length of container track1 and 2 combined does not provide enough for a 8% modal split.
- ❑ Security infrastructure is not in place to operate intermodal operations.

Therefore the new intermodal yard will consist of serval upgrade items which can be broken down in to the following:

- ❑ New rail siding locations and orientation to accommodate 5,000 foot trains.
- ❑ Security provisions for entering and exiting of containers including radiation scanning facilities.
- ❑ Operation of the intermodal yard and how boxes will be loaded and unloaded.
- ❑ Equipment numbers to serve the intermodal yard.

3. Proposed Port Improvements

3.4 Intermodal Yard Improvements

3.4.2 Intermodal Yard Layout

Mott MacDonald have previously produced concept intermodal yard layout options and this work was captured in Mott MacDonald's Report titled, Wilmington Rail Improvements – Landside Rail Improvements Serving the Port and Moving Trains Safely through the Community, 2017, September 6th. Option 6 as shown in the figure opposite has been adopted for this Yard Improvement Project and further refined to incorporate the security and detailed operational requirements. Although intermodal yard Option 7 was recommended in Mott MacDonald's Rail Improvement Report, Option 6 was found to be more compatible with the overall yard improvement constraints uncovered following the detailed yard improvement studies carried out for this project.

Option 6 has the following advantages and disadvantages:

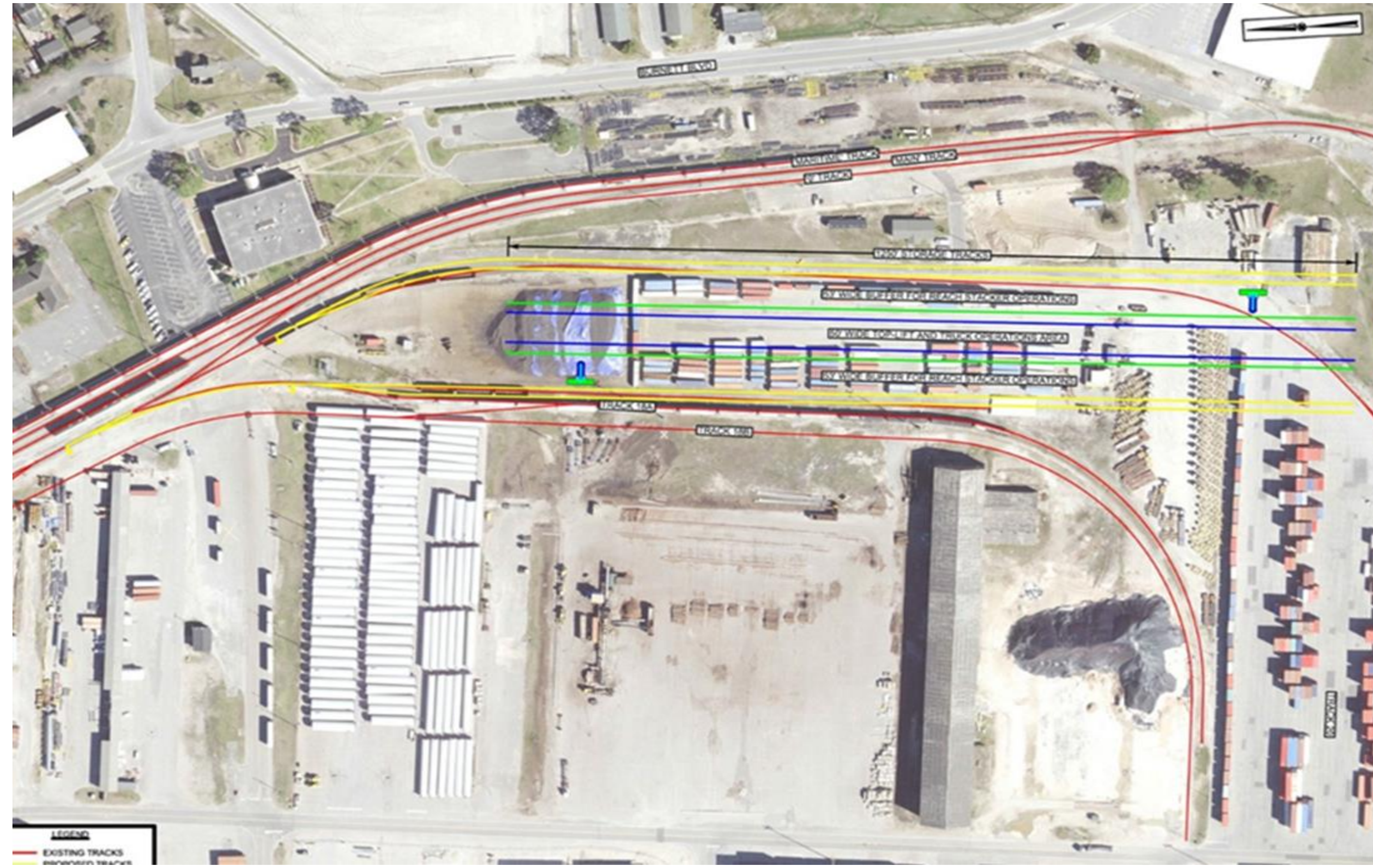
Advantages:

- ❑ Allows for all working tracks to be occupied during operations.
- ❑ Not required to move the Ports America and 1st Seaman's buildings.
- ❑ Potential to integrate with tracks 18A/B in the short term.

Disadvantages:

- ❑ Potential congestion in the transfer area.
- ❑ Not as efficient with transfer area separated from the main terminal.
- ❑ Unused space between the east side of the intermodal yard and the East boundary of the terminal.
- ❑ Limited ability to convert to RMG operations in the future

Figure 43: Mott MacDonald's Intermodal yard Concept Layout 2017



It is assumed that reach stackers will be used in the intermodal yard and will operate over four sidings serving a 5,000 feet train which in turn has the capacity of 385 TEUs per train. Assuming that trains will once a day over a five day week, the total annual capacity of this set up is approximately 100,000 TEUs per annum which is 13% modal split by 2025.

3. Proposed Port Improvements

3.4 Intermodal Yard Improvements

3.4.3 Intermodal Yard and Existing Tracks

Four new rail sidings which are approximately 1,250ft long are proposed to serve the new intermodal yard, These sidings will be installed in pairs, with the first set adjacent to container track 1 and the second set adjacent to track 18. The tracks pairs of sidings are separated – leaving approximately 156 feet in between for the sole use of reach stacker loading and unloading operations. The following changes are proposed:

Container Track 1:

It is envisaged that container track 1 will need to be modified with the current 1000 foot bend be removed and then extended south by 300 feet from the point of truncation. This is required to facilitate the new intermodal entrance and exit gates and to aid free flowing TICO trucks in and out of the intermodal yard.

Track 18:

Track 18 can be retained in this proposed intermodal yard set up. All proposed works to track 18 can be retained without any abortive work, there is potential to also extend track 18 if required to compensate for the length of track removed from the track 1 bend.

Track 18a and 18b: Both tracks 18a and 18b (Enviva line) can be retained including their respective rail bends. The rail bends naturally act as demarcation and physical barrier for the intermodal yard and adjacent container terminal.

Buffer yard: An intermodal buffer yard is proposed as shown in the figure above. The buffer yard is for the lay down of export and import boxes destined for the intermodal yard. The buffer storage will allow TICO trucks to be decoupled from the productivity of the reach stackers and will reduce the number of reach stackers and TICO trucks required to serve the intermodal yard.

3. Proposed Port Improvements

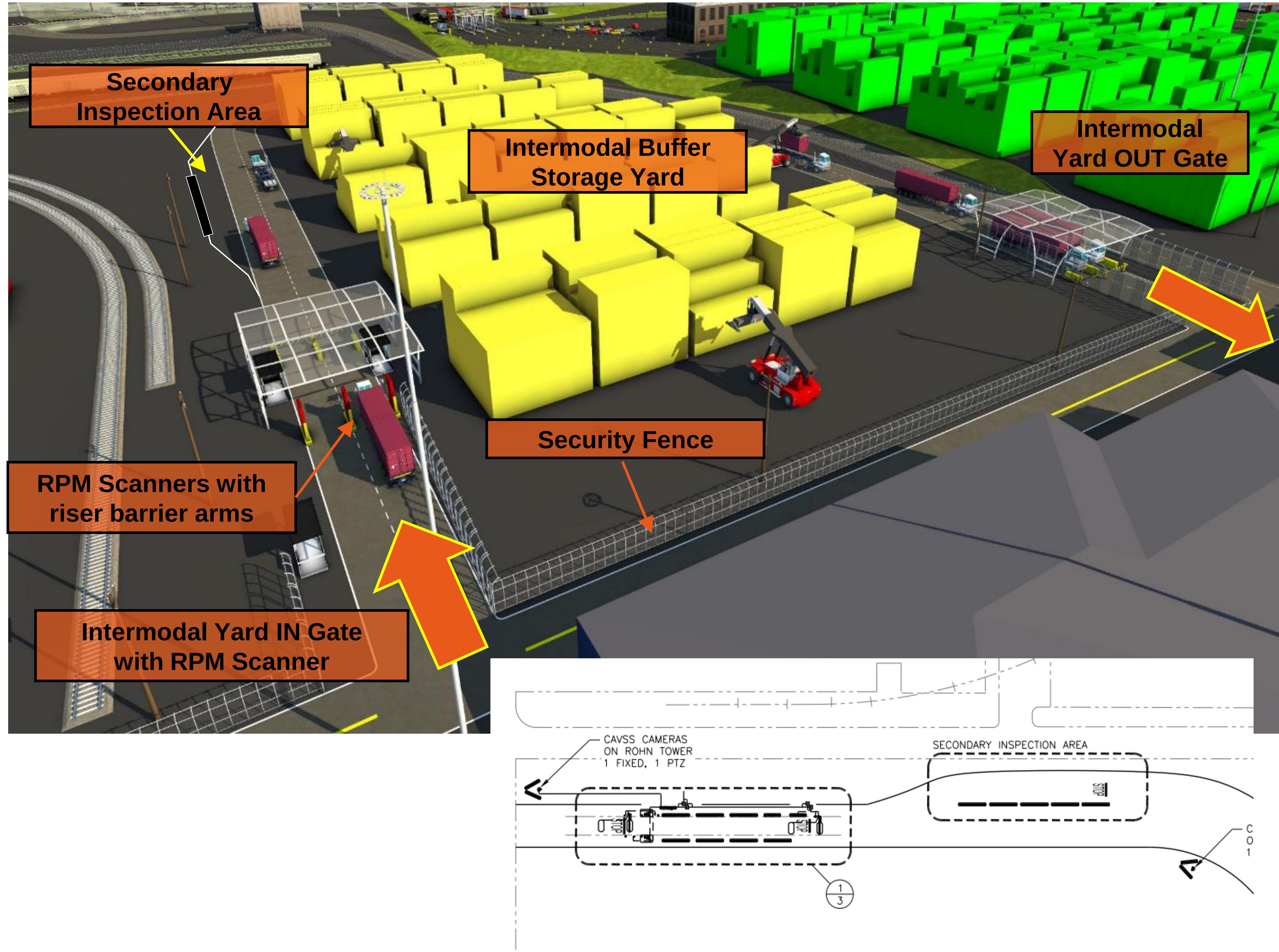
3.4 Intermodal Yard Improvements

3.4.4 Intermodal Yard Security

In accordance with the Department of Homeland Security and CBP, all imported containers must be scanned for radiation and other nuclear threats before the boxes can leave the Port. This requirement will apply to the containers transported out of the intermodal yard. Looking at the proposed intermodal yard layout as presented earlier in this section of the report, several possible options that allow container to be scanned before they are loaded on to the well cars were considered and these are presented in the Section 4.4.4 of the Inception and Basis of Planning Report. Having reviewed all the options available, the final layout proposed for the intermodal entrance and exit is shown in the Figure 44 opposite.

Dedicated entrance and exit gates will be set up either side of the buffer storage area with the entrance gate being north of the buffer yard whilst the exit gates will be located south of the buffer storage. Each gate will have 2 lanes for access whilst the entrance gate will require RPM scanners prior to entry. All TICO trucks which bring boxes into the intermodal yard will first be scanned for radiation at the main entrance gate. If the scan reveals anything suspicious, the trucks will need to be pulled aside and examined further in a secondary inspections area.

Figure 44: Intermodal Yard Entrance and Exit Points



3. Proposed Port Improvements

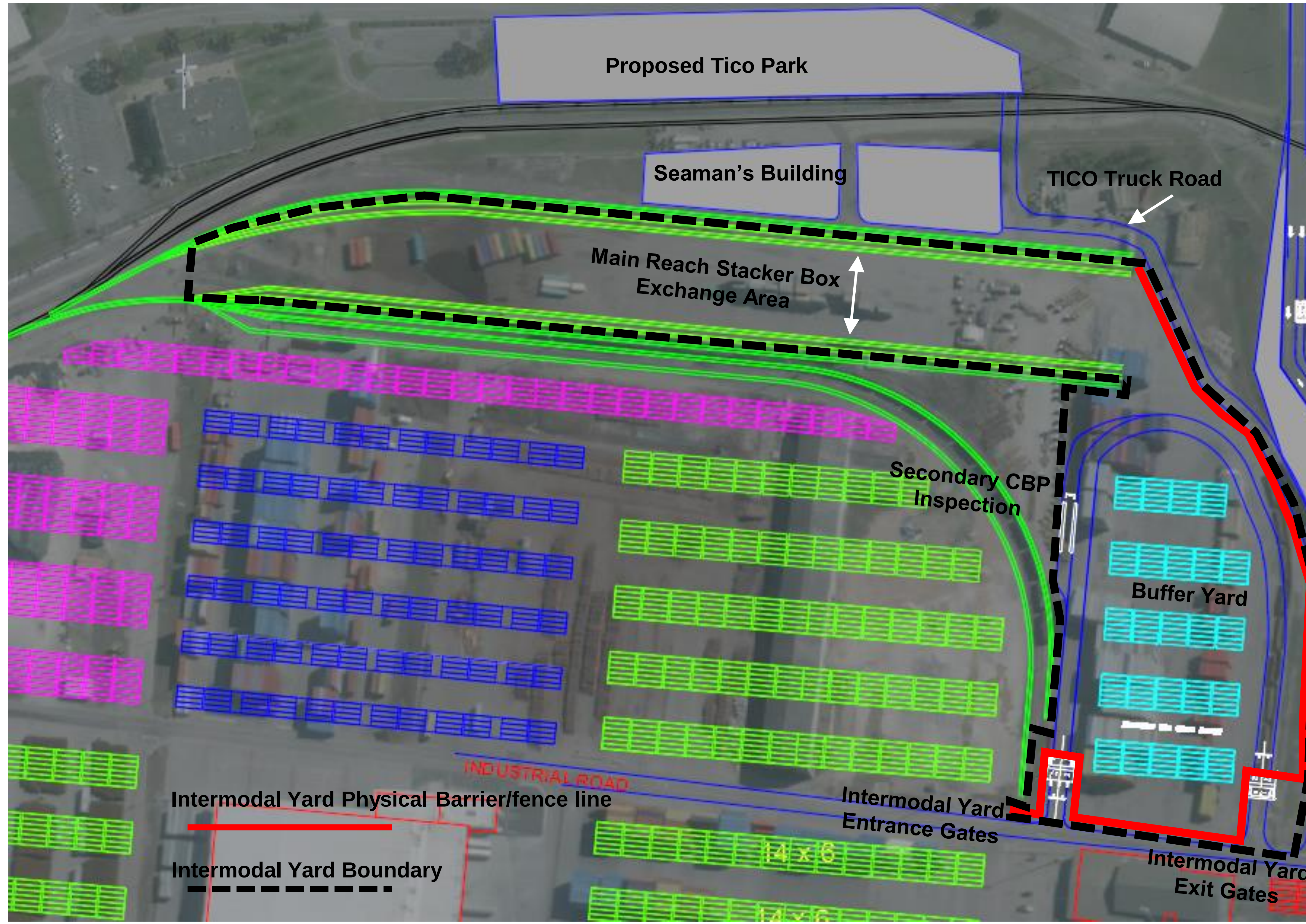
3.4 Intermodal Yard Improvements

3.4.5 Intermodal Yard Boundaries

Figure 45 opposite shows the plan overview of the proposed intermodal yard layout. The total area encapsulated by the intermodal yard boundary is approximately 9 acres.

Physical barriers are proposed to ensure trucks cannot enter or leave the main yard area without first going through the intermodal yard gates. However, it is envisaged that full length fence or vehicle barriers will not be need along the entire perimeter of the intermodal boundary since the existing rail tracks will be utilised as physical obstructions as shown in the figure opposite. Therefore it is proposed that fence or heavy duty vehicle barriers will be installed only along the entrance boundary of the intermodal yard gates and along the proposed TICO truck access road as presented in the figure opposite.

Figure 45: Intermodal Yard Boundaries



3. Proposed Port Improvements

3.4 Intermodal Yard Improvements

3.4.6 Intermodal Yard Operations

It was established that all containers leaving the terminal and transported via rail must be scanned for radiation prior to loading on to well cars. The main logistics for containers to enter and exit the intermodal yard will be via TICO truck transportation. Since the container is attached to the chassis at all times, there are two options for scanning the box.

- **Option A:** Truck based RPM scanners whereby the box is driven through RPMS and the TICO truck will enter into the intermodal yard.
- **Option B:** Container Conveyor System – As utilised in the Los Angeles Port Terminal, containers are transferred into the intermodal yard via conveyor belt systems without the need of the TICO truck to enter.

A description of the truck and box logistics for each option is provided in the next section.

Figure 46:Option A: Truck Based RPM Scanner

Figure 47:Option B: Container Conveyor System

3. Proposed Port Improvements

3.4 Intermodal Yard Improvements

Intermodal Yard Operation – A (Reach Stacker Dominant, utilising conveyor belt technology)

An illustration of the proposed box transfer operation in Option A is shown below:

Unloading Trains

Reach Stackers (1) offloads train to buffer area

Reach Stackers (2) take from buffer area to conveyor

Conveyer takes boxes out of yard

Reach Stacker (3) picks up boxes and adds to stack

Loading Trains

Reach Stacker (4) picks up boxes from stack and takes to conveyor

Conveyer takes boxes through scanner and into yard (5)

Reach Stackers (6) take from conveyor to buffer area

Reach Stackers (7) onload to train

3. Proposed Port Improvements

3.4 Intermodal Yard Improvements

Intermodal Yard Operation – B (Reach Stacker & TICO)

An illustration of the proposed box transfer operation in Option B is shown below:

Unloading Trains

- Reach Stackers (1) offloads train to TICO truck
- TICO Truck drives to stack (2)
- Reach Stacker (3) picks up box from TICO and adds to stack or….
- TICO returns to yard via exit gates with box(4)

Loading Trains

- Reach Stacker (5) picks up boxes from stack and loads to TICO
- TICO Truck drives through RPM scanner (6)
- TICO Truck drives to rail sidings (7)
- Reach Stackers (8) onload to train

3. Proposed Port Improvements

3.4 Intermodal Yard Improvements

3.4.7 Intermodal Yard Operation Options Comparison

The unloading and loading process and the positives and negatives of the two main methods of operation investigated are show in in Table R. As the relative cost of purchasing and operating reach stackers in much larger than for the TICO trucks, Option B was selected as the preferred method of operation. In addition the conveyor belt technology, although utilised in other ports, may be difficult to procure since it is a bespoke piece of technology which is not readily available on the market. Therefore Option B has been taken forward for further simulation modelling to ascertain the performance metrics for this option.

Table R – Comparison of Intermodal yard Operations

Option	Unloading Process	Loading Process	Positive	Negative
A– Container Conveyor System	1. Reach Stackers (1) offloads train to buffer area. 2. Reach Stackers (2) take from buffer area to conveyor. 3. Conveyer takes boxes out of yard. 4. Reach Stacker (3) picks up boxes and adds to stack.	1. Reach Stacker (3) picks up boxes from stack and takes to conveyor 2. Conveyer takes boxes through scanner and into yard 3. Reach Stackers (2) take from conveyor to buffer area 4. Reach Stackers (1) onload to train	• Do not tie up TICOs scanning though RPM scanners • No mixed vehicles in the intermodal yard.	• New Conveyor system required to be precured. • Double handling of boxes produced inefficiency. • Stress on paving due to heavy Reach Stackers. • Lots of Reach Stackers operating in the same area, including turning and reversing, - greater risk
B - Truck Based RPM Scanner	1. Reach Stackers (1) offloads container from train to TICO truck. 2. TICO truck drives to Stack. 3. Reach Stacker (2) picks up box from TICO and adds to stack. 4. TICO returns to sidings.	1. Reach Stacker (2) picks up boxes from stack and loads to TICO. 2. TICO Truck drives through RPM scanner. 3. TICO Truck drives to rail sidings. 4. Reach Stackers (1) onload to train.	• Reduced numbers of Reach Stackers required. • Utilise existing TICO resources. • Reduced double handling of boxes.	• Trucks required to make a U-turn in between the rails. • More staff utilised

3. Proposed Port Improvements

3.4 Intermodal Yard Improvements

3.4.8 Intermodal Operations Simulation (Option B)

For the model, the following assumptions are used within this model:

- *Time to load/unload train is considered the critical factor of the* model. It is assumed that 8 hours maximum for Reach Stacker loading/unloading.
- Reach stackers are dedicated to the railway sidings for the entire process.
- The intermodal yard stack is sufficient to allow it to operate separate from the yard, with yard reach stackers (considered as part of the global model) .
- TICO Speed in this area = 10 miles per hour due to large volume of traffic.
- Trains are assumed full (385 TEU Export off train & 385TEU Import onto train.
- Import & Export processes are considered independent and do not occur concurrently.
- The processing times for the Reach Stackers and the RPM scanner is shown in the Tables S and T.

Table S: Assumed Scanner Processing Time

PROCESSING TIMES	SCANNER
Distribution	TRIA
Minimum (mins)	0.5
Mean (mins)	1
Maximum (mins)	1.5
Nb. Assumed value with improved TOS.	

Table T: Assumed Reach Stacker Processing Times

PROCESSING TIMES	REACH STAKERS – INTERMODAL	REACH STAKERS – YARD
Distribution	TRIA	TRIA
Minimum (mins)	3	1
Mean (mins)	5	2
Maximum (mins)	5	4

3. Proposed Port Improvements

3.4 Intermodal Yard Improvements

3.4.9 Intermodal Simulation Results

The results of the simulation are presented in Table U. A single RPM scanner is assumed with a speed which is conservatively more than taken of the gate process to take account of any additional administration that may be required.

As the gates are now sufficiently fast, the process could be completed as the container enters the intermodal yard, removing one process from the operation. The result from this model is not significantly different from the model with the scanner, and the same number of Reach Stackers and TICO trucks are required.

Table U: Final Output results for Option A

Inputs and Results – Option A: Truck Based RPM Scanner	
Number of Reach Stackers Intermodal Sidings	4
Utilization	15.6%
Time to unload	4
Time to load	3
Average RS used for Unloading	4
Average RS used for Loading	4
Queues for Loading Train Avg/max	3.5min/7min – TICOS waiting
Total Time < 8 hours	**YES**

Table U: Final Output results for Option A

Inputs and Results – Option A: Truck Based RPM Scanner	
Number of Reach Stackers Yard	3
Utilization	20%
Queue Length Average/Max	0.03/5 [Take from Stack Max = 11]
Max Queue Time(hrs) Average/Max	0.006/0.14
Average RS used for Unloading	2.5
Average RS used for Loading	2.5
Number of TICO Trucks	16
TICO Affecting Unloading	**No**
Average Waiting Time	2.3s
Max Waiting Time	4 mins
Average TICO used for Unloading	8
Average TICO used for Loading	16
Number of Scanners	**1**
Queue Length Average/Max	0.02/0.1
Max Queue Time(hrs) Average/Max	0.13/7

3. Proposed Port Improvements

3.4 Intermodal Yard Improvements

3.4.10 Intermodal Simulation –Other Considerations

The final layout of the railyard is shown in Figure Q.

Due to the need of reach stackers & TICO trucks to operate together within a single enclosed area, consideration must be made to the health & safety implications of this option. The following process for operation is recommended aim to minimise the risks:

- It is suggested that the sidings are split into areas designated for each Reach Stacker, so they will not be passing each other. No other vehicles should enter these areas.
- Only one siding will be unloaded/loaded at one time giving the TICO trucks access to the area not via the Reach Stacker working area.
- Speed limit in the railyard sidings should be reduced for both the trucks and the reach stackers.
- The trucks should pass down the opposite side to the operating reach stackers, then turn in the designated turning circle, and all pull into designated bays facing the same direction to receive the containers from the reach stackers.
- The same process is repeated for the loading of the train.

Figure 48: Final Intermodal Yard Layout

4. Yard Improvement Layout Options

Final layout options

4. Yard Improvement Options

4.1 Introduction

Having established the terminal upgrade requirements in the previous Chapter of this report, the various upgrade solutions for the main yard, terminal gate and intermodal yard have been consolidated into holistic and integrated yard upgrade layout options. All options have the following common features.

- Maximum utilisation of all available terminal space in the short and longer term for container stacking.
- All options will provide a minimum 750,000 TEU per annum capacity.
- Integration of an intermodal yard capable of handling a minimum of 8% modal split in 2025 or 60,000 TEUs per annum.
- All options will integrate an upgraded gate system with a minimum of seven in gates and six out gates utilising automation technology.
- All options will require paving upgrades which allow for high container stacking and larger stack utilisation.

The general base layout for all options is such that empty containers are located near the terminal gates such that trucks will not have to enter deep into the terminal to pick up or drop off an empty box. Import and Export boxes will be situated as close to the berth as possible. The intermodal yard buffer storage will occupy present-day area A, whilst area B and C are repurposed for the new reefer yard. The layout is such that routing within the terminal is streamlined with a one-way 'ring-road' running anticlockwise around the terminal; for those trucks performing a dual-move, they can drop off their export container to the north and then pick up their import container to the south on their way to exiting the terminal.

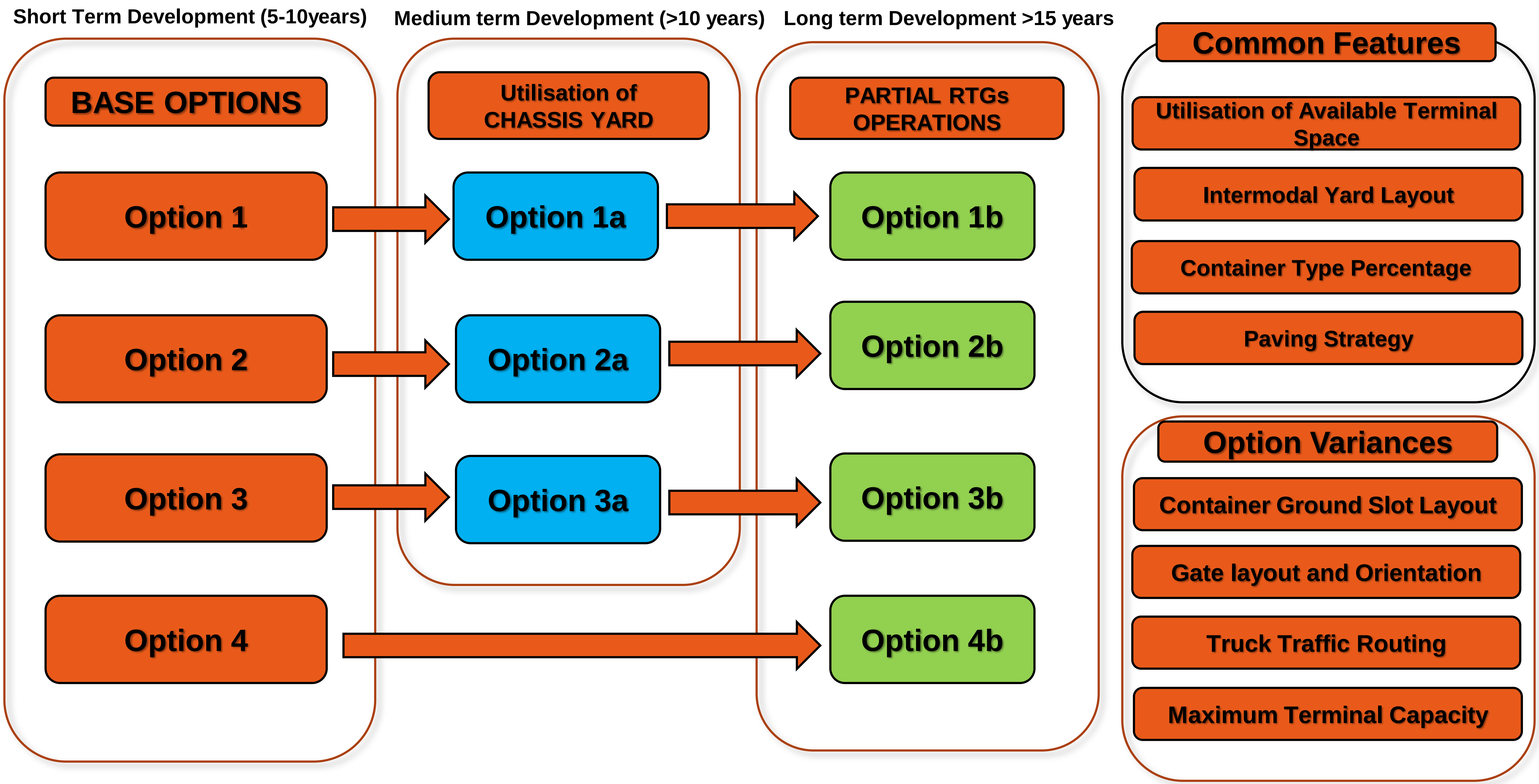
Four base options was developed which contain all of the above features. However, each option have variances in how the core objectives mentioned above are executed.

Further sub options are then extended from the base layouts by considering future expansion of the port into the chassis yard area to further increase terminal capacity.

Finally, the options are partially converted into RTG operations in yard areas F and H to further increase the terminal capacity beyond the targeted 2025 volumes.

The options and their variations are summarised in on Page 102.

4. Yard Improvements Options



4. Yard Improvement Options

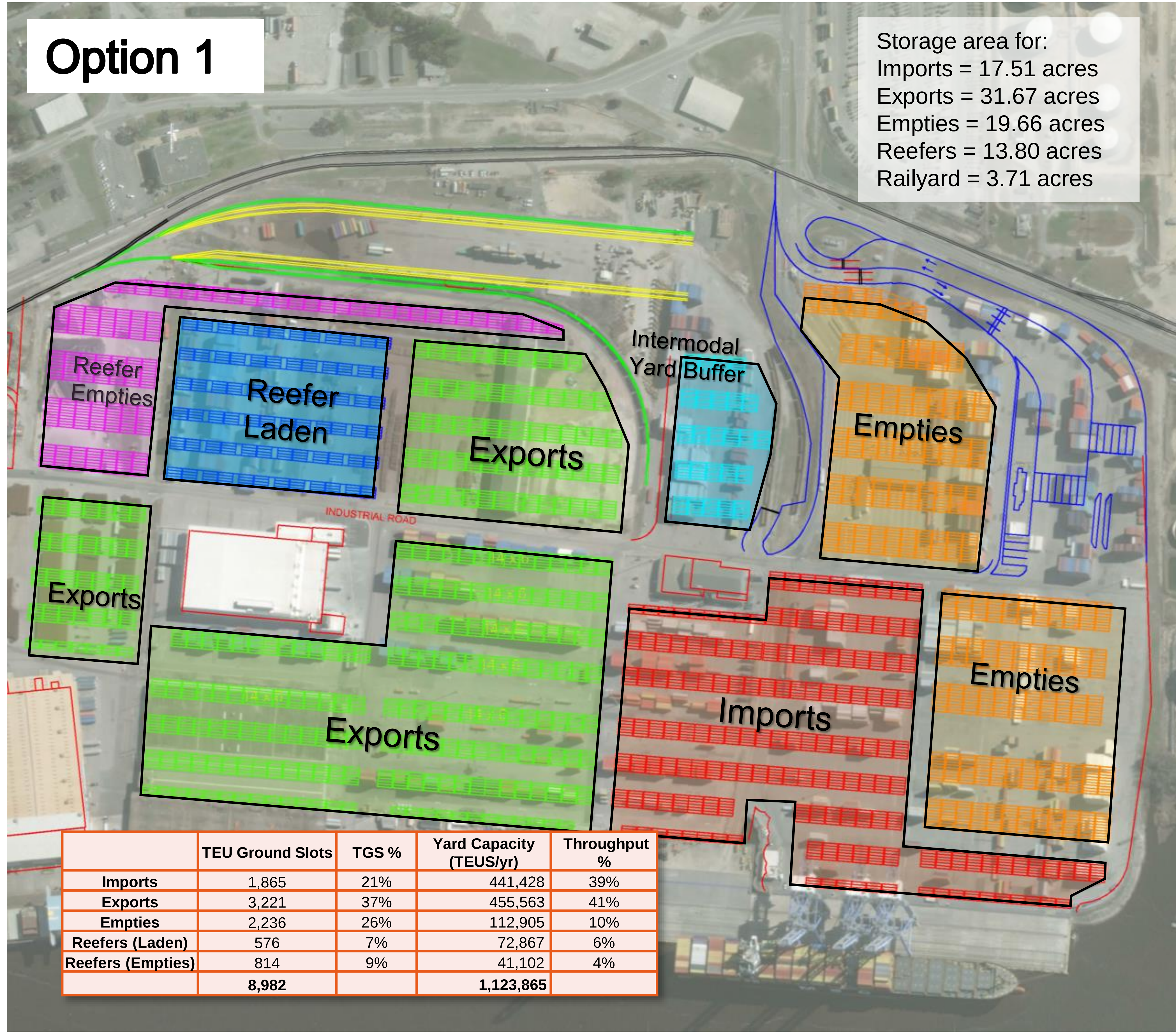
4.2 Option 1 Description

Option 1 utilises all possible terminal space available by taking back leased land such as warehouse T7, the dolomite bulk storage areas, the steel billet storage areas, the DRI building area and the timber logging facilities. The total throughput capacity for Option 1 is estimated at 1,123,865 TEUs per annum with the storage areas shown on the figure opposite.

The philosophy of Option 1 is to maximise all available terminal space within the existing boundary for increasing overall yard storage capacity. The final storage capacity achieved is in excess of the targeted 750,000 TEUs per annum. Therefore it is anticipated that the bulk storage areas, warehouse T 7 and area J do not need to be redeveloped until throughput demands exceed the 750,000 TEU figure and these areas are considered to be development projects beyond 2025.

The individual storage capacities and ground slots for each container type is given in the table opposite. The paving installed will allow for a maximum stacking height of five high laden boxes and average of four high laden boxes, five high empty boxes and a maximum stack utilisation of 70%. The terminal gates are expanded and rebuilt over the existing terminal area ‘L’. The gate will be upgraded as per the solution presented in Section 3.2 with seven in gates and six out gates, utilising automation technology.

The intermodal yard is as per the proposed solution presented in Section 3.4.4.



	TEU Ground Slots	TGS %	Yard Capacity (TEUS/yr)	Throughput %
Imports	1,865	21%	441,428	39%
Exports	3,221	37%	455,563	41%
Empties	2,236	26%	112,905	10%
Reefers (Laden)	576	7%	72,867	6%
Reefers (Empties)	814	9%	41,102	4%
	8,982		1,123,865	

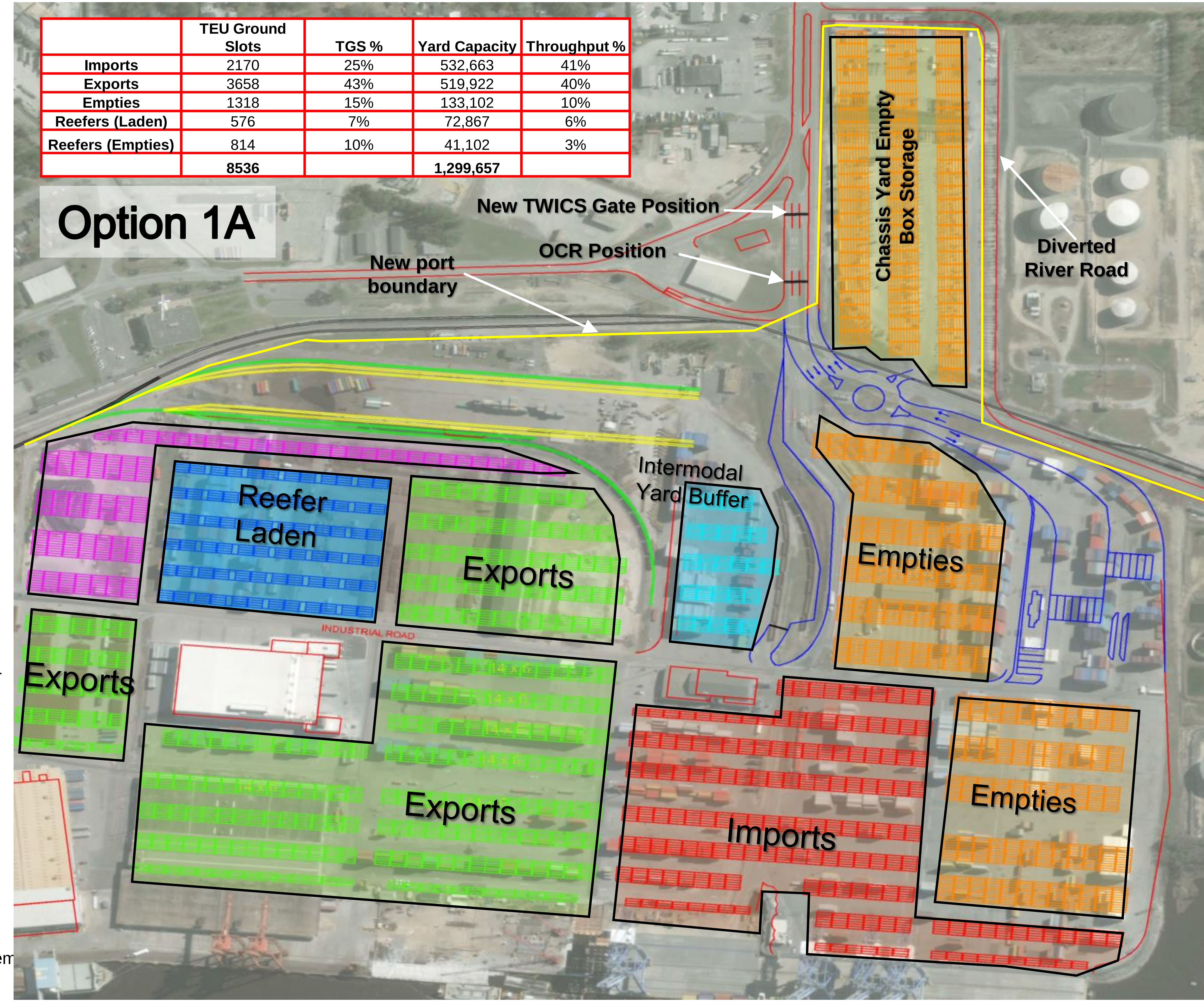
4. Yard Improvement Options

4.2.1 Option 1A Description

Option 1A extends from Option 1 by utilising the chassis yard for empty box storage. By expanding into the chassis yard, the terminal storage capacity is able to increase to 1,299,657 TEUs per annum assuming that the chassis yard will be used as an empties yard. However, in order for the chassis yard to be utilised, conditional pre-requisites exists, these are as follows:

- River road will need to be diverted around the chassis yard towards the east and re-joining Shipyard Boulevard at the east end of the chassis yard as shown on the figure opposite.
- This will allow for the terminal boundary to be expanded east wards encapsulating the land between the existing gate entrance and the chassis yard as well as a portion of the existing river road. The new boundary is represented by the yellow line in the figure opposite.
- Alterations to the access roads leading into the main gates will need further amendments such as a new round about so that trucks can be diverted into the new chassis yard area.
- A separate entry and exit gate will be required for the chassis yard empties storage area potentially with RPM scanning facilities.
- Chassis parking will no longer be made available at the port unless another area can be allocated in the future.

	TEU Ground Slots	TGS %	Yard Capacity	Throughput %
Imports	2170	25%	532,663	41%
Exports	3658	43%	519,922	40%
Empties	1318	15%	133,102	10%
Reefers (Laden)	576	7%	72,867	6%
Reefers (Empties)	814	10%	41,102	3%
	8536		1,299,657	



4. Yard Improvement Options

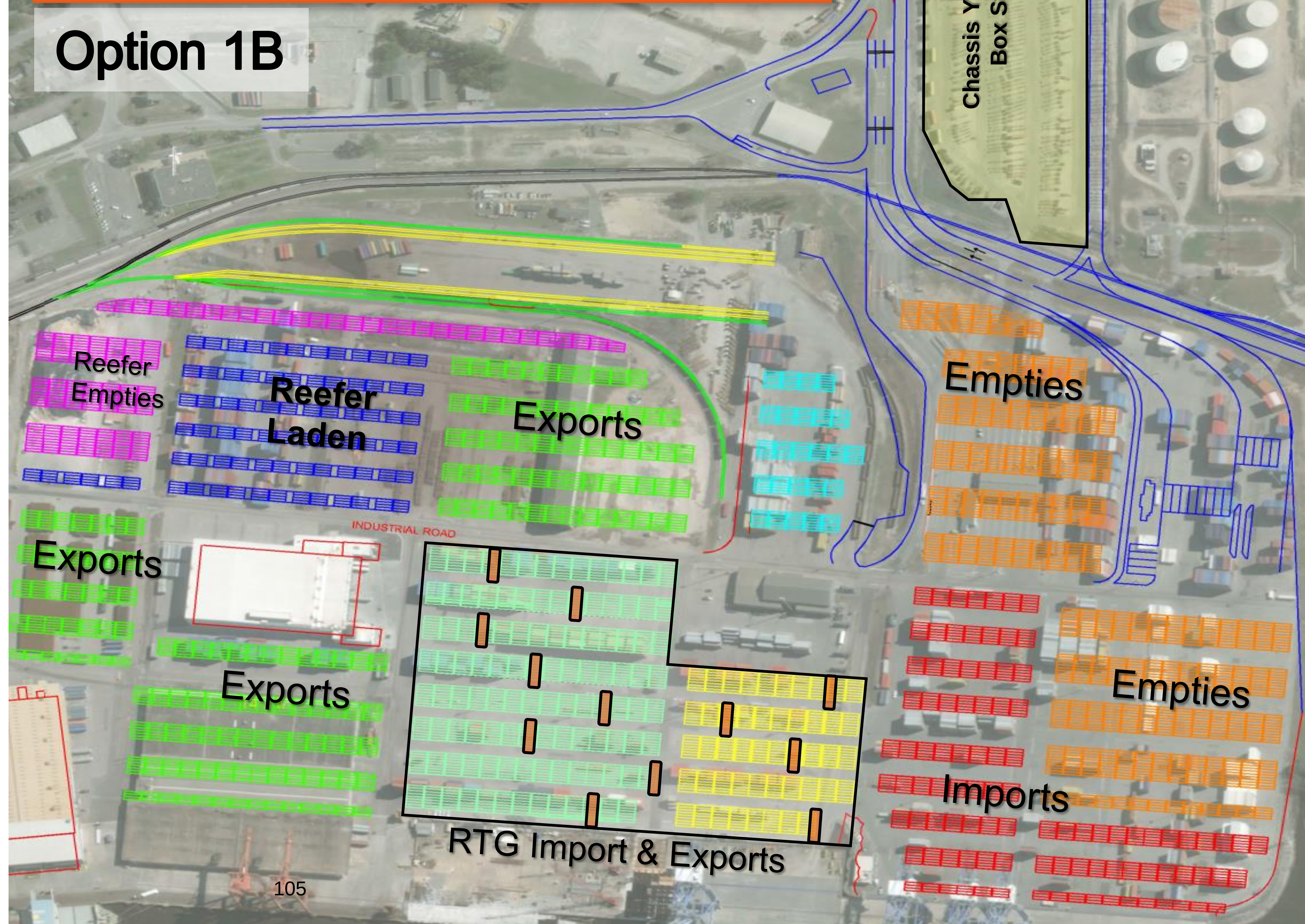
4.2.2 Option 1B Description

Should the port require an additional yard capacity increase beyond Option 1A, partial conversion of reach stacker operations into RTG stacking can be performed to further increase the container stacking densities within the terminal. Option 1B present the potential conversion of areas F and H into RTG stacks.

Providing that the paving in areas F and H are upgraded to allow for RTG expansions in mind, the changeover should not be too complicated since the requirements would only be a switch in the stack orientation which involves new line painting of ground slots. Ideally, heavy duty concrete paving should be installed for areas F and H paving upgrades however, should asphalt be used, concrete runway beams may be retrofitted for RTG operations.

A partial RTG conversion would provide an increased yard capacity to 1,494,889 TEUs per annum.

	TEU Ground Slots	TGS %	Yard Capacity (TEUS/yr)	Throughput %
Imports	1,932	21%	623,859	40%
Exports	3,228	35%	623,958	41%
Empties	2,636	29%	133,102	10%
Reefers (Laden)	576	6%	72,867	6%
Reefers (Empties)	814	9%	41,102	3%
	9,186		**1,494,889**	



4. Yard Improvement Options

4.2.3 Option 2 Description

As with Option 1, Option 2 maximises the available terminal space with in the Port of Wilmington port boundary. The total Throughput capacity for Option 2 is estimated at 1,152,647 TEUs per annum with the following storage areas:

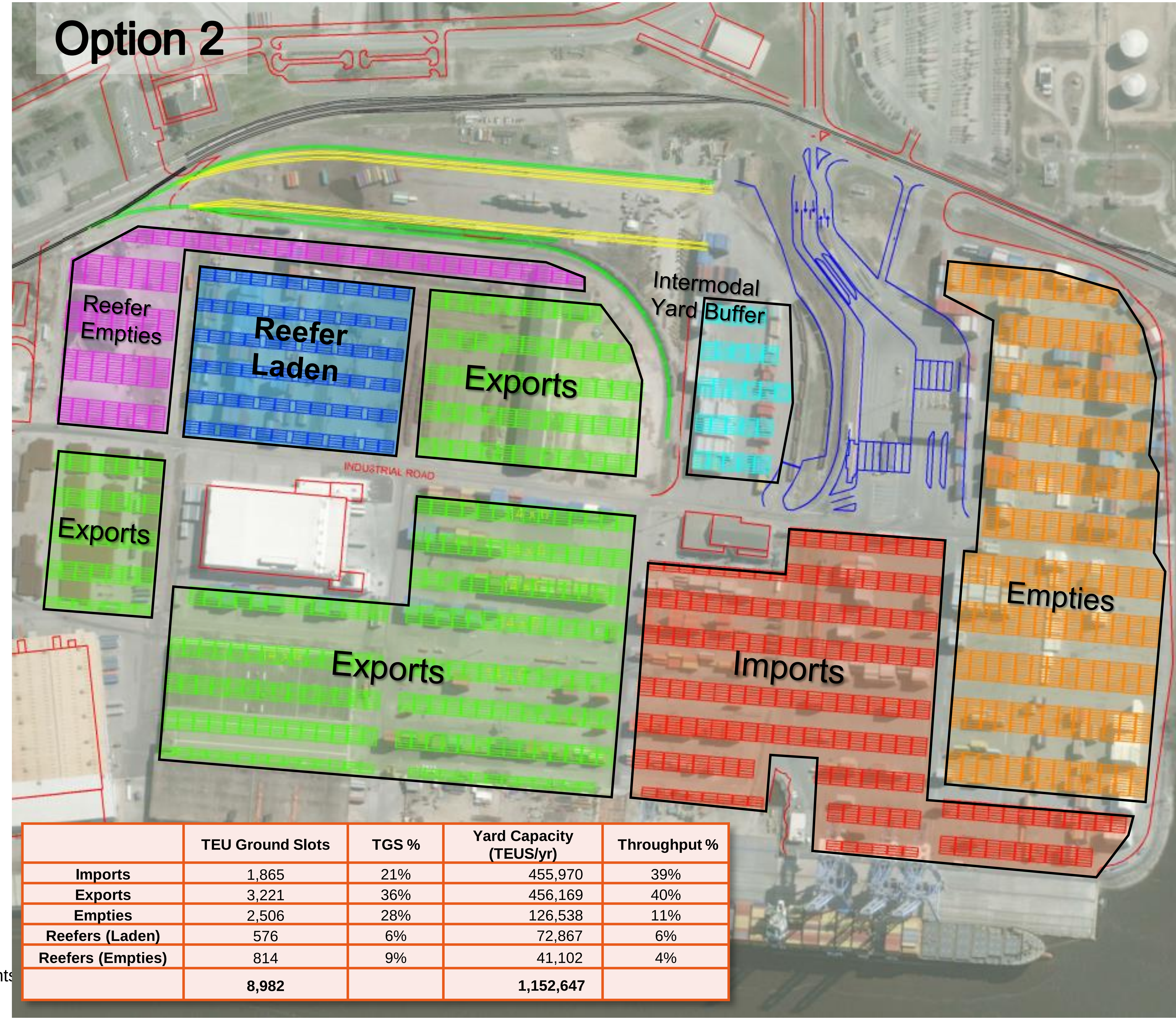
Imports = 17.51 acres.
Exports = 31.67 acres.
Empties = 20.68 acres.
Reefers = 13.80 acres.
Railyard = 3.71 acres.

The individual storage capacities and ground slots for each container type is given in the table opposite.

The paving installed will allow for a maximum stacking height of five high laden boxes and average of four high laden boxes, five high empty boxes and a maximum stack utilisation of 70%.

The terminal gates are expanded over the existing gate complex footprint. The gate will be upgraded as per the solution presented in Section 3.2 with seven 'in' gates and six 'out' gates, utilising automation technology.

The intermodal yard is as per the proposed solution presented in Section 3.4.4.



	TEU Ground Slots	TGS %	Yard Capacity (TEUS/yr)	Throughput %
Imports	1,865	21%	455,970	39%
Exports	3,221	36%	456,169	40%
Empties	2,506	28%	126,538	11%
Reefers (Laden)	576	6%	72,867	6%
Reefers (Empties)	814	9%	41,102	4%
	8,982		**1,152,647**	

4. Yard Improvement Options

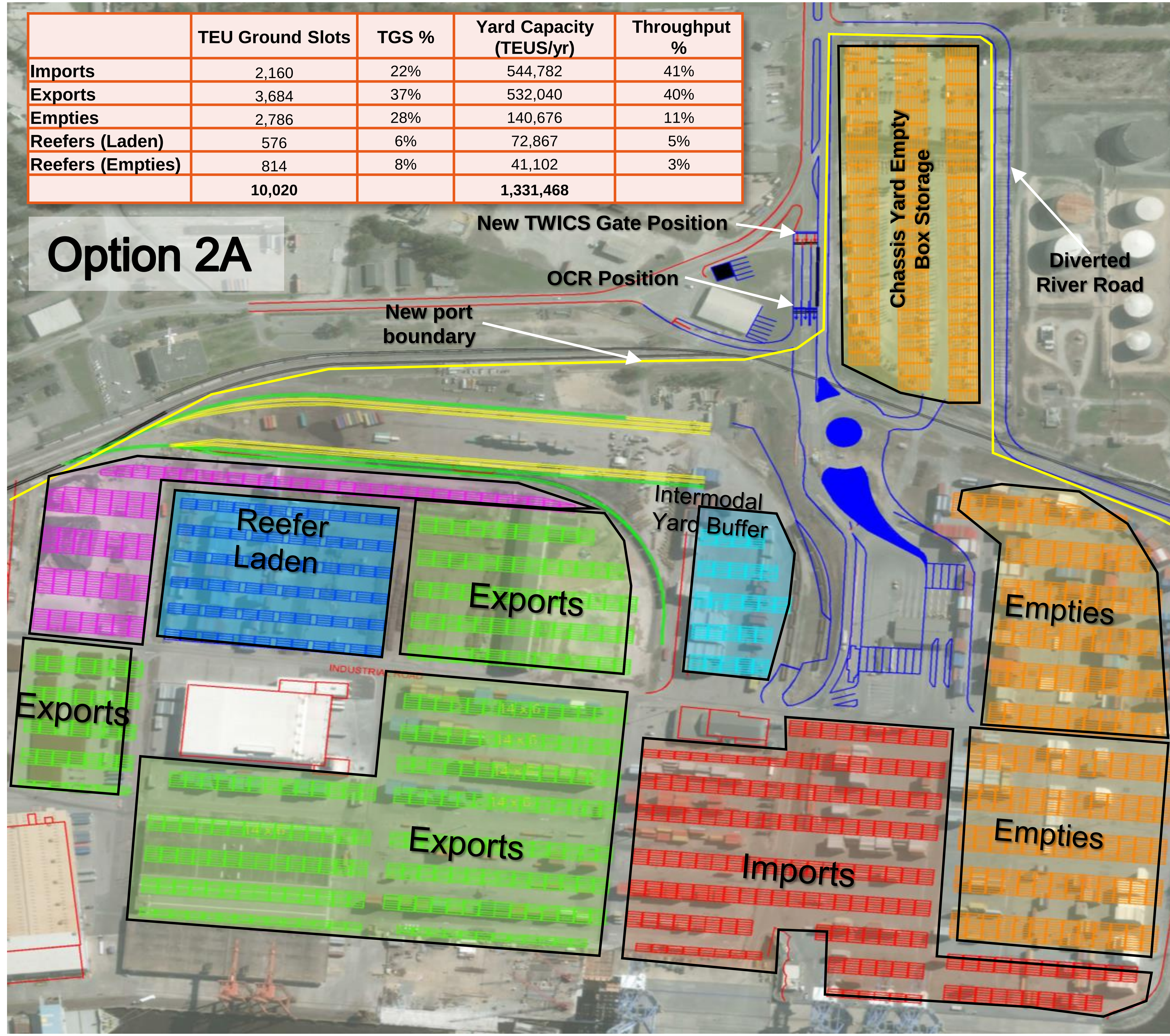
4.2.4 Option 2A Description

Option 2A is the same as Option 2 except that the chassis yard is now utilised for empty box storage. By expanding into the chassis yard, the terminal storage capacity is able to increase to 1,331,468 TEUs per annum. However, in order for the chassis yard to be utilised, conditional pre-requisites exists, these are as follows:

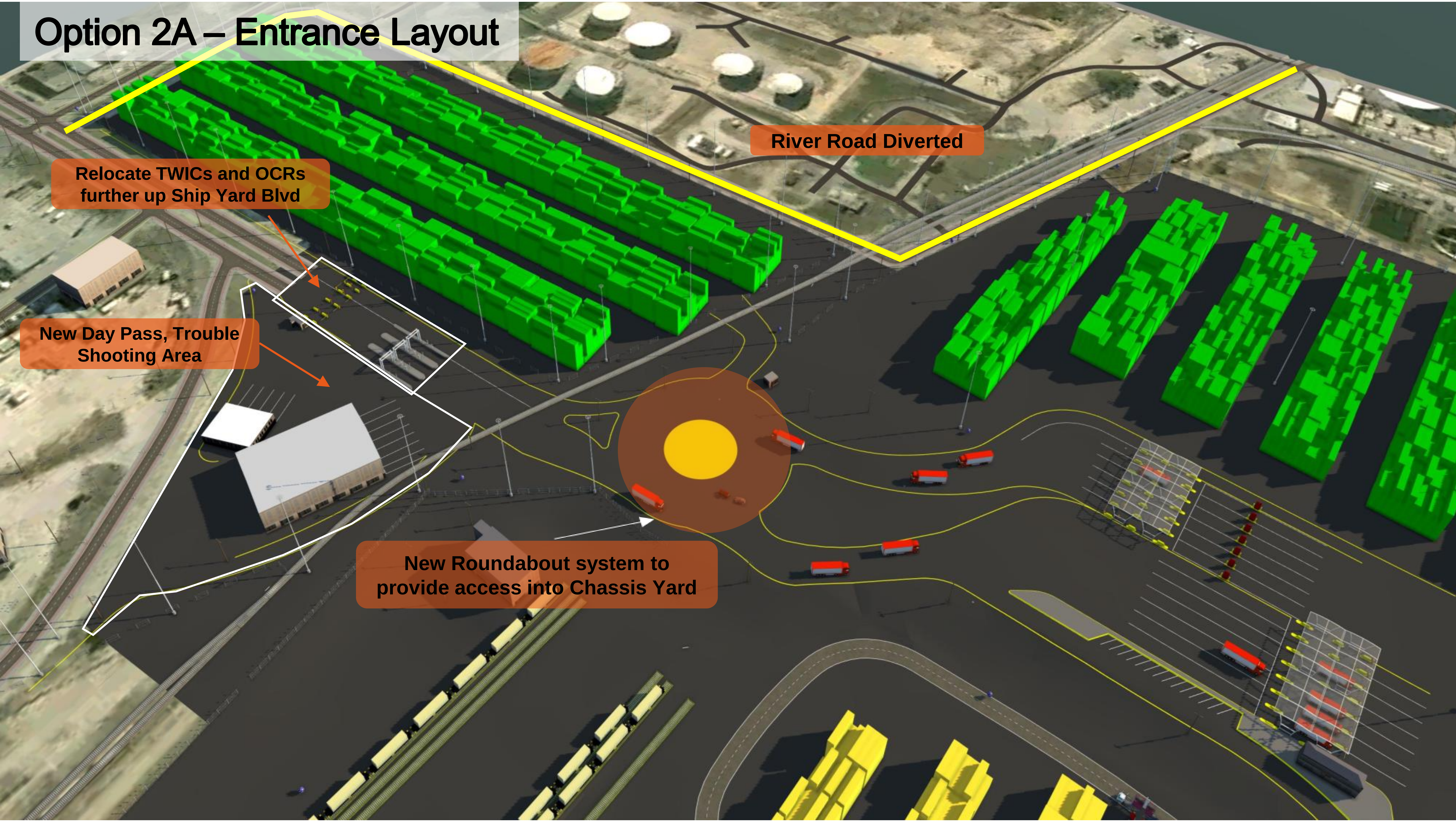
- ❑ River Road will need to be diverted around the chassis yard towards the east and re-joining Shipyard Boulevard at the east end of the chassis yard as shown on the figure opposite.
- ❑ This will allow for the terminal boundary to be expanded east wards encapsulating the land between the existing gate entrance and the chassis yard as well as a portion of the existing river road. The new boundary is represented by the yellow line in the figure opposite.
- ❑ Alterations to the access roads leading into the main gates will need further amendments such as a new round about so that trucks can be diverted into the new chassis yard area.
- ❑ A separate entry and exit gate will be required for the chassis yard empties storage area potentially with RPM scanning facilities.

The change in the terminal entrance area is shown in the figure overleaf.

	TEU Ground Slots	TGS %	Yard Capacity (TEUS/yr)	Throughput %
Imports	2,160	22%	544,782	41%
Exports	3,684	37%	532,040	40%
Empties	2,786	28%	140,676	11%
Reefers (Laden)	576	6%	72,867	5%
Reefers (Empties)	814	8%	41,102	3%
	10,020		**1,331,468**	



Option 2A – Entrance Layout



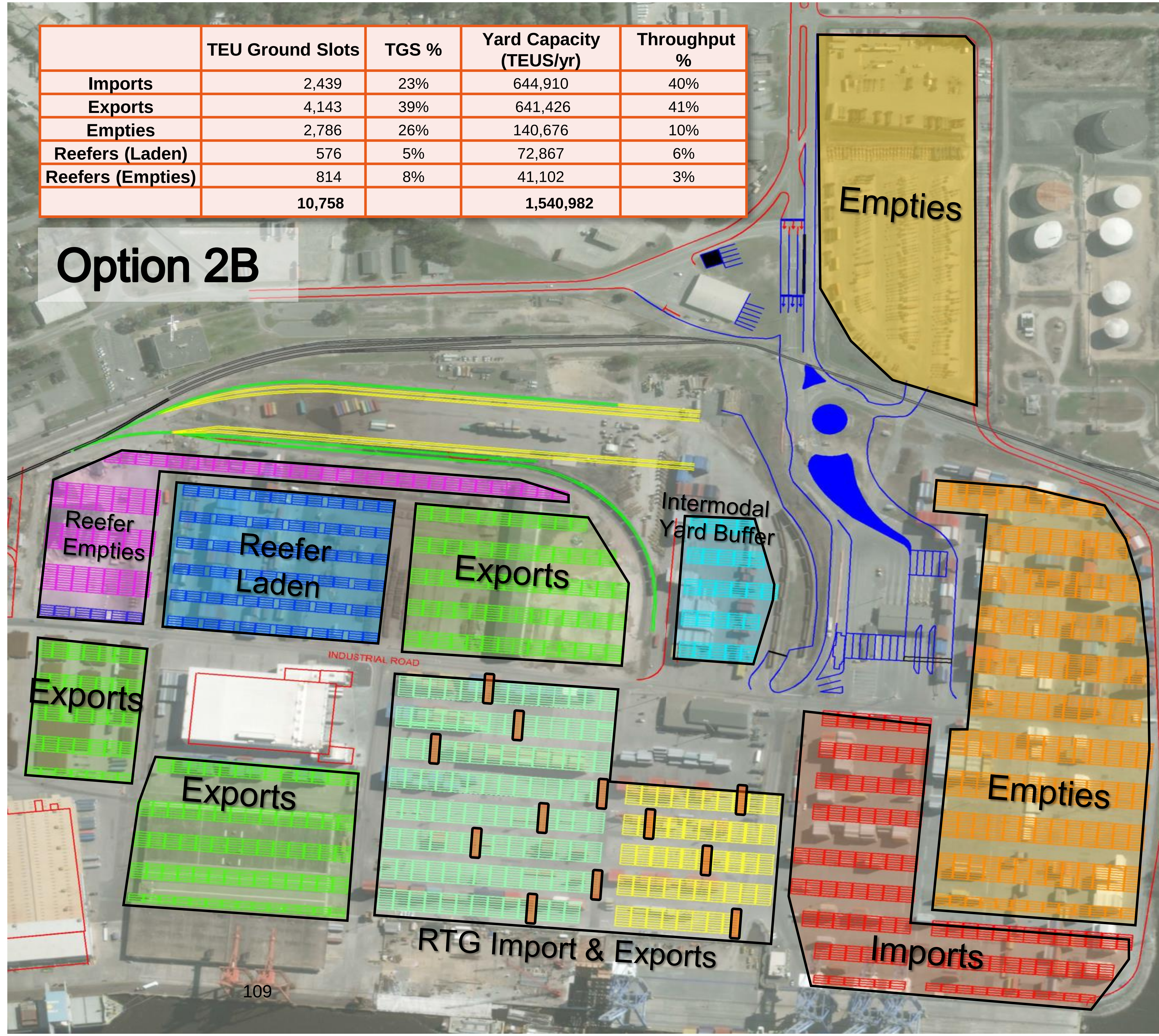
4. Yard Improvement Options

4.2.5 Option 2B Description

Should the port require an additional yard capacity increase beyond Option 2A, partial conversion of reach stacker operations into RTG stacking can be performed to further increase the container stacking densities within the terminal. Option 1B present the potential conversion of areas F and H into RTG stacks.

Providing that the paving in area F and H are upgraded to allow for RTG expansions in mind, the changeover should not be too complicated since the requirements would only be a switch in the stack orientation which involves new line painting of ground slots. Ideally, heavy duty concrete paving should be installed for areas F and H paving upgrades however, should asphalt be used, concrete runway beams may be retrofitted for RTG operations.

A partial RTG conversion would provide an increased yard capacity to 1,540,982 TEUs per annum.



	TEU Ground Slots	TGS %	Yard Capacity (TEUS/yr)	Throughput %
Imports	2,439	23%	644,910	40%
Exports	4,143	39%	641,426	41%
Empties	2,786	26%	140,676	10%
Reefers (Laden)	576	5%	72,867	6%
Reefers (Empties)	814	8%	41,102	3%
	10,758		**1,540,982**	

4. Yard Improvement Options

4.2.6 Option 3 & 3A Description

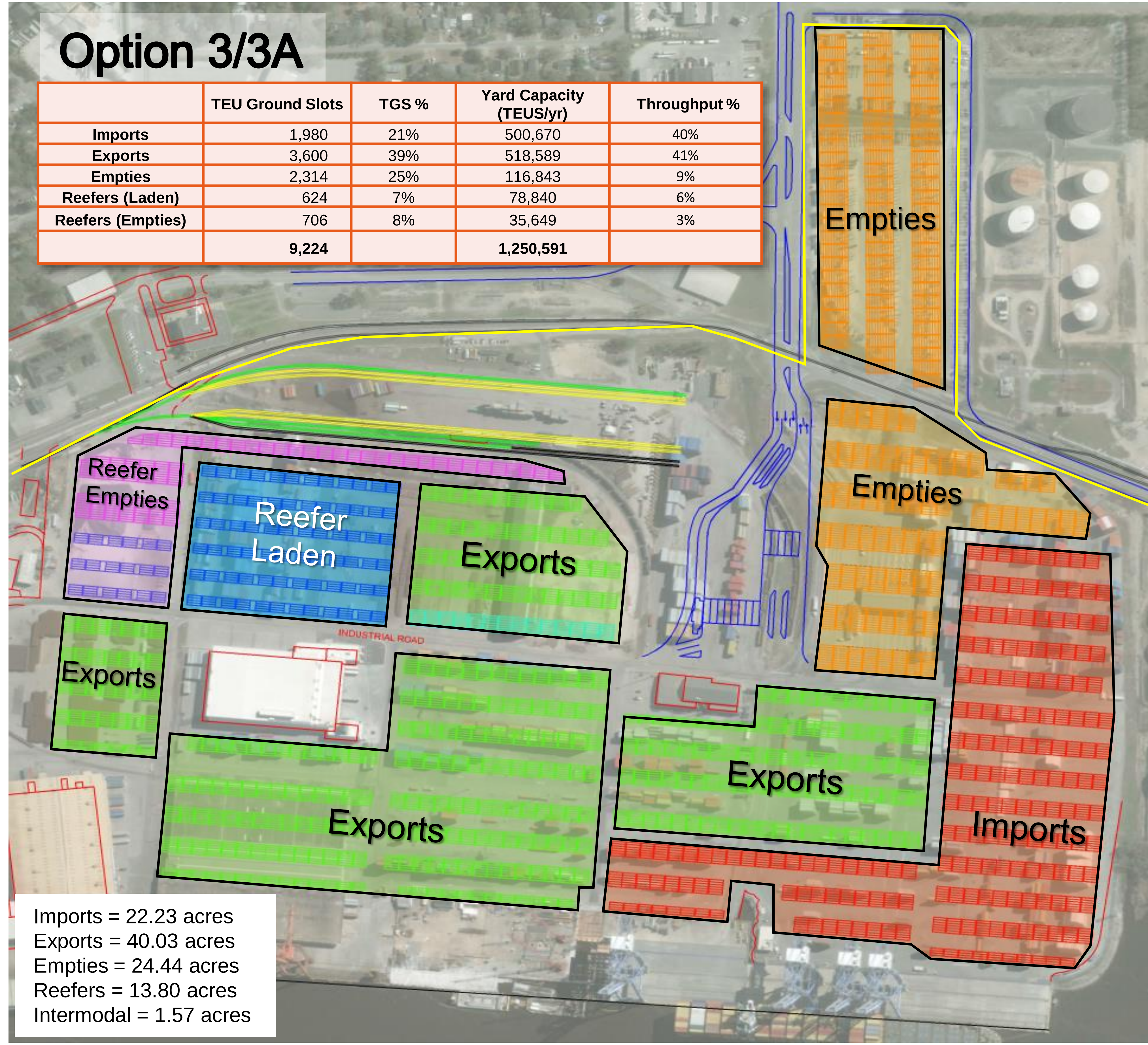
Option 3, as with the previous options, aims to maximise the available terminal space with in the Port of Wilmington port boundary. The total Throughput capacity for Option 3 is estimated at 1,250,591 TEUs per annum.

The individual storage capacities and ground slots for each container type is given in the table opposite. The paving installed will allow for a maximum stacking height of five high laden boxes and average of four high laden boxes, five high empty boxes and a maximum stack utilisation of 70%.

The terminal gates are upgraded and expanded over towards the existing storage area ’A’. The gate will be upgraded as per the solution presented in Section 3.2 with seven ‘in’ gates and six ‘out’ gates, utilising automation technology. By switching the gates over into area ‘A’ as shown in the figure overleaf, the truck entry and exit into the terminal will now be more direct in line with Ship Yard Blvd. However, the proposed location of the new gate will not allow for future extension to the intermodal sidings and will require demotion of all the rail tracks which currently curve around into the proposed gate footprint.

However, in Option 3A, where the chassis yard is to be utilised for empty box storage, the proposed gate location means that no further entrance routing amendments will be required since the incoming traffic does not cut across the entrance of the chassis yard. All other pre-requisites for utilising the chassis yard is the same as that of Option 1A and 2A. The yard capacity for Option 3A is 1,450,836 TEUs per annum.

The intermodal yard is as per the proposed solution presented in Section 3.4.4.



	TEU Ground Slots	TGS %	Yard Capacity (TEUS/yr)	Throughput %
Imports	1,980	21%	500,670	40%
Exports	3,600	39%	518,589	41%
Empties	2,314	25%	116,843	9%
Reefers (Laden)	624	7%	78,840	6%
Reefers (Empties)	706	8%	35,649	3%
	9,224		1,250,591	

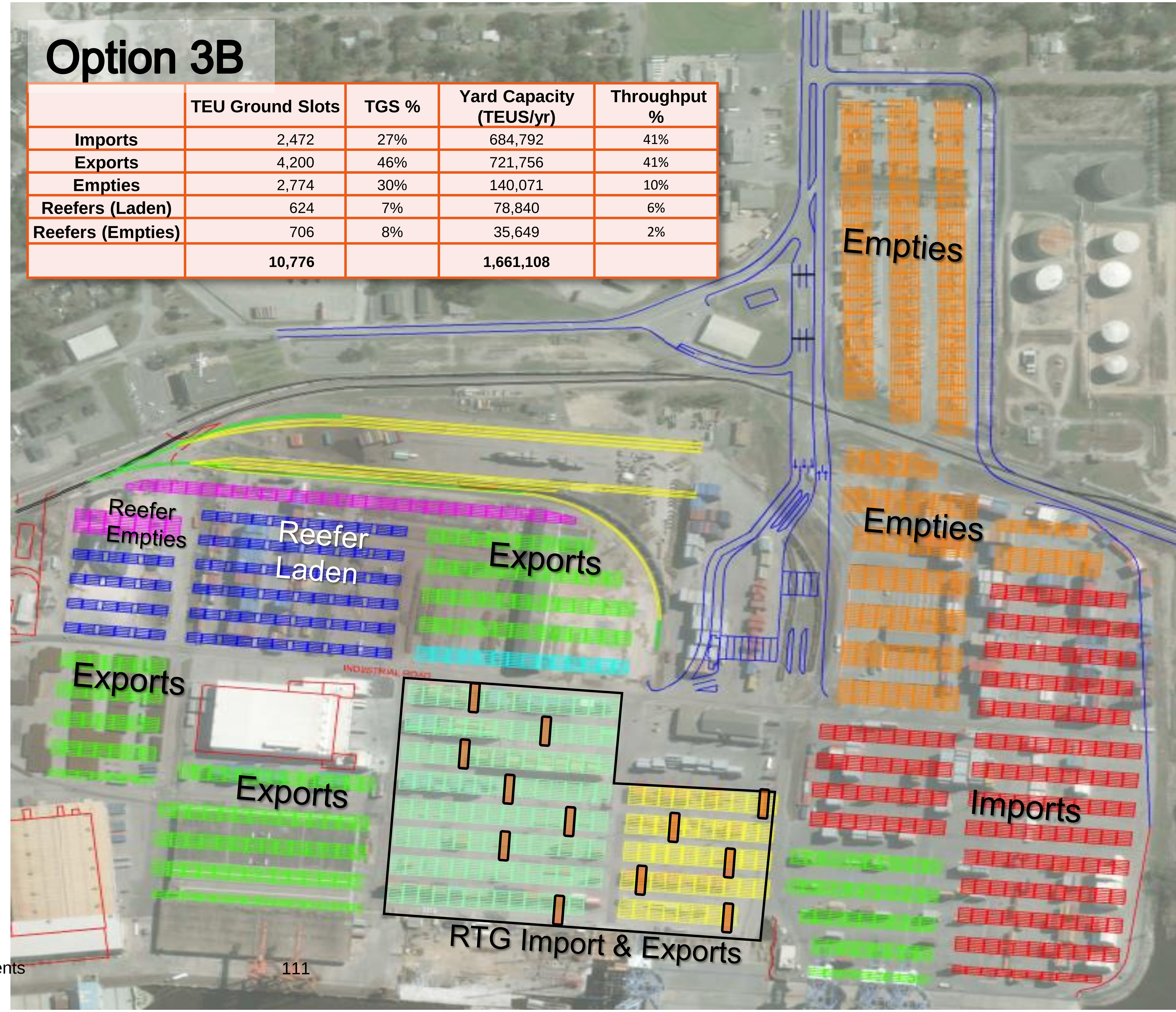
4. Yard Improvement Options

4.2.7 Option 3B Description

Should the port require an additional yard capacity increase beyond Option 3A, partial conversion of reach stacker operations into RTG stacking can be performed to further increase the container stacking densities within the terminal. Option 3B proposes for the potential conversion of areas F and H into RTG stacks.

Providing that the paving in area F and H are upgraded to allow for RTG expansions in mind, the changeover should not be too complicated since the requirements would only be a switch in the stack orientation which involves new line painting of ground slots. Ideally, heavy duty concrete paving should be installed for areas F and H paving upgrades. However, should asphalt be used, concrete runway beams may be retrofitted for RTG operations.

A partial RTG conversion would provide an increased yard capacity to 1,661,108 TEUs per annum.



	TEU Ground Slots	TGS %	Yard Capacity (TEUS/yr)	Throughput %
Imports	2,472	27%	684,792	41%
Exports	4,200	46%	721,756	41%
Empties	2,774	30%	140,071	10%
Reefers (Laden)	624	7%	78,840	6%
Reefers (Empties)	706	8%	35,649	2%
	10,776		**1,661,108**	

4. Yard Improvement Options

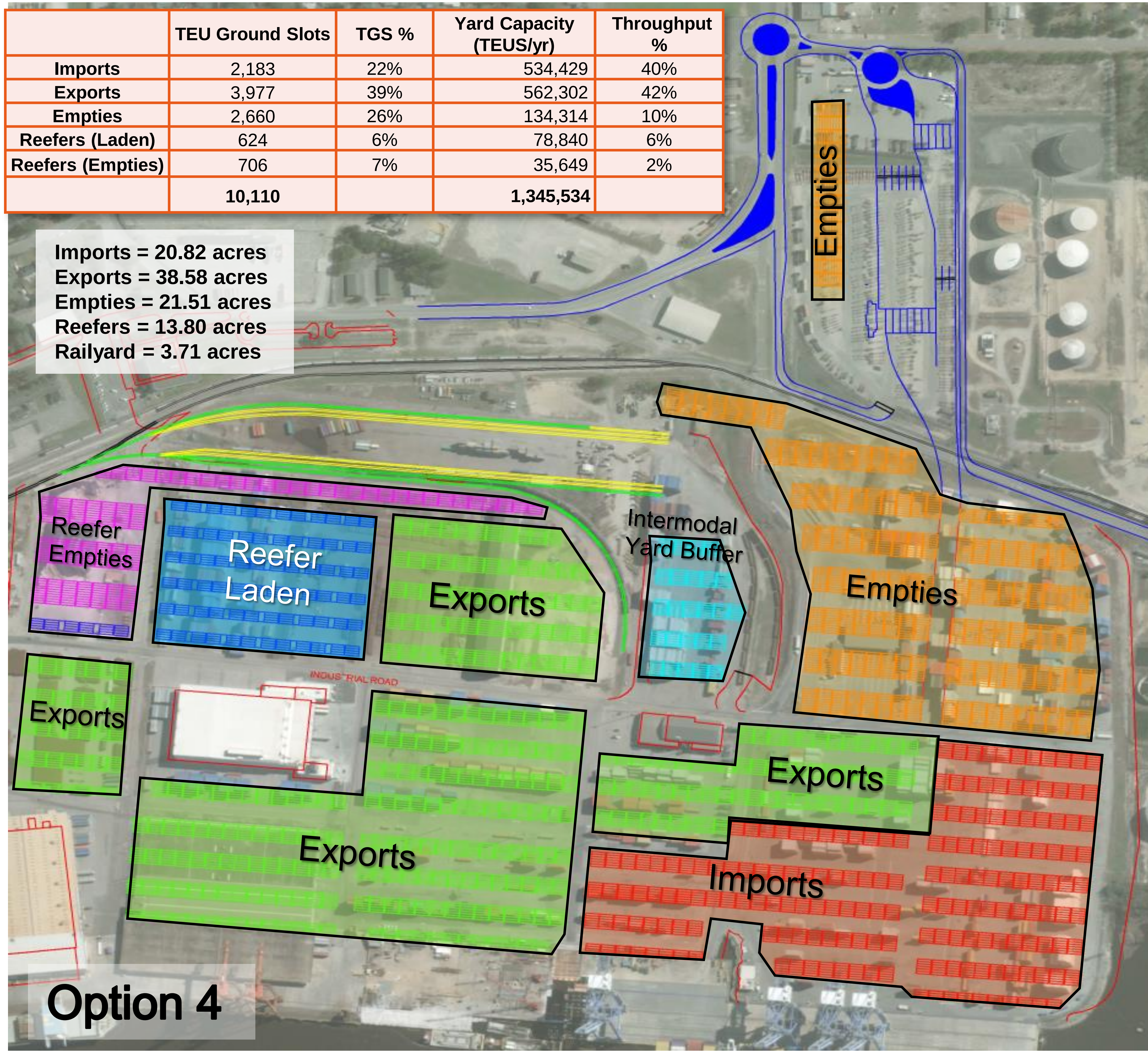
4.2.8 Option 4 Description

Option 4 not only maximises the available terminal space within the Port of Wilmington port boundary, it is proposed for the chassis yard to also be utilised for empty box storage and the relocation of the main terminal gates in the short term. The total Throughput capacity for Option 4 is estimated at 1,345,534 TEUs per annum with the storage areas presented in the figure opposite.

The individual storage capacities and ground slots for each container type is given in the table opposite. The paving installed will allow for a maximum stacking height of five high laden boxes and average of four high laden boxes, five high empty boxes and a maximum stack utilisation of 70%. The terminal gates are relocated into the existing chassis yard footprint. The gate will be upgraded as per the solution presented in Section 3.2 with seven ‘in’ gates and six ‘out’ gates, utilising automation technology. Option 4 will provide the greatest terminal capacity although it is envisaged that for the chassis yard to be developed in the short term the following project development pre-requisites will need to be completed:

- River road will need to be diverted around the chassis yard towards the east and re-joining Shipyard Boulevard at the east end of the chassis yard as shown on the figure opposite.
- This will allow for the terminal boundary to be expanded east wards encapsulating the land between the existing gate entrance and the chassis yard as well as a portion of the existing river road. The new boundary is represented by the yellow line in the figure opposite.
- Alterations to the access roads leading into the main gates will need further amendments such as a new round about so that trucks can be diverted into the new chassis yard area.
- A separate entry and exit gate will be required for the chassis yard empties storage area potentially with RPM scanning facilities.
- Chassis parking will no longer be made available at the port unless another area can be allocated in the future.

	TEU Ground Slots	TGS %	Yard Capacity (TEUS/yr)	Throughput %
Imports	2,183	22%	534,429	40%
Exports	3,977	39%	562,302	42%
Empties	2,660	26%	134,314	10%
Reefers (Laden)	624	6%	78,840	6%
Reefers (Empties)	706	7%	35,649	2%
	10,110		**1,345,534**	



4. Yard Improvement Options

4.2.9 Option 4B Description

Should the port require an additional yard capacity increase beyond Option 4A, partial conversion of reach stacker operations into RTG stacking can be performed to further increase the container stacking densities within the terminal. Option 4B proposes for the potential conversion of areas F and H into RTG stacks.

Providing that the paving in area F and H are upgraded to allow for RTG expansions in mind, the changeover should not be too complicated since the requirements would only be a switch in the stack orientation which involves new line painting for ground slots. Ideally, heavy duty concrete paving should be installed for areas F and H paving upgrades however, should asphalt be used, concrete runway beams may be retrofitted for RTG operations.

A partial RTG conversion would provide an increased yard capacity to 1,547,395 TEUs per annum.

	TEU Ground Slots	TGS %	Yard Capacity (TEUS/yr)	Throughput %
Imports	2,280	22%	636,214	47%
Exports	4,310	41%	662,378	49%
Empties	2,660	25%	134,314	10%
Reefers (Laden)	624	6%	78,840	6%
Reefers (Empties)	706	7%	35,649	3%
	10,580		1,547,395	

4.2.10 Option Comparison

The table below summarises the main qualitative advantages and disadvantages of the four base options presented

Option	Main Advantages	Main Disadvantages
1	❑ Disruption of existing gate complex can be reduced during the construction of the new gates ❑ There is potential space to extend the intermodal rail sidings in the future to accommodate longer trains ❑ There is no need to extend beyond the existing port boundary to achieve target throughput ❑ Better gate security can be integrated in to the gate design	❑ Option 1 has the lowest overall terminal capacity compared to the other options
2	❑ There is potential space to extend the intermodal rail sidings in the future to accommodate longer trains ❑ The proposed terminal layout allows for operational efficiency of the intermodal yard as space is available for a buffer storage area. ❑ There is no need to extend beyond the existing port boundary to achieve target throughput	❑ Phasing constraints for the gate complex needs to be planned such that the gate remains operational during construction which can be difficult ❑ Security is poor as troubleshooting truck identification will continue to be done past the gate once trucks have already entered the terminal.
3	❑ Proposed gates can be built without disruption to the existing gates. ❑ There is no need to extend beyond the existing port boundary to achieve target throughput	❑ Complex regrading of the grade difference in the area adjacent to the existing gate complex; ❑ Security requires additional assessment since the main gates are aligned directly to the incoming traffic of Ship yard Blvd – vehicle speed can be accumulated over a longer stretch of road before approaching the main gate. ❑ Area A is no longer available to be used for intermodal yard storage, hampering the operational efficiency of the intermodal yard.
4	❑ More area made available for container storage; ❑ Proposed gates can be built without disruption to the existing gates. ❑ Terminal layout allows for operational efficiency of the intermodal yard as space is available for a buffer storage area; ❑ Security is good because any troubleshooting in truck identification can be redirected out of the terminal before ever entering the port boundary	❑ Gaining permissions to build a road diversion between River Rd and Shipyard Blvd may cause delays in the projects and rerouting traffic during the works; ❑ Chassis parks need to be relocated.

4. Yard Improvement Options

4.2.11 Operational Performance Comparison of Layout Options

Further to the qualitative analysis of each four base options, all four layouts were modelled and simulated to verify their calculated throughput capacities as well as ascertaining a higher level of detailed performance metrics which otherwise would not have been possible with regards to the future operations of the terminal layout options. The following metrics for each option was considered:

- Container throughput per annum.
- Maximum gate throughput with standard hours of operation.
- Intermodal throughput.
- Gate performance such as maximum and average truck queue lengths.
- Truck waiting time at the gates.
- Yard Statistics such as number and utilisation rate of container handling equipment required.
- Average truck queues at a stack waiting to be served.

The results of the simulation for each base yard upgrade option is presented in Table V opposite.

Table V: Yard Layout Option Performance Metrics

Options	1	2	3	4
Throughputs				
Terminal Throughput (Containers)	642,209.00	658,147	657,315	761,614
Terminal Throughput (TEU)	1,123,866	1,151,757	1,150,302	1,332,825
Maximum Gate Throughput (TEU) 55 hour week - current	1,104,845	1,104,845	1,104,845	1,238,556
Additional Gate Time Required	**No**	**No**	**No**	**Yes**
Assumed Intermodal Percentage	8%	8%	8%	8%
Intermodal Throughput (Containers)	46,410	46,513	48,239	53,868
Intermodal Throughput (TEU)	81,218	81,399	84,419	94,269
Gates Basis Statistics				
Number Entrance Gates	7	7	7	7
Number Exit Gates	6	6	6	6
Hours of Operation	55	55	55	**61**
Number Trucks Processed Entrance Gates	463,720	472,254	471,657	549,658
Number Chassis Changes	55,026	56,300	56,229	65,512
Total Trucks Entering Terminal	408,694	415,953	415,428	484,146
Average Entrance Queue	0.577	0.65	0.62	0.95
Maximum Entrance Queue	46	50	47	60
Average Waiting Time Entrance (hours)	0.011	0.012	0.011	0.015
Maximum Waiting Time Entrance (hours)	0.16	0.179	0.167	0.212
Times Exceed Capacity / Year [40Nr]	5	9	8	48
Exit Gate Processing Total	232,864	237,692	237,392	276,372
Average Exit Queue	0.02	0.019	0.02	0.032
Maximum Exit Queue	15	14	14	16
Average Waiting Time Exit (hours)	0.0008	0.0007	0.0007	0.001
Maximum Waiting Time Exit (hours)	0.06	0.057	0.057	0.065
Times Exceed Capacity / Year [15Nr]	0	0	0	2
Average Turn around Time (hours)	0.267	0.26	0.262	0.28
Average Turn around Time (mins)	16.02	15.6	15.72	16.8
Max Turn around Time (hours) (99th percentile)	0.46	0.48	0.55	0.53
Max Turn around Time (mins) (99th percentile)	27.6	28.8	33	31.8

4.2.11 Operational Performance Comparison of Layout Options

Options	1	2	3	4
Intermodal				
Intermodal Yard (operation)	0.13	0.13	0.13	0.13
Number Reach Stackers (Within Railyard extra to yard)	4	4	4	4
Number of TICOs (For operation)	12	12	12	12
Yard Statistics				
Number of TICOs	55	55	55	60
TICO Utilisation ^	0.309	0.504	0.495	0.37
Number of Reach Stackers (yard)	24	24	24	26
Reach Stacker Utilisation	0.26	0.264	0.27	0.284
Average Number Boxes in Stack	13698	13740	13659	15801
Stack Utilisation: Import	0.65	0.7	0.68	0.66
Stack Utilisation: Export	0.77	0.63	0.67	0.65
Stack Utilisation: Empty	0.7	0.72	0.65	0.73
Stack Utilisation: Reefer Laden	0.71	0.68	0.65	0.75
Average Stack Queue	0	0	0.0003	0.001
Max Stack Queue (number)	13	18	15	21
Max Stack Queue (hours)	0.078	0.08	0.086	0.09
Check Berth Not Limited				
Check graph to check berth occupancy not limited.	No	No	No	No
Sufficient TICOs for Unloading	YES	YES	YES	Yes
Average Time for Request for TICO (seconds)	4	4	5	11
Average number trucks carrying box (unloading process)*	12	12	12	18
Cranes Used per vessel (average)	2.5	2.5	2.5	3.5
Total Reach Stacker	28	28	28	30

Upon examination of the simulation results, it was found that all four options were comparatively similar in terms of their operational performance with minor variances between them.

It is noted that the simulated terminal storage capacity matched that the theoretical calculations based on ground slot numbers and average stack heights, the second area of interest was that the maximum gate throughput possible within an annual cycle was 1,104,845 TEUs per annum for a fifty five hour working week, i.e. as per the current working hours at the port's gate.

All four options were able to work within a fifty five hour gate operation duration except for that of Option 4 where additional gate operational hours are required to match that of the yard capacity demands. An additional eleven hour shift would bring the total gate throughput to 1,238,556 TEUs per annum.

Based on the simulation, the average truck turnaround times for all four options were all below 17 minutes whilst the maximum 99th percentile peak turnaround time was just above 30 minutes for Options 3 and 4 due to the longer truck cycling times caused by the layout of the terminal proposed. Both options 1 and 2 had peak turnaround times just below the 30 minutes mark which is considered acceptable.

The number of reach stackers required to serve the terminal's potential capacity was also consistent across the options with Options 1 to 3 requiring twenty four reach stackers whilst Option 4, with the larger terminal capacity, required twenty six reach stackers.

An additional four dedicated reach stackers were found to be required in the intermodal yard.

5. Cost Estimates

CAPEX estimates for layout options

5. Cost Estimates

5.1 Introduction

The CAPEX for each development option has been estimated to provide an indicative investment value against each solution. The cost estimate accuracy is based on the AACE (American Association of Cost Estimating) guidelines for a Class 5 project. Class 5 being high level concept design cost accuracy. Where possible, MML has liaised with Port of Wilmington to define representative construction rates for the development options based on previous project at the Port and by use of project experience of similar nature.

5.2. Cost Estimate Accuracy

Due to the high level nature of the work at the planning stage, design details and specifications are not available for detailed take offs. Therefore the methodology adopted for the cost estimation used in this estimation involves benchmark capacity factoring using project experience similar to the work proposed for the yard improvement.

The unit rates for the various cost items are based on the following primary sources:

- MML cost data from similar projects in the US and globally.
- Spon's Civil Engineering and Highway Works Price Book 2014 (Adjusted for local costs).
- The 2009 Global Construction Cost and Reference Yearbook 9th Annual Edition.
- Discussions with NCSPA .

Where necessary; unit rates have been adjusted based on location factors between source country and the United States.

The accuracy of the cost estimates is -20% to +30% in accordance with AACE. AACE International (formerly the Association for the Advancement of Cost Engineering) Recommended Practice No. 18R-97 outlines a cost estimate classification system that applies to design, procurement and construction cost estimates. The classification is graded from Estimate Class 1 to Class 5, where Class 1 represents a detailed estimate with high confidence and Class 5 an outline estimate at the conception stage of a project – see Table W below.

Table W: AACE Cost Accuracy Guidelines

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES Expressed as % of complete definition	END USAGE Typical purpose of estimate	METHODOLOGY Typical estimating method	EXPECTED ACCURACY RANGE Typical variation in low and high ranges [a]
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Notes: [a] The state of process technology, availability of applicable reference cost data, and many other risks affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.

5. Cost Estimates

5.3 Cost Items

For each development option, the main project items that have been costed can be categorised into the following areas:

- ❑ Container Yard Paving and Civil Infrastructure Works.
- ❑ Reefer Yard Paving and Civil Infrastructure Works.
- ❑ New South Gate Upgrade Works.
- ❑ Inter-modal Yard.

5.3.1 Container Yard

Paving

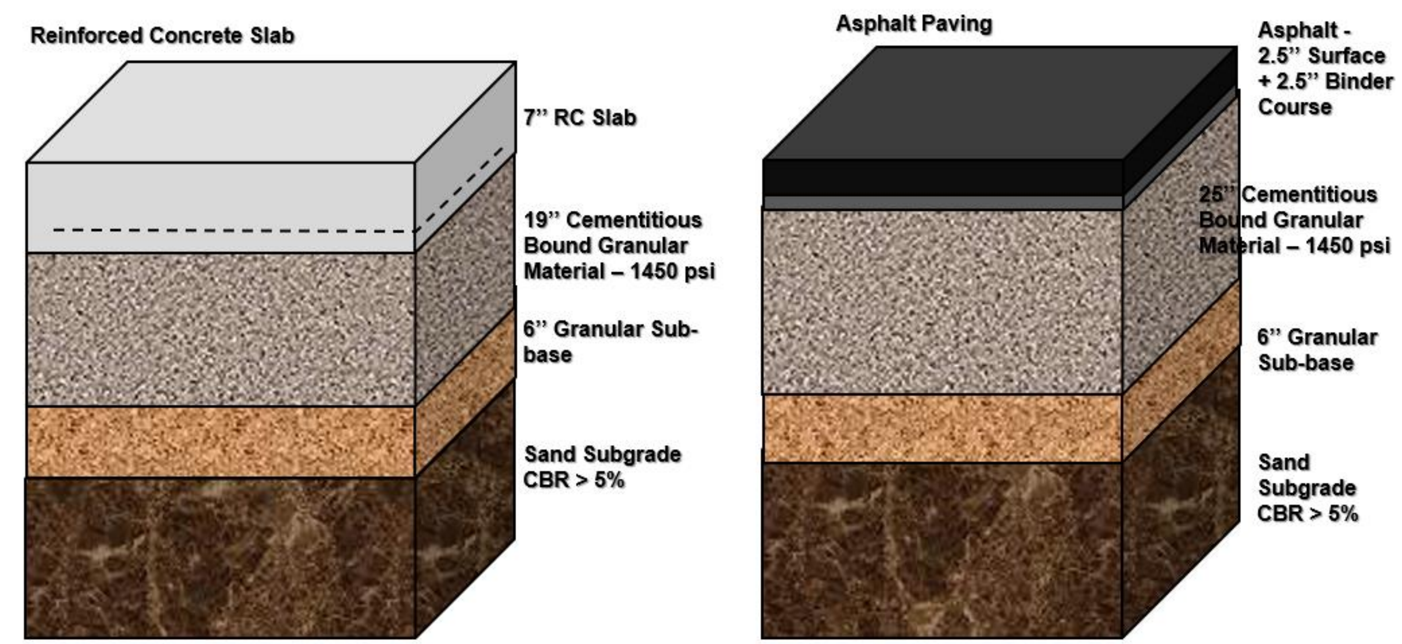
The container yard is by far the most expensive investment project for each development option due to the area the work covers and the variety of infrastructure upgrades required.

The largest development project for the container yard is the paving works upgrade.

For the purpose for this cost estimation exercise a combination of reinforced concrete slab and heavy duty asphalt paving has been considered. Further design development will be required to confirm the most efficient paving type to be utilised for the terminal upgrade works. However, for now, the paving specification considered for the cost estimates are show in Figure 49.

The assumption is that only areas F and H will require concrete paving whilst the rest of the terminal will be repaved using the asphalt specification presented. This is for future proofing areas F and H for RTG operations.

Figure 49: Paving types considered in yard upgrade works



Earth Works

It is assumed that all paving works will be preceded with earth works which consist of the following:

- ❑ Demolition and site clearance of existing paving layer.
- ❑ Excavation of fill material.
- ❑ Re-grading of material to the desired gradients for drainage purposes.

It is assumed for the purpose of the cost estimations that a grade of no steeper than 1 in 100 will be adopted across the terminal. Quantities have been developed from the existing site topography as sourced on the NCSPA GIS website.

All paving sub base and subgrade is assumed to require compaction to the desired CBR % - this assumed to be carried out using dynamic compaction plant spread across the paving area in consideration.

5. Cost Estimates

Civil Infrastructure Upgrades

As part of the container terminal yard upgrade works, it is considered the best opportunity to upgrade all aging and unsuitable infrastructure under the existing terminal paving such as the existing drainage system as report in Mott MacDonald's Inception and Basis of Planning Report. It is assumed for the purpose of the cost estimation that the existing catchment basin drains will be replaced by linear slot drains as detailed in Mott MacDonald's Inception Report. The costs estimated will include all breakout of existing pipe runs and re-installation of new drainage pipes as well as connections into existing manholes and outfalls. The re-routing of electrical ducts for lighting and avoidance of container stacks has also been considered. Other infrastructure items included in the yard upgrade cost include light masts and line markings.

5.3.2 Reefer Yard

Paving
Paving in the reefer yard is excluded for the main container yard upgrade costs and will consist of asphalt paving to the assumes design specifications.

Civil Infrastructure
Just as with the container yard, the reefer yard will also require drainage, electrical cable ducts, line marking and light mast have all been consider in the refer yard construction cost estimate.

South Substation Upgrade
An electrical load required at the new reefer yard has been estimated at 7,000KVa, The south substation is expected to not have sufficient capacity to serve the new reefer yard and therefore would require an upgrade. This project has been costed in the overall reefer yard project estimate. This cost is to be paid to Duke energy for the upgrade works and is to be paid upfront in the project.

Reefer Yard Equipment

The main equipment required in the new reefer yard will be the reefer sockets, which are assumed to be 32 amp pin and sleeve mechanical interlock types. It was assumed that over 1,700 sockets will be required and that the project will salvage as many existing ground reefer socket as possible so they can be re-used in the new refer yard. The sockets will be mounted on steel galvanised masts of nominal 33 feet height. These masts will be mounted on a concrete foundation with a total of 288 masts required for the proposed reefer yard layout. Finally, new cherry pickers are required to operate the reefer sockets, a minimum of two cherry pickers will be required for the reefer yard.

5.3.3 Terminal Gate Upgrade

All gate options will consist of the following items:

Paving: Again, as with the reefer yard, all paving associated with the gate has been isolated from the container yard upgrade budget. It is assumed that asphalt will be used in the gate areas with isolate concrete patches within the main gate interchange where traffic breaks and accelerates frequently.

OCR portals: All optical character recognition cameras and gate operations systems have been excluded from the cost estimate since it has been confirmed by NCSPA that these items will be part of the overall TOS and IT software upgrade budget. For this cost estimate exercise, only the OCR portal structures and barn shelter has been counted for.

RPM Scanner Infrastructure: All RPM scanner equipment are assumed to be provided by CBP and PNNL. However, all associated infrastructure will need to be provided by NCSPA which includes: Power utilities diversion/extensions and connections, ICT cable diversions and connections, all associated earthworks, foundation structures, CBP staff booths and cabins, secondary inspection structures and utilities, lighting and security provisions.

5. Cost Estimates

All approvals and design costs for the RPMs will also need to be included in the cost estimate.

***Main Interchange Gates*:** All gate upgrade options will consist of seven IN gates and six OUT gates. The interchange area will be covered with a steel frame canopy with associated equipment such as security cameras, lights, cabins traffic lights, signage, traffic barriers, raised kerbs and islands. Each gate lane will also need a set of rising barrier arms and a self-service kiosk console.

TWICs Gate: Where options require, the TWICs gate will need to be relocated, the cost for setting up the new TWICs verification station will be included in the cost estimate.

***Weigh-in Motion Sensors*:** Low speed weigh in motion scales are proposed for all gate upgrades. The cost of the equipment and installation has been allowed for in the cost estimate but all GOS and software have been excluded since this will be part of the over TOS and IT upgrade package of works NCSPA have budgeted for separately.

***Civil Infrastructure*:** Infrastructure works included as part of the south gate upgrade includes drainage, electrical connections and ducting, light masts, ISPS security fencing and line markings. However, all fibre optic infrastructure upgrades have been excluded for the works since NCSPA have confirmed that this has already been budgeted for.

Miscellaneous Buildings: Where each option requires, security cabins, CBP kiosk and booths will be included in the cost estimate.

5.3.4 Intermodal Yard

Main track upgrades: All rail sidings and track upgrade and intermodal yard equipment associated with the intermodal yard project Option 6 as estimated in Mott MacDonald's report titled "*Wilmington Rail Improvements – Landside Rail Improvements Serving the Port and Moving Trains Safely through the Community, 2017, September 6th ,"* has been carried forward into this cost estimate for continuity. Infrastructure works included as part of the base intermodal yard includes drainage, electrical connections, ducting and container paving. However, all fibre optic infrastructure upgrades have been excluded for these works since NCSPA have confirmed that this has already been budgeted for elsewhere.

Additional Track Work: Track adjustment works such as the demolition of container track number 1, extension to track 18 where required has been included in the cost estimate specific for the yard improvement options considered.

RPM Scanners: All RPM scanner equipment are assumed to be provided by CBP and PNNL. However, all associated infrastructure will need to be provided by NCSPA which includes: Power utilities diversion/extensions and connections, ICT cable diversions and connections, all associated earthworks, foundation structures, CBP staff booths and cabins, secondary inspection structures and utilities, lighting and security provisions.

Security Gates: The intermodal yard will consist of one entrance gate and exit gate which will both consist of two lanes. The gate area will be covered with a steel frame canopy with associated equipment such as security cameras, lights, cabins traffic lights, signage, traffic barriers, raised kerbs and islands. Each gate lane will also need a set of rising barrier arms.

***Additional Civil Infrastructure*:** Infrastructure works which have not been included in the original intermodal yard cost estimate as presented in Mott MacDonald's rail yard study includes light masts, ISPS security fencing and line markings. These have been estimated and included as part of the final intermodal yard costs.

5. Cost Estimates

5.4 Construction Preliminaries

On top of the base civil CAPEX the following preliminary costs will be included:

- ❑ 15% Mobilisation Costs on Base Civil Cost.
- ❑ 2.5% Inspection and Permitting Costs on Base Civil Cost.
- ❑ 20% Contingency Costs on Base Civil Cost.
- ❑ 10% Design cost on (Contingency, Mobilisation and Base Civil Cost).

5.5 Option Cost Beak Down

5.5.1 Option 1 Costs

The Container Yard paving Cost is broken down in Table X Opposite. The total cost for Option 1 container Yard works is $157,237,640. The container yard cost includes for the repaving works, associated earthworks and civil infrastructure utilities for the following stacking areas:

- ❑ Area F (Concrete Paving).
- ❑ Area B (excluding the DRI building area) (Asphalt Paving).
- ❑ Area H (Concrete Paving).
- ❑ Area J (Asphalt Paving).
- ❑ Area K (Asphalt Paving).
- ❑ Area L (Asphalt Paving).
- ❑ Warehouse T7 (Asphalt Paving).
- ❑ Bulk storage areas (Dolomite and steel billet storage areas towards the north of the terminal) (Asphalt Paving).

The individual costs for paving each of the above areas is shown in Table X1 and X2.

Table X– Option 1 Container Yard Costs

		OPTION 1 - (Preferred Option)				
Item	**Item Description**	**Category**	**Unit**	**Quantity**	**Unit Rate (USD)**	**Cost (USD)**
1	**Container Yard Paving**					
1.1	*Breakout and Demolishing of exisitng paving (8 inch asphalt)*	Container Yard	sq.yds	303,850	8	2,379,147
1.2	*Re-grading (cut)*	Container Yard	yds^3	63,043	4	224,013
1.3	Disposal of excess excavated material	Container Yard	yds^3	0	11	0
1.4	Storage on site of excavated material	Container Yard	yds^3	71,203	5	333,913
1.5	*Re-grading (fill)*	Container Yard	yds^3	55,703	2	86,308
1.6	Imported fill	Container Yard	yds^3	16,616	25	416,559
1.7	*Paving Type A - Concrete Pavement - 5 high stacking (RTG Proof)*	Container Yard	sq yrds	85,533	450	38,489,761
1.8	*Paving Type B - Asphalt Pavement - (Rate includes sub-base materials)*	Container Yard	tons	389,478	118	45,846,567
1.9	Ground Improvement (Dynamic compaction)	Container Yard	sq.yds	303,850	16	4,804,144
1.10	Site mobilisation of Ground improvement Plant	Container Yard	L.S.	10	29,363	293,625
1.11	Kentledge load test	Container Yard	L.S.	10	10,800	108,000
1.12	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	Container Yard	sq.yds	303,850	23	7,014,892
1.13	Electrical Works Network (MV, including ducting, cabling and pits)	Container Yard	sq.yds	303,850	6	1,879,505
1.14	Electrical Works Network (LV, including ducting, cabling and pits)	Container Yard	sq.yds	303,850	3	796,106
1.15	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Container Yard	Ea.	13	23,000	299,000
1.16	Line/corner Marking & Signage	Container Yard	sq.yds	303,850	1	170,306
1.17	Demolition (Warehouse T7)	Container Yard	sq.ft	219,300	5	989,043
	Container Yard Base Cost SUBTOTAL					**104,130,887**
	Mobilization				15%	15,619,633
	Inspection and Permitting				2.5%	2,603,272
	Contingency				20%	20,826,177
	Engineering Services (incl. design and procurement)				10%	14,057,670
	Container Yard Paving TOTAL					***157,237,640***

Areas required to be repaved for 750,000TEUs per Annum storage capacity

Table X1: Paving Area Cost Break Down to Accommodate 750,000 TEUs per annum Yard Storage Capacity

Paving Area	Paving Type	Cost Estimate	
Area F East	Concrete	$	19,068,637
Area F West	Concrete	$	24,841,554
Area B (Mid)	Asphalt	$	6,310,859
Area K East	Asphalt	$	7,919,647
Area K West	Asphalt	$	7,927,429
Area H	Concrete	$	22,290,255
Existing Gate Complex Area	Asphalt	$	14,116,735
Total Paving Cost for 750,000 TEU per annum Yard Storage Capacity		**$**	**102,475,115***

Additional areas required to be paved to reach 1,052,106 TEUs per annum storage capacity

Table X2: Paving Area Cost Break Down to Accommodate 1,052,106 TEUs per annum Yard Storage Capacity

Paving Area	Paving Type	Cost Estimate	
T7 Warehouse	Asphalt	$	14,683,067
Bulk Storage Areas	Asphalt	$	16,756,748
Area J	Asphalt	$	23,322,691
Total Additional Paving Cost to reach 1,052,106 TEU per annum Yard Storage Capacity		**$**	**54,762,507**

Re-paving areas F, B, K, H and the existing gate complex footprint to enable five high container stacking will provide a yard capacity of circa 763,950 TEUs per annum yard capacity which is sufficient to reach the target throughput container volumes by 2025. Should NCSPA wish to increase the yard capacity further, Option 1 allows for the additional repaving of Area J which provides an extra 173,156 TEUS per annum at a cost of $23,322,691. An additional circa 67,000 TEUs can be provided for export containers if warehouse T7 is demolished and repaved at a cost of $14,683,067. An additional circa 48,000 TEUs per annum can be provided if both the bulk storage areas north of the terminal are repaved at a cost of $16,756,748. The total capacity obtainable in option with just repaving alone is 1,052,106 TEUs per annum. In order to achieve the reported maximum potential of 1,123,865 TEUs per annum, the intermodal yard will need to be installed and operating an 8% modal split.

** Note this cost is for increasing the yard storage capacity to 750,000TEUs per annum only. Further investment is required to bring the entire terminal capacity to 750,000 TEUs which include the south gate upgrade and phase 1 of the reefer yard. The total for this is **$158,113,334 (This includes repaving areas F and H with concrete and the rest of the yard with asphalt paving).***

The costs estimates presented in Table X1 and X2 are for repaving of the container stacking yard to achieve increased yard storage capacity only. The investment in yard paving to achieve 750,000 TEU per annum storage capacity, the estimated investment required is $102,475,115. However, for the entire terminal capacity to match the 750,000 TEU storage capacity, the capacity of the gates will also have to be increased. Table X3 below presents the terminal upgrade projects required for each terminal capacity increment along with the associated cost.

Table X3: Terminal Capacity and Associated Projects

Terminal Capacity (TEUs/annum)	Upgrade Projects Required	Cost (USD)
750,000	❑ South gate upgrade ❑ Repaving of terminal areas F & H with concrete and areas B, K and exisitng gate complex area with asphalt ❑ Reefer yard phase 1 ❑ Additional equipment costs	158,113,334
923,156	In addition with the above projects provide repaving of area J with Asphalt	23,322,691
990,156	in addition with the above carry out demolition and repaving of warehouse T7	14,683,067
1,052,106	In addition to the above projects – carry out repaving of bulk storage areas north of the container terminal.	16,756,748
1,123,865	❑ In addition with the above projects - upgrade of intermodal yard to serve 8% modal split ❑ Reefer Yard Phase 2 and 3 ❑ Additional equipment	34,444,840

5. Cost Estimates

Item	Item Description	Unit	Quant	Unit Rate	Cost USD
2	**Reefer Yard**				
2.1	Reefer Substations including equipment - Upgrade to South Substation	Ea.	1	722,470	722,470
2.2	Reefer Masts (Steel Galvanised poles - 33ft nominal height)	Ea.	288	7,520	2,165,760
2.3	Reefer socket outlets	Ea.	1,628	550	895,400
2.4	*Breakout and Demolishing of existing paving (8 inch asphalt)*	sq.yds	43,934	8	344,006
2.5	*Re-grading (cut)*	yds^3	8,160	4	28,996
2.6	*Re-grading (fill)*	yds^3	1,259	2	1,951
2.7	*Paving Type B - Asphalt Pavement - (Rate includes sub-base materials)*	Tons	78,378	118	9,226,110
2.8	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	43,934	23	1,014,290
2.9	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	43,934	6	271,760
2.10	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	43,934	3	115,110
2.11	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	2	23,000	46,000
2.12	Line/corner Marking & Signage	sq.yds	43,934	1	24,625
	Reefer Yard Base Cost SUBTOTAL				**14,856,478**
	Mobilization			15%	2,228,472
	Inspection and Permitting			2.5%	371,412
	Contingency			20%	2,971,296
	Engineering Services (incl. design and procurement)			10%	2,005,624
	Reefer Yard TOTAL				***22,433,281***

The total reefer yard costs is estimated to at $22,433,281

Item	Item Description	Unit	Quant	Unit Rate	Cost USD
3	**South Gate Upgrade**				
3.1	ISPS Perimeter Fence (Including posts and foundations - Chain link)	lin.ft.	1,000	50.00	50,000
3.2	Port Gate In (inc. all associated equipment and furniture)	lane	8	100,000.00	800,000
3.3	Port Gate Out (inc. all associated equipment and furniture)	lane	7	100,000.00	700,000
3.4	Optical Character Recognition (OCR) Portal and Barn only	lane	5	17,000.00	85,000
3.5	Radiation Scanner infrastructure - Utiltiies, earthworks, CBP boothes, secondary inspection structures, lighting etc.	lane.	3	2,000,000.00	6,000,000
3.6	Weighbridge - weigh in motion sensors	Ea.	6	39,900.00	239,400
3.7	TWICS GATE automated kiosks and Rising Barrier Arms	Ea.	12	9,600.00	115,200
3.8	New gate house building - steel clad buidling 3 story high	sq.ft	3,000	220.00	660,000
3.9	Security Booth	sq.ft	538	130.00	69,940
3.10	Breakout and Demolishing of exisitng paving (8 inch asphalt) - Gate	sq.yds	42,147	7.83	330,011
3.11	*Paving Type B - Asphalt Pavement - (Rate includes sub-base materials)*	tons	75,190	118.00	8,872,420
3.12	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	42,147	23.09	973,034
3.13	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	42,147	6.19	260,706
3.14	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	42,147	2.62	110,428
3.15	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	1	23,000.00	23,000
3.16	Line/corner Marking & Signage	sq.yds	42,147	0.56	23,623
	South Gate Upgrade SUBTOTAL				**19,312,762**
	Mobilization			0.15	2,896,914
	Inspection and Permitting			0.03	482,819
	Contingency			0.20	3,862,552
	Engineering Services (incl. design and procurement)			0.10	2,607,223
	South Gate Upgrade TOTAL				***29,162,271***

The total south gate upgrade costs is estimated to at $29,162,271

5. Cost Estimates

4	**Intermodal yard**					
4.1	Removal of Existing Rail tracks - Container Track #1	Intermodal Yard	lin.ft.	1,000	500.00	500,000
4.2	Removal of Existing Rail bend to track 18a	Intermodal Yard	lin.ft.	0	500.00	0
4.3	Removal of Existing Rail bend to track 18b (ENVIVA line)	Intermodal Yard	lin.ft.	0	500.00	0
4.4	Extension of rail road tracks to Container line 1	Intermodal Yard	lin.ft.	300	1,000.00	300,000
4.5	Extension to Rail road tracks to Line 18	Intermodal Yard	lin.ft.	0	1,000.00	0
4.6	Extension to Rail Road Tracks to Line 18a	Intermodal Yard	lin.ft.	0	1,000.00	0
4.7	Extension to Rail Road Tracks to line 18b	Intermodal Yard	lin.ft.	0	1,000.00	0
4.8	New intermodal yard exit gate lanes	Intermodal Yard	Ea.	2	100,000.00	200,000
4.9	New intermodal yard entry gate lanes	Intermodal Yard	Ea.	2	100,000.00	200,000
4.10	Intermodal yard RPM infrastructure - Utilities, CBP booths, foundations, secondary inspection structures etc	Intermodal Yard	Lane	2	2,000,000.00	4,000,000
4.11	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Intermodal Yard	Ea.	16	23,000.00	368,000
4.12	Line/corner Marking & Signage	Intermodal Yard	sq.yds	23,405	0.56	13,118
	Intermodal Yard Base Cost SUBTOTAL					**5,581,118**
	Mobilization				0.15	837,168
	Inspection and Permitting				0.03	139,528
	Contingency				0.20	1,116,224
	Engineering Services (incl. design and procurement)				0.10	753,451
	MML Rail Yard Study Base Intermodal Yard Cost					18,000,000
	Intermodal Yard TOTAL					***26,427,489***

The total intermodal yard upgrade costs is estimated to at $26,427,489.

5	**Plant/equipment**					
5.1	Reach stackers	Equipment	Ea.	12	1,000,000	12,000,000
5.2	Cherry pickers	Equipment	Ea.	2	30,000	60,000
	Plant/equipment SUBTOTAL					**12,060,000**
	Plant/equipment TOTAL					***12,060,000***

The total equipment cost is estimated to at $12,060,000.

The total CAPEX estimate for Option 1 is $247,320,680 to achieve the full terminal capacity of 1,123,865 TEUS per annum.

Option 1 Project	Costs (USD)
Container Yard	157,237,640
Reefer Yard	22,433,281
South Gate Upgrade	29,162,271
Intermodal Yard	26,427,489
Equipment	12,060,000
TOTAL CAPEX for Full Capacity	**247,320,680**

The total CAPEX estimated for obtaining a minimum terminal capacity of 750,000 TEUs per annum is **$158,113,334.** This cost includes for the repaving of stacking areas 'F' and 'H' with concrete and the rest of the yard repaved in asphalt. This cost also includes for the south gate upgrade and phase 1 of the refer yard expansion.

This cost excludes the repaving of warehouse T7, bulk storage areas north of the terminal and area J. This cost also excludes the installation of the new intermodal yard and phase 2 and 3 of the reefer yard upgrades.

5.5 Option Cost Beak Down

5.5.1.1 Option 1A Costs

Option 1A extends from Option 1 by utilising the existing chassis yard for empty box storage. By expanding into the chassis yard, the terminal storage capacity is able to increase to 1,299,657 TEUs per annum assuming that the chassis yard will be used as an empties yard.

The total cost estimated for expanding into the chassis yard is circa $296,846,342.

The break down for the individual project items are as follows:

Option 1A Project	Costs (USD)
Container Yard	157,237,640
Reefer Yard	22,433,281
South Gate Upgrade	29,162,271
Intermodal Yard	26,427,489
Equipment	12,060,000
Chassis yard expansion	46,354,662
TOTAL CAPEX for Option 1A	**293,675,342**

As observed, the main difference in the CAPEX estimates between Option 1 and 1A is the chassis yard expansion project with the residual civil works costs remaining identical. The cost breakdown of the chassis yard expansion works is shown opposite. Therefore the additional investment required post Option 1 completion is $46,354,291 to increase the yard storage capacity by 175,792 TEUs per annum.

6	Chassis yard conversion				
6.1	Suspended deck over storm retention basins	sq.yds	2,156	4,786.65	10,317,890
6.2	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	1	23,000.00	23,000
6.3	Port Gate In (inc. all associated equipment and furniture)	lane	1	100,000.00	100,000
6.4	Port Gate Out (inc. all associated equipment and furniture)	lane	1	100,000.00	100,000
6.5	Optical Character Recognition (OCR) Portal and Barn only	lane	2	17,000.00	34,000
6.6	Radiation Scanner Infrastructure	lane.	2	2,000,000.00	4,000,000
6.7	New roads alignments	lin.ft	3,000	745.78	2,237,334
6.8	New roundabouts	lin.ft	1,068	745.78	796,491
6.9	Breakout and Demolishing of exisitng paving (8 inch asphalt) - Area A	sq.yds	52,300	7.83	409,507
6.10	Paving Type B - Asphalt Pavement - (Rate includes sub-base materials)	Tons	93,303	117.71	10,982,952
6.11	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	52,300	23.09	1,207,428
6.12	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	52,300	6.19	323,507
6.13	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	52,300	2.62	137,029
6.14	Line/corner Marking & Signage	sq.yds	52,300	0.56	29,314
	Chassis Yard Conversion Base Cost SUBTOTAL				**30,698,452**
	Mobilization			15.00%	4,604,768
	Inspection and Permitting			2.50%	767,461
	Contingency on Construction			20.00%	6,139,690
	Engineering Services (incl. design and procurement)			10.00%	4,144,291
-	**Chassis Yard Conversion TOTAL**				***46,354,662***

5.5 Option Cost Beak Down

5.5.1.2 Option 1B Costs

Option 1B is identical to Option 1A but with the addition of areas F and H being converted into a RTG operated container yard. The total estimated cost for Option 1B is estimated to be $318,581,342. The final yard capacity offered by Option 1B is 1,494,889 TEUs per annum. The cost difference between Option 1B and 1A is made up of the new RTG equipment costs. It is estimated that a minimum of 12 RTG cranes are required at $1,000,000 each. Note that the concrete paving designed and installed in the initial phases of Option 1 has allowed for the RTG transition and therefore no further infrastructure work is required for Option 1B. The cost breakdown for Option 1B is as follows:

Option 1B Project	Costs (USD)
Container Yard	157,237,640
Reefer Yard	22,433,281
South Gate Upgrade	29,162,271
Intermodal Yard	26,427,489
Equipment	36,060,000
Chassis yard expansion	46,354,662
TOTAL CAPEX for Option 1A	**318,581,342**

With an additional investment of $24,906,000 the yard capacity is extended by a further 195,232 TEUs.

5. Cost Estimates

5.5.2 Option 2 Costs

Item	Item Description	Unit	Quantity	Unit Rate (USD)	Cost (USD)
1	**Container Yard Paving**				
1.1	*Breakout and Demolishing of existing paving (8 inch asphalt)*	sq.yds	314,855	8	2,465,318
1.2	*Re-grading (cut)*	yds^3	35,264	4	125,305
1.3	Disposal of excess excavated material	yds^3	0	11	0
1.4	Storage on site of excavated material	yds^3	43,425	5	203,642
1.5	*Re-grading (fill)*	yds^3	33,760	2	52,308
1.6	Imported fill	yds^3	40,891	25	1,025,117
1.7	*Paving Type A - Concrete Pavement - 5 high stacking (RTG Proof)*	sq.yds	85,533	450	38,489,761
1.8	*Paving Type B - Asphalt Pavement - 4 high stacking*	Tons	412,639	118	48,691,451
1.9	Ground Improvement (Dynamic compaction)	sq.yds	314,855	16	4,978,149
1.10	Site mobilisation of Ground improvement Plant	L.S.	1	29,363	29,363
1.11	Kentledge load test	L.S.	1	10,800	10,800
1.12	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	314,855	23	7,270,012
1.13	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	314,855	6	1,947,580
1.14	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	314,855	3	824,941
1.15	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	14	164,812	2,307,369
1.16	Line/corner Marking & Signage	sq.yds	314,855	1	176,474
1.17	Demolition (Warehouse T7)	sq.ft	219,300	5	989,043
	Container Yard Base Cost SUBTOTAL				**109,586,632**
	Mobilization			15%	16,437,995
	Inspection and Permitting			2.5%	2,739,666
	Contingency on Construction			20%	21,917,326
	Engineering Services (incl. design and procurement)			10%	14,794,195
	Container Yard Paving TOTAL				***165,475,814***

The total Option 2 container yard cost is estimated at $165,475,814

Item	Item Description	Unit	Quantity	Unit Rate (USD)	Cost (USD)
2	**Reefer Yard**				
2.1	Reefer Substations including equipment - Upgrade to South Substation	Ea.	1	722,470	722,470
2.2	Reefer Masts (Steel Galvanised poles - 33ft nominal height)	Ea.	288	7,520	2,165,760
2.3	Reefer socket outlets	Ea.	1,628	550	895,400
2.4	*Breakout and Demolishing of existing paving (8 inch asphalt)*	sq.yds	43,934	8	344,006
2.5	*Re-grading (cut)*	yds^3	8,160	4	28,996
2.6	*Re-grading (fill)*	yds^3	1,259	2	1,951
2.7	*Paving Type B - Asphalt Pavement - 4 high stacking*	Tons	78,379	118	9,226,217
2.8	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	43,934	23	1,014,444
2.9	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	43,934	6	271,762
2.10	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	43,934	3	115,111
2.11	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	2	23,000	46,000
2.12	Line/corner Marking & Signage	sq.yds	43,934	1	24,625
	Reefer Yard Base Cost SUBTOTAL				**14,856,741**
	Mobilization			15%	2,228,511
	Inspection and Permitting			2.5%	371,419
	Contingency on Construction			20%	2,971,348
	Engineering Services (incl. design and procurement)			10%	2,005,660
	Reefer Yard TOTAL				***22,433,680***

The total Option 2 reefer yard cost is estimated at $22,433,680

5. Cost Estimates

5.5.2 Option 2 Costs

3	**South Gate Upgrade**				
3.1	ISPS Perimeter Fence (Including posts and foundations - Chain link)	lin.ft.	1,000	50	50,000
3.2	Port Gate In (inc. all associated equipment and furniture)	lane	8	100,000	800,000
3.3	Port Gate Out (inc. all associated equipment and furniture)	lane	7	100,000	700,000
3.4	Optical Character Recognition (OCR) Portal with equipment and software	lane	5	17,000	85,000
3.5	Radiation Scanner infrastructure, including utilities, foundation, CBP boothes and lighting etc.	lane.	3	2,000,000	6,000,000
3.6	Weighbridge - weigh in motion sensors	Ea.	6	39,900	239,400
3.7	TWICS GATE automated kiosks and Rising Barrier Arms	Ea.	12	9,600	115,200
3.8	New gate house building - steel clad buidling 3 story high	sq.ft	3,000	220	660,000
3.9	Security Booth	sq.ft	538	130	69,940
3.10	Breakout and Demolishing of exisitng paving (8 inch asphalt) - Gate	sq.yds	0	8	0
3.11	Paving Type B - Asphalt Pavement - 4 high stacking - Gate	Tons	0	118	0
3.12	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	0	23	0
3.13	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	0	6	0
3.14	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	0	3	0
3.15	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	1	23,000	23,000
3.16	Line/corner Marking & Signage	sq.yds	0	1	0
	South Gate Upgrade SUBTOTAL				**8,742,540**
	Mobilization			0	1,311,381
	Inspection and Permitting			0	218,564
	Contingency on Construction			0	1,748,508
	Engineering Services (incl. design and procurement)			0	1,180,243
	South Gate Upgrade TOTAL				***13,201,235***

The total Option 2 south gate upgrade cost is estimated at $13,201,235

4	**Intermodal yard**				
4.1	Removal of Existing Rail tracks - Container Track #1	lin.ft.	1,000	500	500,000
4.2	Removal of Existing Rail bend to track 18a	lin.ft.	0	500	0
4.3	Removal of Existing Rail bend to track 18b (ENVIVA line)	lin.ft.	0	500	0
4.4	Extension of rail road tracks to Container line 1	lin.ft.	300	1,000	300,000
4.5	Extension to Rail road tracks to Line 18	lin.ft.	0	1,000	0
4.6	Extension to Rail Road Tracks to Line 18a	lin.ft.	0	1,000	0
4.7	Extension to Rail Road Tracks to line 18b	lin.ft.	0	1,000	0
4.8	New intermodal yard exit gate lanes	Ea.	2	100,000	200,000
4.9	New intermodal yard entry gate lanes	Ea.	2	100,000	200,000
4.10	Intermodal yard RPM infrastructure - utilities, foundations, CBP boothes, secondary inspection structures etc.	Lane	2	2,000,000	4,000,000
4.11	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	16	23,000	368,000
4.12	Line/corner Marking & Signage	sq.yds	23,405	1	13,118
	Intermodal Yard Base Cost SUBTOTAL				**5,581,118**
	Mobilization			0	837,168
	Inspection and Permitting			0	139,528
	Contingency on Construction			0	558,112
	Engineering Services (incl. design and procurement)			0	697,640
	MML Rail Study Base Intermodal Yard Cost				18,000,000
	Intermodal Yard TOTAL				***25,813,566***

The total Option 2 intermodal yard cost is estimated at $25,813,566

5. Cost Estimates

5.5.2 Option 2 Costs

5	**Plant/equipment**				
5.1	Reach stackers	Ea.	12	1,000,000	12,000,000
5.2	Cherry pickers	Ea.	2	30,000	60,000
	Plant/equipment SUBTOTAL				**12,060,000**

Option 2 Project	Costs (USD)
Container Yard	165,475,814
Reefer Yard	22,433,680
South Gate Upgrade	13,201,235
Intermodal Yard	25,813,566
Equipment	12,060,000
TOTAL	**238,984,294**

5. Cost Estimates

5.5.3 Option 3 Costs

Item	Item Description	Unit	Quantity	Unit Rate (USD)	Cost (USD)
1	**Container Yard Paving**				
1.1	*Breakout and Demolishing of existing paving (8 inch asphalt)*	sq.yds	354,222	8	2,773,561
1.2	*Re-grading (cut)*	yds^3	19,994	4	71,045
1.3	Disposal of excess excavated material	yds^3	0	11	0
1.4	Storage on site of excavated material	yds^3	73,646	5	345,366
1.5	*Re-grading (fill)*	yds^3	38,802	2	60,120
1.6	Imported fill	yds^3	49,860	25	1,249,969
1.7	*Paving Type A - Concrete Pavement - 5 high stacking (RTG Proof)*	sq.yds	85,533	450	38,489,761
1.8	*Paving Type B - Asphalt Pavement - 4 high stacking*	Tons	479,342	118	56,562,367
1.9	Ground Improvement (Dynamic compaction)	sq.yds	354,222	16	5,600,574
1.10	Site mobilisation of Ground improvement Plant	L.S.	1	29,363	29,363
1.11	Kentledge load test	L.S.	1	10,800	10,800
1.12	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	354,222	23	8,178,993
1.13	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	354,222	6	2,191,089
1.14	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	354,222	3	928,084
1.15	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	16	23,000	368,000
1.16	Line/corner Marking & Signage	sq.yds	354,222	1	198,539
1.17	Demolition (Warehouse T7)	sq.ft	219,300	5	989,043
	Container Yard Base Cost SUBTOTAL				**118,046,673**
	Mobilization			0.15	17,707,001
	Inspection and Permitting			0.025	2,951,167
	Contingency on Construction			0.2	23,609,335
	Engineering Services (incl. design and procurement)			0.1	15,936,301
	Container Yard Paving TOTAL				***178,250,476***

The total Option 3 container yard cost is estimated at $178,250,476.

Item	Item Description	Unit	Quantity	Unit Rate (USD)	Cost (USD)
2	**Reefer Yard**				
2.1	Reefer Substations including equipment - Upgrade to South Substation	Ea.	1	722,470	722,470
2.2	Reefer Masts (Steel Galvanised poles - 33ft nominal height)	Ea.	288	7,520	2,165,760
2.3	Reefer socket outlets	Ea.	1,628	550	895,400
2.4	*Breakout and Demolishing of existing paving (8 inch asphalt)*	sq.yds	43,934	8	344,006
2.5	*Re-grading (cut)*	yds^3	8,160	4	28,996
2.6	*Re-grading (fill)*	yds^3	1,259	2	1,951
2.7	*Paving Type B - Asphalt Pavement - 4 high stacking*	Tons	78,378	118	9,226,110
2.8	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	43,934	23	1,014,444
2.9	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	43,934	6	271,762
2.10	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	43,934	3	115,111
2.11	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	2	23,000	46,000
2.12	Line/corner Marking & Signage	sq.yds	43,934	1	24,625
	Reefer Yard Base Cost SUBTOTAL				**14,856,635**
	Mobilization			0.15	2,228,495
	Inspection and Permitting			0.025	371,416
	Contingency on Construction			0.2	2,971,327
	Engineering Services (incl. design and procurement)			0.1	2,005,646
	Reefer Yard TOTAL				***22,433,518***

The total Option 3 reefer yard cost is estimated at $22,433,518.

5. Cost Estimates

5.5.3 Option 3 Costs

3	**South Gate Upgrade**				
3.1	ISPS Perimeter Fence (Including posts and foundations - Chain link)	lin.ft.	1,000	50	50,000
3.2	Port Gate In (inc. all associated equipment and furniture)	lane	8	100,000	800,000
3.3	Port Gate Out (inc. all associated equipment and furniture)	lane	7	100,000	700,000
3.4	Optical Character Recognition (OCR) Portal with equipment and software	lane	5	17,000	85,000
3.5	Radiation Scanner infrastructure - utiltiies, foundations, secondary inspection structures, lighting etc.	lane.	3	2,000,000	6,000,000
3.6	Weighbridge - weigh in motion sensors	Ea.	6	39,900	239,400
3.7	TWICS GATE automated kiosks and Rising Barrier Arms	Ea.	12	9,600	115,200
3.8	New gate house building - steel clad buidling 3 story high	sq.ft	3,000	220	660,000
3.9	Security Booth	sq.ft	538	130	69,940
3.10	Breakout and Demolishing of exisitng paving (8 inch asphalt) - Gate	sq.yds	34,330	8	268,802
3.11	Re-grading (cut)	yds^3	34	4	121
3.12	Re-grading (fill)	yds^3	35,004	2	54,236
3.13	Paving Type B - Asphalt Pavement - 4 high stacking - Gate	Tons	61,244	118	7,226,824
3.14	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	34,330	23	792,674
3.15	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	34,330	6	212,351
3.16	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	34,330	3	89,946
3.17	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	1	23,000	23,000
3.18	Line/corner Marking & Signage	sq.yds	34,330	1	19,242
	South Gate Upgrade SUBTOTAL				**17,352,378**
	Mobilization			15%	2,602,857
	Inspection and Permitting			3%	433,809
	Contingency on Construction			20%	3,470,476
	Engineering Services (incl. design and procurement)			10%	2,342,571
	South Gate Upgrade TOTAL				***26,202,091***

The total Option 3 south gate upgrade cost is estimated at $26,202,091.

4	**Intermodal yard**				
4.1	Removal of Existing Rail tracks - Container Track #1	lin.ft.	1,000	500	500,000
4.2	Removal of Existing Rail bend to track 18a	lin.ft.	0	500	0
4.3	Removal of Existing Rail bend to track 18b (ENVIVA line)	lin.ft.	0	500	0
4.4	Extension of rail road tracks to Container line 1	lin.ft.	300	1,000	300,000
4.5	Extension to Rail road tracks to Line 18	lin.ft.	0	1,000	0
4.6	Extension to Rail Road Tracks to Line 18a	lin.ft.	0	1,000	0
4.7	Extension to Rail Road Tracks to line 18b	lin.ft.	0	1,000	0
4.8	New intermodal yard exit gate lanes	Ea.	2	100,000	200,000
4.9	New intermodal yard entry gate lanes	Ea.	2	100,000	200,000
4.10	Intermodal yard RPM infrastructure including utilities, foundations, CBP boothes, secondary inspection structures, lighting etc.	Lane	2	2,000,000	4,000,000
4.11	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	16	23,000	368,000
4.12	Line/corner Marking & Signage	sq.yds	23,405	1	13,118
	Intermodal Yard Base Cost SUBTOTAL				**5,581,118**
	Mobilization			15%	837,168
	Inspection and Permitting			3%	139,528
	Contingency on Construction			20%	1,116,224
	Engineering Services (incl. design and procurement)			10%	753,451
	MML Rail Study base intermodal Yard Cost				18,000,000
	Intermodal Yard TOTAL				***26,427,489***

The total Option 3 intermodal yard cost is estimated at $26,427,489.

5. Cost Estimates

5.5.3 Option 3 Costs

5	**Plant/equipment**				
5.1	Reach stackers	Ea.	12	1,000,000	12,000,000
5.2	Cherry pickers	Ea.	2	30,000	60,000
	Plant/equipment SUBTOTAL				**12,060,000**

Option 3 Project	Costs (USD)
Container Yard	178,250,476
Reefer Yard	22,433,518
South Gate Upgrade	26,202,091
Intermodal Yard	26,427,489
Equipment	12,060,000
TOTAL	**265,373,574**

5. Cost Estimates

5.5.4 Option 4 Costs

Item	Item Description	Unit	Quantity	Unit Rate (USD)	Cost (USD)
1	<u>**Container Yard Paving**</u>				
1.1	*Breakout and Demolishing of existing paving (8 inch asphalt)*	sq.yds	352,245	8	2,758,077
1.2	*Re-grading (cut)*	yds^3	65,451	4	232,569
1.3	Disposal of excess excavated material	yds^3	0	11	0
1.4	Storage on site of excavated material	yds^3	73,646	5	345,366
1.5	*Re-grading (fill)*	yds^3	38,802	2	60,120
1.6	Imported fill	yds^3	49,860	25	1,249,969
1.7	*Paving Type A - Concrete Pavement - 5 high stacking (RTG Proof)*	sq.yds	85,533	450	38,489,761
1.8	*Paving Type B - Asphalt Pavement - 4 high stacking*	Tons	479,342	118	56,562,367
1.9	Ground Improvement (Dynamic compaction)	sq.yds	352,245	16	5,569,309
1.10	Site mobilisation of Ground improvement Plant	L.S.	1	29,363	29,363
1.11	Kentledge load test	L.S.	1	10,800	10,800
1.12	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	352,245	23	8,133,334
1.13	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	352,245	6	2,178,857
1.14	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	352,245	3	922,903
1.15	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	14	23,000	322,000
1.16	Line/corner Marking & Signage	sq.yds	352,245	1	197,431
1.17	Demolition (Warehouse T7)	sq.ft	219,300	5	989,043
	Container Yard Base Cost SUBTOTAL				**118,051,267**
	Mobilization			0.15	17,707,690
	Inspection and Permitting			0.025	2,951,282
	Contingency on Construction			0.2	27,742,048
	Engineering Services (incl. design and procurement)			0.1	11,805,127
	<u>**Container Yard Paving TOTAL**</u>				***178,257,413***

The total Option 4 container yard cost is estimated at $178,257,413.

2	<u>**Reefer Yard**</u>				
2.1	Reefer Substations including equipment - Upgrade to South Substation	Ea.	1	722,470	722,470
2.2	Reefer Masts (Steel Galvanised poles - 33ft nominal height)	Ea.	288	7,520	2,165,760
2.3	Reefer socket outlets	Ea.	1,628	550	895,400
2.4	*Breakout and Demolishing of existing paving (8 inch asphalt)*	sq.yds	43,934	8	344,006
2.5	*Re-grading (cut)*	yds^3	8,160	4	28,996
2.6	*Re-grading (fill)*	yds^3	1,259	2	1,951
2.7	*Paving Type B - Asphalt Pavement - 4 high stacking*	Tons	78,378	118	9,226,110
2.8	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	43,934	23	1,014,444
2.9	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	43,934	6	271,762
2.10	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	43,934	3	115,111
2.11	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	2	23,000	46,000
2.12	Line/corner Marking & Signage	sq.yds	43,934	1	24,625
	Reefer Yard Base Cost SUBTOTAL				**14,856,635**
	Mobilization			0.15	2,228,495
	Inspection and Permitting			0.025	371,416
	Contingency on Construction			0.2	3,491,309
	Engineering Services (incl. design and procurement)			0.1	1,485,663
	<u>**Reefer Yard TOTAL**</u>				***22,433,518***

The total Option 4 reefer yard cost is estimated at $22,433,518.

5. Cost Estimates

5.5.4 Option 4 Costs

3	**South Gate Upgrade**				
3.1	ISPS Perimeter Fence (Including posts and foundations - Chain link)	lin.ft.	5,000	50	250,000
3.2	Port Gate In (inc. all associated equipment and furniture)	lane	8	100,000	800,000
3.3	Port Gate Out (inc. all associated equipment and furniture)	lane	7	100,000	700,000
3.4	Optical Character Recognition (OCR) Portal with equipment and software	lane	5	17,000	85,000
3.5	Radiation Scanner infrastructure - utilities,foundations, lighting, secondary inspection, CPB boothes etc.	lane.	3	2,000,000	6,000,000
3.6	Weighbridge - weigh in motion sensors	Ea.	6	39,900	239,400
3.7	TWICS GATE automated kiosks and Rising Barrier Arms	Ea.	12	9,600	115,200
3.8	New gate house building - steel clad buidling 3 story high	sq.ft	3,000	220	660,000
3.9	Security Booth	sq.ft	538	130	69,940
3.10	Breakout and Demolishing of exisitng paving (8 inch asphalt) - Gate	sq.yds	52,300	8	409,507
3.11	Paving Type B - Asphalt Pavement - 4 high stacking - Gate	Tons	93,303	118	11,009,729
3.12	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	52,300	23	1,207,602
3.13	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	52,300	6	323,507
3.14	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	52,300	3	137,029
3.15	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	1	23,000	23,000
3.16	Line/corner Marking & Signage	sq.yds	52,300	1	29,314
	South Gate Upgrade SUBTOTAL				**22,059,227**
	Mobilization			15.0%	3,308,884
	Inspection and Permitting			2.5%	551,481
	Contingency on Construction			20.0%	4,411,845
	Engineering Services (incl. design and procurement)			10.0%	2,977,996
	South Gate Upgrade TOTAL				***33,309,433***

4	**Intermodal yard**				
4.1	Removal of Existing Rail tracks - Container Track #1	lin.ft.	1,000	500	500,000
4.2	Removal of Existing Rail bend to track 18a	lin.ft.	0	500	0
4.3	Removal of Existing Rail bend to track 18b (ENVIVA line)	lin.ft.	0	500	0
4.4	Extension of rail road tracks to Container line 1	lin.ft.	300	1,000	300,000
4.5	Extension to Rail road tracks to Line 18	lin.ft.	0	1,000	0
4.6	Extension to Rail Road Tracks to Line 18a	lin.ft.	0	1,000	0
4.7	Extension to Rail Road Tracks to line 18b	lin.ft.	0	1,000	0
4.8	New intermodal yard exit gate lanes	Ea.	2	100,000	200,000
4.9	New intermodal yard entry gate lanes	Ea.	2	100,000	200,000
4.10	Intermodal yard RPM infrastructure - CBP bopothes, utilities, secondary inspection structures, lighting etc.	Lanes	2	2,000,000	4,000,000
4.11	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	16	23,000	368,000
4.12	Line/corner Marking & Signage	sq.yds	23,405	1	13,118
	Intermodal Yard Base Cost SUBTOTAL				**5,581,118**
	Mobilization			15.0%	837,168
	Inspection and Permitting			2.5%	139,528
	Contingency on Construction			20.0%	1,116,224
	Engineering Services (incl. design and procurement)			10.0%	753,451
	MML Rail Yard Study Base Intermodal Yard Cost				18,000,000
	Intermodal Yard TOTAL				***26,427,489***

The total Option 4 south gate upgrade cost is estimated at $33,309,433.

The total Option 4 intermodal yard cost is estimated at $26,427,489.

5. Cost Estimates

5.5.4 Option 4 Costs

5	**Plant/equipment**				
5.1	Reach stackers	Ea.	12	1,000,000	12,000,000
5.2	Cherry pickers	Ea.	2	30,000	60,000
	Plant/equipment SUBTOTAL				**12,060,000**
	Plant/equipment TOTAL				***12,060,000***

5	**Chassis yard conversion**			
5.1	Suspended deck over storm retention basins	19,400	532	10,320,800
5.2	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	1	23,000	23,000
5.3	Chassis Yard Exit Gate	1	100,000	100,000
4.1	New roads alignments	3,000	746	2,237,334
4.2	New roundabouts	1,068	746	796,491
	Chassis Yard Conversion Base Cost SUBTOTAL			**13,477,625**
	Mobilization		0.15	2,021,644
	Inspection and Permitting		0.025	336,941
	Contingency on Construction		0.2	2,695,525
	Engineering Services (incl. design and procurement)		0.1	1,819,479
-	**Chassis Yard Conversion TOTAL**			***20,351,214***

The total Option 4 chassis yard conversion cost is estimated at $20,351,214.

Option 4 Project	Costs (USD)
Container Yard	178,257,413
Reefer Yard	22,433,518
South Gate Upgrade	33,309,433
Intermodal Yard	26,427,489
Equipment	12,060,000
Chassis Yard Conversion	20,351,214
TOTAL	**292,839,068**

5. Cost Estimates

5.6 Summary

Table Y to the right presents a summary of the cost breakdown for each of the options presented in this report.

The cost per TEU generated for each option is relatively consistent across all options (averaging about $214/TEU/annum), showing that scaling up the capacity of the terminal from 1,123,865 TEU/annum in Option 1 to 1,345,534 TEU/annum in Option 4 provides only a relatively small reduction in marginal cost. Option 2 provided the most TEU capacity per dollar investment but is only marginally more efficient than the other options.

There is a 22.5% difference in overall CAPEX between the most expensive and cheapest options whilst the capacity difference between the two is 19.7%.

The results seem to favour the cheaper option since the value per dollar investment is not great enough to warrant building out a terminal which provides significantly more capacity than what is required at 750,000 TEUs per annum.

Based on cost alone, it appears that Option 2 provides the greatest value. However, other factors must also be considered before a firm selection is made. A multicriteria selection analysis has been carried out and is detail in the next chapter.

Table Y: Option Costs Comparison

Yard Improvement Project	Option 1 (US$)	Option 2 Base Cost (US$)	Option 3 Base Cost (US$)	Option 4 Base Cost (US$)
Reefer Yard	157,237,640	165,475,814	178,250,476	178,257,413
South Gate Upgrade	22,433,281	22,433,680	22,433,518	22,433,518
Container Yard	29,162,271	13,201,235	26,202,091	33,309,433
Intermodal Yard	26,427,489	25,813,566	26,427,489	26,427,489
Equipment and Other Works	12,060,000	12,060,000	12,060,000	32,411,214
TOTAL CAPEX (Nearest million USD)	**247,320,680**	**238,984,294**	**265,373,574**	**292,839,068**
Throughput Capacity (TEU/annum)	**1,123,865**	**1,152,647**	**1,250,591**	**1,345,534**
Marginal Cost (CAPEX/TEU/annum)	**$220.06**	**$207.34**	**$212.20**	**$217.64**

6. Options Screening

Multi-criteria analysis of layout options

6. Options Screening

6.1 Introduction

In order to finalise a preferred terminal yard development option for recommendation to NCSPA for adoption and implementation, a multi- criteria decision analysis (MCDA) of the options was performed.

A MDCA was used to aid the team focus on what is important, is logical and consistent, by dividing the decision and option features into smaller, more understandable parts. The 'parts' or selection criteria for each option was selected jointly between MML and NCSPA. The selection criteria ranged from qualitative to quantitative factors with each criteria weighted for its importance. The weighting was categorised in to low, 'medium' and high' importance. A brief description of the high and medium importance selection criteria adopted is provided below.

Maximum Yard Capacity and Cost (High Importance)
Naturally, the terminal capacity offered by the option was a clear selection criteria. However, since the capacity of the terminal is linked directly to the overall CAPEX, cost is need to balance off the terminal capacity selection criterion, especially the CAPEX per TEU metric.

Ease of Upgrading the Gate Complex (High Importance)
One of the most complex upgrade projects proposed is the upgrade of the current south gate complex. Being the only entry and exit points to the container terminal, it is important that any future developments and alterations to the gate can be executed with the minimal of disruption to truck traffic entering the port. The relative ease of construction and disruption caused to current operations were taken in to consideration.

Need for Adjusting Existing Rail Tracks (Medium Importance)
This criteria focuses on the intermodal yard development and whether the proposed layout option requires excessive amendment and possible demolition of existing rail tracks and sidings. A lot of investment and upgrade works are currently being carried out by NCSPA. Although not an essential requirement, it is preferred if all existing tracks can be integrated within the new intermodal yard layout for the future to prevent any abortive construction and investment.

Intermodal Yard Efficiency (High Importance)
The layout of the yard options may have an impact on how the intermodal yard is operated. Factors such as how TICO trucks enter and exit the yard and how the trucks will route around the terminal to enter the intermodal yard are all key factors to efficient intermodal yard operation. All options are reviewed for their ability to achieve this.

Gate Security (High Importance)
Security at the gates and especially improvements to the existing gate complex are considered high importance factors. Layout options which provide segregation and safe rejection of non-security cleared trucks from the terminal are deemed to be more favourable.

Need to Extend Beyond Existing Boundary (High Importance)
Option which do not require the need to develop outside of the current port boundary are deemed more favourable. This is because any work outside of the current port boundary will involve lengthy approvals processes which are outside the jurisdiction of NCSPA. Road alignment and property boundaries will have to be renegotiated which will involve additional resources and time. However, the port currently requires urgent capacity upgrades and any additional time required to implement the options is seen as a disadvantage.

6. Options Screening

Stack Utilisation to Meet 750,000 TEUs per Annum (Med Importance)
Although the options considered allow for a potential 70% stack utilisation to be achieved during future operation of the terminal, prolonged high stack utilisation rates will lead to pressures on terminal staff, equipment and lowered margin of error. Therefore the options will investigate the stack utilisation required to meet the target throughput capacity. The lower the stack utilisation the more favourable the option will be.

Reach Stacker Numbers required (Medium Importance)
Reach stackers are efficient modes of container handling, however, they are known for being relatively more dangerous to other staff and vehicles on site due to their size and weight. A large amount of reach stackers operating at the same time is not ideal and therefore, the options which have the lowest requirement of reach stackers is deemed to be more favourable.

Truck Turn Around Time(Med Importance)
Port of Wilmington have been serving their customers at the highest level and one of the key metrics that the port is judged against is truck turnaround times. This is how quickly a truck at enter the terminal, exchange boxes and leave the terminal. Currently, a 30 minute truck turnaround time is considered to be the bench mark across neighbouring ports and any option which can achieve turnaround times below this value will be more favourable.

Construction Complexity (Med Importance)
All options will require a period of time to be fully implemented and phased to ensure that interim construction capacity will stay within the port's operational throughput requirements at the time. However, options which require multiple phases and lengthy construction implementation will be less favourable.

6.2 Scoring

Having established the selection criteria and weighting for each, the options were scored against the selection criteria.

For each criteria, the option which was deemed to be most favourable will be given 4 points with the least favourable given 1 point.

The points were then multiplied by its respective weighting where by:

- ‘High Importance’ criterion multiplied by ‘3’.
- ‘Medium Importance’ criterion multiplied by ‘2’.
- ‘Low Importance’ criterion multiplied by ‘1’.

The results of the MCDA and scoring for each option is shown overleaf.

Any option which does not score more than 70% will automatically be rejected.

6. Options Screening

6.3 Multi Criteria Analysis Results

The results of the MCDA indicates that Option 1 is the most preferred solution to take forward scoring 116 points out of a maximum of 132 which represents 88% scoring which is above the pass mark. All scoring was carried out jointly with NCSPA.

Options 3 and 4 scored 84 and 82 points respectively. Both these options, therefore, did not achieve the 70% pass mark which were automatically rejected.

	Scoring Criteria	Weighting	Option 1	Option 2	Option 3	Option 4
1	**Maximum Yard Capacity**	High	1,123,865 TEUs/Yr	1,152,647 TEUs/Yr	1,250,591 TEUs/Yr	1,343,534 TEUs/Yr
			3	**6**	**9**	**12**
2	**Ease of Upgrading Gate Complex**	High	Proposed gates can be built without disruption to existing gates	Difficult phasing - reconfigure within existing complex	Proposed gates can be built without disruption to existing gates but will need re-grading land in vicinity	Planning issues and chassis yard closures required but dies not disrupt existing gate ops
			12	**3**	**9**	**3**
3	**Need for Adjusting Existing Rail Sidings**	Med	**8**	**8**	**2**	**8**
4	**Ability to Extend the Intermodal Yard in the Future**	Med	**8**	**2**	**2**	**6**
5	**Ability to operate intermodal yard efficiently**	High	**12**	**12**	**3**	**12**
6	**Gate security**	High	**12**	**3**	**3**	**12**
7	**Need to extend beyond existing Port Boundary**	High	**12**	**12**	**12**	**3**
8	**Stack Utilisation to meet 750,000 TEUs per annum**	Med	46.70%	45.50%	45.50%	39%
			4	**6**	**6**	**8**
9	**Additional Gate Operational Changes to match theoretical gate capacity**	Med	**8**	**8**	**8**	**2**
10	**Reach stacker numbers required**	Med	24	24	24	26
			8	**8**	**8**	**2**
11	**TICO truck numbers required**	Low	55	55	55	60
			4	**4**	**4**	**1**
12	**Truck Turn Around Times**	Med	15mins	15.6mins	15.7mins	16.8mins
			8	**8**	**8**	**6**
13	**Construction Complexity**	Med	**8**	**2**	**4**	**4**
14	**Cost**	High	**9**	**12**	**6**	**3**
	TOTAL		**116**	**94**	**84**	**82**

7. Conclusion and Preferred Option

Discussion of selected yard improvement option

7. Conclusion and Preferred Option

7.1 Introduction

Following the multi-criteria assessment presented in Chapter 6, the outright preferred yard development option was Option 1. Despite Option 1 having the lowest terminal capacity out of the four, it was considered to be sufficient for the targeted 750,000 TEUs per annum by 2025. It was also considered to have, relatively, the most straightforward constriction phasing. The implementation of the south gate upgrade in terminal yard 'L' appears to be the most favourable since the gates new footprint allows for temporary utilisation of the existing gate complex during construction. More importantly, Option 1 allows the gate to be developed with upgraded security integration as compared with the other options which helped the decision making process.

However, the base option layout required refinement with the following details revisited:

- ❑ Traffic routing detailing at the south gate.
- ❑ Construction phasing details.
- ❑ Interim capacities during construction.
- ❑ Truck processing at the new gates.
- ❑ Gate technology requirements.
- ❑ Cost Sensitives – utilisation of alternative paving materials.

This Section of the report details the refined Option 1 layout and provides a 'walk through' of the new gate layout and terminal facilities.

7. Conclusion and Preferred Option

7. Conclusion and Preferred Option

7.2 Refined South Gate Upgrade Layout

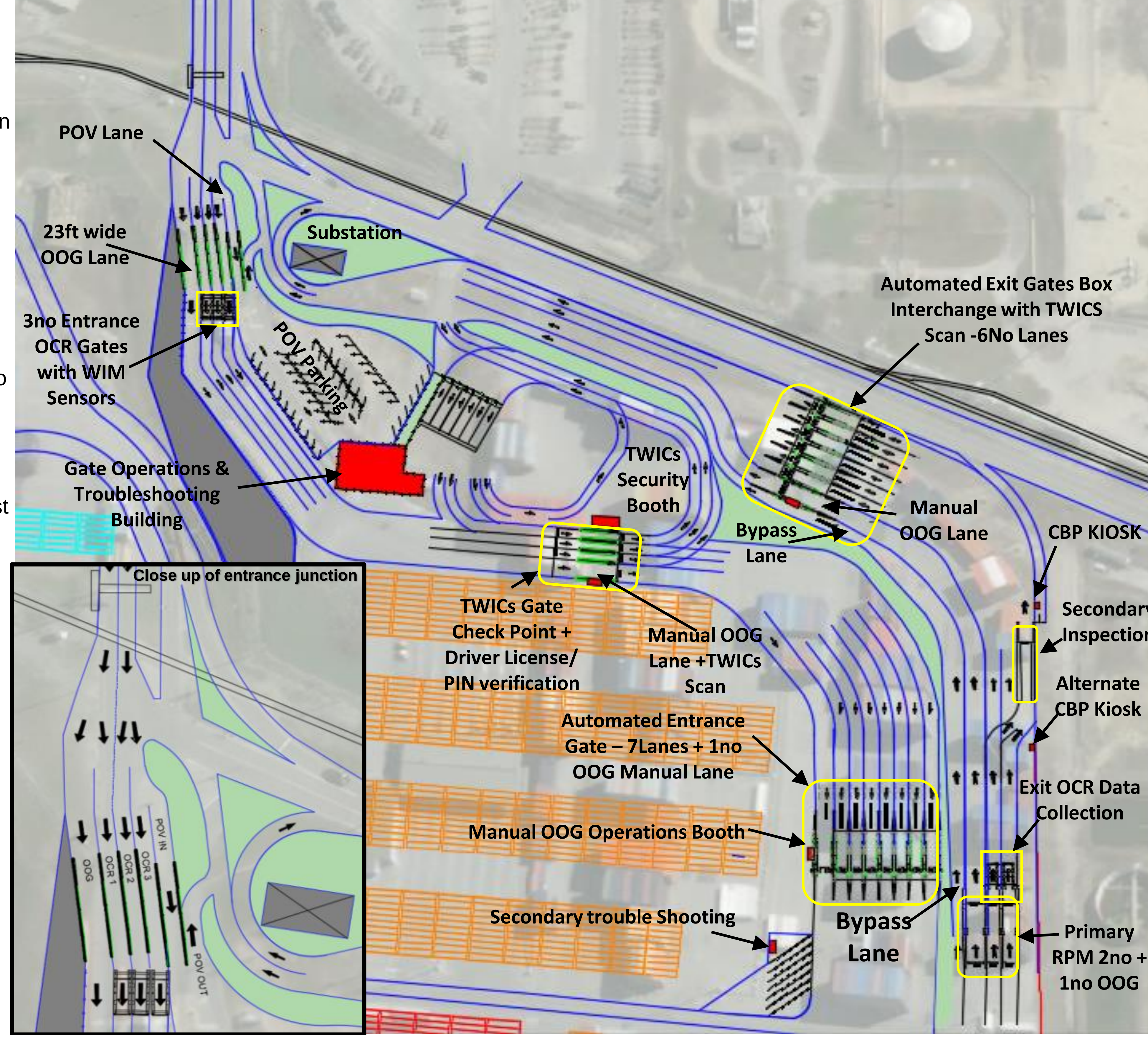
Once Option 1 was selected as the preferred option various refinements to the layout were investigated and introduced to the model. Figure 50 shows the revised final layout of the south gate upgrade, which as a critical factor in the operation of the terminal has been investigated to try and improve the running of the process.

All the key requirements as established for the south gate upgrade are still present such as the need for OCR automation, a minimum of seven ‘In’ gates and six ‘Out’ gates. Improvements were made to ensure better traffic flow and to better comply with CBP requirements on RPM scanning.

The aim was also to allow an operation whereby if problems or errors were identified within the entrance OCR process that the trucks can be diverted to a holding area without passing through the entrance gates first. This will reduce the queuing at the gates and improve security. Creating an “island” to house this holding and troubleshooting area, also provides an alternative entrance to the gate house for POV vehicles which can be isolated outside the main terminal secured areas, and can lead to a reduction in building cost if the troubleshooting office can be combined with the gatehouse. However, this solution does occupy a significant amount of terminal real estate which will need to be deliberated at the next stage of design. An alternative would be to route problem trucks out of the terminal and carry out troubleshoot away from the main terminal. This would allow the in and outbound lanes to be aligned closer together and potentially increasing the storage space for empty containers.

Following discussion with the NCSPA, the TWICs gate on exit has been incorporated with the main exit gate. A lane has been included within this layout for out of gauge (OOG) traffic for project cargo and other oversized vehicles. This is not included within the simulation modelling as it operates as a separate system. The new layout and operational and parameters were used to assess the effect on the overall process using the ARENA simulation model. The simulations results are presented later in this report The process of traffic entering and exiting the proposed south gate is explained in the next Section.

Figure 50: Plan of South Gate Upgrade Layout



7.2.1 Traffic Routing at New Gate

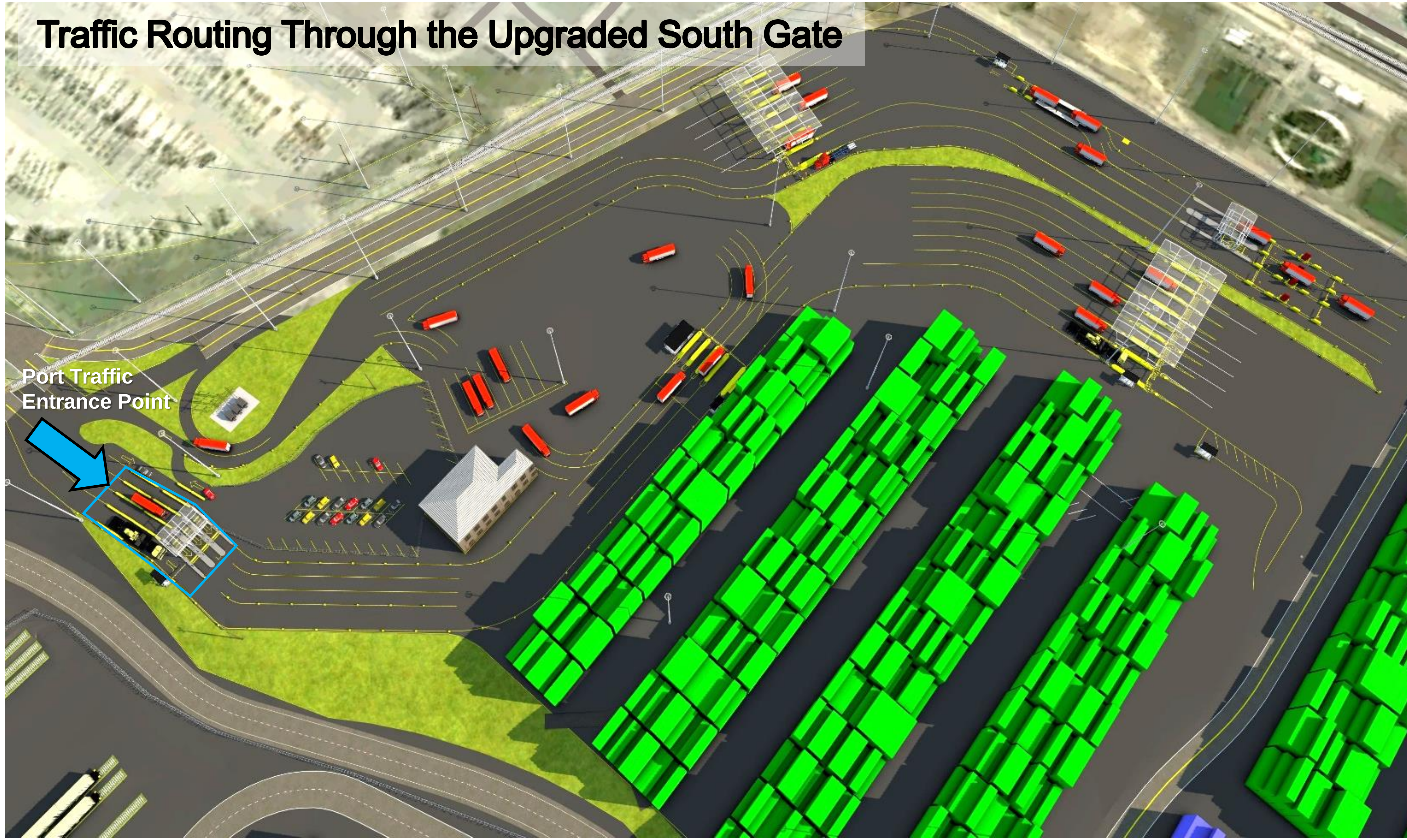
Inbound Trucks:

The first feature to note in the refined Option 1 gate layout is that inbound truck traffic will enter the terminal via three sets of OCRs first instead of the current system whereby truck drivers verify their TWIC a the point of entry.

This allows the automation process to begin as the OCR captures the truck data before they reach the TWIC and appointment verification check point.

Trucks will enter the port via Ship Yard Boulevard as usual.

For the gate automation process to function properly, aa appointment system is required to be collected by the port from the used/customer.



7.2.1 Traffic Routing at New Gate

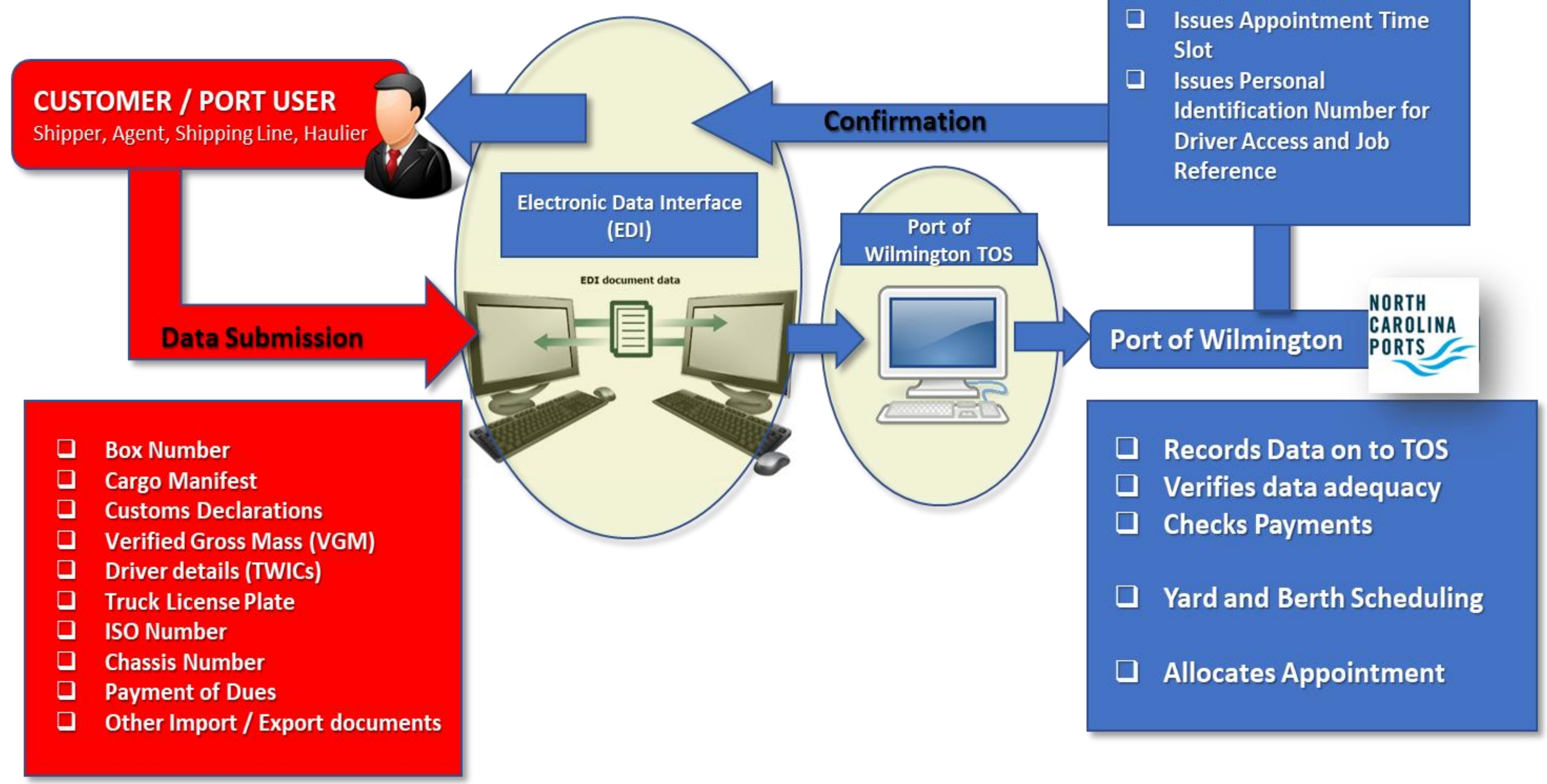
Truck Appointment System

Before the arrival of the container truck, it is proposed for the port user/customer to submit all shipping data associated with their import and export transaction. This data will include but not limited to the container number, cargo manifest, customs declarations, VGM, driver details, truck license number, IMDG codes ISO number, chassis number etc…

It is proposed for this information to be submitted electronically and no paper work is required. For this to happen, the Port of Wilmington will need to upgrade their current phone booking system to an electronic data Interface whereby users can login and submit data which will be captured, stored and verified by the future port terminal operating system (TOS).

Once the TOS has verified the data in the appointment system, it will match that data to the yard/berth scheduling module to select a preferred truck/box arrival time slot. The described truck appointment system will aid the terminal by reducing peak truck traffic flow rates.

Truck Appointment System – Data Requirements



Once the data has been verified and an appointment is allocated, the TOS will send to the customer a confirmation message via the EDI system. The appointment will be clearly notified to the customer and trucker along with a personal identification number (PIN) for entry into the terminal.

7.2.1 Traffic Routing at New Gate

Inbound Trucks:

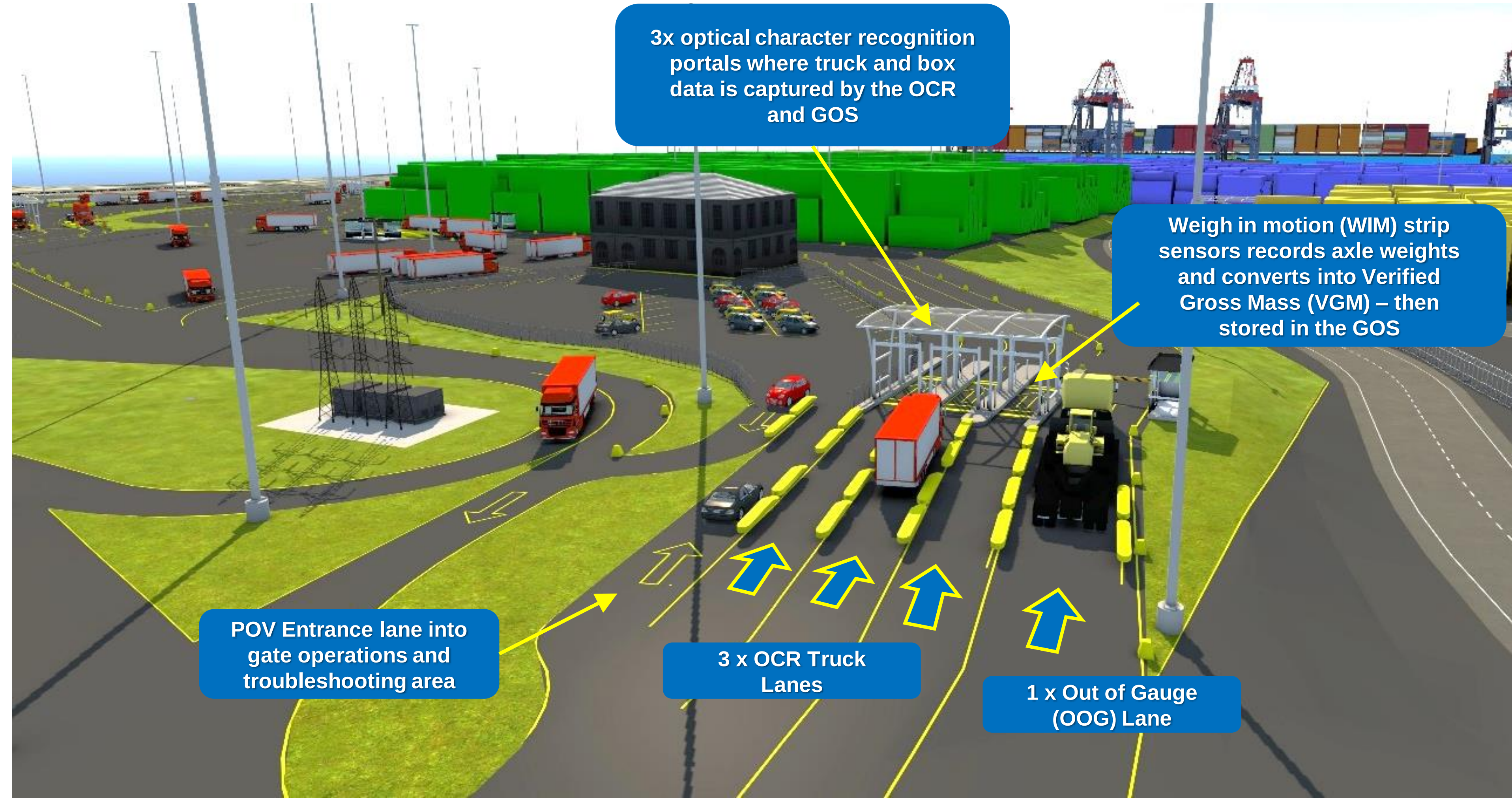
On the day of the truck arrival appointment, the driver will enter the port via the OCR portals where automated cameras will read the box number, chassis number, truck license plate number, ISO number, IMDG code, capture images of the container and truck for condition records and in addition, weight the truck and container via integrate weight in motion sensors in the pavement directly in lane of the OCR portals. A video example of the weight in motion sensor is provided in box A opposite.

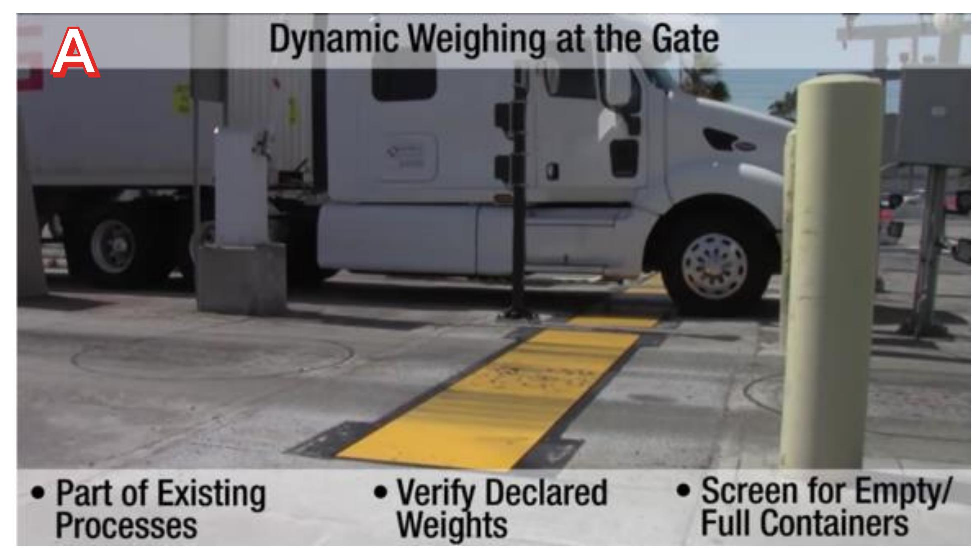
The data captured from the OCRs will be stored in the Gate Operating System for retrieval by the TOS.

A video of the OCR truck processing is provided in Box B opposite.

Other new features included in the south gate upgrade proposed are a separate privately owned vehicle (POV) entry and exit lane which allows POVs to access and leave the isolated gate operations and troubleshooting office without having to go through security first. Note that he isolated gate operations area is fenced off front he rest of the terminal.

An additional OOG lane of minimum 23 feet width is provided to the north of the OCR portals, this lane will be manned by security staff and is manually operated.





7.2.1 Traffic Routing at New Gate

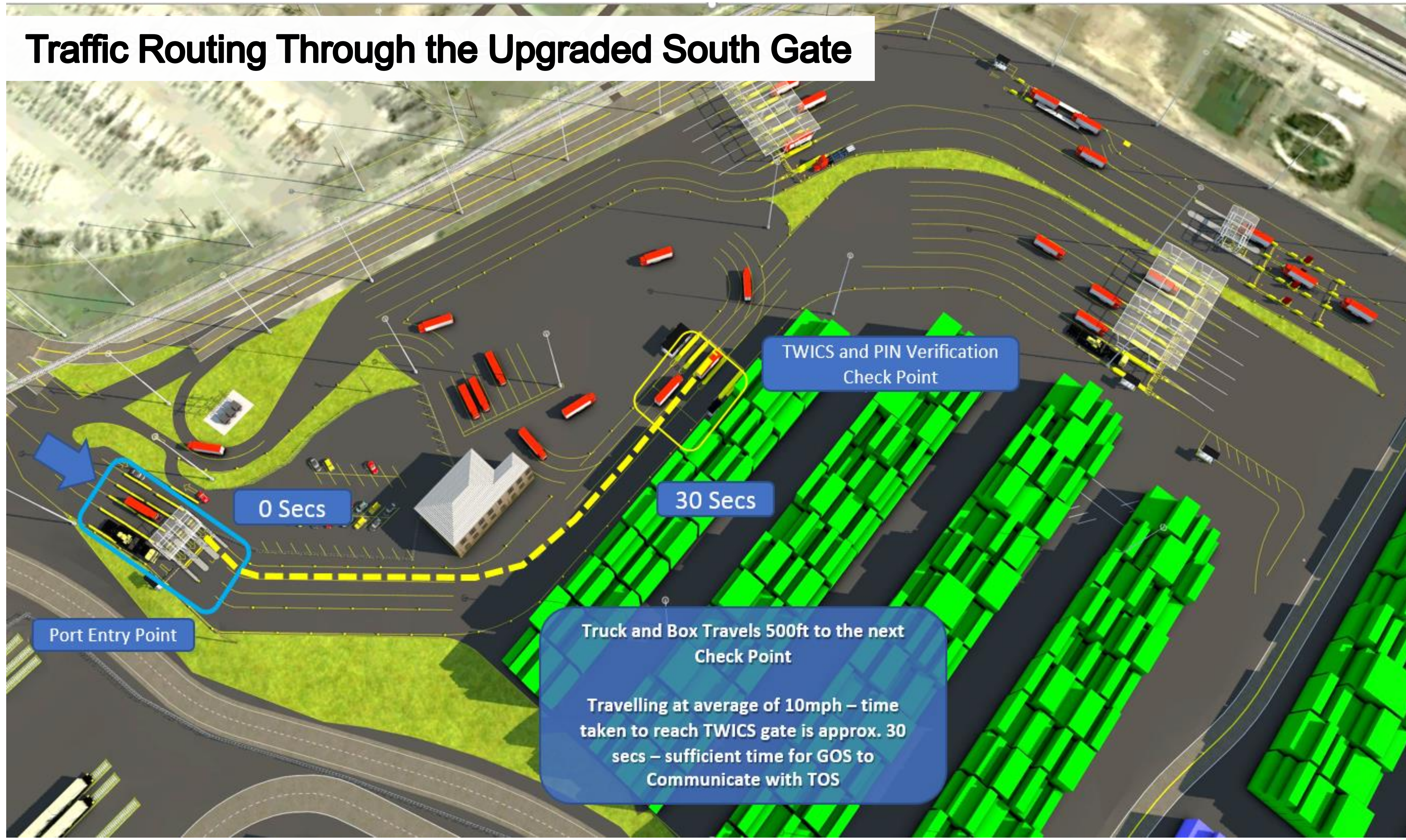
Inbound Trucks:

The OCR portals are designed such that trucks do not need to stop and can drive straight though the OCR cameras. A width narrowing at the OCR lanes will be proposed to make sure the trucks do not enter the lanes at high speeds and also to ensure the OCR cameras work at the optimum accuracy although speeds up to 20mph can be accommodated.

Once the trucks have cleared the OCRs, they will travel towards the TWICs and PIN verification station which is situated 500ft away.

Travelling at an average speed of 10mph, it will provide at least 30 seconds over the 500ft for the GOS to communicate with the TOS, providing the captured OCR data to the TOS for processing.

Therefore from the entry of the OCR through to the arrival at the TWICS gate, the average time taken will be approximately 30 seconds.

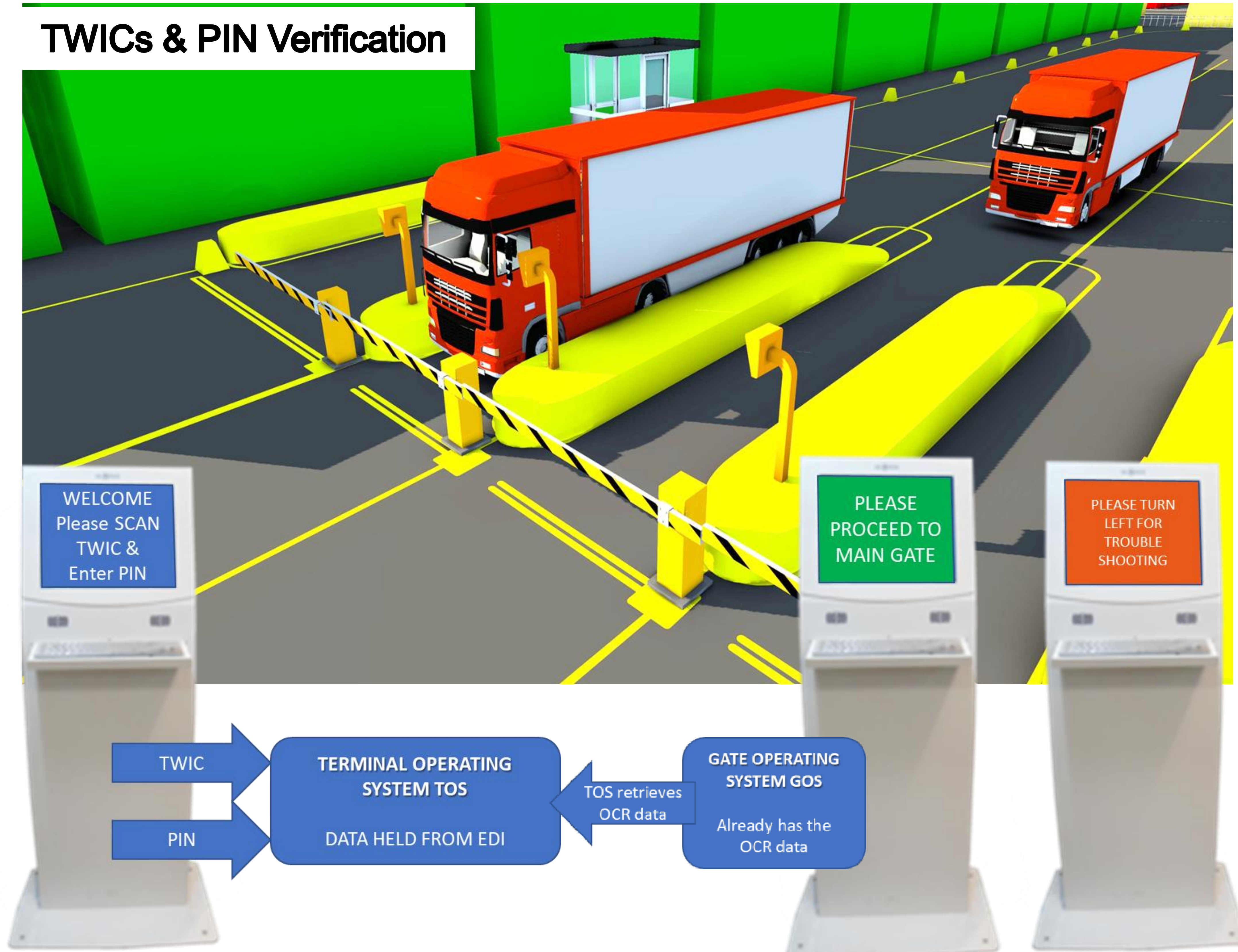


7.2.1 Traffic Routing at New Gate

Inbound Trucks: At the TWICs Gate

Once the trucks have arrived at the TWICs gate the driver will be faced with a self-service KIOSK and TWICs scanner machine. The trucks will be prevented from progressing in to the terminal by a riser barrier arm The driver is asked to scan their TWIC and then enter their PIN which was given to them during the appointment process. The TWIC details and PIN will be Processed by the TOS which by now the TOS would have also retrieved the OCR data from the GOS. With the information the TOS can match the pre arrival data to ensure the driver and container are have legitimate reasons for entering the terminal. If all is cleared, the riser barrier arm is lifted and the driver is instructed to proceed towards the main entrance gates. However, if the data provided does not match the data stored in the TOS, the driver will be asked to turn left into the central trouble shooting area for resolution of the issue.

Note that security presence will be available alongside the TWICs and PIN verification station at all times.



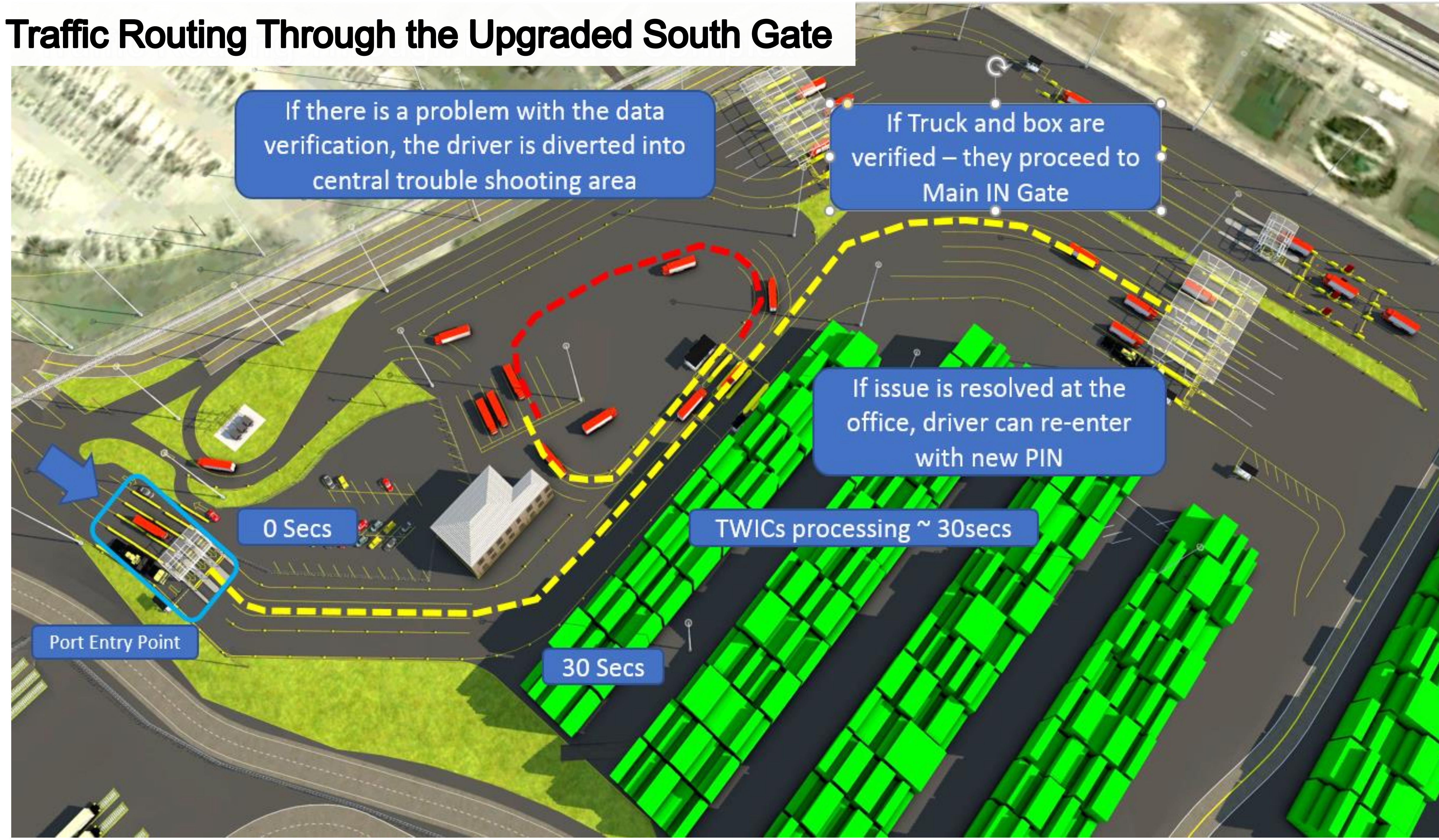
7.2.1 Traffic Routing at New Gate

Inbound Trucks:

Once the truck driver has cleared the TWIC and PIN verification check point, the truck can travel towards the main IN gate interchange area. However, should there be an issue with the data provided, the trucks will need to turn left into the trouble shooting area where the truck driver will need to park up and attempt to try and resolve the issue in the central trouble shooting office.

If the matter is successfully resolved, the driver will be given a other PIN to enter the TWICS gate again and then proceed as normal. However, if the problem cannot be resolved, the truck will be rejected off the premises via the exit lanes provided without having to enter the secure area of the terminal.

The processing time at the TWICs and PIN verification station is assumed to take on average 30 seconds to 1 minute, therefore the total average time elapsed from the point of entry to clearing the TWICS station is approximately 1.5 minutes.



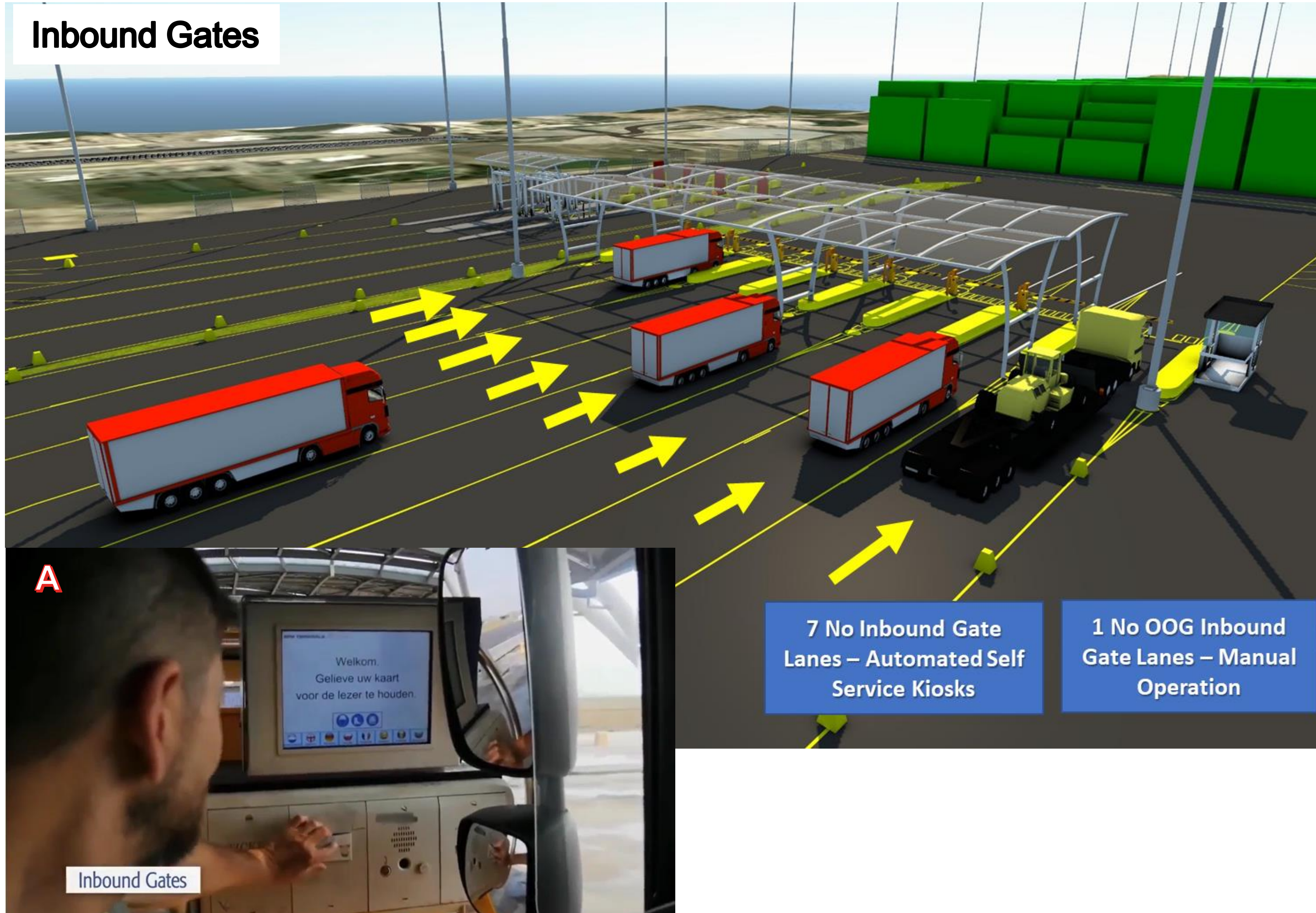
7.2.1 Traffic Routing at New Gate

Inbound Trucks: Main In Gates

Once the trucks have cleared the TWICs and PIN verification check point, the drivers will proceed towards the main Inbound gate interchange. Trucks will be offered seven inbound gate lanes to choose from and one number OOG lane. All seven inbound gates lanes will be have self-service kiosks where by the driver will be asked to enter their PIN again. The PIN will be sent to the TOS and the associated mission and container slot will be identified. A mission ticket will be printed at the kiosk providing the driver with the location and stack number the driver will need to go to.

A video example of the self-service kiosk machine in operation is shown in box A opposite.

Any OOG cargo will need to enter via the manual OOG lane on the end of the complex. This lane will be manned by staff in a separate cabin next the inbound gates.



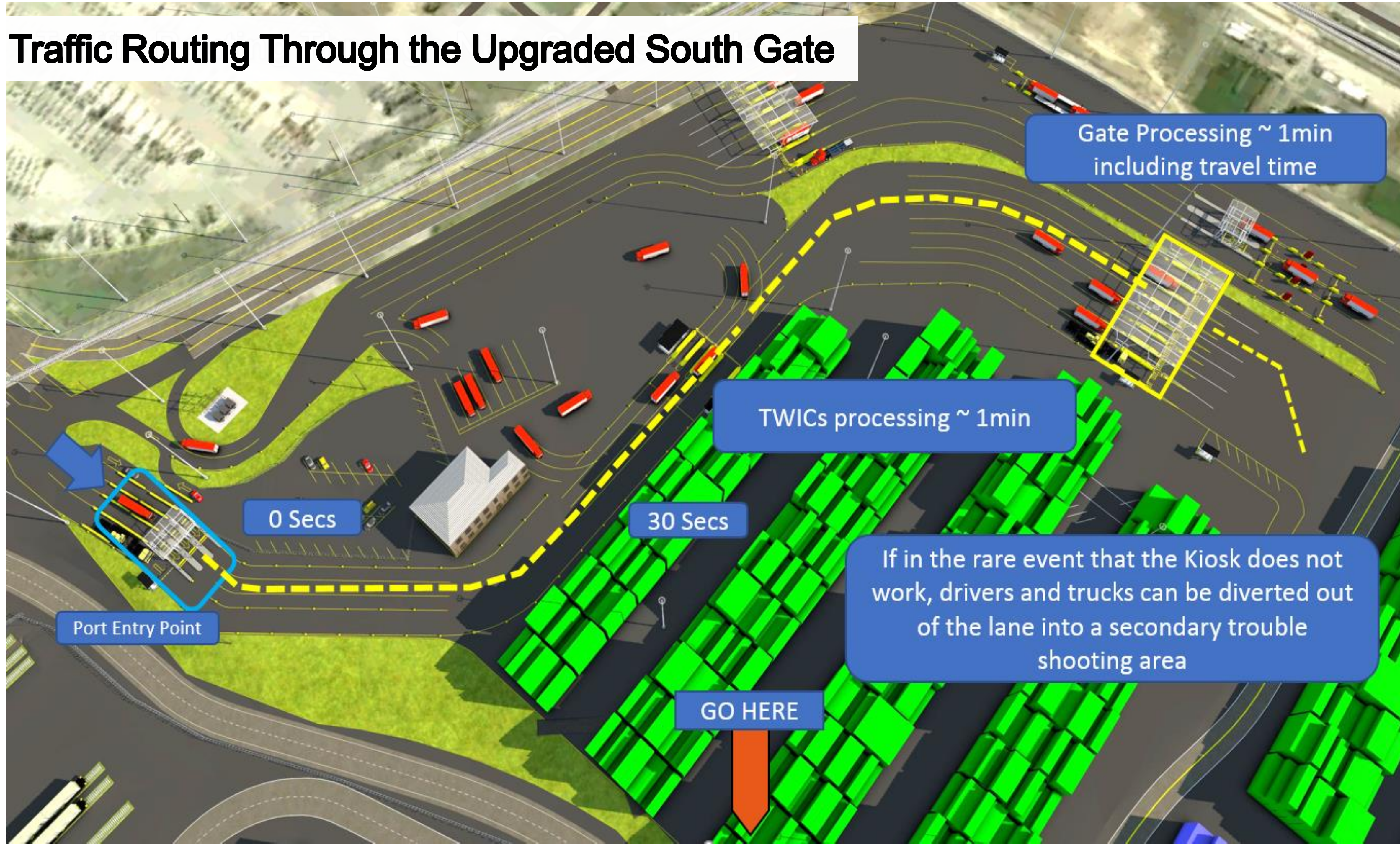
7.2.1 Traffic Routing at New Gate

Inbound Trucks:

Once the truck driver has been given a mission ticket, the riser barrier arm at the inbound gates will lift and the driver will approach the destination printed on the ticket.

However, there may be occasions when the self-service kiosk may not function as intended and in this situation, instead of trying to resolve the issue in-lane, a secondary trouble shooting area is provided 100 feet away in the terminal after the gate barrier. The driver will be able to communicate with gate operations staff via intercom at the self-service kiosk and the driver will be instructed to move into the secondary troubleshooting area as indicated on the figure apposite. This will allow the truck to vacate the gate lane and prevent congestion during peak times.

The time taken to travel from the TWICs gate and be issued with a mission ticket is approximately 1 minute. The total time elapsed from the truck entering the port to entering the terminal is now approximately 2.5 minutes on average.

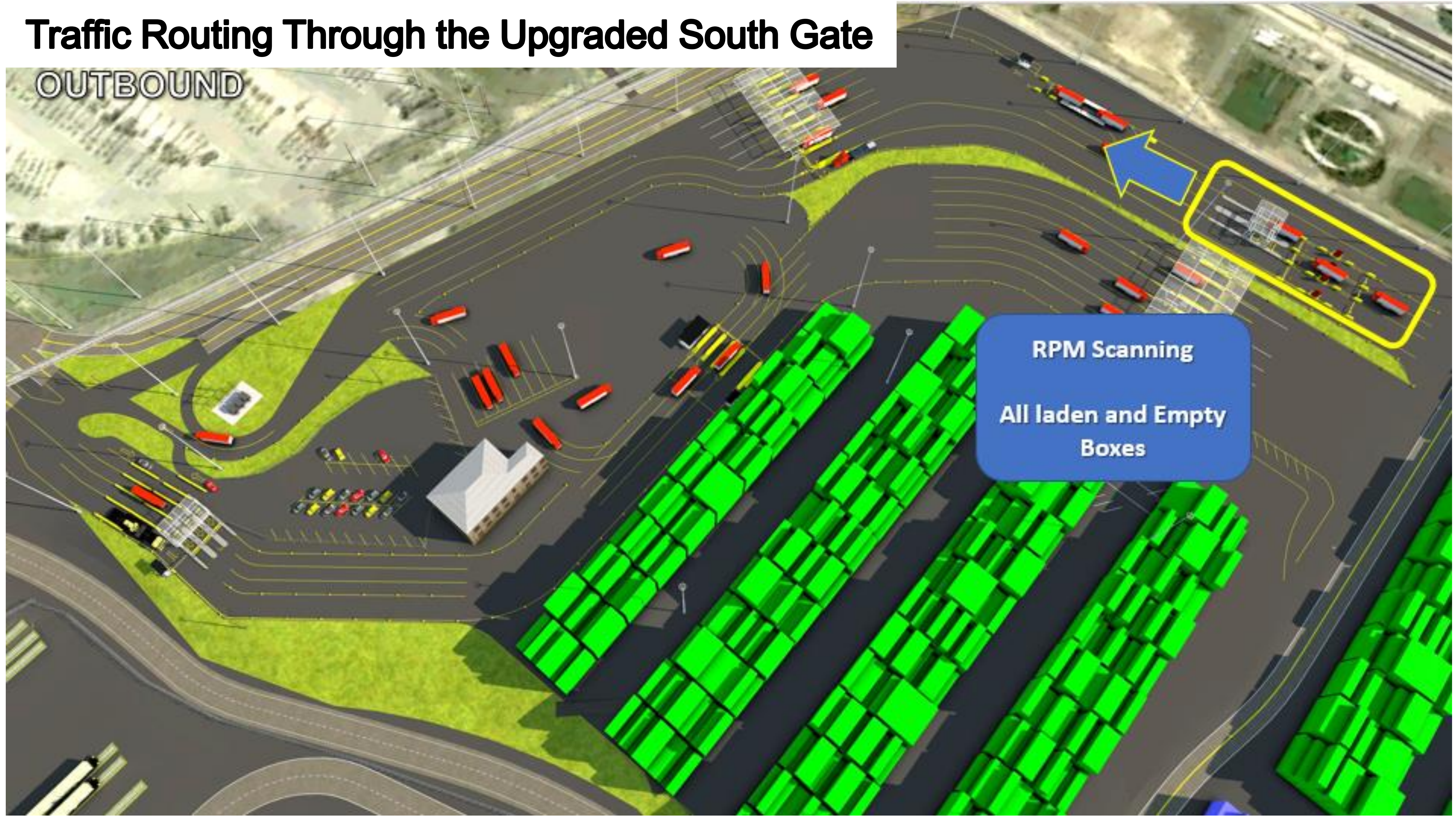


7.2.1 Traffic Routing at New Gate

Out-bound Trucks:
After a box has been picked up or dropped off at the terminal the truck driver will proceed to exit the terminal via the main exit lanes provided on the far south of the gate complex.

Note that the TOS will still identify the truck and container as still being in the terminal at his stage.

The first process that needs to be cleared by trucks exiting the terminal will be the radiation scanning check point. This will be required for all laden and empty boxes.



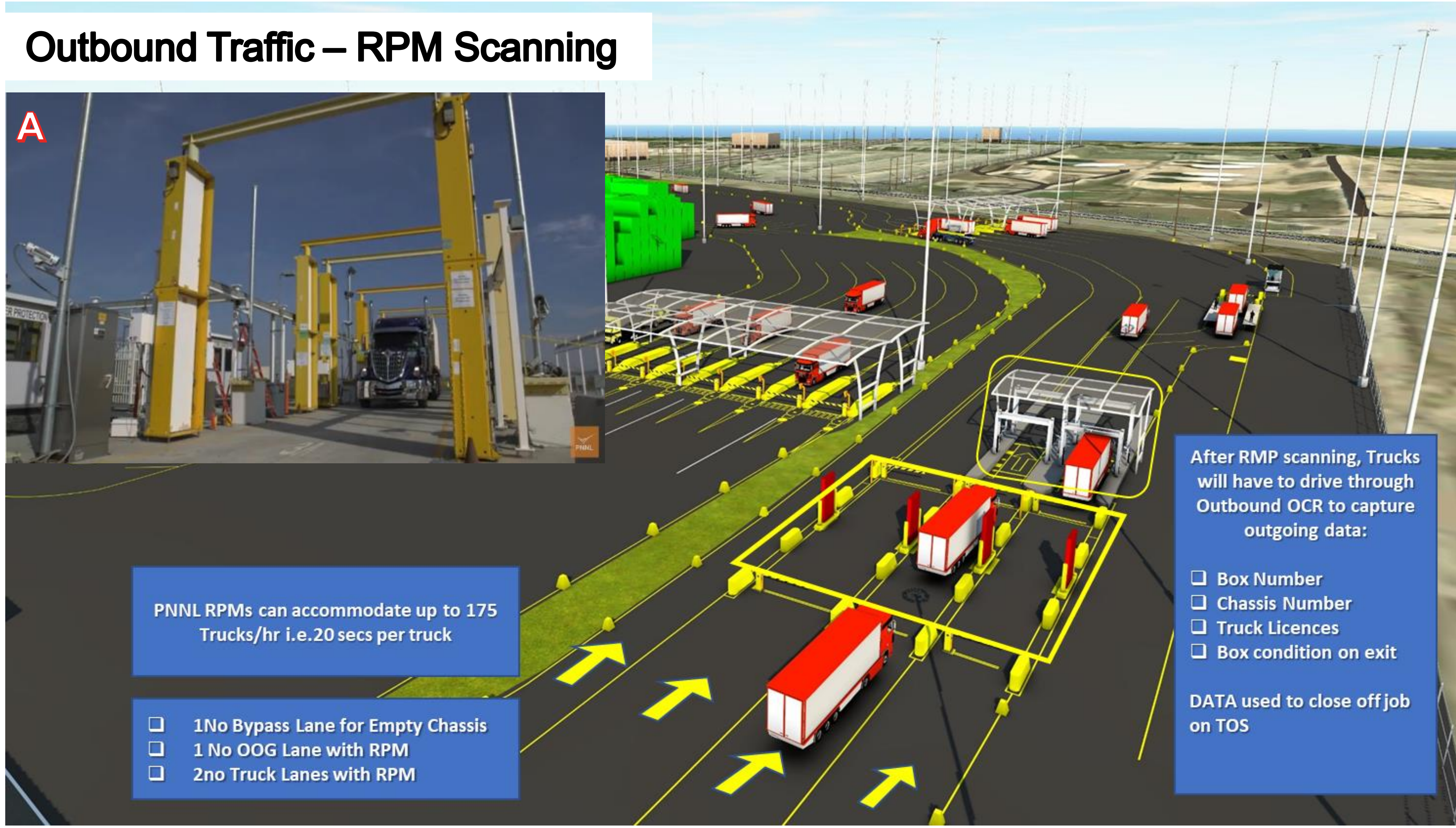
7.2.1 Traffic Routing at New Gate

Out-bound Trucks: At the RPMs
At the exit lane, truck drivers with either an empty or laden box on the chassis will need to drive past the RPM scanners. Two dedicated lanes are provided for these trucks. The RPM scanners provided by PNNL are able to process trucks at a rate of 175 truck per hour which is approximately 20 seconds per truck which is more than sufficient to deal with the peak traffic flow rate exiting the terminal at the specified terminal capacity.

A separate OOG lane is also provided with additional RPM scanning facilities.

A bypass lane has also been provided for empty chassis and those who require to exit the terminal and change the chassis for dual move purposes.

A video example of the RPM scanning process is provided in BOX A opposite.



After the trucks have passed through the RPM scanners, they will be required to proceed forward through a set of exit OCR portals. The OCR cameras will pick up and record the Box number, chassis number, truck license plate number box condition etc. This will be passed on to the TOS to close off the job on the system.

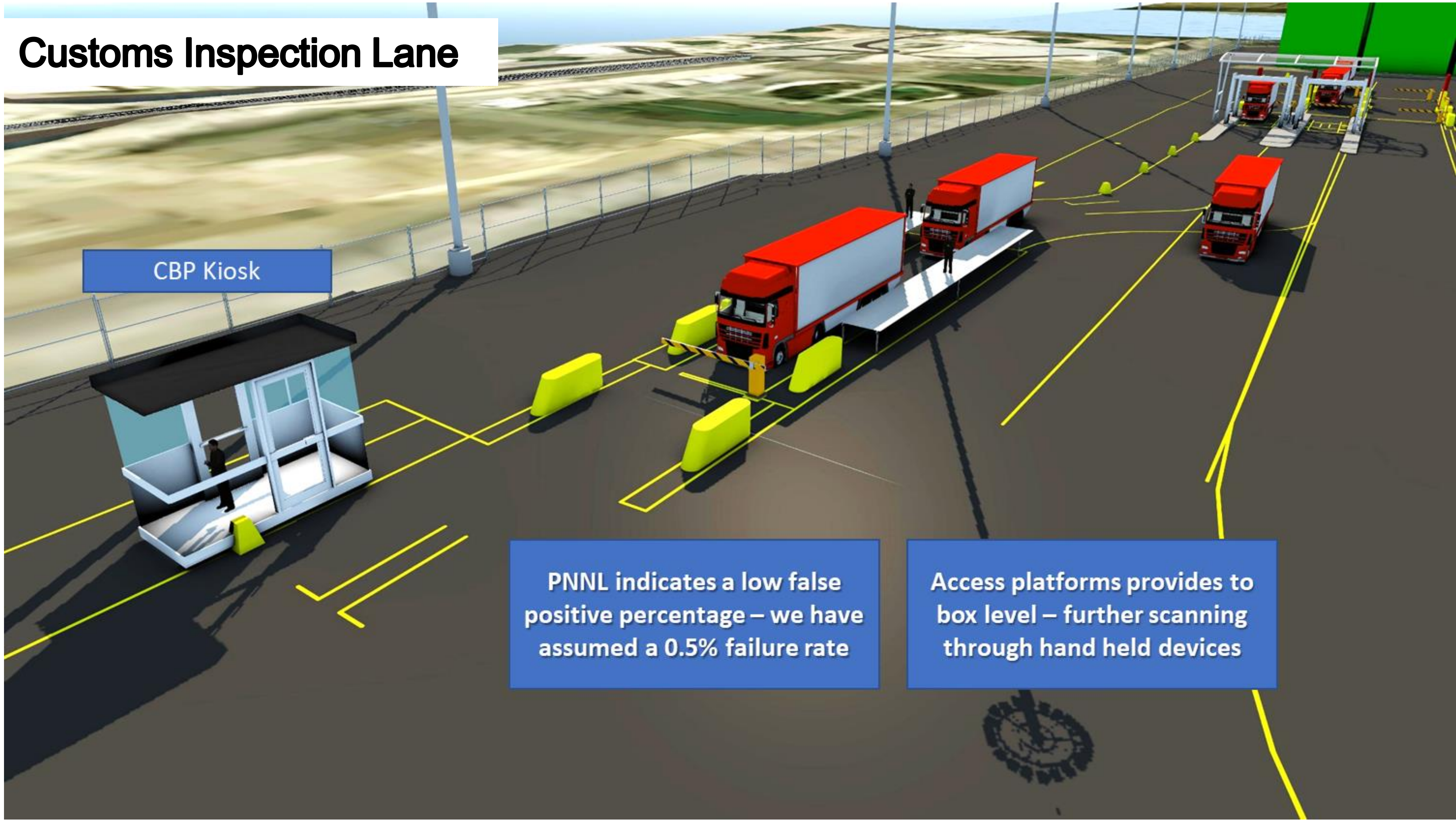
7.2.1 Traffic Routing at New Gate

Out-bound Trucks: Secondary Inspection

Should an anomaly be picked up at the initial RPM scan, a secondary inspection has been provided where by truck will pull aside under the supervision of CBP officers. The trucks will be examined again to verify the issue using hand held radiation scanners. Access platforms for operatives will be installed so that inspectors have access to the container.

False positives for RPM scanning is usually quite low and a value of 0.5% has been assumed for the simulation process.

Customs and border protection staff will be provided with a kiosk in the vicinity of the secondary inspection and RPM scanning facilities.

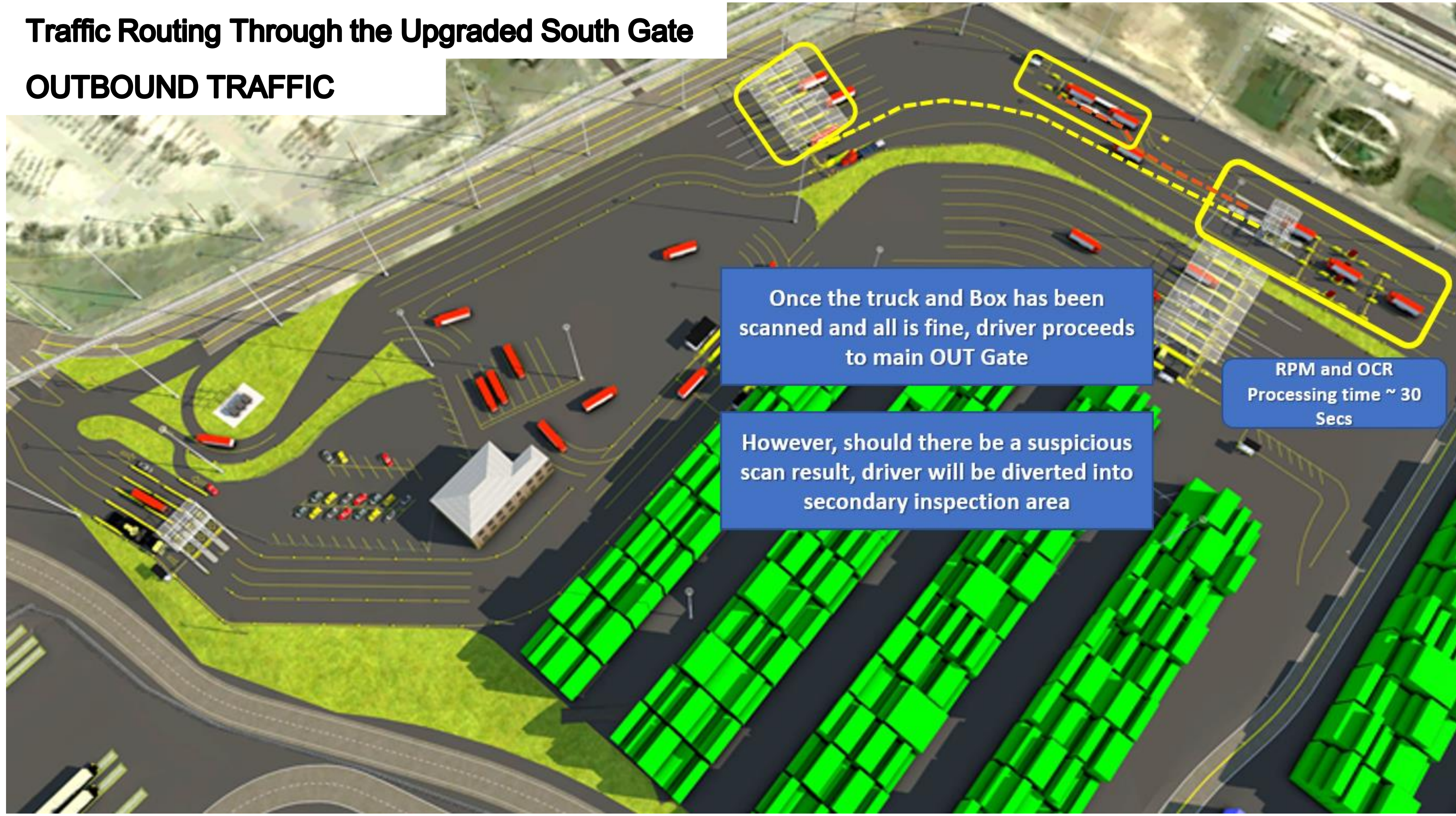


7.2.1 Traffic Routing at New Gate

Out-bound Trucks

If the RPM scan is negative, trucks can proceed directly to the main Outbound gate interchange area as shown.

The total time elapsed since the truck entered the RPM to arriving at the main out bound gate is approximately 1 minute.



7.2.1 Traffic Routing at New Gate

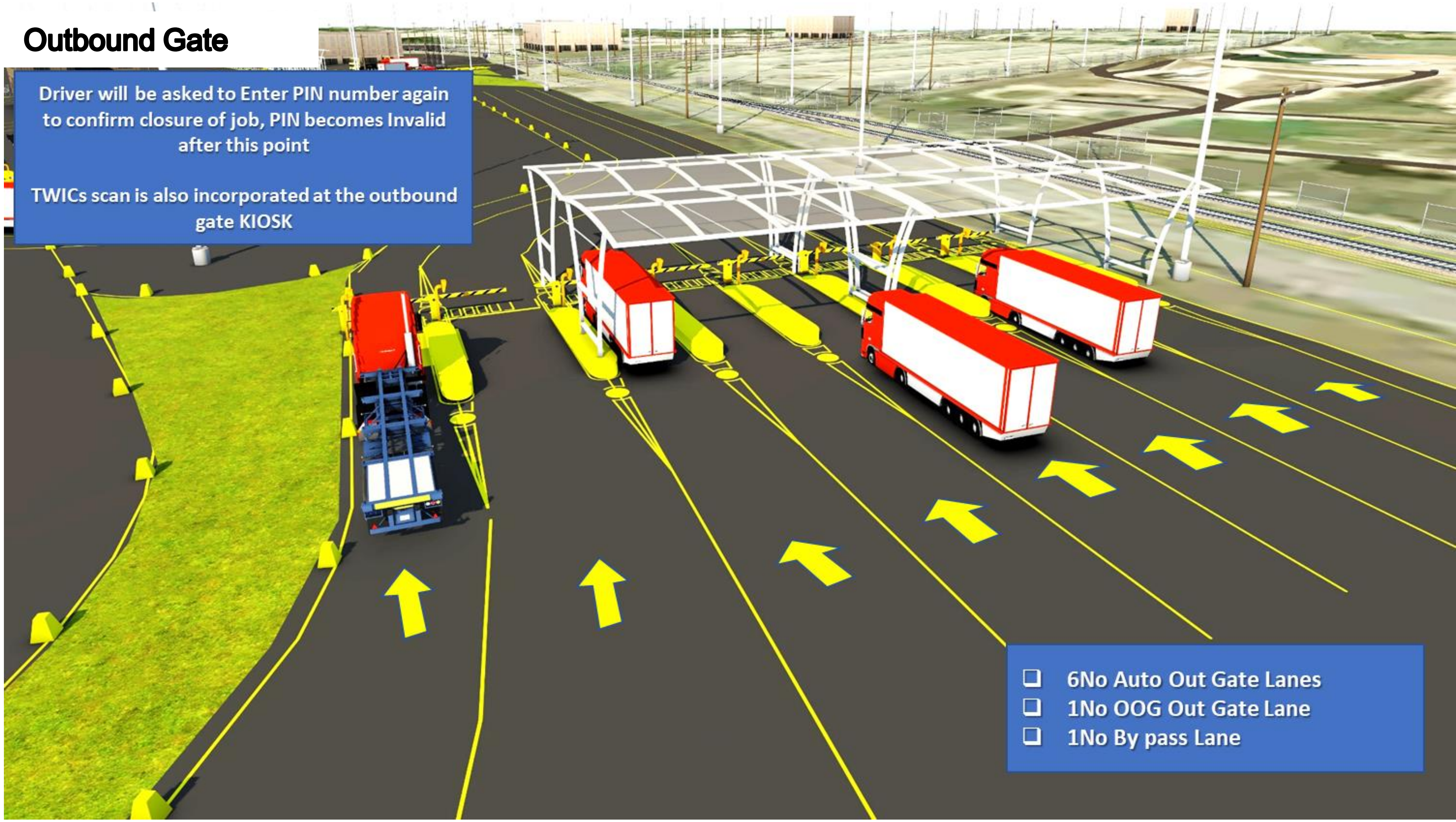
Out-bound Trucks: At the outbound gate

Once the trucks leave the exit lane OCRs, the drivers are presented with six exit lanes to choose from. In addition there is a dedicate bypass lane for empty chassis and a Manual OOG lane for project cargo.

All lanes will be provided with an integrated TWICs check station which must be cleared before the riser barrier arm is lifted.

At the outbound gate lane, the driver will be presented with self-service kiosk where the driver will first scan his TWIC and then enter the PIN given to the driver to enter the terminal. Once the TWIC and PIN has been entered and verified, the PIN becomes invalid, and the job associated with the PIN and will be closed off on the TOS.

The outbound gates will have a permanent security presence at all times with kiosk provided to manually process OOG trucks.



Trucks leaving the outbound gates will be directed toward the exit point of the port where trucks can leave via Shipyard Blvd or River Road heading south.

7.2.2 Gate Boundaries

The proposed south gate upgrade layout will also have a new set of terminal boundaries as shown in the figure opposite.

- ❑ The Boundary highlighted in Yellow is the Pre-security Area. Trucks in this area have not technically entered the secure zone of the terminal security is still required to be verified.
- ❑ The Secured Terminal areas highlighted in blue is also the customs bonded area of the terminal. Within this zone, all containers will be under the custody of the port and cannot leave the terminal unless customs dues are paid for. No vehicle or personnel which have not been cleared for security are allowed into eh secured blue zone.

7. Conclusion and Preferred Option

7.2.3 Final Gate Model Assessment

The parameters that have been used for the final gate model are shown in Table Z. The time for the TWICs gate on exit has been added to the exit gate increasing the time required for each truck at this station.

The other change in the model is that it has been noted that in the future scenario all trucks carrying empty containers need to be scanned via the RPM scanner and cannot use the bypass lane. This increases the number of trucks in total passing through both the RPM and the exit gates, and only empty chassis trucks can use the bypass lane. OCRs are used post the RPM scanners to record the data for the exiting trucks.

The intermodal percentage is set at 8%. This is the maximum considered as part of the study. If an increased amount of intermodal transit was increased, the overall terminal throughput would increase. Also, the number of chassis changes has not been reduced from existing.

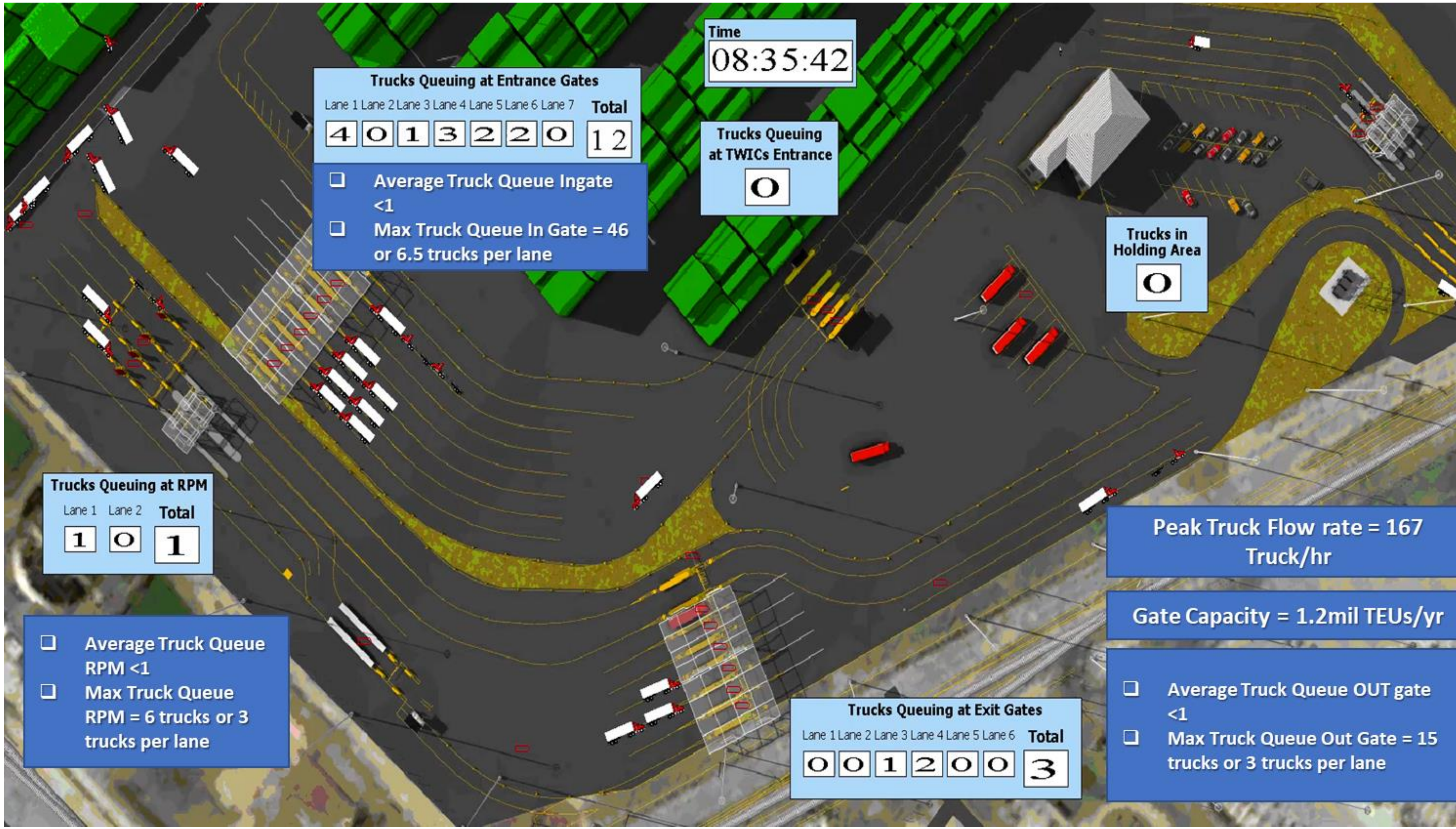
Table Z: Parameters for Final Gate Complex Model

	Operation	Baseline Case
1	TWICs IN processing time	25 seconds
2	TWICs IN Max Capacity	10 trucks
3	Weigh-in-motion time	0 seconds
4	OCRs	5 seconds
5	In Gates Number	7
6	In gate Processing Time	Triangular Distribution from gate data: Min (1.2min), Mean (1.5min), Max (1.8min)
7	In gate Max Queue Capacity	40 trucks
8	RPM Scanner Duration	25 seconds
9	RPM Queue Capacity	6
10	Out gate Processing Time (Now Incorporating TWICs OUT)	Triangular Distribution from gate data: Min (1.45min), Mean (1.75min), Max (2.05min)
11	Out Gates Number	6
12	Out gate Max Queue Capacity	25 trucks
13	Failure Capacity of System	Queue length exceeds the given capacity 50 times per year.

7. Conclusion and Preferred Option

7.2.3 Final Gate Model Assessment

Gate simulation animation – please click play to view.



7. Conclusion and Preferred Option

7.2.4 Final Gate Simulation Results

Results

The basic statistics for the baseline gate are shown in Table AA. The gate throughput is less than the terminal throughput due to the percentage of containers that are transported in and out of the terminal via rail.

Even with the changes made in the process since the initial Option 1 model, the gate is still able to operate at the same throughput as it is governed by the entrance process which is little changed. The average and maximum queue length for the exit gates has increased and is now not significantly under-utilized in comparison with the entrance gates.

The RPM scanners ae located close within the terminal so a large queue could affect the smooth operation of the yard areas. From the model the maximum queue is only six trucks and on average the queue is well below one truck so it is considered that they will not have a significant knock on effect on the terminal.

Table AA: Option 1 Final Gate Output Results

	TEU	Containers
Gate Throughput (per annum):	1,106,100	632,057
% Intermodal:	8%	
Terminal Throughput (per annum):	**1,192,769**	681,582

Container IN Via Truck	299,879	**Container OUT by Truck**	332,179
Container IN Via Ship	357,053	**Container OUT by Ship**	324,529
Container IN Via Rail	24,650	**Container OUT by Rail**	24,874

IN GATE (7 Number)	**Average**	**Max**
IN Gate Processing Total	489,642	
Number Chassis Changes	58,804	
Total Trucks IN	430,838	
IN Gate Queue Time (hours)	0.015	0.19
IN Gate Queue Number	0.85	55
Times Exceed Capacity / Year [40Nr]	49	

OUT GATE (6 Number)	**Average**	**Max**
OUT Gate Processing Total	301,444	
% Total Trucks	70.0%	
OUT Gate Queue Time (hours)	0.004	0.112
OUT Gate Queue Number	0.13	23
Times Exceed Capacity / Year [15Nr]	31	

7. Conclusion and Preferred Option

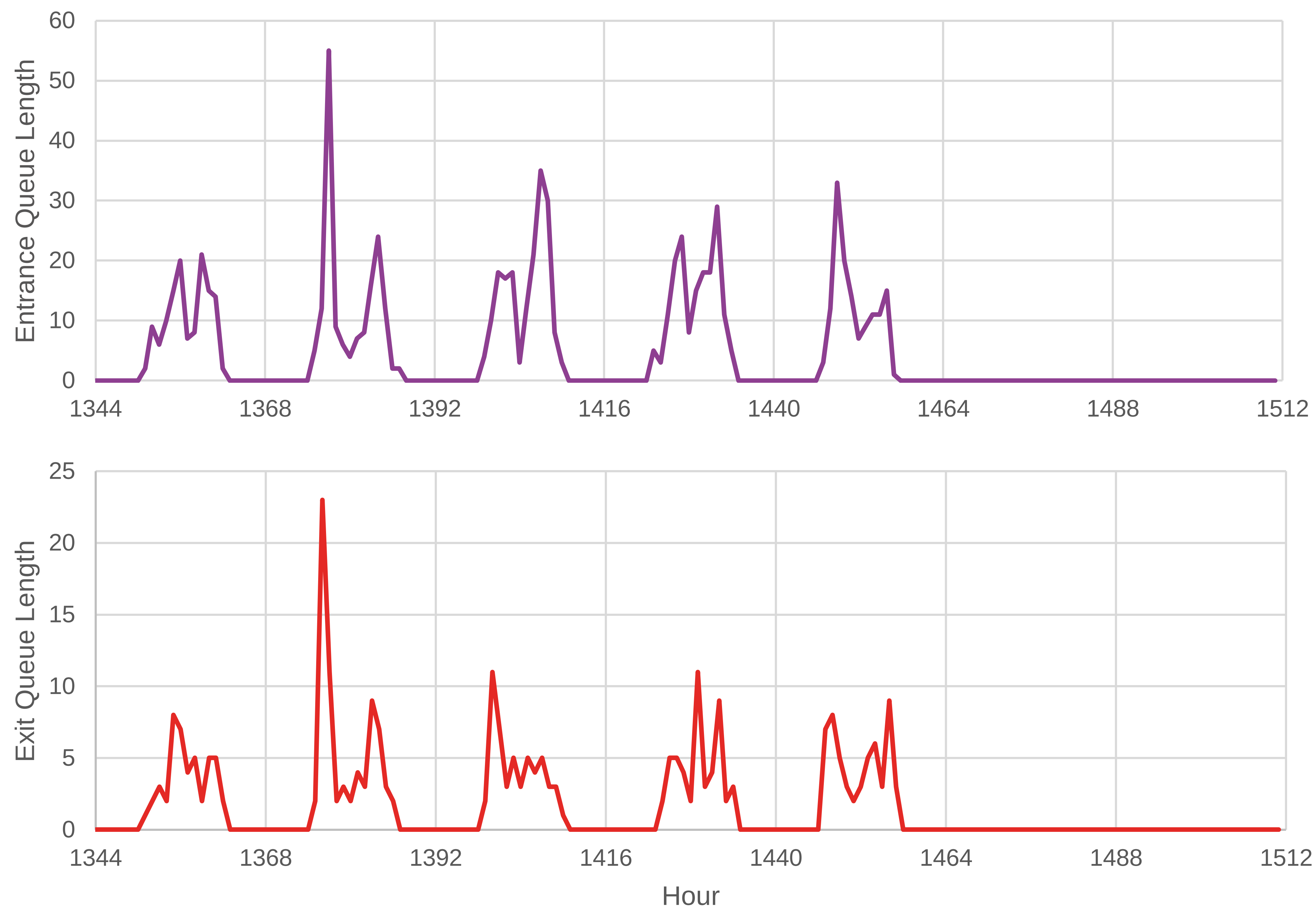
Results

Graphs of example weeks of the entrance and exit gates queue lengths are shown in Figure 51.

The queue length is variable through the day and the week. The queue at the entrance gate has not changed from the original model of Option 1.

The increase of the number of trucks passing through the exit gates due to empty trucks needing to pass through the RPM scanners. The combination of this and the addition time for the TWICs operation to occur has increased the queuing at the exit gates, however the model is still limited by the entrance gates.

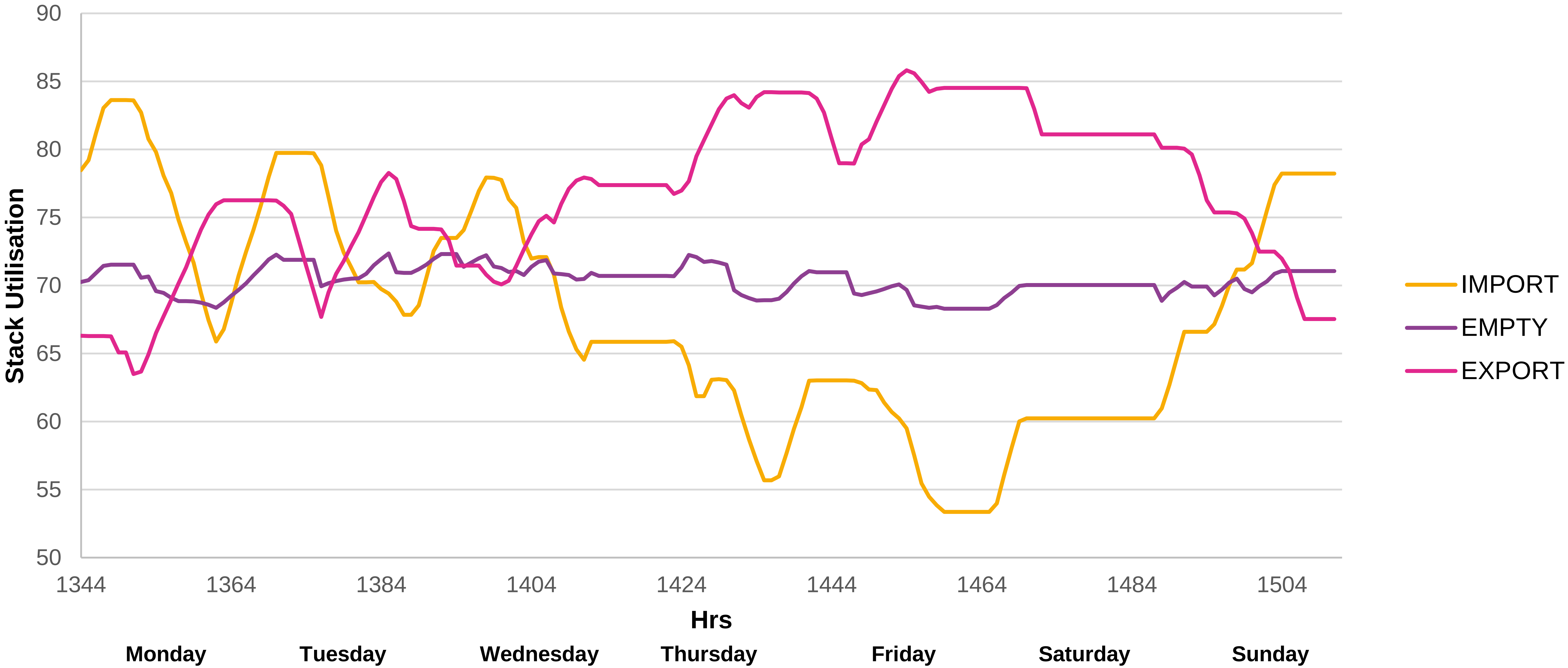
Figure 51: Queue lengths of the entrance and exit gates for the final option.



7. Conclusion and Preferred Option

7.2 Preferred Option Development

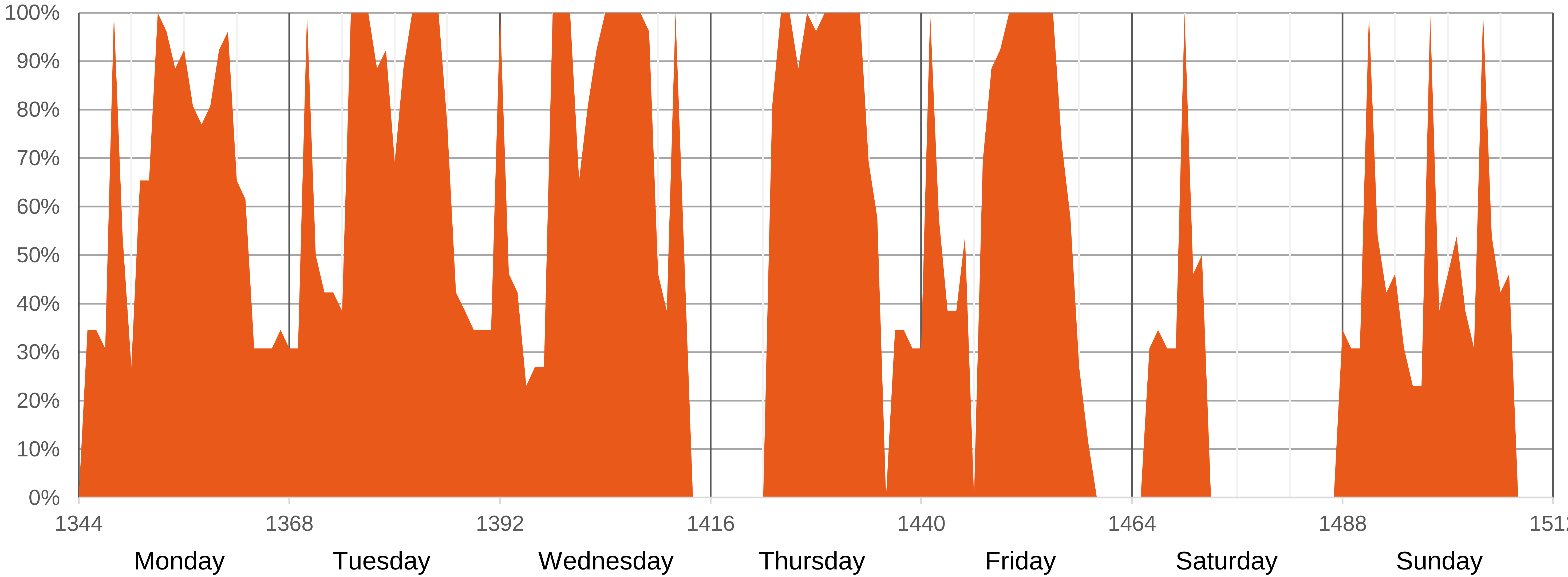
Figure 52: Stack Utilization for Import, Export and Empty Stacks over a sample week in the ARENA simulation. The empty stack remains constant over the week whereas the import export stack vary more due to large ship arrivals and the weekend where trucks do not arrive.



7. Conclusion and Preferred Option

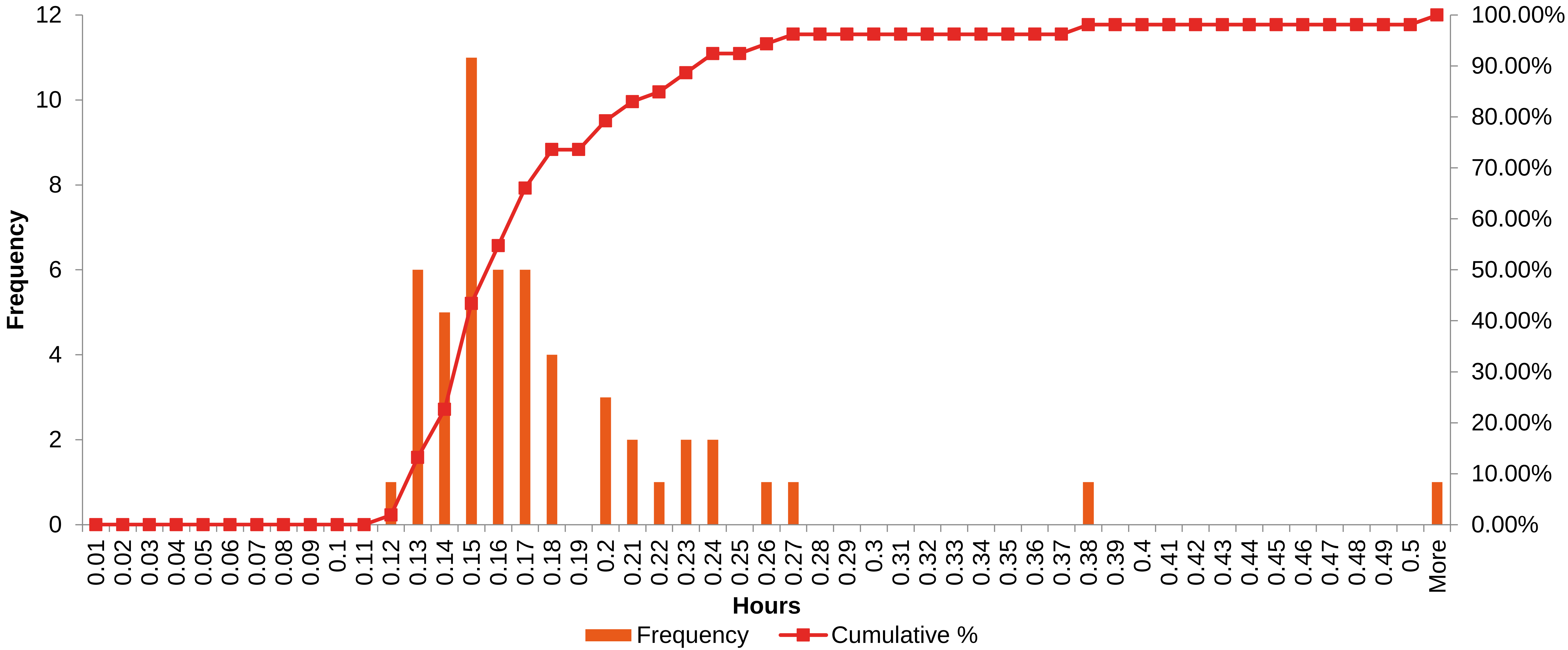
7.2 Preferred Option Development

Figure 53: Sample Reach Stacker Utilisation for a sample week in the global port model. IT can be seen that the use of all the reach stacker is quite rare, and the average is much lower. The only times where no reach stackers are in operation are overnight and at the weekends where no trucks or ships need to be serviced.



7.2 Preferred Option Development

Figure 54: Histogram Showing Truck Turn Time (Time from Entrance to Exit Gate for Trucks). The average (median) time is 0.152 hours/ 9 mins 7 seconds.



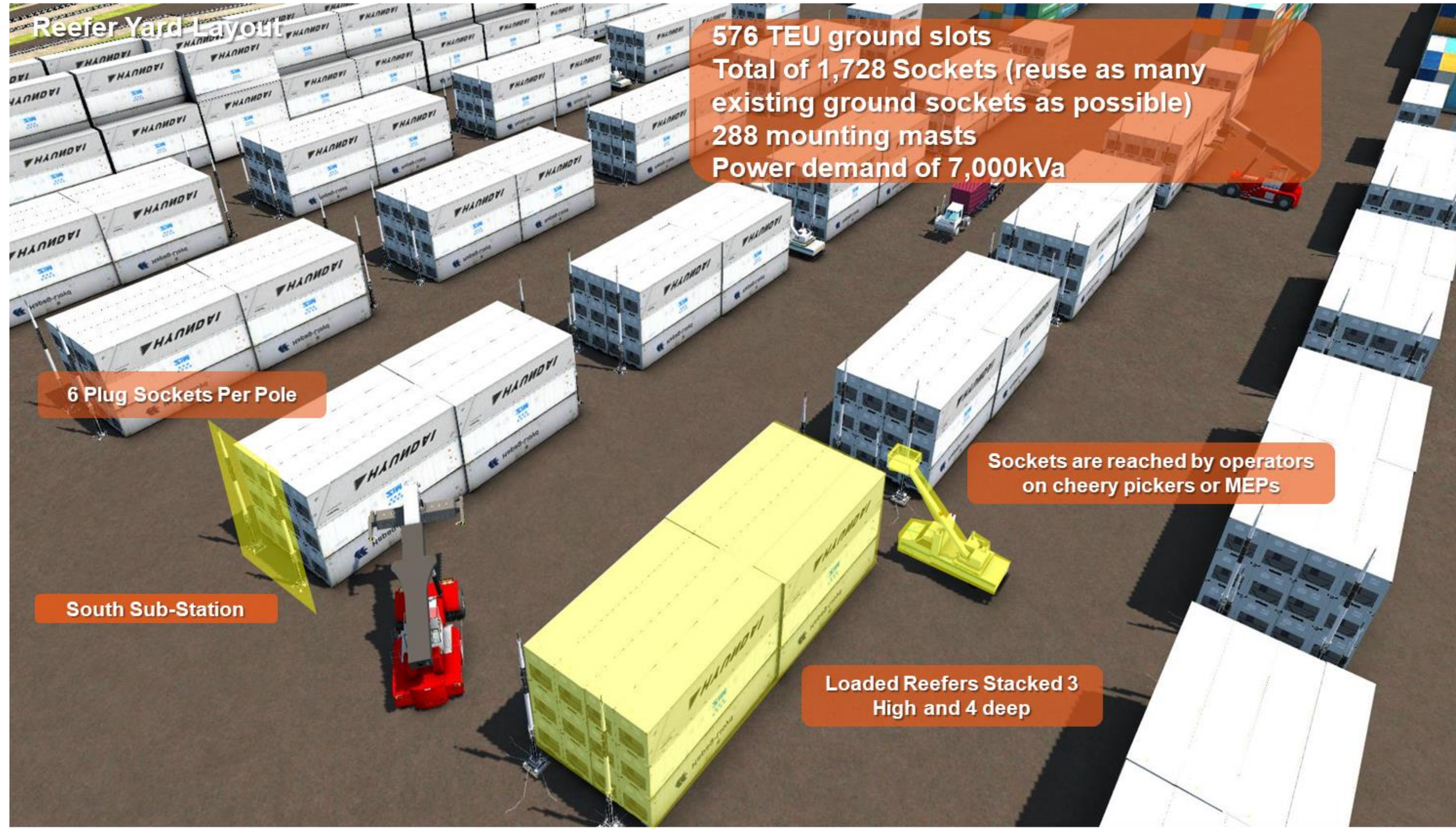
7. Conclusion and Preferred Option

7.3 Preferred Layout Reefer Yard

The main reefer yard in Option 1 propose still retains the key features required, these are as follows:

- Laden reefers will be stacked three high and four deep.
- Reefer sockets will be mounted on steel masts at each end of the stack.
- A total of six sockets will be attached to each mast.
- The fully built out reefer yard will have up to 576 TEU ground slots.
- A total number of mounting masts required in the final phase of the reefer yard will be 288.
- Total sockets required will be 1,728 sockets although up to 100 sockets has been assumed salvageable from the existing terminal.
- The total power load required for the final reefer yard has been estimated at 7,000kVA. The power is assumed to be distributed from the south substation where the upgrades will be required to meet the power demands of the reefer yard.

New Laden Reefer Yard Operation



The reefer yard will be operated using reach stackers and cherry pickers for plugging and unplugging reefer plugs from the mounted sockets.

7. Conclusion and Preferred Option

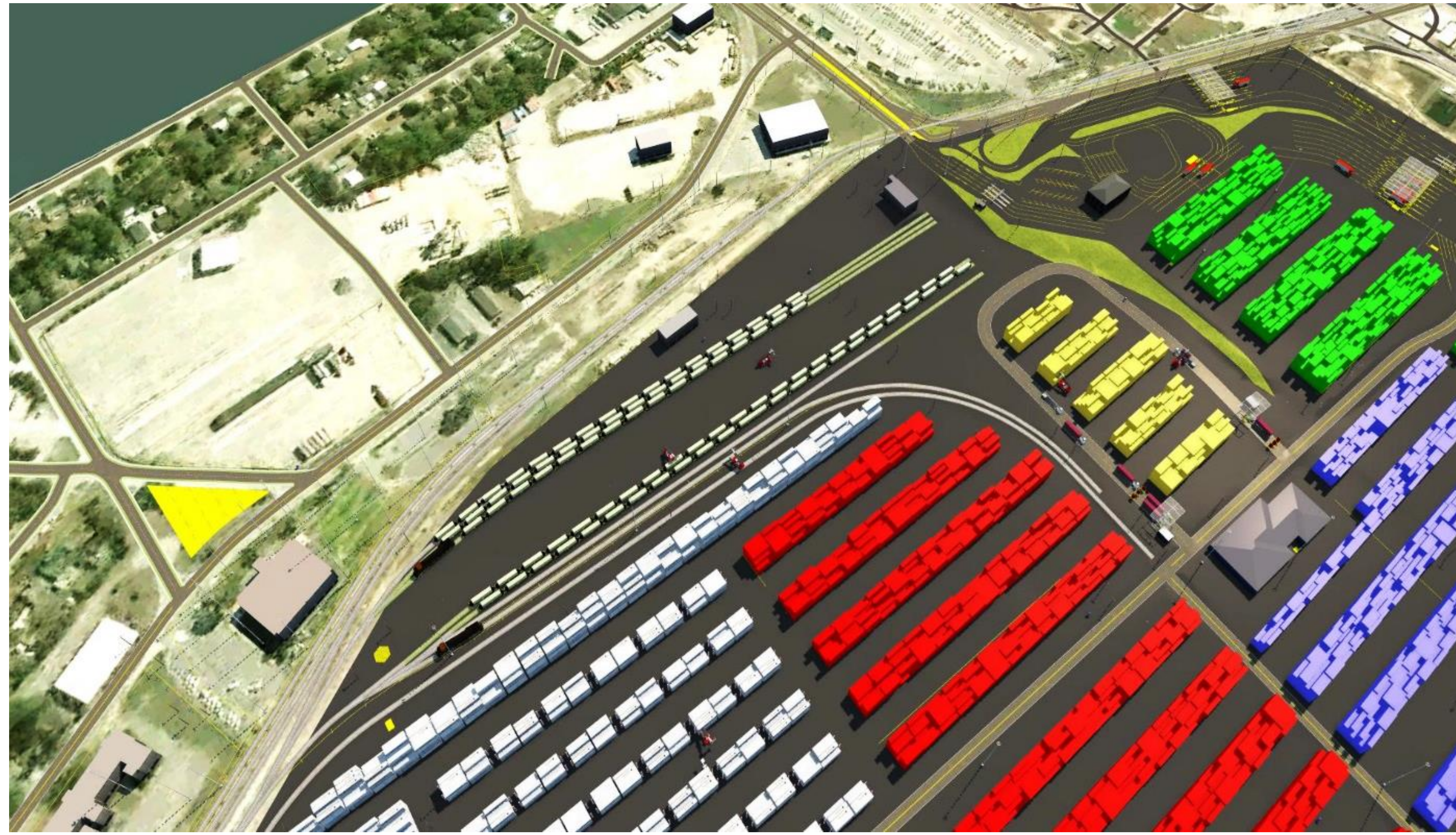
7.4 Preferred Layout – Intermodal Yard

The final intermodal yard layout has not changed from presented in Section 3.4.

Key features of the final intermodal yard layout are:

- Number of Reach Stackers Required to Operate Intermodal Yard =four dedicated to loading/unloading train + two in buffer yard.
- Time taken to turn around 5,000 feet train = within eight hours.
- Number of TICO trucks required to service train is sixteen.
- Average and maximum waiting times for TICO trucks = 3.4 minutes / 7 minutes.
- Track 18, 18a and the Enviva track can all be retained.
- Intermodal yard is set for an 8% modal split with potential to increase to 16% in the future if required.

Model of preferred Intermodal Layout.



7. Conclusion and Preferred Option

7.5 Preferred Layout – Yard Paving

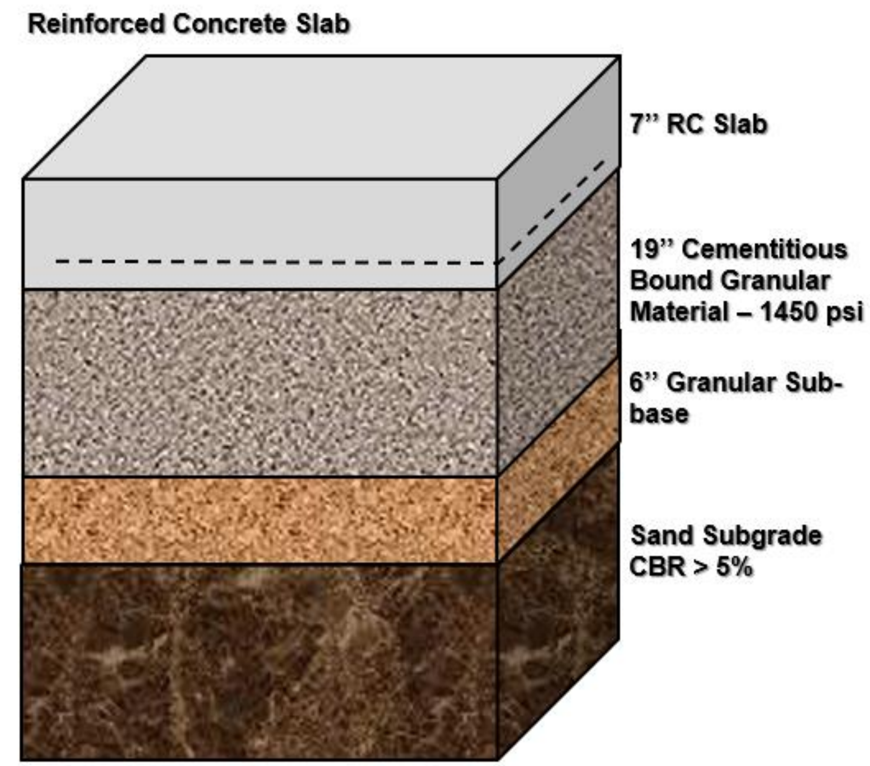
As explained in Section 5.3.1, it is assumed that all yard paving will be based on the asphalt paving specification shown in the figure opposite except for areas F and H which will be paved as concrete shown in the section opposite.

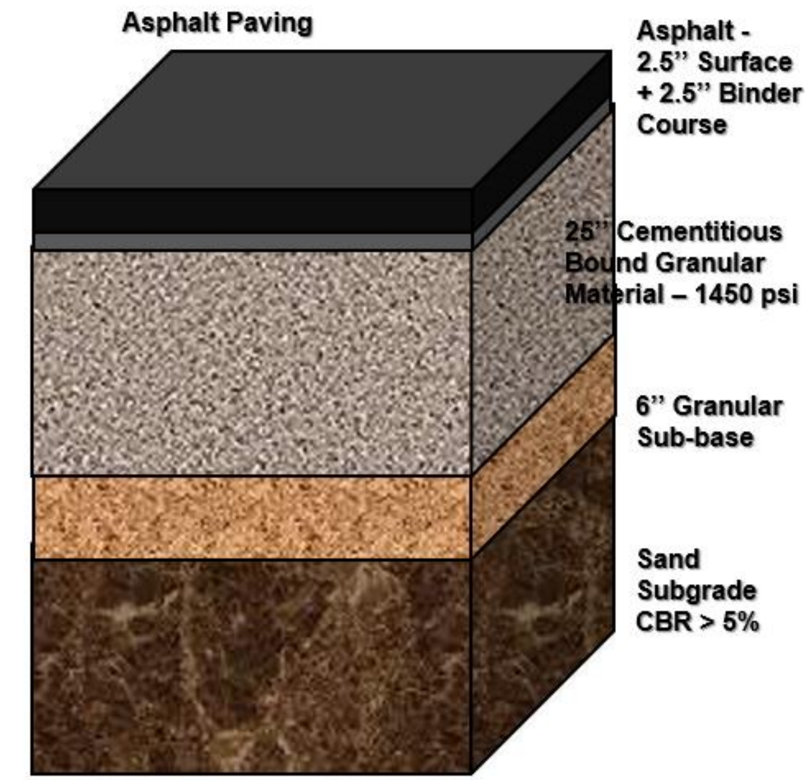
However, for the refine Option 1 layout, cost sensitivity assessments have been carried out to determine the cost delta between the original paving strategy and the alternative option whereby all paving areas in the terminal will be paved as asphalt.

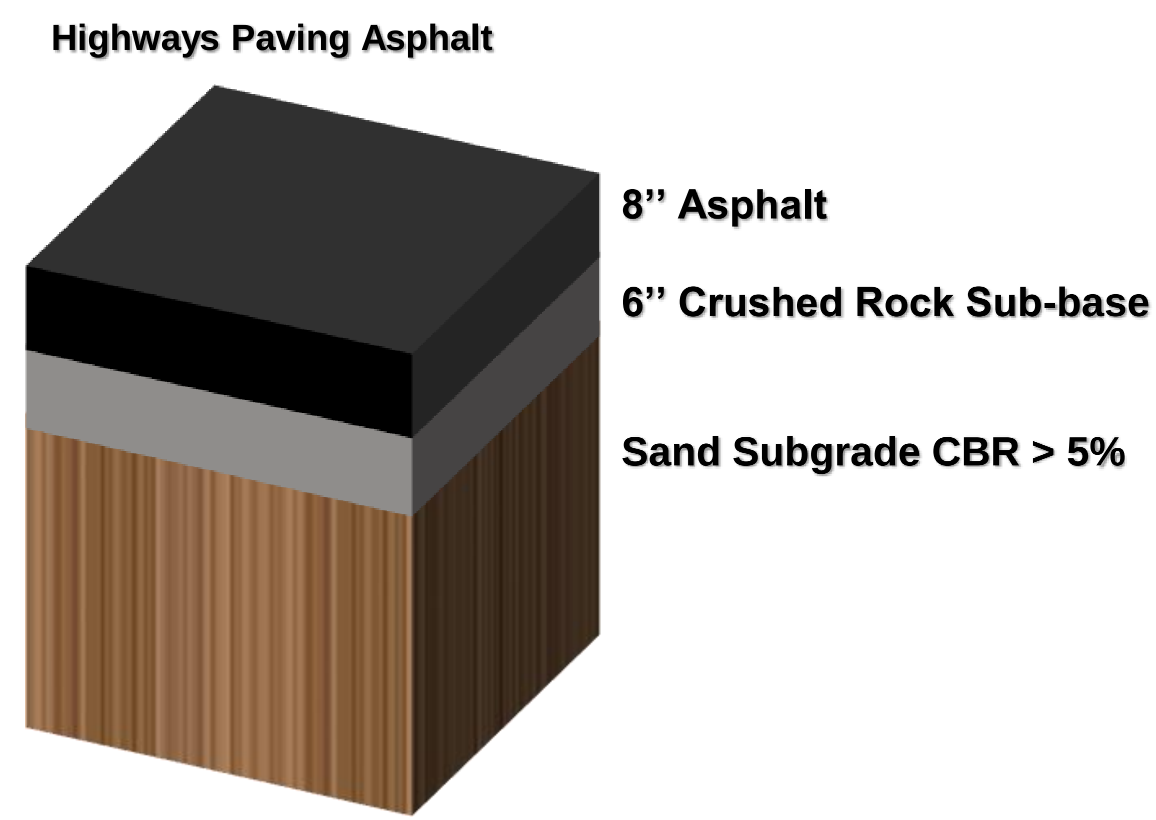
In addition, the south gate area paving can potentially be paved to an asphalt paving specification which is closer to highways standards, leaving only the main gate interchange areas paved as concrete to prevent rutting from frequent acceleration and braking of trucks.

At present the cost rates for the paving solution considered are as follows:

- ❑ Reinforced Concrete Slab Paving = $450 sq. feet.
- ❑ Heavy Duty Asphalt Paving = $118 / ton.
- ❑ Highway Duty Paving = $80 /ton.







8. Construction and Implementation Plan

Construction phasing and interim port capacity

8. Construction and Implementation Plan

8.1 Introduction

The implementation plan for the preferred Option 1 is explained in this section of the report. The construction phasing along with the budgetary requirements for developing Option 1 will also be presented.

8.2 Alternative Option 1 Costs

As mentioned in Section 7.6, an alternate paving strategy can be adopted whereby concrete is eliminated entirely from the terminal and asphalt will used instead. The paving specification around the south gate upgrade area will also be reduced since landing of container boxes will not be required in these areas. By adopting this approach the estimated cost for this solution is as follows:

Option 1 Project	Costs (USD) Asphalt Paving	Costs (USD) Concrete and Asphalt Paving
Container Yard	126,240,553	157,237,640
Reefer Yard	22,433,281	22,433,281
South Gate Upgrade	18,229,125	29,162,271
Intermodal Yard	26,427,489	26,427,489
Equipment	12,060,000	12,060,000
TOTAL	**205,390,448**	**247,320,680**

For comparison the original paving strategy cost for the Option 1 which included both concrete and asphalt paving has been included in the table against the exclusive asphalt paving solution. As can be seen the cost differential is approximately 20.19%. Minimized costs, where applicable, make the overall project more viable and therefore the recommended option has adopted asphalt exclusively as the main terminal paving solution.

The breakdown of the revised Option 1 costs are shown below:

Item	Item Description	Unit	Quantity	Unit Rate (USD)	Cost (USD)
1	<u>**Container Yard Paving**</u>				
1.1	*Breakout and Demolishing of existing paving (8 inch asphalt)*	sq.yds	303,850	8	2,379,147
1.2	*Re-grading (cut)*	yds^3	63,043	4	224,013
1.3	Disposal of excess excavated material	yds^3	0	11	0
1.4	Storage on site of excavated material	yds^3	71,203	5	333,913
1.5	*Re-grading (fill)*	yds^3	55,703	2	86,308
1.6	Imported fill	yds^3	16,616	25	416,559
1.7	*Paving Type B – Asphalt Pavement for stacking areas F and H*	tons	152,591	118	17,961,888
1.8	*Paving Type B - Asphalt Pavement - (Rate includes sub-base materials)*	tons	389,478	118	45,846,567
1.9	Ground Improvement (Dynamic compaction)	sq.yds	303,850	16	4,804,144
1.10	Site mobilisation of Ground improvement Plant	L.S.	10	29,363	293,625
1.11	Kentledge load test	L.S.	10	10,800	108,000
1.12	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	303,850	23	7,014,892
1.13	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	303,850	6	1,879,505
1.14	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	303,850	3	796,106
1.15	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	13	23,000	299,000
1.16	Line/corner Marking & Signage	sq.yds	303,850	1	170,306
1.17	Demolition (Warehouse T7)	sq.ft	219,300	5	989,043
	Container Yard Base Cost SUBTOTAL				**83,603,015**
	Mobilization			15%	12,540,452
	Inspection and Permitting			3%	2,090,075
	Contingency			20%	16,720,603
	Engineering Services (incl. design and procurement)			10%	11,286,407
	<u>**Container Yard Paving TOTAL**</u>				***126,240,553***

8. Construction and Implementation Plan

8.2 Alternative Option 1 Costs

2	**Reefer Yard**				
2.1	Reefer Substations including equipment - Upgrade to South Substation	Ea.	1	722,470	722,470
2.2	Reefer Masts (Steel Galvanised poles - 33ft nominal height)	Ea.	288	7,520	2,165,760
2.3	Reefer socket outlets	Ea.	1,628	550	895,400
2.4	*Breakout and Demolishing of existing paving (8 inch asphalt)*	sq.yds	43,934	8	344,006
2.5	*Re-grading (cut)*	yds^3	8,160	4	28,996
2.6	*Re-grading (fill)*	yds^3	1,259	2	1,951
2.7	*Paving Type B - Asphalt Pavement - (Rate includes sub-base materials)*	Tons	78,378	118	9,226,110
2.8	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	43,934	23	1,014,290
2.9	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	43,934	6	271,760
2.10	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	43,934	3	115,110
2.11	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	2	23,000	46,000
2.12	Line/corner Marking & Signage	sq.yds	43,934	1	24,625
	Reefer Yard Base Cost SUBTOTAL				**14,856,478**
	Mobilization			15%	2,228,472
	Inspection and Permitting			3%	371,412
	Contingency			20%	2,971,296
	Engineering Services (incl. design and procurement)			10%	2,005,624
	Reefer Yard TOTAL				***22,433,281***

3	**South Gate Upgrade**				
3.1	ISPS Perimeter Fence (Including posts and foundations - Chain link)	lin.ft.	1,000	50	50,000
3.2	Port Gate In (inc. all associated equipment and furniture)	lane	8	100,000	800,000
3.3	Port Gate Out (inc. all associated equipment and furniture)	lane	7	100,000	700,000
3.4	Optical Character Recognition (OCR) Portal and Barn only	lane	5	17,000	85,000
3.5	Radiation Scanners Infrastructure - secondary inspection structures, CBP booths and utilities + foundations for rpm scanners etc.	Lane	3	2,000,000	6,000,000
3.6	Weighbridge - weigh in motion sensors	Ea.	6	39,900	239,400
3.7	TWICS GATE automated kiosks and Rising Barrier Arms	Ea.	12	9,600	115,200
3.8	New gate house building - steel clad buidling 3 story high	sq.ft	3,000	220	660,000
3.9	Security Booth	sq.ft	538	130	69,940
3.10	Breakout and Demolishing of exisitng paving (8 inch asphalt) - Gate	sq.yds	42,147	8	330,011
3.11	*Paving Type B - Asphalt Pavement - (Rate includes sub-base materials)*	tons	20,399	80	1,631,926
3.12	Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	sq.yds	42,147	23	973,034
3.13	Electrical Works Network (MV, including ducting, cabling and pits)	sq.yds	42,147	6	260,706
3.14	Electrical Works Network (LV, including ducting, cabling and pits)	sq.yds	42,147	3	110,428
3.15	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	1	23,000	23,000
3.16	Line/corner Marking & Signage	sq.yds	42,147	1	23,623
	South Gate Upgrade SUBTOTAL				**12,072,269**
	Mobilization			15%	1,810,840
	Inspection and Permitting			3%	301,807
	Contingency			20%	2,414,454
	Engineering Services (incl. design and procurement)			10%	1,629,756
	South Gate Upgrade TOTAL				***18,229,125***

8. Construction and Implementation Plan

8.2 Alternative Option 1 Costs

4	**Intermodal yard**				
4.1	Removal of Existing Rail tracks - Container Track #1	lin.ft.	1,000	500	500,000
4.2	Removal of Existing Rail bend to track 18a	lin.ft.	0	500	0
4.3	Removal of Existing Rail bend to track 18b (ENVIVA line)	lin.ft.	0	500	0
4.4	Extension of rail road tracks to Container line 1	lin.ft.	300	1,000	300,000
4.5	Extension to Rail road tracks to Line 18	lin.ft.	0	1,000	0
4.6	Extension to Rail Road Tracks to Line 18a	lin.ft.	0	1,000	0
4.7	Extension to Rail Road Tracks to line 18b	lin.ft.	0	1,000	0
4.8	New intermodal yard exit gate lanes	Ea.	2	100,000	200,000
4.9	New intermodal yard entry gate lanes	Ea.	2	100,000	200,000
4.10	Intermodal yard RPM utilities, power and lighting,foundations, CBP booths etc	Lane	2	2,000,000	4,000,000
4.11	Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	Ea.	16	23,000	368,000
4.12	Line/corner Marking & Signage	sq.yds	23,405	1	13,118
	Intermodal Yard Base Cost SUBTOTAL				**5,581,118**
	Mobilization			15%	837,168
	Inspection and Permitting			2.50%	139,528
	Contingency			20%	1,116,224
	Engineering Services (incl. design and procurement)			10%	753,451
	MML Rail Study Base Intermodal Yard Cost				18,000,000
	Intermodal Yard TOTAL				***26,427,489***

5	**Plant/equipment**				
5.1	Reach stackers	Ea.	12	1,000,000	12,000,000
5.2	Cherry pickers	Ea.	2	30,000	60,000
	Plant/equipment SUBTOTAL				**12,060,000**
	Plant/equipment TOTAL				***12,060,000***

8. Construction and Implementation Plan

8.3 Yard Upgrade Implementation Schedule

The four main projects which make up the Option 1 yard upgrade works include the south gate upgrade, reefer yard, container terminal paving upgrades and the intermodal yard. Out of the four main projects the south gate upgrades and the reefer yard are deemed to be the most urgent projects since they are required to increase the terminal capacity in the short term. Repaving of the terminal is also high important however, due to the quantity of repaving required, the works will need to be distributed over a longer period of time with a construction phasing plan that allows the port to match the forecasted container terminal throughput growth rate.

The key implementation dates for Option 1 is as follows:

Terminal Improvement Package	Construction Start Date	Completion Date
Terminal Paving Upgrades	**September 2018**	**~ January 2025 (full completion)**
Reefer Yard Upgrades	**April 2019**	**September 2019 (PH1)**
South Gate Upgrade	**October 18 - 2019**	**September 2020**
Intermodal Yard	**July 2024**	**~ January 2025**
<u>Total Project Duration</u>	**<u>September 2018</u>**	**<u>~ January 2025</u>**

8.3.1 Key assumptions

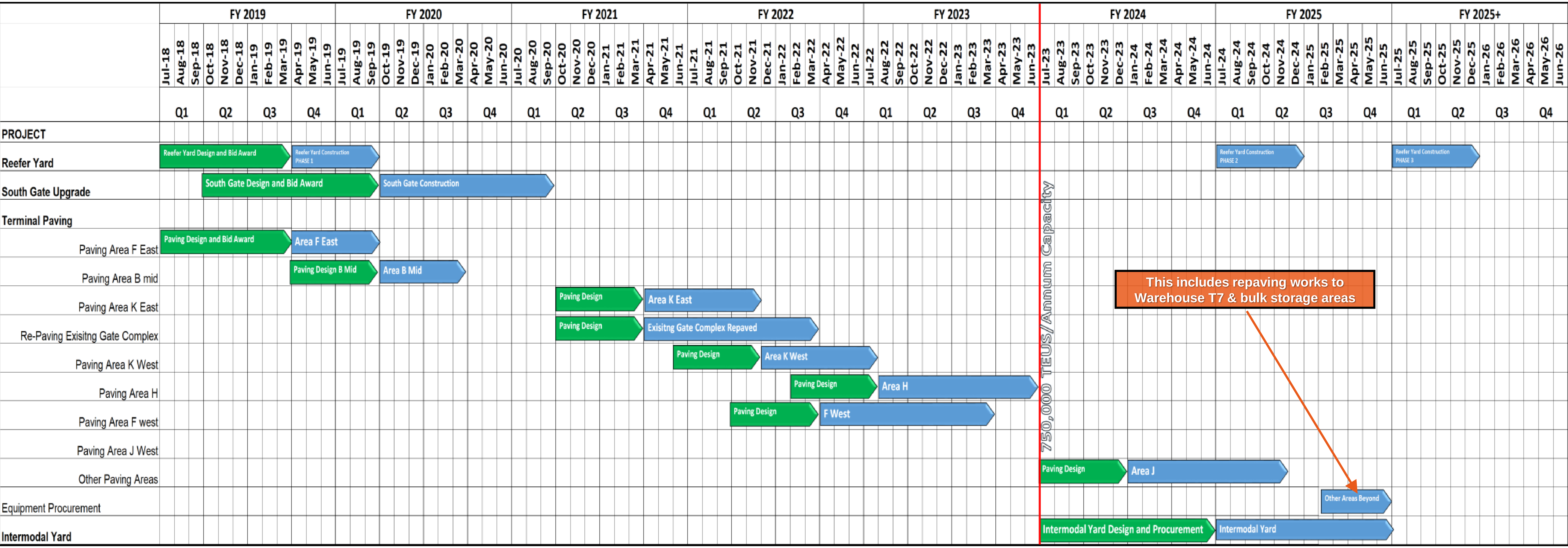
The key assumptions for the implementation plan are as follows:

- The reefer yard will be built out in three phases. The first phase involves the repaving of area B north (5.5acres) and the installation of 500 reefer sockets. The second phase will be the repaving of Area C and a further installation of 500 sockets. The final phase will be for the installation of the balance of reefer sockets and masts. Phase 1 of the reefer works will commence as early as possible.
- The south gate upgrades will commence as early as possible.
- The implementation and construction phasing will ensure that the terminal's interim capacity will be above the lower bound container volume forecast provided by NCSPA.
- For paving, the priority will be to reach the 750,000 TEUs per annum target, all other paving areas that contribute towards a capacity higher than the 750,000 TEU mark will be not be given priority.
- The DRI building and repaving works is assumed to be finished by September 2018.
- The bulk storage areas to the north of the terminal and Warehouse T7 are not available before 2024.
- Concrete paving can be laid at a rate of 300 yd2/day, and the breakout of existing pavement and subsequent backfill are each done at a rate of 175 square yards per day.

8. Construction and Implementation Plan

8.3.2 Project Implementation Schedule

The propose project implementation schedule is presented graphically in the Gannt chart below. The green bars represent the design and procurement period whilst the blue bars represent the construction work for each individual project.



8. Construction and Implementation Plan

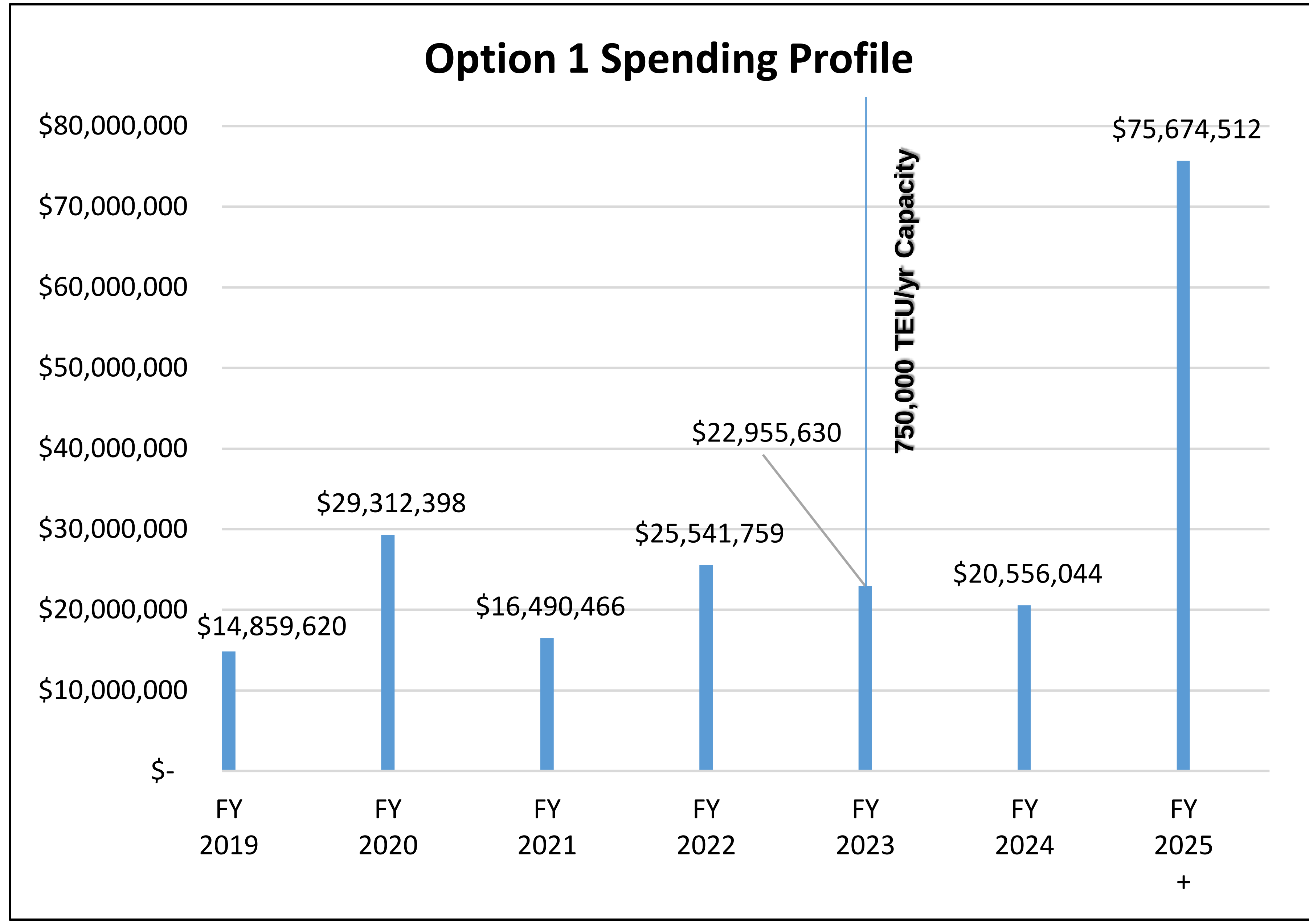
8.4 Investment Profile and Budgeting

Using the project schedule defined in Section 8.3, the cost estimated for the complete build out of Option 1 has been distributed and represented in the bar chart opposite. The forecasted budget required for each fiscal year start from July 2018 (FY2019) is clearly labelled.

The total cost for Option 1 (asphalt paving only) is estimated at $205,390,448. However, for the terminal to reach a yard capacity of 750,000 TEUs per annum, a total investment of $109,159,873 (which includes the repaving of the stacking yard with asphalt paving only, south gate upgrades and phase 1 of the reefer yard works) is required by the end of fiscal year 2023. The budgets proposed for fiscal year 2024 and 2025 and beyond include the following projects:

- ❑ Repaving of stacking area J.
- ❑ Phase 2 + 3 of the proposed reefer yard.
- ❑ Intermodal yard.
- ❑ Demolition and repaving of Warehouse T7.
- ❑ Repaving of the bulk storage areas north of the terminal.

These projects are only required if an additional terminal capacity beyond the 750,000 TEU per annum figure is required.



The budget and investment profile presented above does not include for the expansion of Option 1 beyond the current terminal boundary as presented in Section 4.2.1 - Option 1A and the partial RTG conversion as presented in Section 4.2.2 - Option 1B. Both these options are considered to be long term development options beyond fiscal year 2025 and should these options be required the additional investment required beyond fiscal year 2025 is as follows:

- ❑ **Option 1A** – expansion of terminal into the chassis yard – Additional Investment = $46,354,772, Additional capacity acquired = 175,792 TEUs per annum.

- ❑ **Option 1B** – Partial RTG conversion in Area F and H – Additional Investment = $25,094,797, Additional capacity acquired = 195,232 TEUs per annum.

8. Construction and Implementation Plan

The specific areas of the terminal that requires upgrading to reach the 750,000 and 1,123,865 TEUs per annum capacity figures are presented in the figure opposite.

Areas of the terminal marked in Red represented the terminal areas and projects required to obtain a terminal capacity of 750,000 TEUs per annum.

Areas of the terminal marks in Blue represents the terminal areas and projects required in addition to the initial upgraded areas to reach the maximum terminal capacity of 1,123,865 TEUs per annum.

Additional capacity can be achieved for the terminal if other NCSPA land outside of the existing terminal boundary is developed in the future. The chassis yard areas marked in green can be developed to increase the terminal capacity to 1,299,657 TEUs per annum.

Finally, should additional terminal capacity beyond 1.3million TEUs is required, areas F and H marked with the dashed black line can be converted into a RTG operated container stacks to acquire a terminal capacity of circa 1.49million TEUs per annum.

8. Construction and Implementation Plan

8.4.1 Paving Cost Break Down

The paving cost is by far the greatest investment required of NCSPA in the implementation of Option 1. The individual cost for each paving areas is shown in the tables below split into the paving areas required to reach the targeted 750,000 TEUs per annum and the areas which exceeds this value. Re-paving areas F, B, K, H and the existing gate complex footprint to enable five high container stacking will provide a yard capacity of circa 763,950 TEUs per annum yard capacity which is sufficient to reach the target throughput container volumes by 2025. Should NCSPA wish to increase the yard capacity further, Option 1 allows for the additional repaving of Area J which provides an extra 173,156 TEUS per annum at a cost of $23,322,691. An additional circa 67,000 TEUs can be provided for export containers if warehouse T7 is demolished and repaved at a cost of $14,683,067. An additional circa 48,000 TEUs per annum can be provided if both the bulk storage areas north of the terminal are repaved at a cost of $16,756,748. The total capacity obtainable in option with just repaving alone is 1,052,106 TEUs per annum. In order to achieve the reported maximum potential of 1,123,865 TEUs per annum, the intermodal yard will need to be installed and operating an 8% modal split.

Area F east is proposed to be paved first and will be included in the FY2019 budget requirements.

Areas required to be repaved for 750,000TEUs per annum storage capacity

Table X3: Paving Area Cost Break Down to Accommodate 750,000 TEUs per annum Yard Storage Capacity

Paving Area	Paving Type	Cost Estimate
Area F East	Asphalt	$ 10,204,464
Area F West	Asphalt	$ 13,179,427
Area B (Mid)	Asphalt	$ 6,332,197
Area K East	Asphalt	$ 7,919,647
Area K West	Asphalt	$ 7,927,429
Area H	Asphalt	$ 11,799,128
Existing Gate Complex Area	Asphalt	$ 14,116,735
Total Paving Cost for 750,000 TEU per annum Storage Capacity		**$ 71,479,027**

Additional areas required to be paved to reach 1,052,106 TEUs per annum storage capacity

Table X4: Paving Area Cost Break Down to Accommodate 1,052,106 TEUs per annum Yard Storage Capacity

Paving Area	Paving Type	Cost Estimate
T7 Warehouse	Asphalt	$ 14,683,067
Bulk Storage Areas	Asphalt	$ 16,756,748
Area J	Asphalt	$ 23,322,691
Total Additional Paving Cost to reach 1,052,106 TEU per annum Storage Capacity		**$ 54,762,507**

8. Construction and Implementation Plan

8.4.2 Reefer Yard Break Down

The reefer yard as stated will be built out in three phases. The first phase of work involves the installation of 500 sockets and the associated infrastructure. Phase 1 is considered a priority to ease the pressure on the short term reefer capacity requirements in the terminal. Phase 2 of the reefer yard is required when the 750,000 TEU per annum capacity is reached as by phase 2, 1000 reefer sockets will be required to enable the port to achieve the target 6% reefer throughput. Phase 2 therefore is targeted for FY2024 when the yard capacity is proposed to reach the targeted 750,000 TEU per annum capacity. Phase 3 sees the balance of the reefer sockets installed but is not required until the throughput exceeds 750,000 TEUs, therefore phase 3 can be delayed beyond FY2028.

8.4.2 Reefer Yard Break Down

The reefer yard as stated will be built out in three phases. The cost break down for each phase of the works is shown in the following tables.

Phase 1 Reefer Yard Costs

PHASE 1 Project Items	Total Estimate Phase 1	
Reefer Yard Design and Procurement Costs (All three Phases)	***$***	***2,005,624.48***
Reefer Substations including equipment - Upgrade to South Substation	$	993,396
84 number reefer socket masts	$	868,560
500 Reefer Sockets	$	378,125
Breakout and Demolishing of existing paving (8 inch asphalt)	$	287,545
Re-grading (cut)	$	24,237
Re-grading (fill)	$	1,631
Paving Type B - Asphalt Pavement - (Rate includes sub-base materials)	$	7,711,923
Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	$	847,823
Electrical Works Network (MV, including ducting, cabling and pits)	$	227,158
Electrical Works Network (LV, including ducting, cabling and pits)	$	96,218
Container Stacking Yard Lighting (inc. masts, 20No 453W LED luminaires, foundations, fixings and connections)	$	63,250
Line/corner Marking & Signage	$	20,583
Phase 1 Total Reefer Construction Costs	***$***	***11,520,448***
TOTAL PHASE 1 Cost	***$***	***13,526,073***

8. Construction and Implementation Plan

Phase 2 Reefer Yard Costs

Reefer Yard Phase 2 Project Items	Total Estimate Phase 2	
84 number reefer socket masts	$	868,560
500 Reefer Sockets	$	378,125
Breakout and Demolishing of existing paving (8 inch asphalt)	$	185,464
Re-grading (cut)	$	15,633
Re-grading (fill)	$	1,052
Paving Type B - Asphalt Pavement - (Rate includes sub-base materials)	$	4,974,124
Surface Water Drainage System (including pipes, channels, manholes, gullies, slot drains)	$	546,838
Electrical Works Network (MV, including ducting, cabling and pits)	$	146,515
Electrical Works Network (LV, including ducting, cabling and pits)	$	62,060
Line/corner Marking & Signage	$	13,276
PHASE 2 Total Reefer Construction Costs	***$***	***7,191,646***

Phase 3 Reefer Yard Costs

Reefer Yard Phase 3 Project Items	Total Estimate Phase 3	
120 No Reefer socket Masts	$	1,240,800
628 No Reefer Sockets	$	474,925
PHASE 3 Total Reefer Construction Costs	***$***	***1,715,725***

8. Construction and Implementation Plan

8.4.3 Budgets for the Initial Project Developments

The initial projects which are a priority requirement which needs to be budgeted for in FY2019 are considered to be:

- ❑ Reefer Yard Phase 1.
- ❑ South Gate Upgrade.
- ❑ Area F east repaving works.

The budgetary requirements for these three projects in are as follows:

Project	Cost
Reefer Yard Phase 1	$13,526,073
South Gate Upgrade	$18,229,125
Area F East	$10,204,464
TOTAL Budget	**$41,959,662**

8. Construction and Implementation Plan

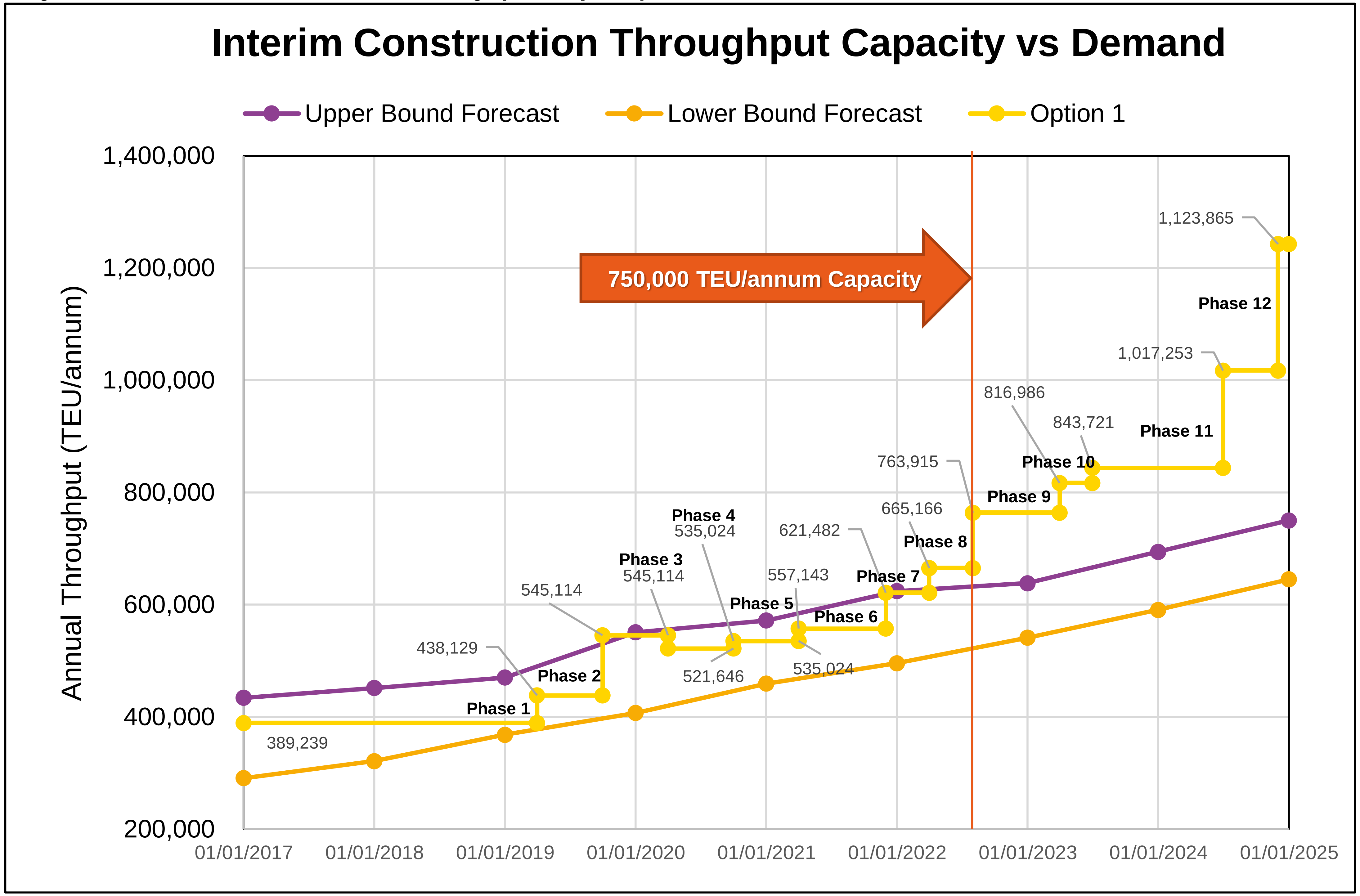
8.5 Construction Phasing

The full implementation of Option 1 can be completed within twelve phases. At the completion of each phase, the terminal capacity will be increased. The aim of the construction phasing is to ensure that the interim terminal capacity will always remain higher than the lower bound forecast container volumes at all times. This has been achieved and is represented in Figure 55.

The terminal capacity is able to meet the targeted throughput of 750,000 TEUs per annum by the end pf Phase 8 and the capacity of terminal exceed the upper bound market forecast by the end of phase 7 in early 2022.

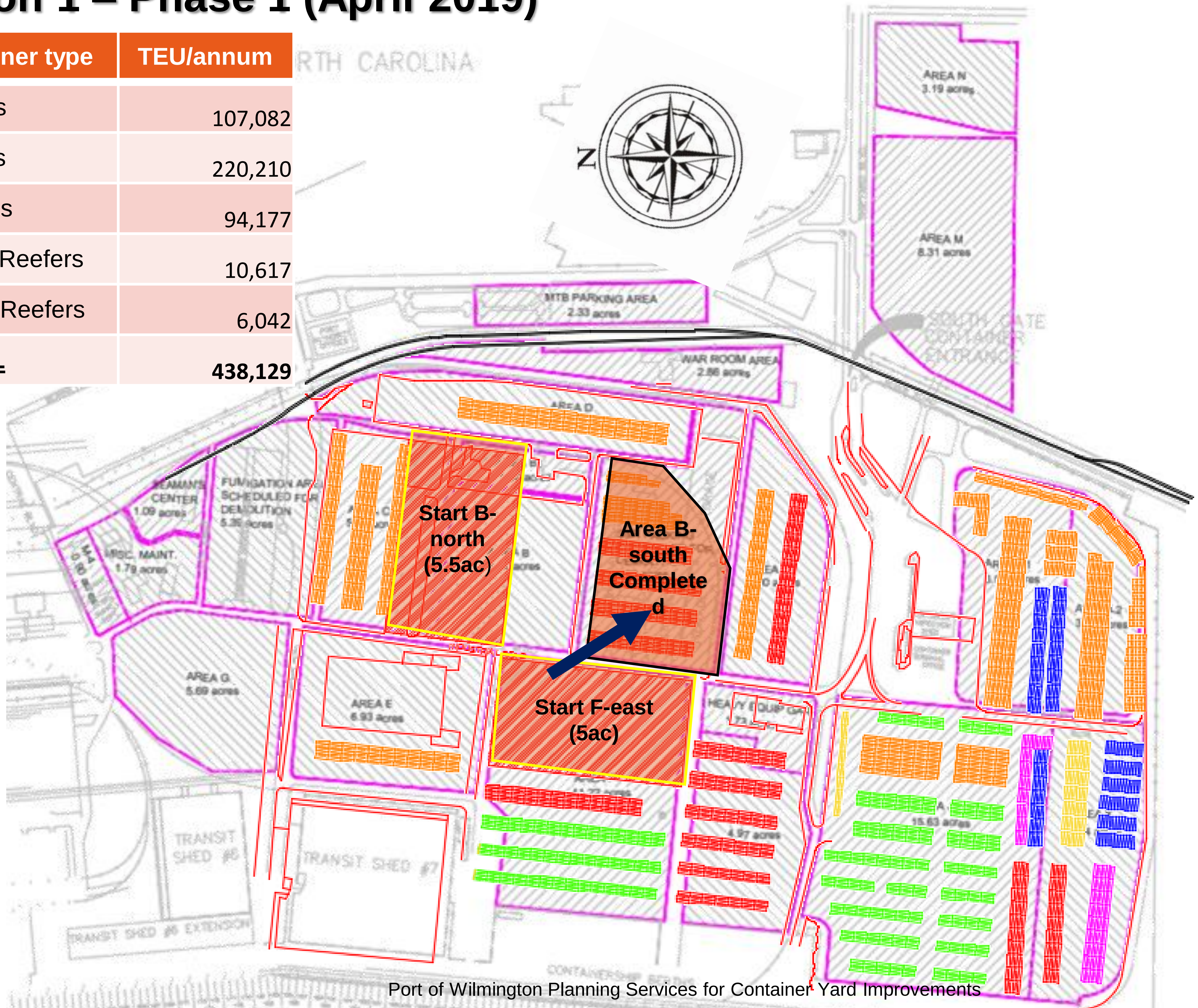
The construction phasing at each phase has been illustrated over the pages in the next 11 pages.

Figure 55: Interim Construction Throughput Capacity vs Demand



Option 1 – Phase 1 (April 2019)

Container type	TEU/annum
Exports	107,082
Imports	220,210
Empties	94,177
Laden Reefers	10,617
Empty Reefers	6,042
TOTAL	**438,129**

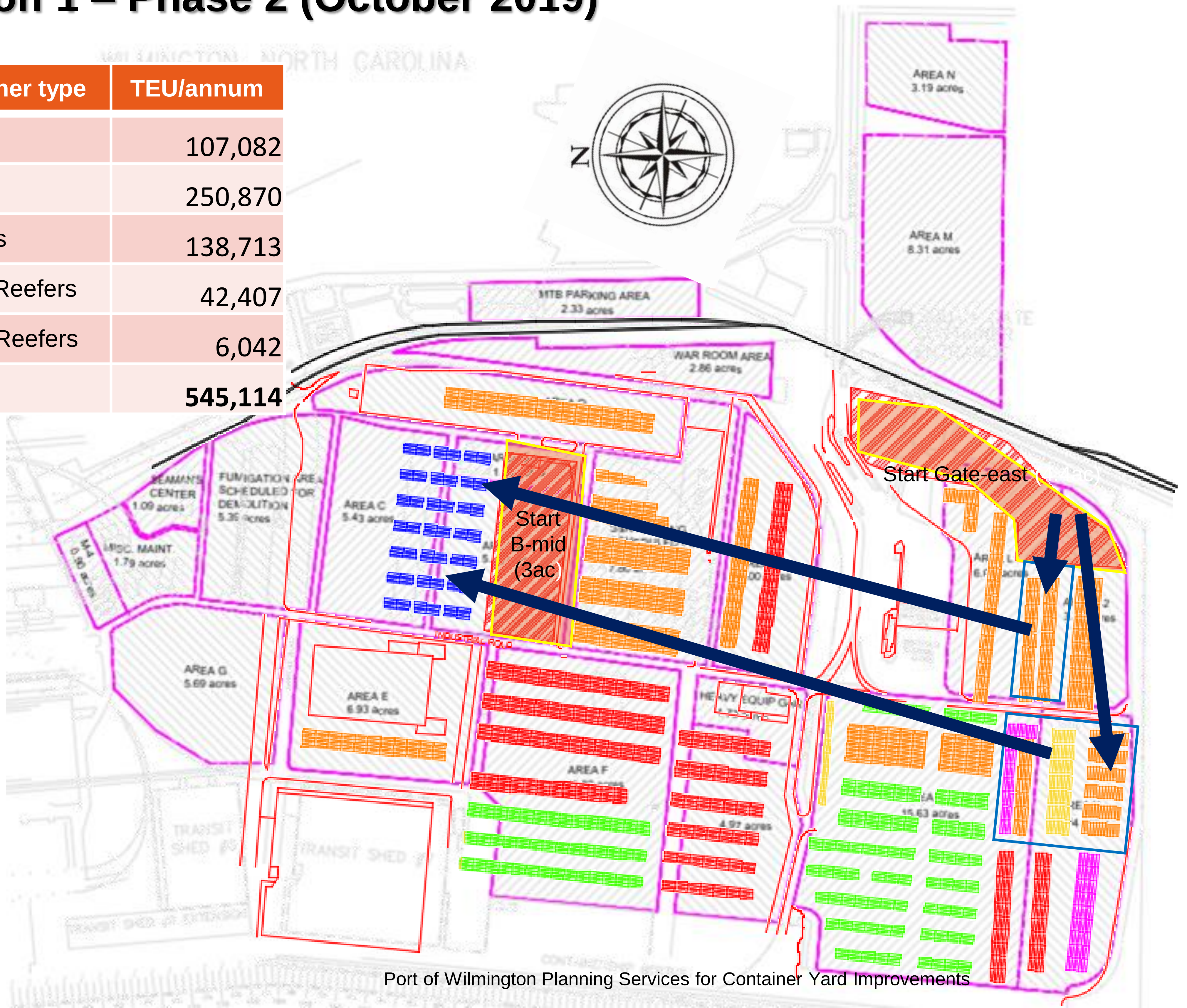


Pave Area F-east

- Imports and Empties are moved to the newly available space in Area B-south.
- Assumed that rest of Area B made available by start of 2019.
- Area F-east is repaved. (Concrete Paving Upgrades)
  - Work commencing: April 2019
  - Works completed: October 2019
- Area B-north is repaved (Concrete Paving Upgrades and Reefer Socket Installation)
  - Work commencing: April 2019
  - Works completed: October 2019

Option 1 – Phase 2 (October 2019)

Container type	TEU/annum
Exports	107,082
Imports	250,870
Empties	138,713
Laden Reefers	42,407
Empty Reefers	6,042
TOTAL	**545,114**



Pave area B-mid

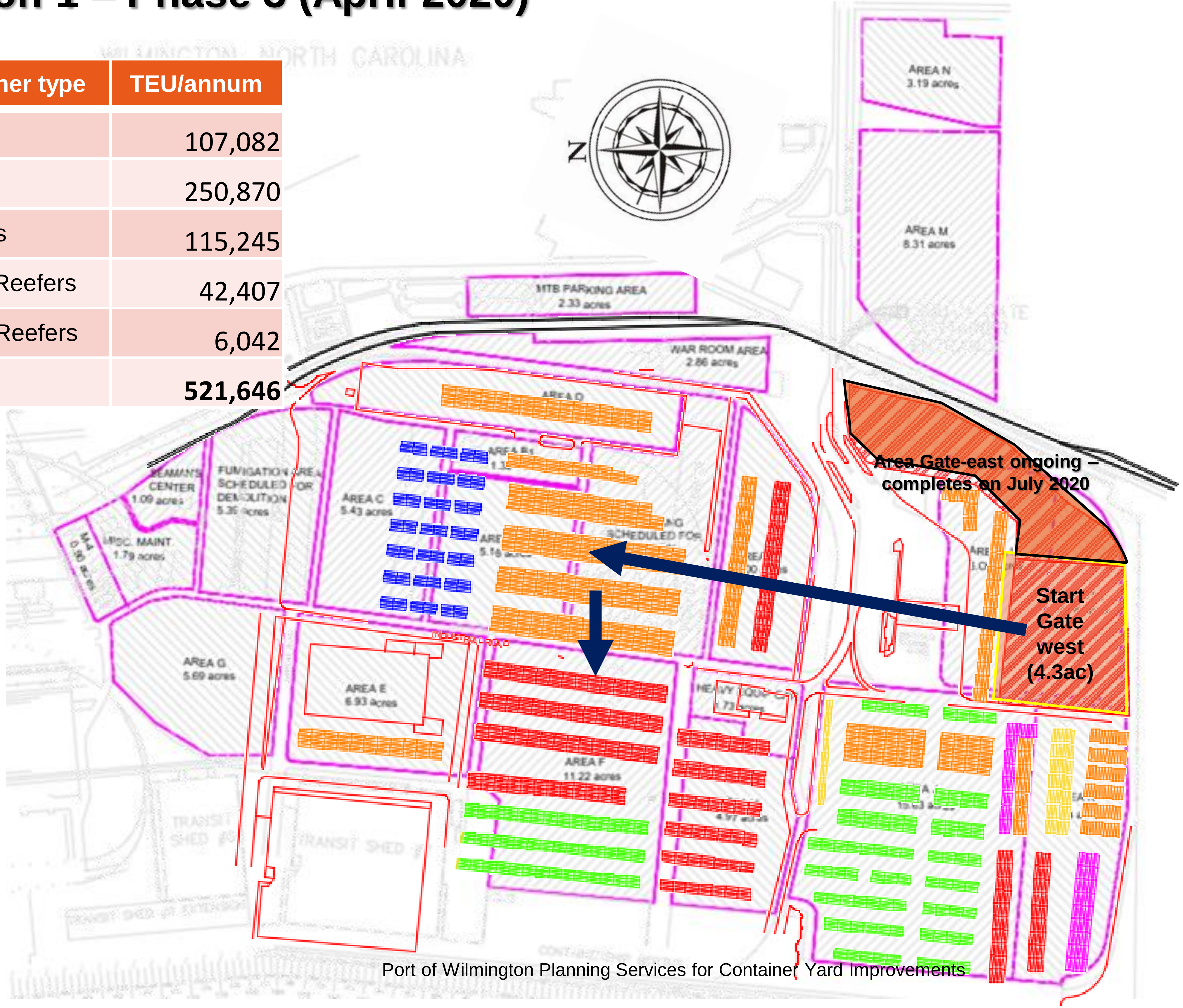
- Area F-east and Area B-north completed
- Area B-mid is repaved (Concrete Paving Upgrades)
  - Works commencing: October 2019
  - Works completed: April 2020

Pave area Gate-east

- Laden Reefers from Area K and Area L moved to Area B-north
- Laden Reefers in Area K and Area L replaced with Empties.
- Area L-east is repaved (Concrete Paving Upgrades and Services for upgraded south gate)
  - Works commencing: October 2019
  - Works completed: July 2020

Option 1 – Phase 3 (April 2020)

Container type	TEU/annum
Exports	107,082
Imports	250,870
Empties	115,245
Laden Reefers	42,407
Empty Reefers	6,042
TOTAL	**521,646**

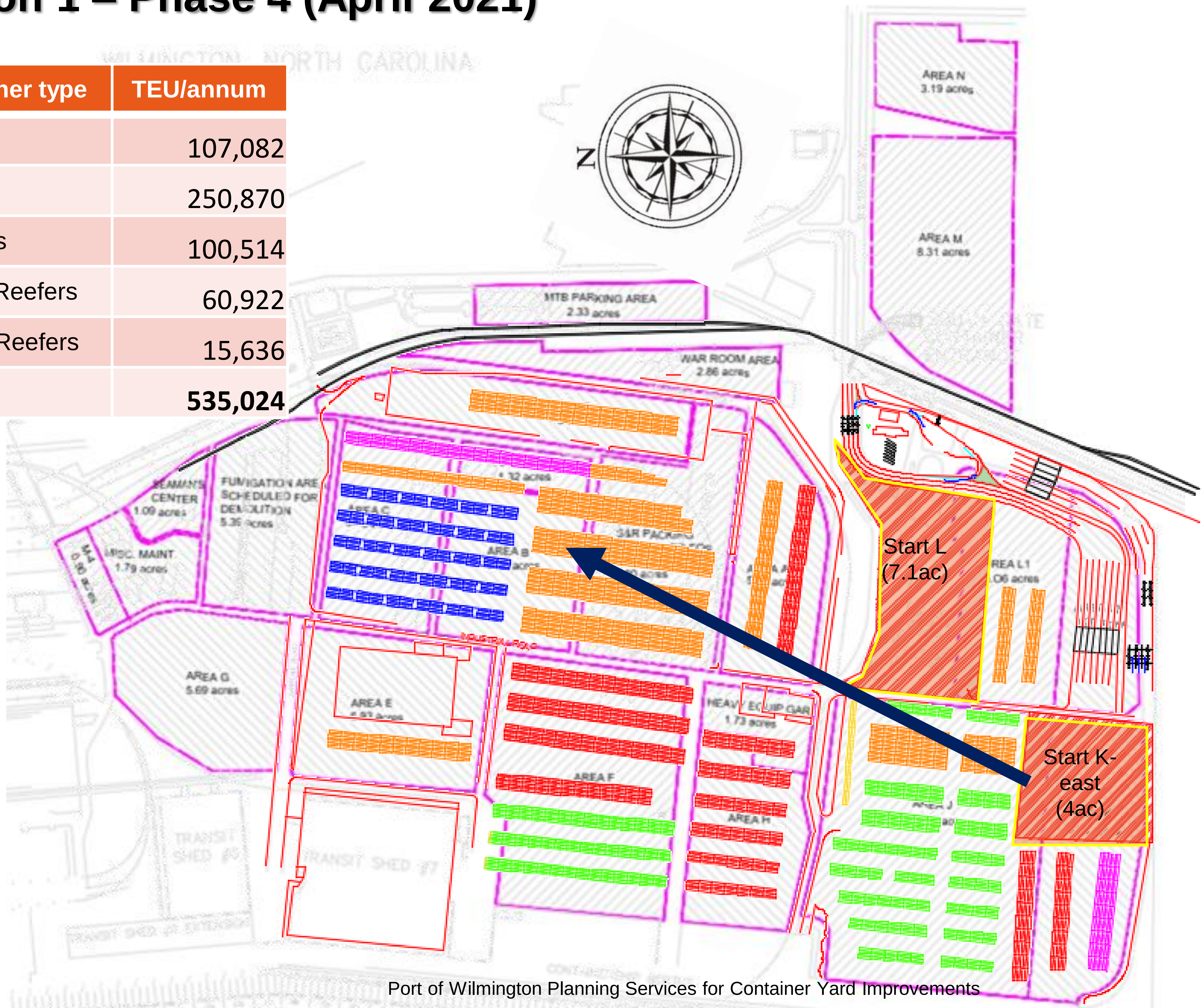


Pave area Gate-west

- ❑ Area B-mid completed.
- ❑ Empties from Area Gate-west moved to Area B-south
- ❑ Area Gate-west is repaved (Concrete Paving Upgrades and Services for upgraded south gate)
  - ❑ Works commencing: 13 January 2020
  - ❑ Works completed: 19 September 2020
  - ❑ Ongoing works in area Gate-east (completes July 2020)

Option 1 – Phase 4 (April 2021)

Container type	TEU/annum
Exports	107,082
Imports	250,870
Empties	100,514
Laden Reefers	60,922
Empty Reefers	15,636
TOTAL	**535,024**



Decommission Old Gate and Pave

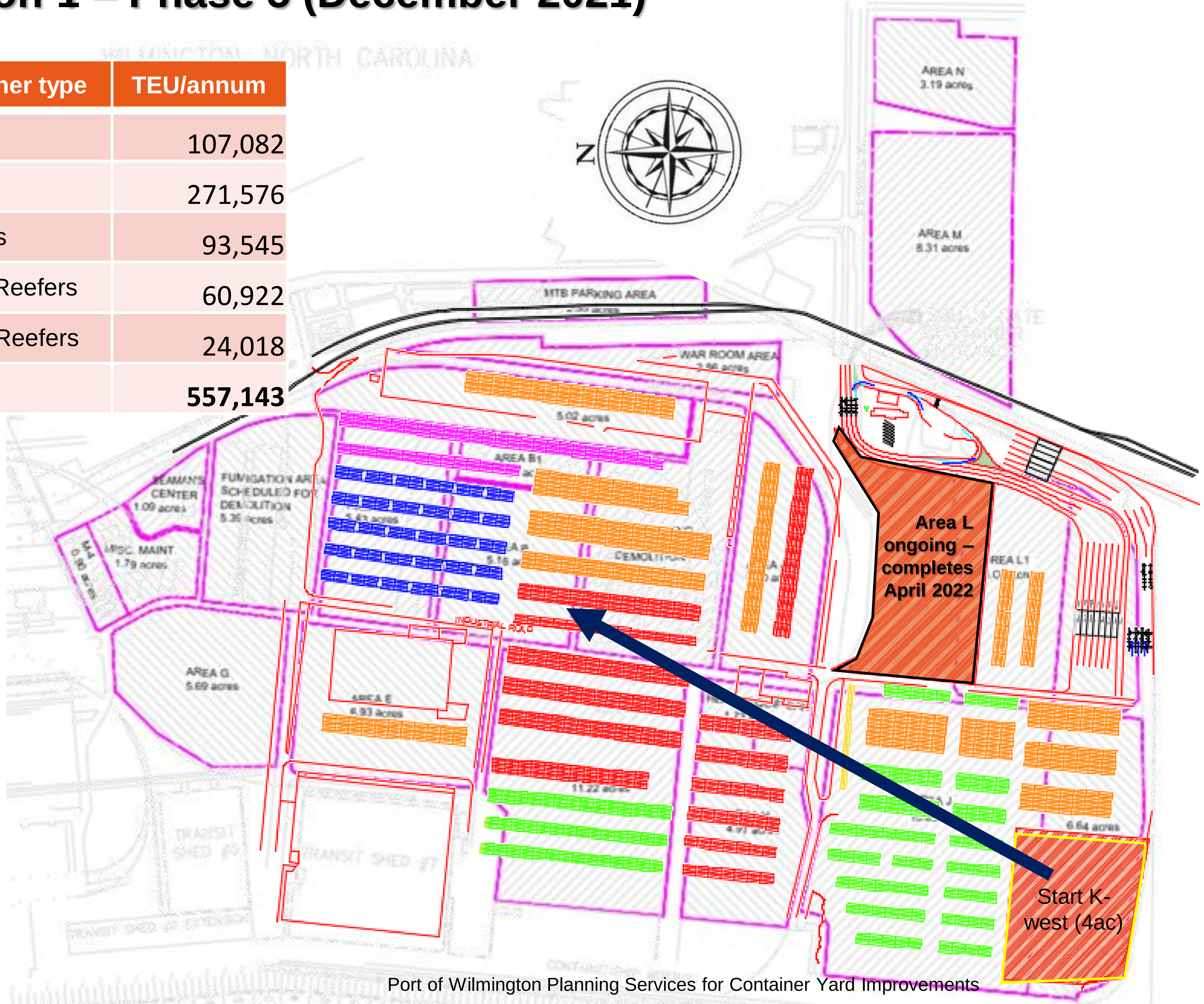
- ❑ South gate upgrade is complete and ready for operation.
- ❑ Old gate complex is decommissioned and repaved as the new area L (Concrete Paving Upgrades)
  - ❑ Works commencing: April 2021
  - ❑ Works completed: April 2022

Pave area K-east

- ❑ Empties from Area K-east moved to Area B-south
- ❑ Area K-east is repaved (Concrete Paving Upgrades)
  - ❑ Works commencing: April 2021
  - ❑ Works completed: December 2021

Option 1 – Phase 5 (December 2021)

Container type	TEU/annum
Exports	107,082
Imports	271,576
Empties	93,545
Laden Reefers	60,922
Empty Reefers	24,018
TOTAL	**557,143**

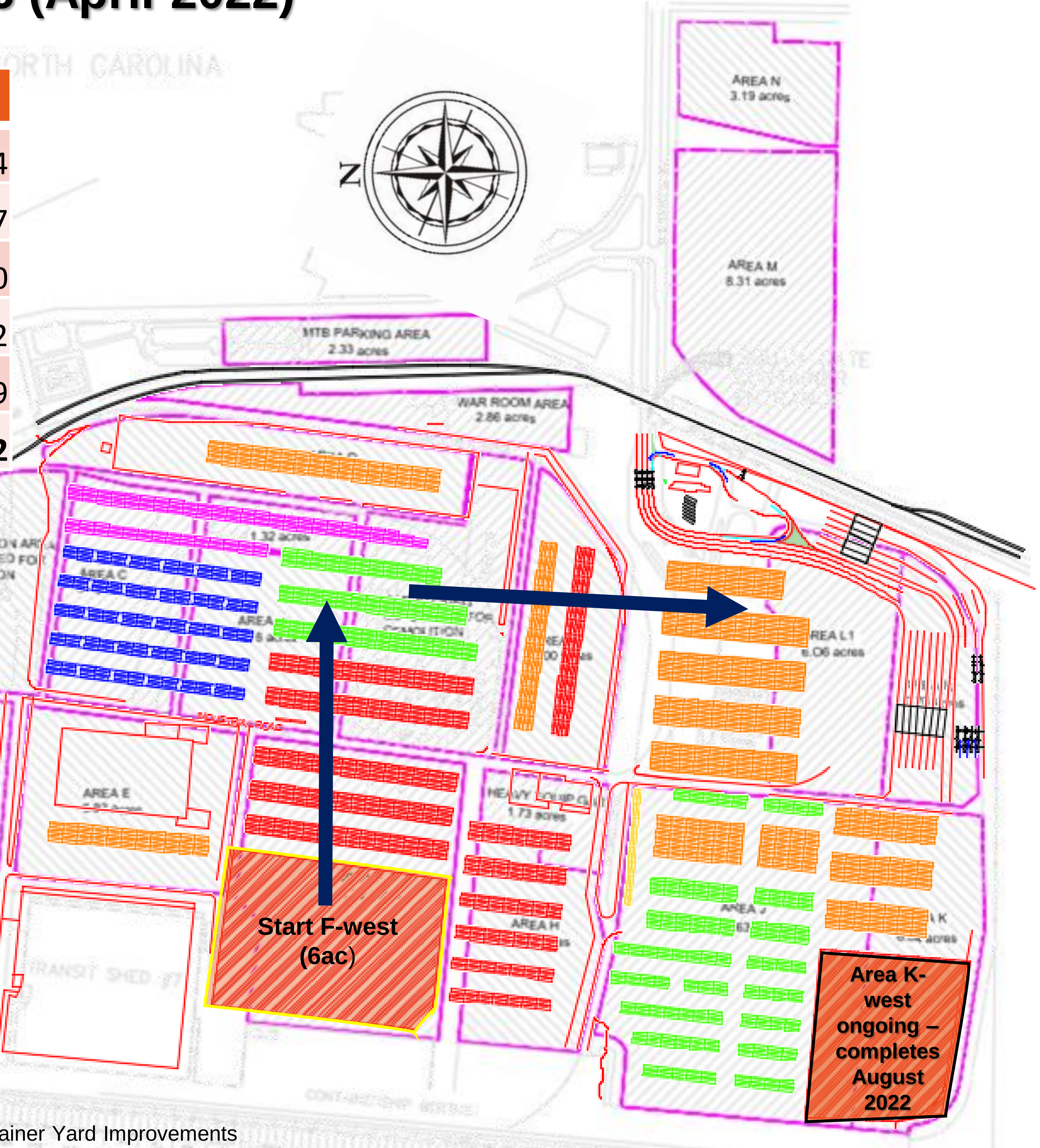


Pave area K-west

- Area K-east completed.
- Empties from Area B moved to Area K-east
- Imports from Area K-west moved to Area B
- Area K-west is repaved (Concrete Paving Upgrades)
  - Works commencing: December 2021
  - Works completed: August 2022
  - Ongoing works in area L (completes April 2022)

Option 1 – Phase 6 (April 2022)

Container type	TEU/annum
Exports	133,334
Imports	291,087
Empties	113,100
Laden Reefers	60,922
Empty Reefers	23,039
TOTAL	**621,482**

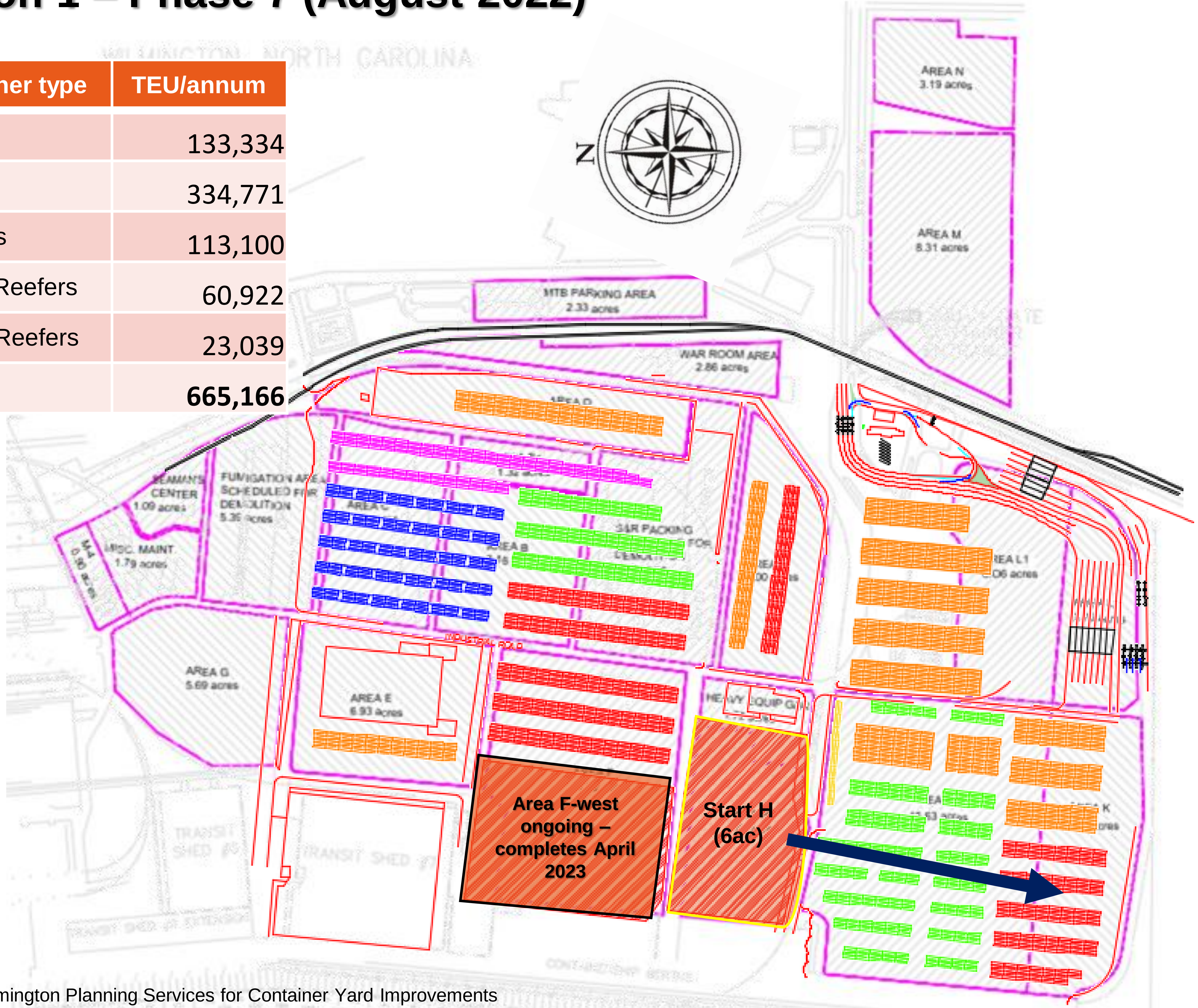


Pave area F-west

- Area L completed.
- Empties from Area B-south moved to Area L
- Exports from Area F-west moved to Area B-south
- Area F-west is repaved (Concrete Paving Upgrades)
  - Works commencing: April 2022
  - Works completed: April 2023
  - Ongoing works in area K-west (completes August 2022)

Option 1 – Phase 7 (August 2022)

Container type	TEU/annum
Exports	133,334
Imports	334,771
Empties	113,100
Laden Reefers	60,922
Empty Reefers	23,039
TOTAL	**665,166**

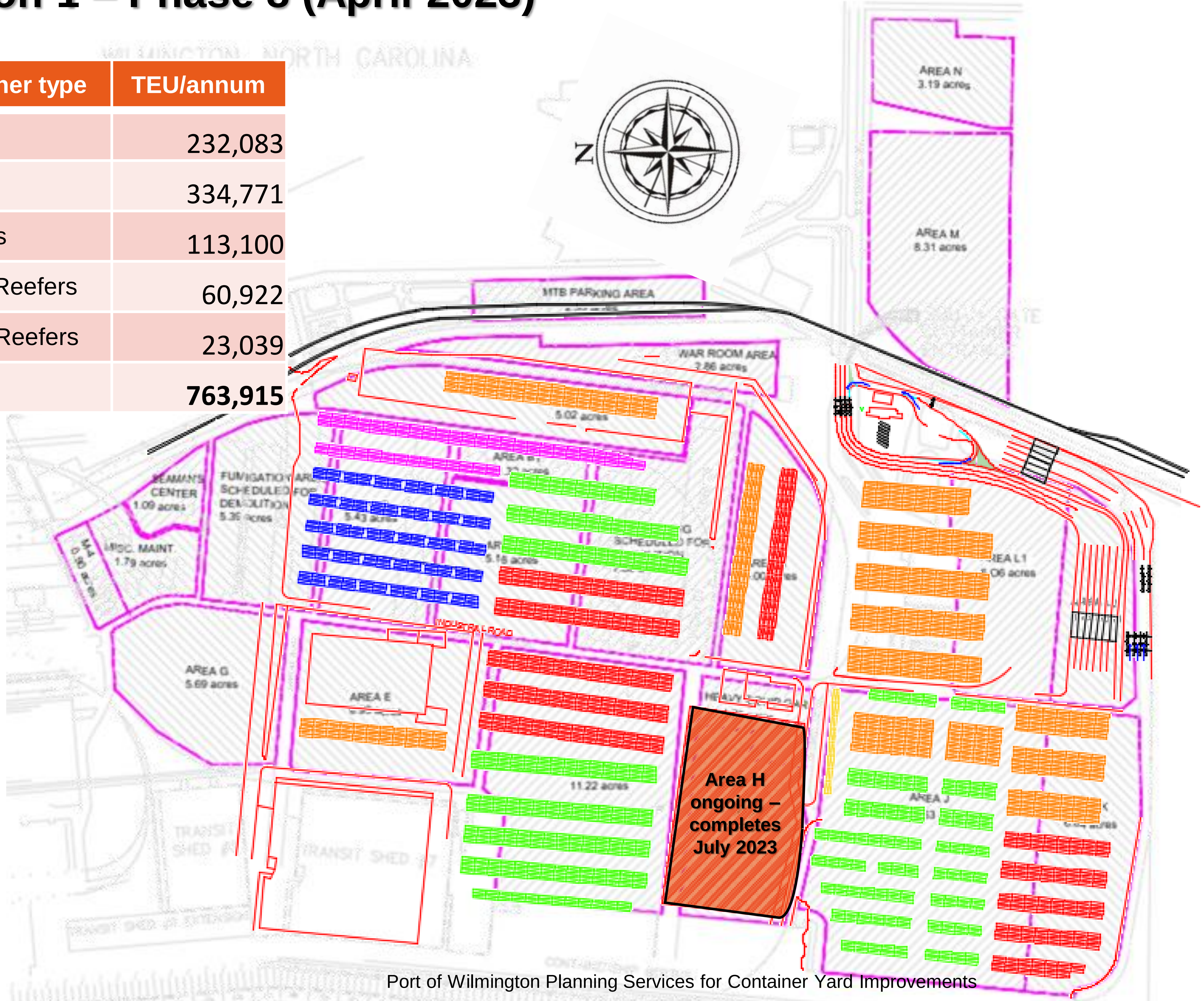


Pave area H

- ❑ Area K-west completed.
- ❑ Imports from Area H moved to Area K-west
- ❑ Area H is repaved (Concrete Paving Upgrades)
    - ❑ Works commencing: August 2022
    - ❑ Works completed: July 2023
    - ❑ Ongoing works in area F-west (completes April 2023)

Option 1 – Phase 8 (April 2023)

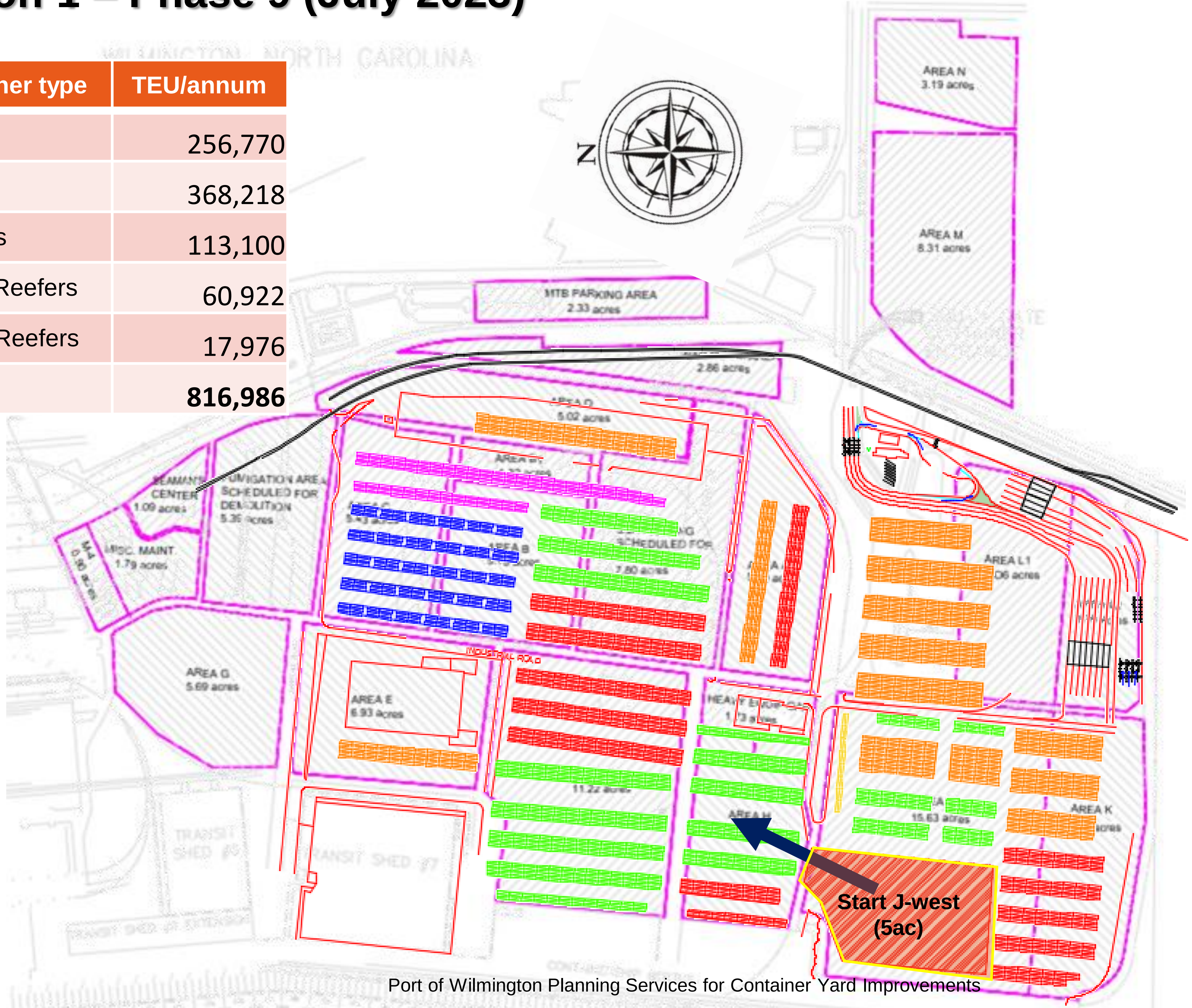
Container type	TEU/annum
Exports	232,083
Imports	334,771
Empties	113,100
Laden Reefers	60,922
Empty Reefers	23,039
<u>TOTAL</u>	**763,915**



Paving of Area F-west completed, work in Area H continues until July 2023

Option 1 – Phase 9 (July 2023)

Container type	TEU/annum
Exports	256,770
Imports	368,218
Empties	113,100
Laden Reefers	60,922
Empty Reefers	17,976
TOTAL	**816,986**

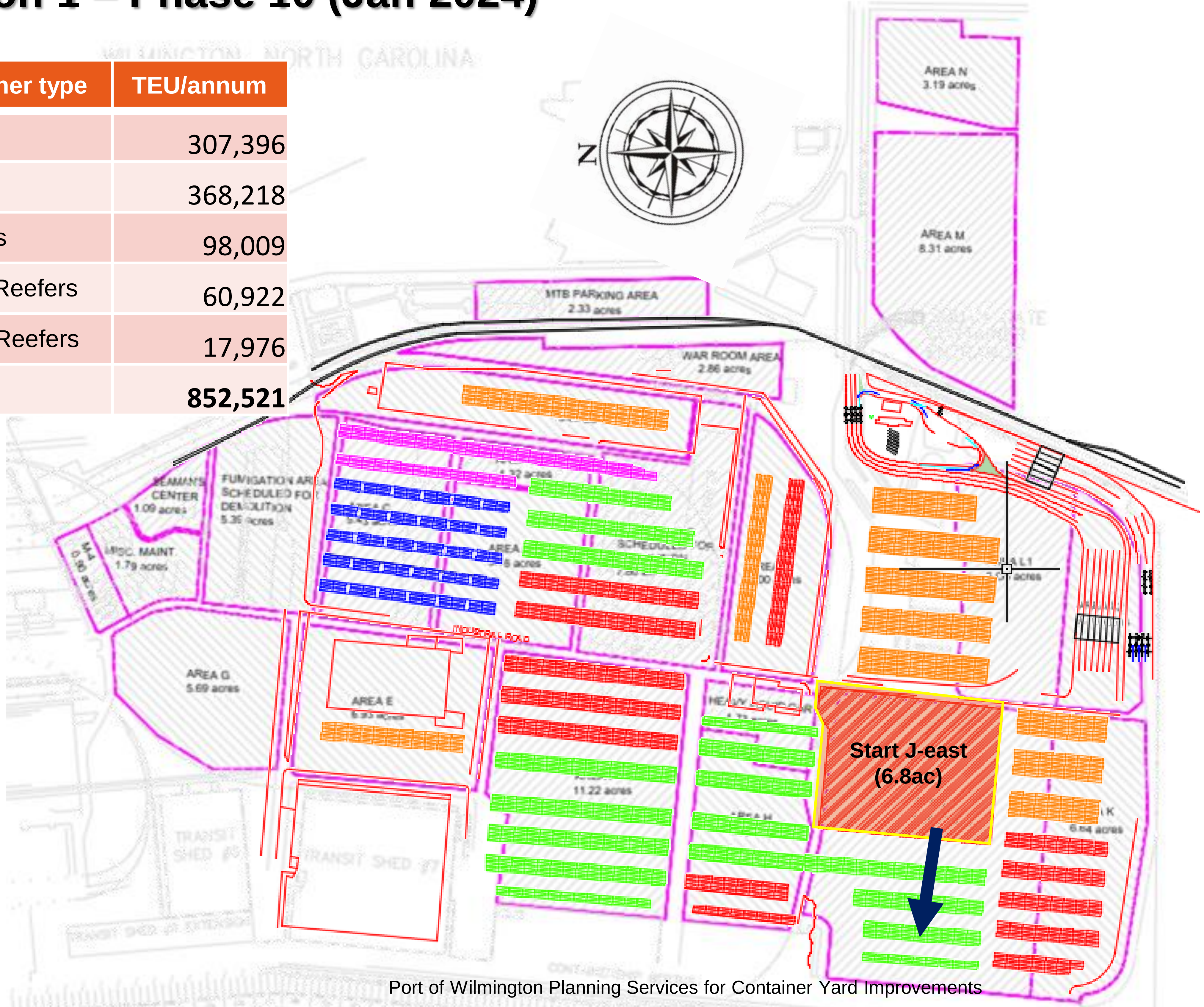


Pave area J-west

- ❑ **Area H completed.**
- ❑ **Exports from Area J-west moved to Area H**
- ❑ **Area J-west is repaved (Concrete Paving Upgrades)**
  - ❑ **Works commencing: July 2023**
  - ❑ **Works completed: January 2024**

Option 1 – Phase 10 (Jan 2024)

Container type	TEU/annum
Exports	307,396
Imports	368,218
Empties	98,009
Laden Reefers	60,922
Empty Reefers	17,976
TOTAL	**852,521**

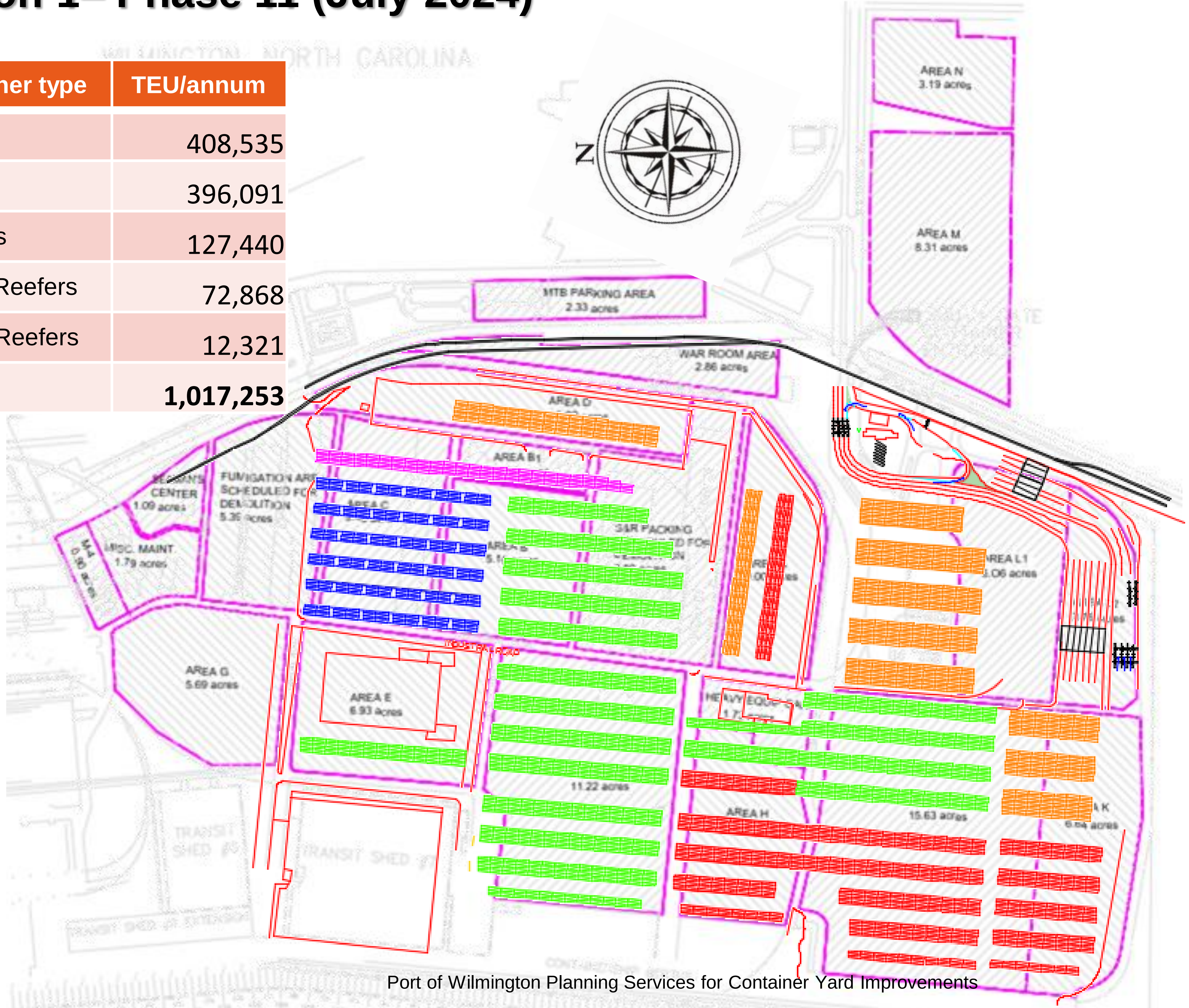


Pave area J-east

- ❑ **Area J-west completed.**
- ❑ **Exports from Area J-east moved to Area J-west**
- ❑ **Area J-east is repaved (Concrete Paving Upgrades)**
  - ❑ **Works commencing: January 2024**
  - ❑ **Works completed: July 2024**

Option 1– Phase 11 (July 2024)

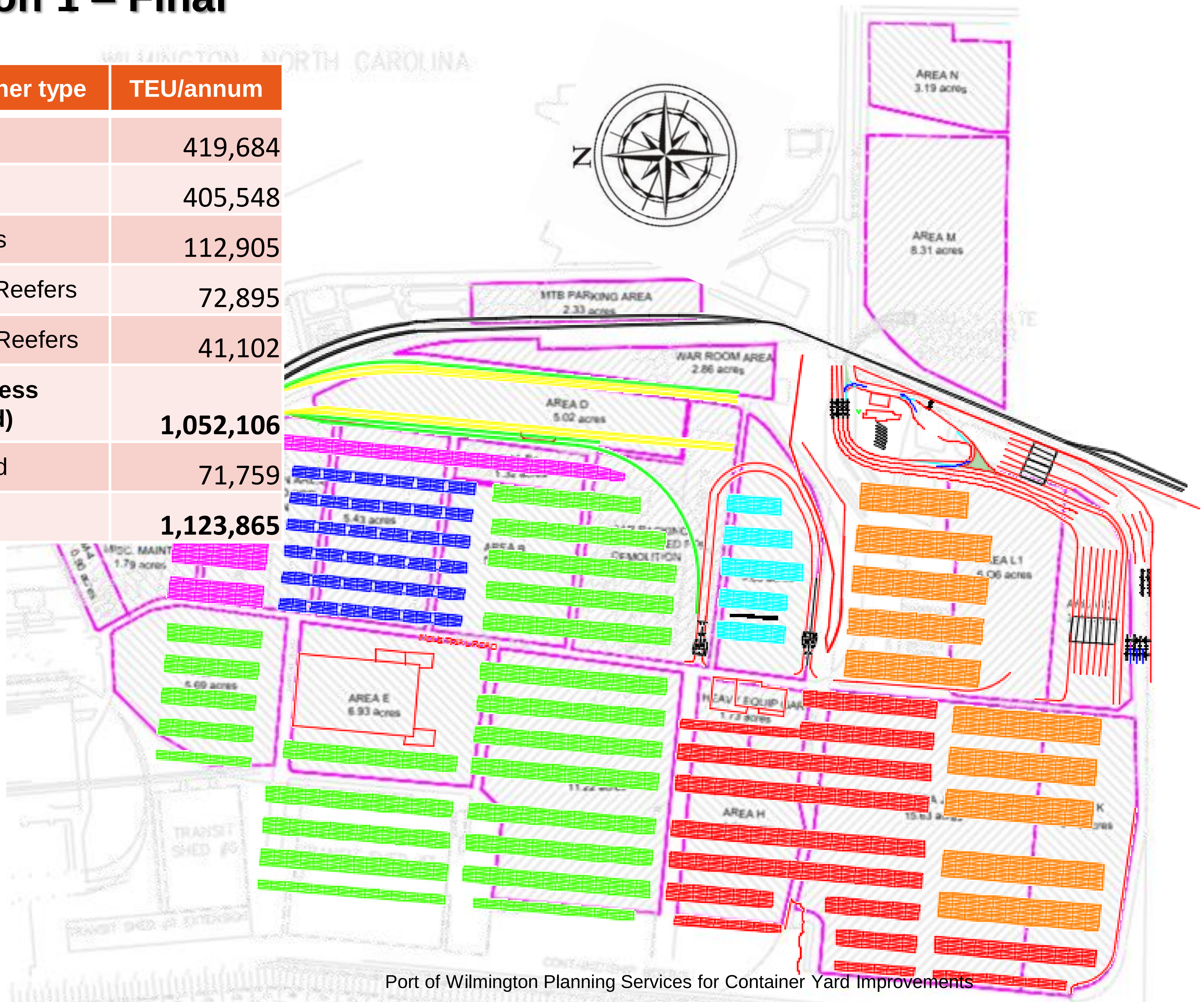
Container type	TEU/annum
Exports	408,535
Imports	396,091
Empties	127,440
Laden Reefers	72,868
Empty Reefers	12,321
TOTAL	**1,017,253**



Terminal maximised before the availability of bulk storage areas, warehouse and intermodal capacity.

Option 1 – Final

Container type	TEU/annum
Exports	419,684
Imports	405,548
Empties	112,905
Laden Reefers	72,895
Empty Reefers	41,102
Total (less railyard)	**1,052,106**
Railyard	71,759
TOTAL	**1,123,865**



Terminal maximised when the bulk storage areas, warehouse and intermodal capacity is available.

- ❑ **Percentage intermodal at 8% minimum**

9. Appendices

A. Hinterland Capacity Calculations

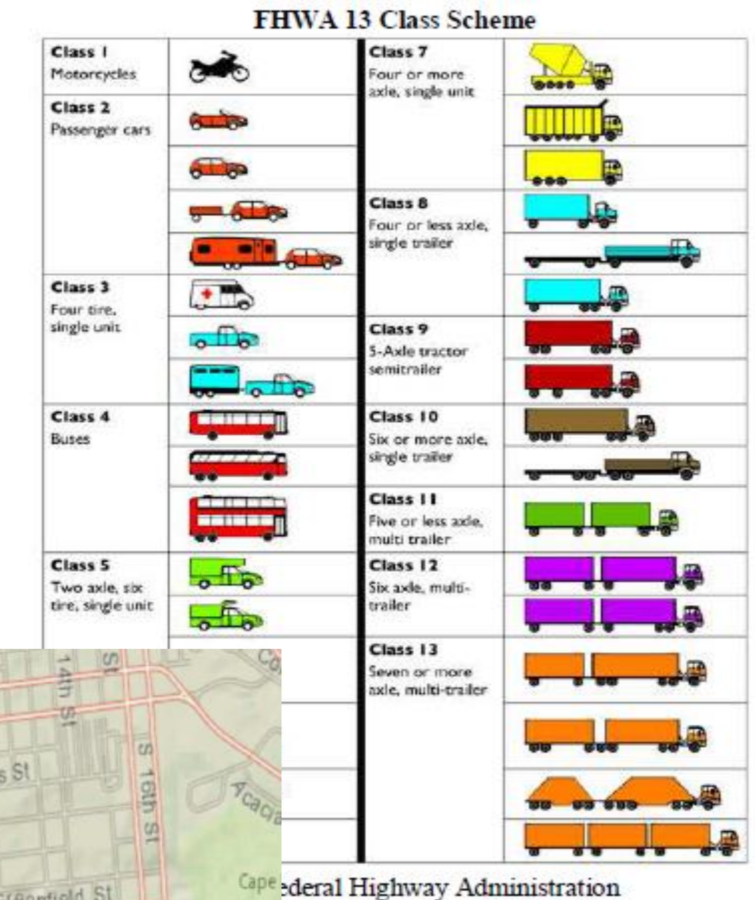
Confidential

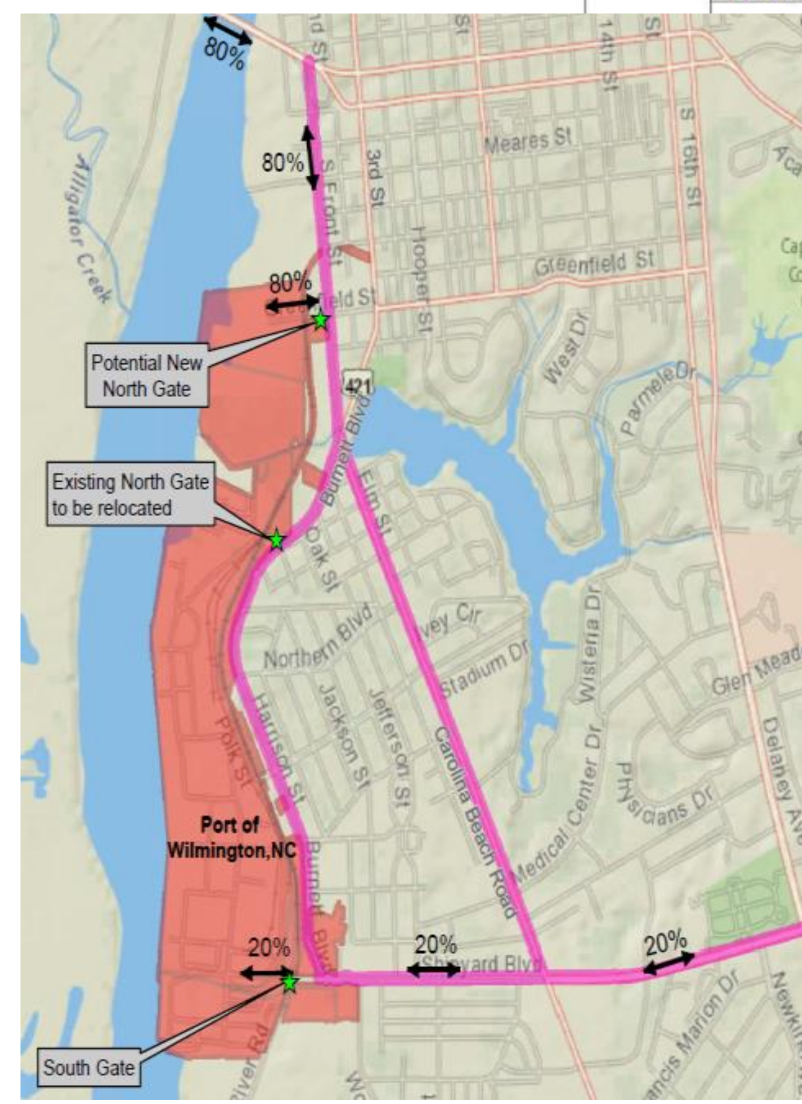
Hinterland Capacity Calculations

Port of Wilmington Masterplan

The North Carolina Department of Transportation (NCDOT) has made available traffic data for North Carolina's road network. The data provides the Annual Average Daily Traffic (AADT) in Passenger Car Units (PCU) for the years between 2003-2016. The data also gives the percentage of AADT for each vehicle class. Of interest to this report are those vehicles that would carry containers to and from the port, and these can be identified as vehicle classes 8-13, denoted as Multiple-Unit Trucks (MUTs).

Trucks to enter the port's container terminal can only access the South-Gate through Shipyard Blvd, as Burnett Blvd is closed to truck traffic. Shipyard Blvd links to Carolina Beach Rd, which is a major arterial road through Wilmington running South from Carolina Beach State Park to the North where it joins with 3rd St. The prevailing traffic conditions on Carolina Beach Rd on this link are congested during peak periods, which has led to the consideration of a North South Corridor that would take northbound traffic through the bulk terminal and out onto Front St, by-passing Carolina Beach Rd. As Shipyard Blvd and Carolina Beach Rd are the main roads that service the port, the capacities of these roads need to be assessed for future capacities.





Hinterland Capacity Calculations

Port of Wilmington Masterplan

This also includes the need to assess key junctions that trucks negotiate on their way to the container terminal. The interchange nearest the port is a staggered junction off Shipyard Blvd to River Rd to the south and Burnett Blvd to the north (Figure 4a).

A major interchange is also present at the crossroads between Carolina Beach Rd and Shipyard Blvd (Figure 4b). For the purposes of this study, the road segments at the crossroads are referred to as follows (clockwise from the west): Shipyard Blvd West; Carolina Beach Rd North; Shipyard Blvd East; and Carolina Beach Rd South

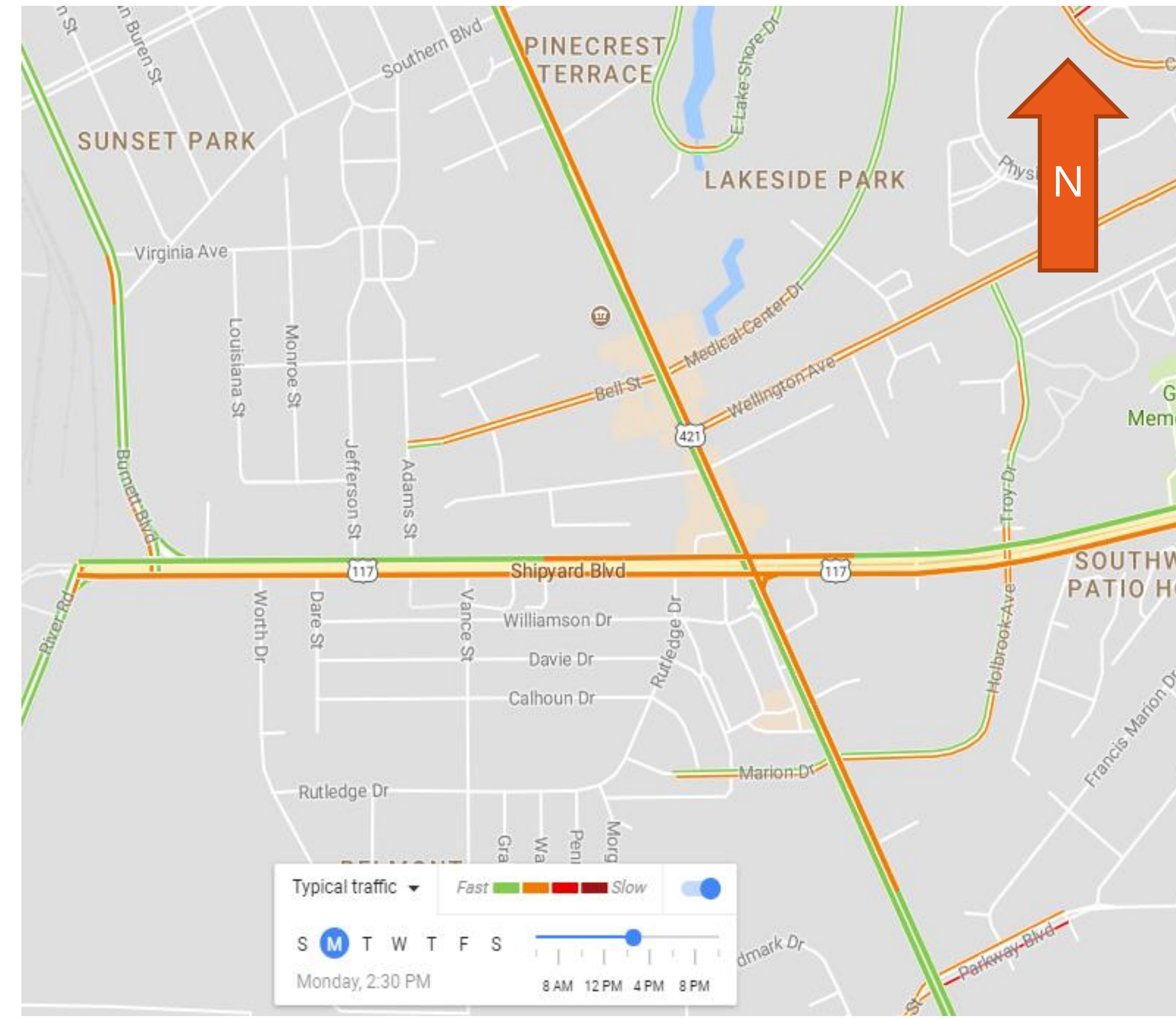
Hinterland Capacity Calculations

Port of Wilmington Masterplan

On inspection of typical traffic patterns for the road network relevant to the South-Gate using google maps traffic information, it is seen that between 14:00-15:00, peak traffic at the port, traffic in the direction going out of the port, headed North-East, is most critical.

NCDOT data below shows the Average Annual Truck Traffic (AATT) in the hinterland for 2015. However, it is known that truck traffic intended for the port only exists on weekdays, when the South Container gate facility is in operation. With this in mind, an adjustment need to be made to the AATT to account for a 5-day working week ($AATT_w$):

- Shipyard Blvd West — 2,111 PCU/day (14.1% AADT)
    - $AATT_w$: 2,955 PCU/day
- Carolina Beach Road North — 1,204 PCU/day (3.4% AADT)
    - $AATT_w$: 1,686 PCU/day
- Shipyard Blvd East — 222 PCU/day (1.1% AADT)
    - $AATT_w$: 311 PCU/day
- Carolina Beach Road South — 195 PCU/day (0.7% AADT)
    - $AATT_w$: 273 PCU/day
- Front St — 1,912 PCU/day (8.0% AADT)
    - $AATT_w$: 2,676 PCU/day



Source: Google Maps

This is important in addressing the increased demand from the port as it will determine how the junction capacities are to be assessed with respect to turning moves by vehicles travelling to and from the port.

Hinterland Capacity Calculations

Port of Wilmington Masterplan

2015 figures for AADT for the same road links are shown below. Again, these must be adjusted to account for MUTs only operating on weekdays (AADTw):

- Shipyard Blvd West 15,000 PCU/day
  - AADTw: 15,845 PCU/day
- Carolina Beach Road North 35,000 PCU/day
  - AADTw: 35,482 PCU/day
- Shipyard Blvd East 20,000 PCU/day
  - AADTw: 20,089 PCU/day
- Carolina Beach Road South 26,000 PCU/day
  - AADTw: 26,078 PCU/day
- Front St 24,000 PCU/day
  - AADTw: 24,765 PCU/day

K-Factor	D-Factor	Two-Lane Streets LOS B	LOS C	LOS D	LOS E	Four-Lane Streets LOS B	LOS C	LOS D	LOS E	Six-Lane Streets LOS B	LOS C	LOS D	LOS E
Posted Speed = 30 mi/h													
0.09	0.55	NA	5.9	15.4	19.9	NA	11.3	31.4	37.9	NA	16.3	46.4	54.3
	0.60	NA	5.4	14.1	18.3	NA	10.3	28.8	34.8	NA	15.0	42.5	49.8
0.10	0.55	NA	5.3	13.8	17.9	NA	10.1	28.2	34.1	NA	14.7	41.8	48.9
	0.60	NA	4.8	12.7	16.4	NA	9.3	25.9	31.3	NA	13.5	38.3	44.8
0.11	0.55	NA	4.8	12.6	16.3	NA	9.2	25.7	31.0	NA	13.4	38.0	44.5
	0.60	NA	4.4	11.5	14.9	NA	8.4	23.5	28.4	NA	12.2	34.8	40.8
Posted Speed = 45 mi/h													
0.09	0.55	NA	10.3	18.6	19.9	NA	21.4	37.2	37.9	NA	31.9	54.0	54.3
	0.60	NA	9.4	17.1	18.3	NA	19.6	34.1	34.8	NA	29.2	49.5	49.8
0.10	0.55	NA	9.3	16.8	17.9	NA	19.3	33.5	34.1	NA	28.7	48.6	48.9
	0.60	NA	8.5	15.4	16.4	NA	17.7	30.7	31.3	NA	26.3	44.5	44.8
0.11	0.55	NA	8.4	15.3	16.3	NA	17.5	30.5	31.0	NA	26.1	44.2	44.4
	0.60	NA	7.7	14.0	14.9	NA	16.1	27.9	28.4	NA	23.9	40.5	40.7

Engineering consultants HDR conducted a traffic analysis survey for the Port of Wilmington as part of their report on the North South Gate Corridor Project (2013), which looked at the feasibility of establishing a corridor running North to South of the Port of Wilmington in order for trucks to by-pass the Carolina Beach Rd north approach. The report outlined their findings in a report prepared for the North Carolina State Ports Authority (NCSPA). All roads in the port's hinterland are designed for a Level of Service (LOS) standard of D, or to accommodate a traffic density of between 26-35 PCU/mile/lane (Highway Capacity Manual 2010). LOS D describes conditions whereby the facility provides reasonably fluid flow but friction and interactions between vehicles is likely in cases of adverse signal progression, inappropriate signal timing, increases in flow, or a combination of these factors (HCM 2000). A vehicle's freedom to select individual speed and to by-pass other vehicles is restricted. HDR's report utilizes the table presented in Exhibit 16-14 of HCM 2010, Table 2, to determine the various LOS for each of the road links in the port's hinterland.

Hinterland Capacity Calculations

Port of Wilmington Masterplan

The peak hour flow volume (V_P) can determined from Chapter 10 of Highway Capacity Manual (HCM 2010):

$$V_P = \frac{AADT \times K\ factor \times D\ factor}{PHF \times f_{HV}}$$

Where the K-factor is the proportion of the 24-hour volume that occurs in the design hour, the D-factor is the proportion of traffic in the critical direction, PHF is the Peak-hour Factor accounting for greater volumes during the peak, and f_{HV} is an adjustment factor accounting for the proportion of heavy vehicles. For urban freeways, a K-factor of 0.09 and D-factor of 0.60, and a Peak-hour factor of 0.95 are recommended. f_{HV} decreases with greater proportion of heavy vehicles:

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

Where P_T and P_R are the percentage multi-unit and single-unit trucks respectively. Values for E_T and E_R are determined based on the terrain; for level terrain, these values are E_T = 1.5 and E_R = 1.2.

Listed below in the Table below are the relevant road links giving information on speed limits and service volumes derived from Exhibit 16-14 of HCM 2010, interpolating where required.

	No. of Lanes both ways	Speed limit (mph)	Daily Maximum Service Volumes for each LOS (AADT/peak-hour)			Operational Volumes, AADT/peak-hour (2015)	Current LOS	Utilization LOS D (%)
			C	D	E			
Carolina Beach Rd North	4	40	16,500 / 992	32,333 / 1,945	34,800 / 2,093	35,482 / 2,148	F	110.44%
Carolina Beach Rd South	4	45	19,600 / 1,161	34,100 / 2,020	34,800 / 2,061	26,078 / 1,547	D	76.59%
Shipyard Blvd East	5	35	16,617 / 986	43,031 / 2,552	49,800 / 2,954	20,089 / 1,194	D	46.79%
Shipyard Blvd West	4	35	13,369 / 850	30,549 / 1,942	34,800 / 2,213	15,844 / 1,029	D	52.96%
Burnett Blvd	2	30	5,400 / 317	14,100 / 828	18,300 / 1,074	5,500 / 323	D	39.01%
River Rd	2	30	5,400 / 317	14,100 / 828	18,300 / 1,074	8,600 / 505	D	60.99%
Front St	2	35	6,733 / 414	15,100 / 929	18,300 / 1,074	24,765 / 1,544	F	166.23%

Hinterland Capacity Calculations

Port of Wilmington Masterplan

To increase the future throughput from the present day 210,000 TEUs per annum, truck traffic will need to increase proportionally:

$$AATT_{future} = AATT \times \frac{future\ throughput}{current\ throughput}$$

There will need to be an increase in truck traffic in order to meet the target of 750,000 TEUs per annum by 2025. It is worth noting that there are also plans to develop the intermodal yard at the terminal, which may see up to 25% of containers transported by rail and 75% by road. This scenario would lead to about 562,500 TEUs being transported by road annually. The Table opposite below shows future utilization rates in the case of commissioning the intermodal yard (minimum) and in the case that the intermodal yard is not developed (maximum).

Currently Carolina Beach Road North is highly utilized at 110.44% of the adopted LOS standard and is expected only increase in utilization as a result of increasing the throughput to 750,000 TEUs per annum, with or without the development of the intermodal yard.

Road	LOS D (daily/ peak-hour)	2015 operational volume (AADTw/ peak-hour)	2015 AATT	Future AATT (min/max)	Future AADTw Traffic (min/max)	Future Peak-hour Traffic (min/max)	Future utilization (min/max)	Future LOS
Carolina Beach Rd North	32,333 / 1,945	35,482 / 2,148	1,686	4,515 / 6,020	38,311 / 39,816	2,381 / 2,531	122.43% / 130.16%	F
Carolina Beach Rd South	34,100 / 2,020	26,078 / 1,547	273	731 / 975	26,536 / 26,780	1,579 / 1,609	78.16% / 79.66%	D
Shipyard Blvd East	43,031 / 2,552	20,089 / 1,194	311	832 / 1,110	20,611 / 20,888	1,234 / 1,265	48.36% / 49.55%	D
Shipyard Blvd West	30,549 / 1,942	15,844 / 1,029	2,955	7,914 / 10,553	20,804 / 23,442	1,436 / 1,618	73.96% / 83.34%	D
Burnett Blvd	14,100 / 828	5,500 / 323	0	0/0	5,500 / 5,500	323 / 323	39.01% / 39.01%	D
River Rd	14,100 / 828	8,600 / 505	0	0/0	8,600 / 8,600	505 / 505	60.99% / 60.99%	D
Front St	15,100 / 929	24,765 / 1,544	2,676	7,169 / 9,558	29,257 / 31,647	1,928 / 2,154	207.47% / 231.81%	F

B. North-South Corridor Option

North-South Corridor

Port of Wilmington Masterplan

Background

Taking October gate data as ‘typical’, projected throughput for the container terminal is 449,328 TEU/annum. Under October conditions, the gate facility runs over capacity ~3 times a month. Throughput is to increase to 750,000 TEU/annum by 2025. If the intermodal yard is operational, 25% container traffic will be transported by rail, leaving 562,500 TEU/annum to be transported by road in 2025. At present, container traffic can only pass through the South Gate to access the container yard. Traffic from North must pass Carolina Beach Rd and Front St, both of which are beyond capacity.

Options explored to address congestion at the South Gate include: increasing the number of gates; repurpose other areas of the port property for a relocated gate complex; or build another gate in the North Property and construct a corridor running North-South through the port. This third option has been presented in previous reports and optioneering exercises. The justification for a North-South Corridor involves the following:

- The majority of container traffic approaches from the North;
- The traffic from the North passes through Front St and Carolina Beach Rd, both of which are beyond capacity;
- The current North Gate that services traffic destined for the bulk terminal currently conflicts with rail operations because the gates are located South of the rail switch;
- Rerouting traffic through the North Gate would greatly reduce strain on the South Gate if no improvements are made to the South Gate, such that only 3 entrance and 2 exit gates would be required at the South Gate, with a significantly reduced queuing area, is needed. This also frees up more space in the container terminal to be repurposed as container storage.

North-South Corridor

Port of Wilmington Masterplan

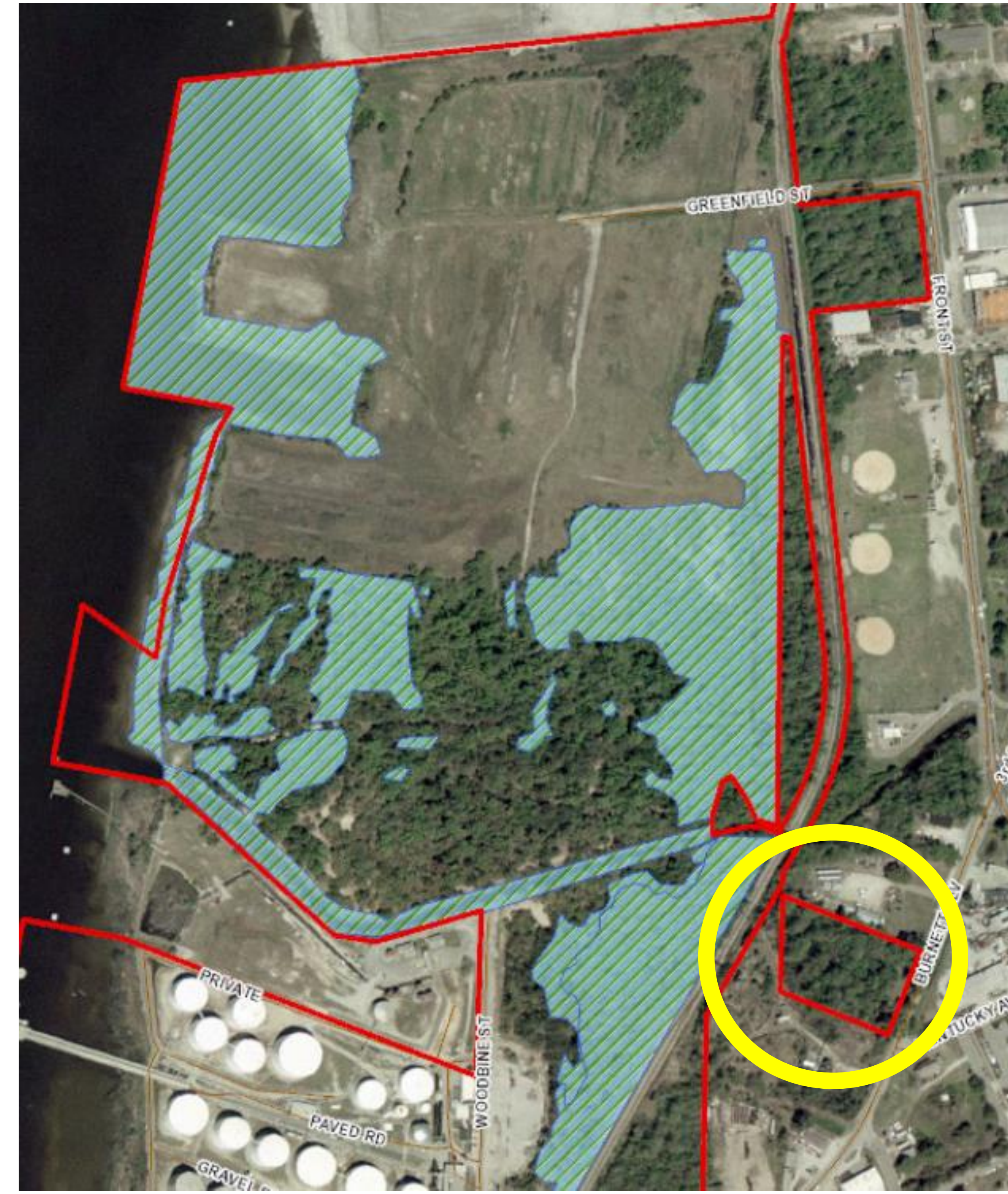
Considerations

Relocating the North Gate facility to the North Property will allow trucks to by-pass Carolina Beach Rd, but traffic will still need to pass through Front St. In order for this option to be effective, Truck traffic will need to be rerouted through 3rd St., which when in effect will utilize 3rd St. by 71.22%, significantly under full capacity.

The GIS Data provided by NCSPA shows a parcel of land owned by the port which is outside the port boundary (highlighted by the yellow circle). If this land is without purpose, it may be worth considering this to be the site of the new North Gate as it is positioned just north of the rail switch and traffic road-bound from this point can travel onto 3rd St. without crossing Front St.

Limitations

The North Property is a greenfield site which contains sizeable areas of wetland (shown in blue). Any option involving the North Property will be scrutinized for potential impact to wetlands. Any work in the North Property will need to be coordinated with ongoing remediation of the Southern Wood Piedmont National Priority List (NPL) site. If a significant area of wetland is affected, work can only go ahead on receiving an Individual Permit from the US Army Corps of Engineers, under Section 404 of the Clean Water Act. This will also likely require documents prepared under the National Environmental Policy Act (NEPA) ad an Environmental Impact Statement (EIS). An EIS process is costly and can take about 5 years.



North-South Corridor

Port of Wilmington Masterplan

NSC Option 1

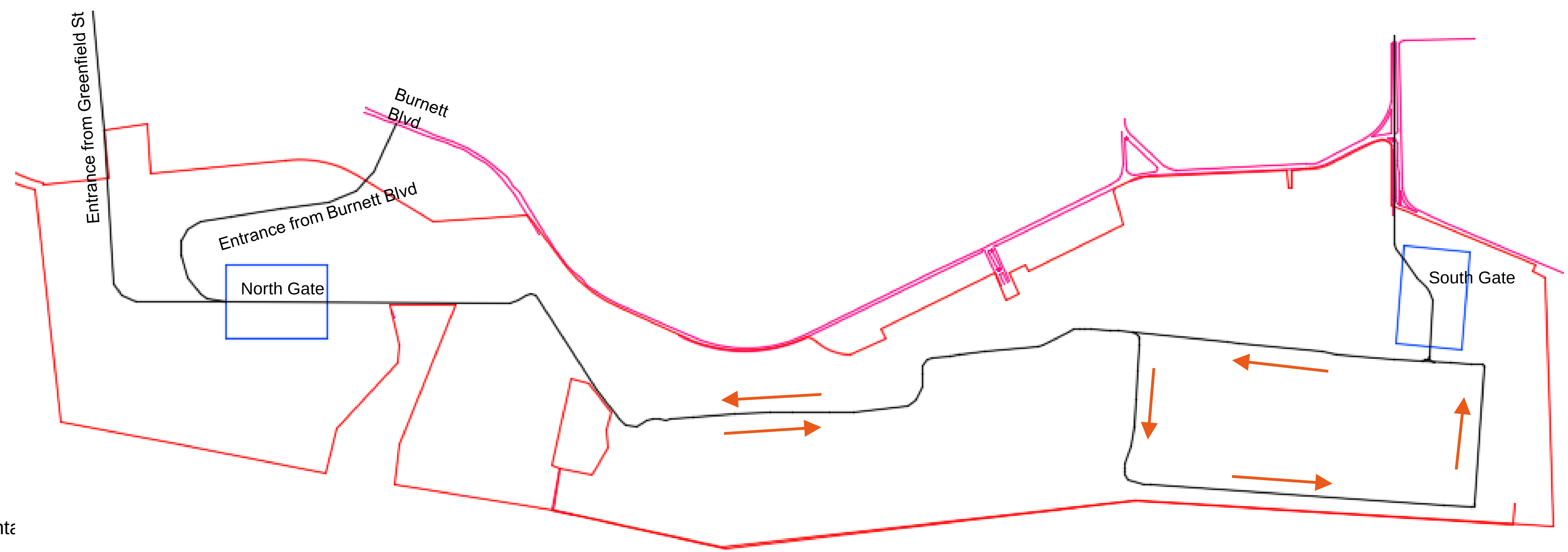
The first option for the North-South Corridor considered in this study (NSC Option 1) entails routing container truck traffic through the bulk terminal. To avoid clashing with rail operations, the North Gate will be built inside the North Property, with trucks entering the gate either from Greenfield St or Burnett Blvd, the latter being dependant on the availability of the parcel of land owned by NCSPA just east of the North Property. The North Gate and the entrance route to the gates would be planned to minimize impact on wetland areas.

Pros

- Utilizing existing internal routes will limit the upfront capital cost.

Cons

- The main drawback of NSC Option 1 is that the bulk terminal will become significantly busier from container traffic, which may cause disruption to the current operations.



North-South Corridor

Port of Wilmington Masterplan

NSC Option 2

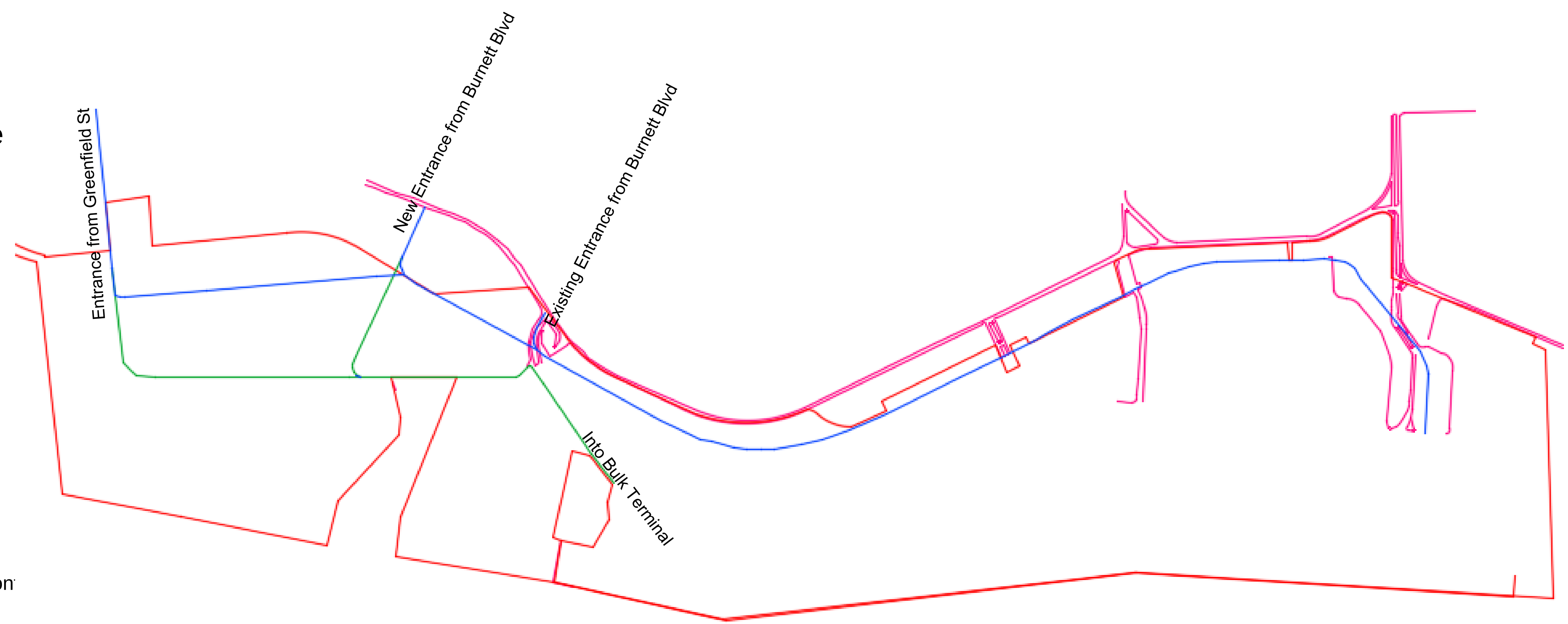
This option entails routing container truck traffic east of the railway and through the South Gate (in blue). The routing of Bulk Terminal traffic is shown in green. To avoid clashing with rail operations, trucks could be routed from either Greenfield St or Burnett Blvd, the latter being dependant on the availability of the parcel of land owned by NCSPA just east of the North Property. The entrance route to the gates would be planned to minimize impact on wetland areas. This option aids container traffic to by-pass Carolina Beach Rd and the Bulk Terminal. This option does not reduce congestion at the South Gate. Some parts of the corridor lie outside the existing port boundary and land may need to be bought/negotiated.

Pros

- Aligning the corridor east of the railway allows to the corridor to by-pass the bulk terminal.

Cons

- All trucks must still be processed at the South Gate as the route will inevitably end at the South Gate.
- Construction may cause significant disruption to railway operations.



North-South Corridor

Port of Wilmington Masterplan

Cape Fear Crossing

Future plans for the Cape Fear Crossing will potentially change the truck routing in the hinterland. The new crossing is intended to alleviate pressure from the Cape Fear Memorial Bridge. As of the end of last year, options for the new crossing have been reduced to three, one of which connects at River Road and continues onto Independence Boulevard (labelled Option 3 on the right). Option 1 and Option 3 are preferable to Option 2 (Spectrum News, 2017).

If Option 3 is implemented, truck traffic that would originally come from the North will be rerouted through road links to the South, relieving pressure on Front St and Carolina Beach Rd northern approach.

Reasons for not progressing with the North-South Corridor

After consideration, it is decided that this option is not feasible for the following reasons:

- If a significant amount of wetland is impacted by the planned corridor, permissions and environmental assessments are required, which can take up to 5 years;
- Any plans for a North-South Corridor through the port are disruptive to current operations;
- The capital costs for establishing the North-South Corridor are potentially high;
- Plans for the Cape Fear Crossing, particular if Option 3 is chosen, will address the issues of congestion on Carolina Beach Rd and Front St which the North-South Corridor is aiming to address.

Options for Cape Fear Crossing (Star News Online, 2016)

MOTT MACDONALD

C. Single Equivalent Wheel Load Passes

Single Equivalent Wheel Load Passes

Port of Wilmington Masterplan

As the Asphalt Institute does not outline how best to derive wheel loads for trucks, the BPA manual is used to supplement the design. The BPA manual gives guidance on the influence of vehicle geometry on the nominal wheel load. This influence is determined by the relations shown on the right.

For the reach stacker, W_1 is the load on the front axle when the equipment is laden, and W_2 is the load on the rear axle. W_c is the weight of the container, M is the number of wheel on the front axle, and W_T is the self-weight of the stacker. The design reach stacker considered is a Kone Cranes SMV 4535 TB5.

For the truck, W_1 is the load on the front axle of the tractor laden, W_2 is the load on the rear axle of the tractor laden, and W_3 is the load on the rear axle of the trailer laden. M_1, M_2, and M_3 are the number of wheel on each respective axle. U_1, U_2, and U_3 are the unladen load on each respective axle. The design truck considered has a tractor with wheelbase of 9 feet and a trailer with distance of 33 feet between trailer axle and hook up point, and a total unladen weight 16,500 kg.

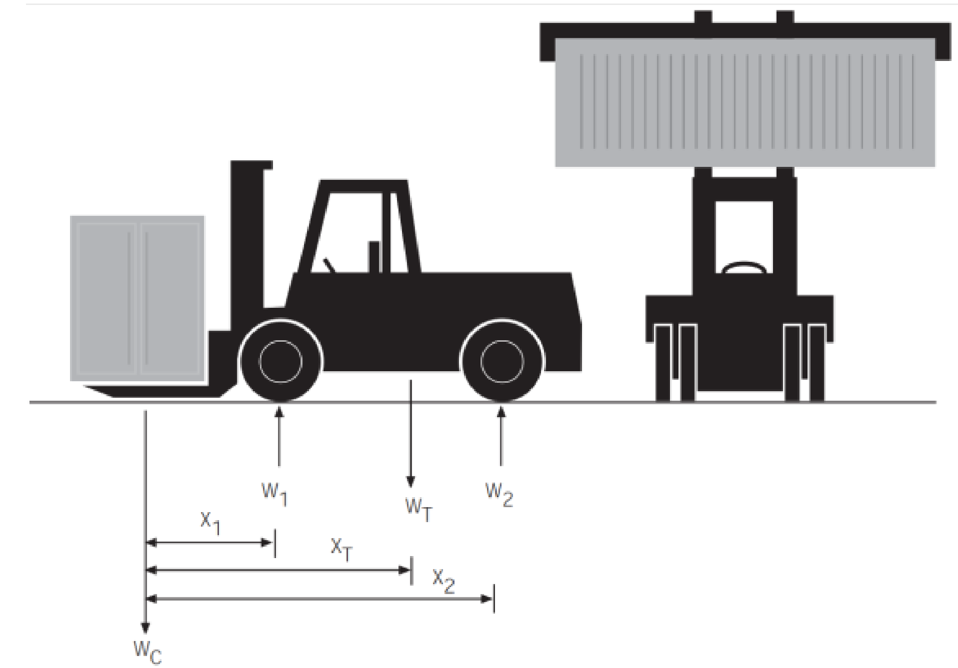
The design container of weight 22,000 kg is assumed. f_d is the dynamic factors that add to the severity of the load through vehicle manoeuvres, summarised in Section 3.3.2.1.

$$W_1 = f_d \times \frac{A_1 . W_c + B_1}{M}$$

$$W_2 = f_d \times \frac{A_2 . W_c + B_2}{2}$$

$$A_1 = \frac{-X_2}{X_1 - X_2} \qquad A_2 = \frac{-X_1}{X_2 - X_1}$$

$$B_1 = \frac{W_T\ (X_T - X_2)}{X_1 - X_2} \qquad B_2 = \frac{W_T\ (X_T - X_1)}{X_2 - X_1}$$

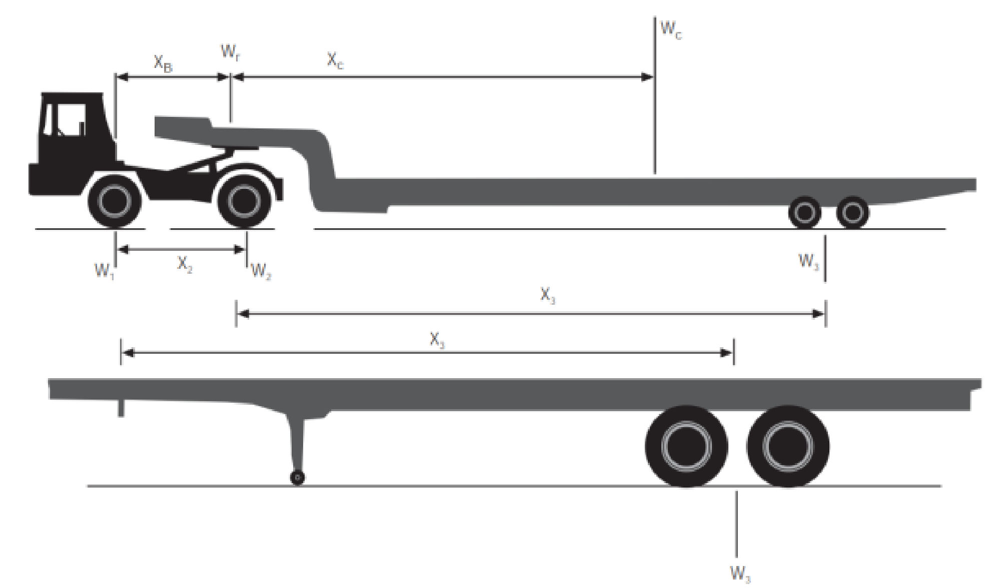


$$W_1 = f_d \times \left[U_1 + \frac{W_c\ [1-A] \times [1-B]}{M_1} \right]$$

$$W_2 = f_d \times \left[U_2 + \frac{W_c\ [1-A] \times B}{M_2} \right]$$

$$W_3 = f_d \times \left[U_3 + \frac{W_c \times A}{M_3} \right]$$

$$A = \frac{X_c}{X_3} \qquad B = \frac{X_b}{X_2}$$



Single Equivalent Wheel Load Passes

Port of Wilmington Masterplan

The effective wheel load is determined by loads on nearby tyres, which can provide extra-over loads on the nominal wheel load. These extra-over loads are found by applying a proximity factor to the nearby wheel load, and then adding this factored wheel load to the nominal wheel load (See Table opposite). For example, if a vehicle travels over an effective depth of subgrade of 2,000 mm, and four wheels exist on a single axis (two in both channels), adjacent wheels at 600 mm apart and the spacing between inner wheel at 1800 mm, then the inner wheel will have a factor of 82% from its adjacent wheel, 19% from the opposite inner wheel, and 2% from the outer wheel on the opposite channel. These factors are added up (103%) and applied to the inner wheel load (100%) to give an effective wheel load that is 203% of the nominal wheel load. For the purpose of preliminary design, a CBR value of 15% is assumed, as the Asphalt Institute does not recommend using values above this, which gives an effective depth of 1,850 mm. The proximity factors are adjusted accordingly. The design wheel load is identified as being from the trucks, as these are expected to pass more frequently, with a maximum deign wheel load of 35.6 kN.

The largest effective wheel load in a channel is taken as the design load. To find the total equivalent wheel load passes, each effective wheel load in the channel is taken as a proportion of the design wheel load and the proportions are added to give a factor by which to multiply the number of passes computed using the method detailed in Section 2.2.4.4. The number of single equivalent wheel load passes amounts to 3,942,000 passes over the 25 year design life.

Wheel Spacing (mm)	Proximity factor for effective depth to base of:		
	1000mm	2000mm	3000mm
300	1.82	1.95	1.98
600	1.47	1.82	1.91
900	1.19	1.65	1.82
1200	1.02	1.47	1.71
1800	1.00	1.19	1.47
2400	1.00	1.02	1.27
3600	1.00	1.00	1.02
4800	1.00	1.00	1.00

$$\text{Effective depth} = 300 \times \sqrt[3]{\frac{35{,}000}{\text{CBR} \times 10}}$$

D. Paving Thickness Calculations using Asphalt Institute Design Guidance

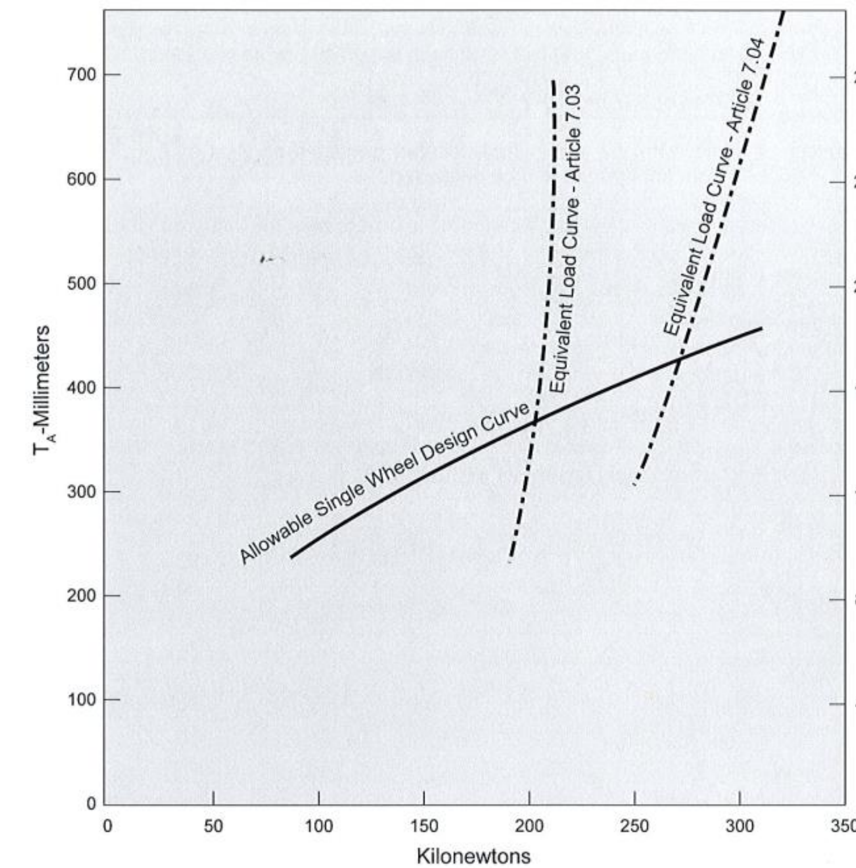
Confidential

Paving Thickness Calculation using Asphalt Institute Guidance

Port of Wilmington Masterplan

The geometry of the trucks dictates that it is best to design the paving with dual wheel loads in mind. The Asphalt Institute's design procedure for dual wheel loads is most appropriate. This procedure involves drawing an 'Allowable Single Wheel Load Design Curve' and an 'Equivalent Single Wheel Load Design Curve'. The intersecting value of these curved is the full-depth asphalt design thickness.

The first step is to draw the 'Allowable Single Wheel Load Design Curve'. To do this, first the $T_{A/a}$ must be established. The $T_{A/a}$ is the is the ratio of T_A and *a*, where T_A is the full-depth asphalt thickness in mm, and *a* is the radius of the single equivalent wheel load in mm. The $T_{A/a}$ is dependent on the tire ground pressure, the subgrade, number of load repetitions, and the yearly average temperature. The table opposite shows the $T_{A/a}$ values for pavements experiencing yearly average temperatures above 55ºF and a subgrade with CBR = 15. Assuming a tire contact pressure of 150 kPa and for the total load repetitions of 3,942,000 over the 25 year design life, $T_{A/a}$ = 2.25. To draw the curve, a range of contact radii, *a*, must be derived for a range of single wheel load values, P.



DESIGN $T_{A/a}$ VALUES FOR YEARLY AVERAGE DAILY TEMPERATURE ABOVE 13°C (55°F)

Subgrade M_r (CBR)	Load Repetitions	Tire Ground Contact Pressure, kPa (psi) 275 (40)	415 (60)	550 (80)	690 (100)	1035 (150)	1380 (200)
30 MPa 4,500 psi (3)	10,000	0.59	0.81	1.00	1.16	1.50	1.79
	100,000	0.75	1.00	1.22	1.41	1.79	2.12
	1,000,000	0.92	1.22	1.46	1.68	2.11	2.47
50 MPa 7,500 Psi (5)	10,000	0.47	0.70	0.88	1.04	1.37	1.63
	100,000	0.63	0.87	1.10	1.28	1.66	1.97
	1,000,000	0.81	1.08	1.33	1.55	1.97	2.33
100 MPa 15,000 psi (10)	10,000	0.39*	0.48*	0.67	0.84	1.17	1.44
	100,000	0.40	0.67	0.89	1.07	1.45	1.75
	1,000,000	0.60	0.88	1.13	1.35	1.75	2.10
150 MPa 22,500 psi (15)	10,000	0.39*	0.48*	0.55*	0.67	1.03	1.29
	100,000	0.39*	0.51	0.73	0.93	1.30	1.60
	1,000,000	0.42	0.74	0.98	1.20	1.59	1.93

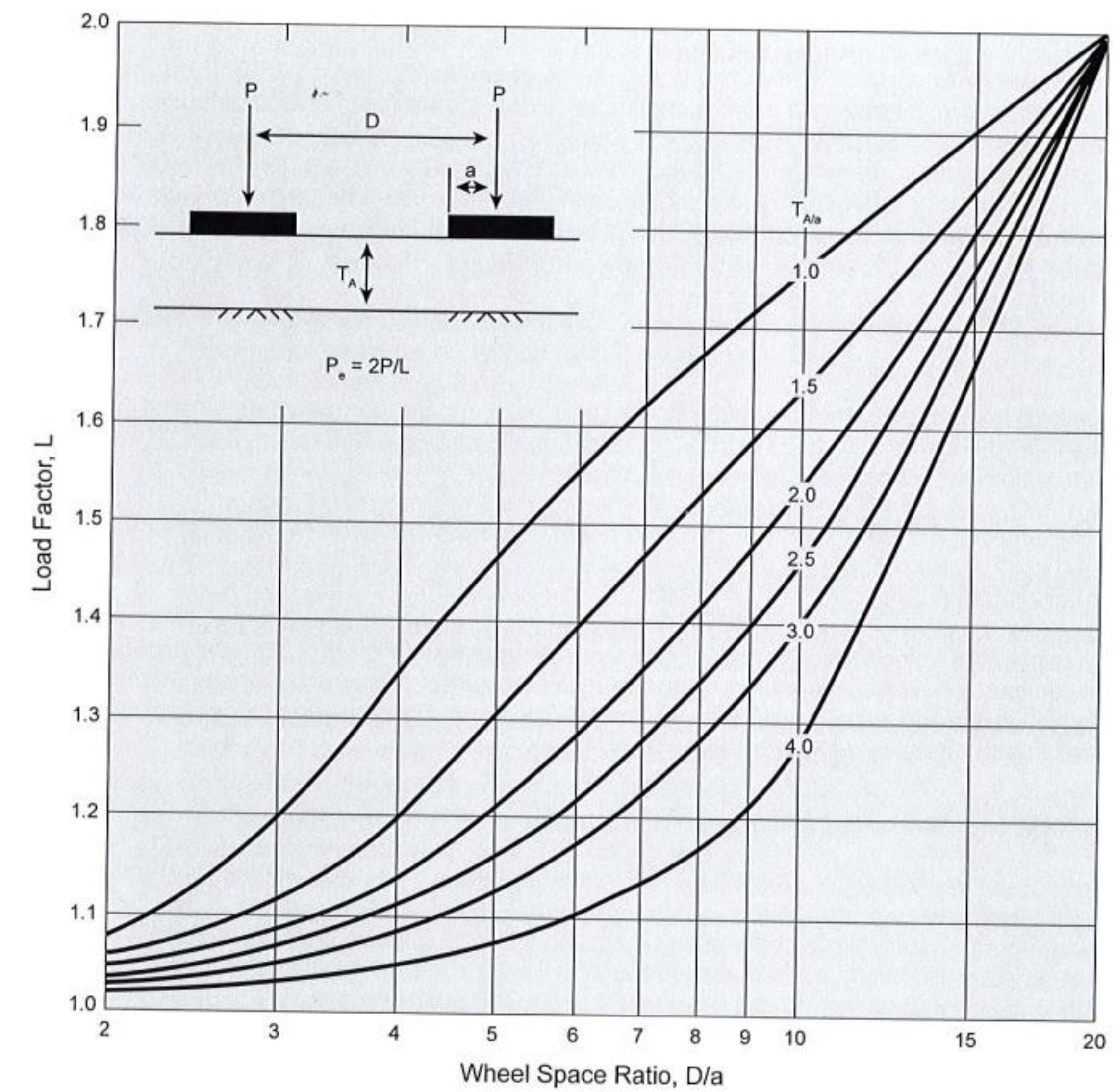
*Minimum $T_{A/a}$

Paving Thickness Calculation using Asphalt Institute Guidance

Port of Wilmington Masterplan

The next step is to draw the ‘Equivalent Single Wheel Load Design Curve’. To do this, first D, the center-to-center spacing between dual tires, is identifies. Using *a* derived from the deign wheel load (35.6 kN) and design tire pressure (750 kPa), a wheel space ration (D/*a*) is found. A range of $T_{A/a}$ (typically between 1.0 and 4.0) is selected to determine a range of load factors, L, from the graph on the right. For each value of L, and equivalent wheel load, P_e, is found by $P_e = 2P/L$, and also for each corresponding value of $T_{A/a}$ T_A is calculated. Then P_e is plotted against T_A to draw the ‘Equivalent Single Wheel Load Design Curve’.

From this procedure, it is found that the design full-depth thickness of asphalt required according to the Asphalt Institute guidance is 450 mm, or 18 inches.



E. Gate Sensitivity Investigation

Sensitivity of Gates to Failure

Port of Wilmington Masterplan

In reality due to variety of factors there will be breakdowns of the elements within the gate complex, either due to damage or failure of components. The knock on effect on the whole gate system needs to be investigated to ensure some suitable redundancy in the system and to understand the critical elements

Sensitivity was performed on the following components:

- Failure of IN lane (OCR/IN TWICs Gate/ Weigh in Motion)
- Failure of IN Gate
- Failure of RPM
- Failure of Out Gate
- Failure of TWICS out Lane

Sensitivity of Gates to Failure

Port of Wilmington Masterplan

All of the models were run using the following characteristics and remained constant throughout all models:

Model Input	Value
OCR	3
TWICs Gates IN	3
IN Gates	7
RPM Gates	3
OUT Gates	6
TWICs Gate Out	2

Model Input	Value
TEU Throughput/year	1,152,000
% Intermodal	8%
Average Throughput / day (containers)	2532
Number Trucks IN Gates / day	1824
Chassis Changes	241
Number Trucks OUT Gates / day	911

Nb. These values are averages taken from the ARENA models

Sensitivity – TWICs IN

Port of Wilmington Masterplan

- 7 IN – 6 OUT
- 8% Intermodal

This is representative if one of the entrance lanes are put out of action by either the OCR, TWICs gate or weigh in motion sensor. The max capacity is to prevent trucks queuing onto the road.

With 3 TWICs IN Gates

1,152,000 TEU	Average	Max	Limit
TWICs In	0.067	6	6
In Gate (Number)	1.70	26	45
RPM	0.032	5	6
Out Gate (Number)	0.26	8	25
TWICs Out	0.079	7	6
In gate (time)	1.3min	18 min	-
Out gate (time	0.41 min	7.2 min	-
TWICs IN Time	0.078 min	1.8 mins	-

With 2 TWICs IN Gates

1,152,000 TEU	Average	Max
TWICs In	0.20	10
In Gate (Number)	1.67	26
RPM	0.032	5
Out Gate (Number)	0.26	8
TWICs Out	0.079	7
In gate (time)	1.3min	24 min
Out gate (time	0.41 min	7.2min
TWICs IN Time	0.15min	3.1 min

Sensitivity – IN Gate

Port of Wilmington Masterplan

It is likely that one of the in gate lanes may be out of service. The max capacity is to prevent trucks interfering with the TWICs in gate procedure.

With 7 IN Gates

1,152,000 TEU	Average	Max	Limit
TWICs In	0.067	6	10
In Gate (Number)	1.70	26	45
RPM	0.032	5	6
Out Gate (Number)	0.26	8	25
TWICs Out	0.079	7	6
In gate (time)	1.3min	18 min	-
Out gate (time	0.41 min	7.2 min	-

With 6 IN Gates

1,152,000 TEU	Average	Max
TWICs In	0.067	6
In Gate (Number)	2.87	54
RPM	0.032	5
Out Gate (Number)	0.26	8
TWICs Out	0.079	7
In gate (time)	2.4 min	42 mins
Out gate (time	0.42 min	7.2 min

Sensitivity RPM Scanners

Port of Wilmington Masterplan

The maximum capacity of the RPM is to ensure that the queueing for the scanners does not affect the operation of the terminal. Reducing to 2 RPM scanners does not have a sufficient impact on the output, however it was decided that 3 should be used to combat the risk of only have one RPM due to a failure.

With 2 RPMs on EXIT

1,152,000 TEU	Average	Max
TWICs In	0.067	6
In Gate	1.70	26
RPM	0.056	5
Out Gate	0.25	10
TWICs Out	0.078	6

With 3 RPMs on EXIT

1,152,000 TEU	Average	Max	Limit
TWICs In	0.067	6	10
In Gate	1.70	26	45
RPM	0.032	5	6
Out Gate	0.26	8	25
TWICs Out	0.079	7	6

Sensitivity – OUT Gate

- 7 IN – 6 OUT
- 8% Intermodal

Port of Wilmington Masterplan

It is likely that one of the in gate lanes may be out of service. The max capacity is to prevent trucks interfering with the TWICs in gate procedure.

With 6 Out Gates

1,152,000 TEU	Average	Max	Limit
TWICs In	0.067	6	10
In Gate (Number)	1.70	26	45
RPM	0.032	5	6
Out Gate (Number)	0.26	8	25
TWICs Out	0.079	7	6
In gate (time)	1.3min	18 min	-
Out gate (time)	0.41 min	7.2 min	-

With 5 OUT Gates

1,152,000 TEU	Average	Max
TWICs In	0.067	6
In Gate (Number)	1.70	26
RPM	0.032	5
Out Gate (Number)	0.35	12
TWICs Out	0.038	7
In gate (time)	1.3min	18 min
Out gate (time)	0.56 min	9.6 min

Sensitivity – TWICs OUT

Port of Wilmington Masterplan

- 7 IN – 6 OUT
- 8% Intermodal

This is representative if one of the exit lanes are put out of action. The max capacity is to prevent trucks queuing disrupting the out gates.

With 2 TWICs Out Gates

1,152,000 TEU	Average	Max	Limit
TWICs In	0.067	6	6
In Gate (Number)	1.70	26	45
RPM	0.032	5	6
Out Gate (Number)	0.26	8	25
TWICs Out	**0.079**	**7**	**6**
In gate (time)	1.3min	18 min	-
Out gate (time	0.41 min	7.2 min	-
TWICs Out Time	**0.06 min**	**1.26 min**	**-**

With 1 TWICs OUT Gates

1,152,000 TEU	Average	Max
TWICs In	0.067	6
In Gate (Number)	1.70	26
RPM	0.032	5
Out Gate (Number)	0.26	9
TWICs Out	**0.37**	**16**
In gate (time)	1.3min	18 min
Out gate (time	0.41 min	7.2 min
TWICs IN Time	**0.30 min**	**3.84 min**

Sensitivity of Gates to Failure

Port of Wilmington Masterplan

- From all of the above results it can be seen that there may be some impact due to the failure or some of the gate aspects.

- Reduction of the numbers of IN gates & the TWICs out gates cause the maximum queuing to exceed the maximum allowable. This will have a knock on effect on the rest of the process. However the average values are still sufficient and the gates would operate sufficiently for the majority of the time.

- Reduction in the numbers of the OUT gates, RPM & TWICs IN do not exceed the maximum capacity but the queuing and the waiting times increase.

- Therefore it is considered that there is sufficient redundancy in the system to allow sufficient operation of the terminal if there are temporary failures of parts of the system.

F. Port Planning Order Requirements

Military Port Planning Order

Port of Wilmington Masterplan

The NCSPA's status as a Strategic Support requires the Port of Wilmington to always be ready to meet military requirements while continuing commercial operations. The Port Planning Order (PPO), set out as part of the Strategic Support role, requires space to be made available for military operation on execution of the order. The total staging area required is 30 acres, 6,900 feet of rail spurs need to be available and 2,200 feet of berth is needed for military ships.

During the pavement upgrades of the container terminal, Zone 15, Cargo Shelter 1, Warehouse T7, Area A and Area C can be made available to satisfy the conditions of the PPO without causing a large decrease in the terminal's capacity, giving a total of 30.9 acres. This is subject to the possibility of vacating the covered storage areas of Cargo Shelter 1 and Warehouse T7.

Once the works in the container terminal are completed, much of the terminal area will need to be made available for staging areas to meet the PPO, causing a large decrease in the terminal capacity. Zone 15, Cargo Shelter 1, Area B-South, Area C and Area K-west can provide a total of 29.4 acres for staging, but giving up Area B-South and Area K-west present a diminished capacity for the terminal. Again, the availability of Cargo Shelter 1 is subject to the possibility of vacating the covered storage area.

Providing Berth 5, Berth 6, and Berth 8 for military ships will give 2,475 feet , satisfying the PPO.

Figure D1: Possible areas made available for staging during construction

Figure D2: Possible areas made available for staging on completion