SUCCESSFUL DELIVERY
OF CONTAINER TERMINAL INFRASTRUCTURE

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Infrastructure is highly important to any container terminal development. Good infrastructure is essential to efficient operations, and represents a major development cost. This is particularly relevant to automated or semi-automated terminal yards that have typically a higher cost per TEU capacity in comparison to conventional terminal yards and most of this capital expenditure has to be spent upfront in the necessary infrastructure and equipment. This article provides some experience-based recommendations for the successful development of the container terminal infrastructure.

INTRODUCTION

On April 26, 1956, the converted oil tanker Ideal X was loaded with 58 containers and sailed from Port Newark, New Jersey, to Port of Houston, Texas (Levinson, 2006). In the almost sixty years that passed, the total containers handled globally have increased to about 650 million TEU (see Figure 1). A noticeable rise in container growth rate can be observed after 2001 where global throughput has grown from 239 million TEU in 2001 to almost 520 million TEU by the end of 2008, fuelled by the accession of China to the WTO in 2001 and the continuing strong global demand for many products manufactured in Asia. In this globalised supply chain from the manufacturer in Asia to the consumer in Europe or America, the marine container terminal is a key link, where the cargo transfer mode changes from waterborne to land-based.

Arguably the main reasons for the establishment and dominance of the containerisation as a form of cargo transfer are:

- Standard dimensions of load unit, handled by similar equipment at every port. Thanks to the work of the International Organization for Standardization (ISO) in 1961, standard sizes for all containers allow them to be very efficiently lifted, stacked and loaded on ships, trains, trucks and Ship to Shore (STS) cranes and other cargo handling equipment (CHE) in ports can be designed to a single specification (World Shipping Council).
- Capability for intermodal transport (ship to truck/rail): The container can be loaded and unloaded from a vessel to a truck or a train seamlessly, and in the same way.
- Drastic reduction in handling costs as percent of the overall transport cost: Levinson (2006) mentions that the cost of loading the Ideal X was 15.8 cents per ton compared to $5.83 per ton for loading a loose cargo ship in 1956.

This massive reduction in the port handling cost precipitated by the increase in vessel sizes that further reduced the unit transfer cost, allowed goods from low labour cost countries to be competitively priced in the large consumer markets of America and Europe.

Interestingly, apart from the containers themselves and the handling equipment, very little is common among the world's container terminals and their hosting ports.

Particular differences can be noted in the business model, operations and handling methods, customs and security practices and regulations, health and safety practices, environmental regulations and various power requirements, design norms etc.

With respect to Operations & Handling methods, there are manually, semi and fully automated container terminals, depending on the degree of automation in the handling and storage processes. All these parameters affect the terminal operations and hence reflected in the terminal layouts and operating practices.

The objective of this article is to give an overview of the various issues encountered during the planning, design and development of a container terminal and provide some experience-based insight for navigating the various potential challenges.

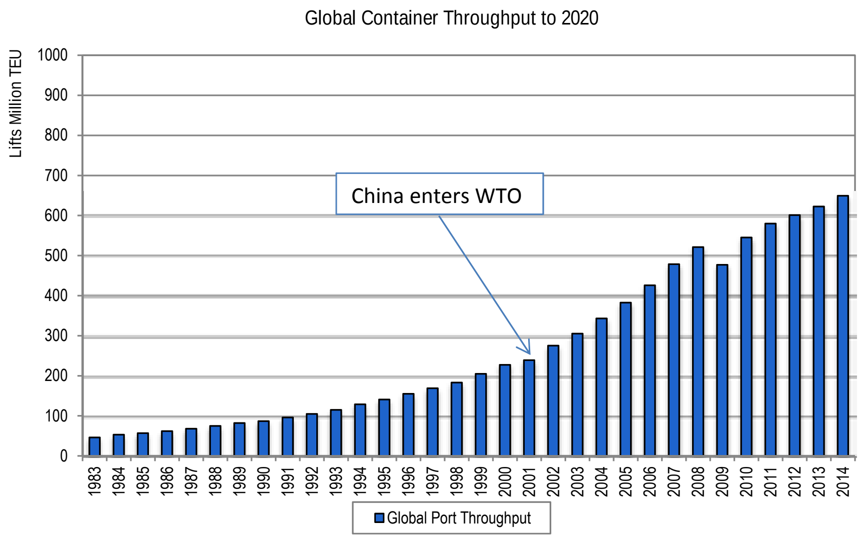


Figure 1. World Container Throughput. Source: Ocean Shipping Consultants from Clarksons.

WHY IS INFRASTRUCTURE IMPORTANT?

Infrastructure is highly important to any container terminal storage yard. Good infrastructure is essential to efficient operations, and is a major cost in the terminal development. This is particularly relevant to automated or semi-automated terminal yards that have typically a higher cost per TEU capacity in comparison to conventional terminal yards and most of this capital expenditure has to be spent upfront in the necessary infrastructure and equipment.

DIFFERENCES BETWEEN AUTOMATED AND MANNED TERMINAL PLANNING AND DESIGN

As shown in Figure 2, when using either manned or automated equipment, there is a contrast in the planning process. This is because the automated terminal is more like an industrial plant where the equipment, infrastructure and software are seamlessly integrated.

The conventional terminal yard is a paved area with minimal above ground infrastructure and maximum operational flexibility. The yard often consists of a uniform heavy-duty pavement and minimal above-ground infrastructure (light towers and fire hydrants when necessary). The planning process therefore allocates the necessary space for utility corridors (power, communications, and drainage) and pavement types for each type of use. Finally, the equipment and necessary buildings are determined by the operator and fit around the existing infrastructure. Because the non-automated equipment moves on rubber tyres, there is more flexibility to change the layout without major infrastructure changes. The process can initially be driven by the Landlord (a role played by the Port Authority), who will sometimes build up to the pavement base and then handed over the area to the tenant (Terminal Operator) to consider the operations and procure and commission the equipment.

A typical automated yard uses automated stacking equipment on fixed crane rails, with the result that the infrastructure is fixed for its economic life. It is therefore critical to predict performance and operating cost criteria for the life of the infrastructure. Automated terminals therefore require a different design approach in comparison to the conventional. The planning procedure for an automated yard is then effectively the reverse of that of a conventional yard. As operations and logistics are so important for an automated yard to function, these are planned first. Following this, pavement and underground utilities are then planned later to adapt to the operational concept. For an automated yard, the whole design process should be directed by a core team from start to finish (go live date) to ensure continuity of the decision process and rationale.

Planning either type of terminal correctly is fundamental in achieving the intended functionality and performance. But human-operated terminals are more adaptable to changes, provided no major utility relocation is required and the pavement has been designed for a variety of equipment loads. Correcting problems following construction, or changing the layout in an automated terminal is very costly and causes delays in the starting day after which revenue can be earned (time to market). Because of the complexity of the operations and interaction between infrastructure and operations it may be better for the developer to opt for a fully detailed design for automated terminals. Leaving it to the contractor to figure it out may leave the operator with a terminal that is different than originally envisioned. Having said that, there are succesful cases of automated terminals that were procured with the Design & Build method.

WHY DOES THE TERMINAL INFRASTRUCTURE HAVE TO BE PRECISE BUT ALLOW FLEXIBILITY?

In a conventional terminal once the infrastructure is in place, it is very expensive to move again. Any lack of precision can cause conflict in the vertical and horizontal clearances. Once in place, buildings and other permanent structures limit further expansion of the terminal. The construction of the pavement is also important as it has to allow for changes in operating modes.

In an automated terminal, precision is fundamental due to the use of robots/machines replacing what is normally done by humans and they cannot see, hear or react to change. Robots must be pre-programmed for every conceivable event and situation. If the event is not recognised, the robot stops and waits for instructions. The Terminal Operating System (TOS) must be developed to anticipate these pre-programmed scenarios/instructions. It must be flexible and expandable to be able to adapt. Hence, all infrastructure must be planned and designed to facilitate smooth function of robotic equipment throughout the life of the project.

THE IDEAL PLANNING AND DESIGN PROCESS

The first stage of the ideal process would be the composition and selection of the core team that will be at the centre of the design process with a broad range of skills and experience. This ideal core team would have a multi-disciplinary composition with representatives in the following areas:

- Operations
- Equipment
- Infrastructure
- Finance
- TOS and IT Systems

Members of the operator/tenant and the landlord/port authority decide together on what order each aspect should be considered and its importance. The ideal production plan would eventually result in a composition that has integrated the key demands of the project as well as demonstrating a clear consideration to all aspects of design. As the planning and design proceed, experts in infrastructure, equipment, IT and construction can give input so that by the time the tender documents are issued most of the decisions have been finalised.

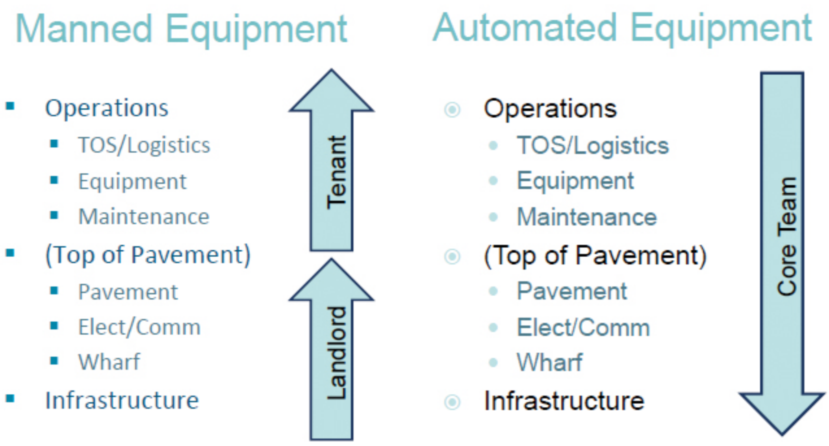


Figure 2. Design Process in manned vs. automated terminals

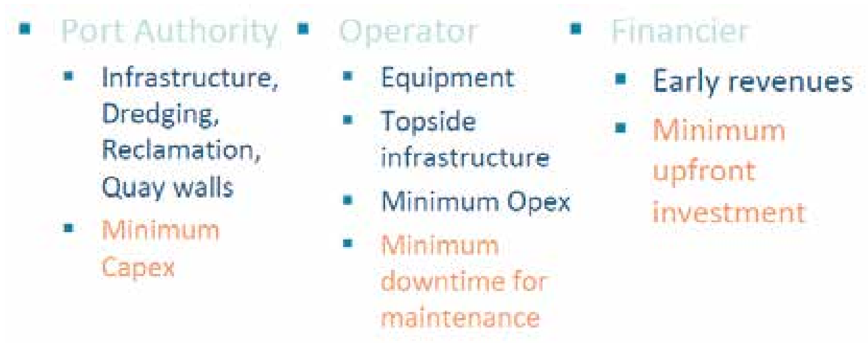


Figure 3. Interests of key stakeholders

CHALLENGES IN IMPLEMENTATION

Despite the intentions, and due to all sorts of constraints and circumstances, among which is the lack of experienced staff, it is difficult to follow the ideal process described above. This section describes some typical challenges that are usually encountered and that the design team has to address.

During the design process, the interests and risks of the key stakeholders can clash and cause conflict, often delaying the project. As Figure 3 shows, the interests and risk mitigation actions that key players have during the design process are not necessary aligned and this is a result of the fundamentally different economic viewpoint that each organisation has. In such cases the Planner and the Engineer, depending on their fiduciary duty, have to strike a balance as well as prioritise what is best for the project overall. Some examples of conflicting interests in actual design are as follows:

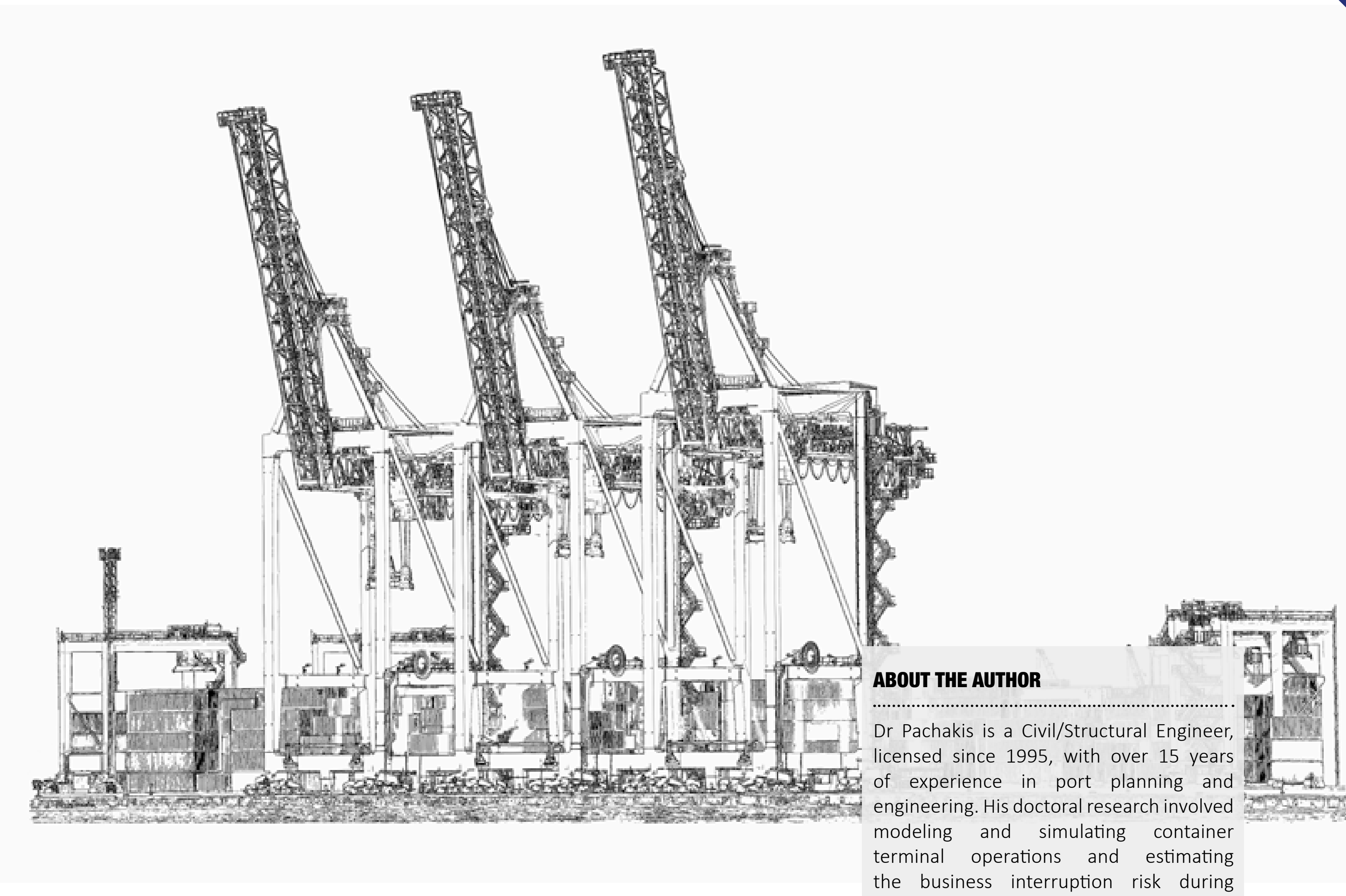
- Pavement: Concrete pavement has the highest initial capital cost but results in lower annual maintenance. Asphalt on the other hand has lower installation costs but results in higher annual maintenance. In the case that the Port Authority pays for the pavement and the Operator pays for the maintenance it is easy to see the conflict.
- Automated Stacking Crane Rail Foundations: Similar to pavement the lowest cost solution (sleepers (UK)/ ties (US) on ballast) results in high maintenance which also requires closing part of the stacks. The most expensive solution (Pile-supported beams) requires almost no maintenance, but is very expensive and takes a long time to implement due to the pile driving.
- Planning for maintenance downtime: To minimise the effects of maintenance downtime, the planner would have to allow extra stacks in the layout so that the operations are not affected by maintenance. This option would nonetheless result in developing a larger yard than required.

One possible challenge that could be faced is the prospect of an operator not even being selected during the design phase. In some cases the operator can change halfway through the design phase. The design has to be flexible enough to accommodate late changes similar to these examples and anticipate/facilitate different modes of operation and equipment. Providing extra headroom and flexibility results in extra costs but it is usually cheaper than re-building sections of the terminal due to changes in requirements.

Projects can incur conflict between different contracts at the interface. Although there are preferred theoretical processes and procedures to adapt the design to changes, often there are constraints due to budget, permits and schedule which prevent this. Each design responds very particularly to constraints and local conditions. Therefore it is not recommended to 'copy what was done last time' as it may not work and we may not know the reason the design developed in a certain way. Usually construction phasing has to adapt to market conditions and there are cases where the infrastructure that was planned is obsolete when it actually needs to be in place. An example is when the berth and apron is developed with a design vessel that is already too small when the development finally goes ahead.

Sometimes decisions that make sense in the short term have unpredictable long term effects. For example, particularly in greenfield projects a costly campaign of site investigations may be required (nearshore geotechnical investigation, met ocean study, geophysical and bathymetric survey etc.). As the cost is significant, there is a temptation on the part of the developer to assign them as part of the contractor's work to avoid the early expenditures. However, the results may render the initial planning and site orientation infeasible and a significant re-design may be necessary with the resulting variation orders. The costs then during the construction phase can change significantly and if no permanent solution can be found, high maintenance costs occur.

While it is important to have top soil good bearing capacity, which is easy to achieve with compaction, the long term consolidation of the deeper layers may cause differential settlements and



affect the yard operations. Accelerating consolidation is however costly. An Operator may take a decision to forego complete consolidation in order to achieve earlier 'time to market', at the cost of additional maintenance. However this maintenance cost and downtime can be higher than predicted because of the soil behaviour.

CONCLUSIONS

A container terminal is a subsystem within a port system. As the revenue yield per unit of land is higher than other cargoes, it plays a significant part in the business structure of a port and is highly important that it is planned and executed correctly.

Clearly by considering the examples and challenges of different infrastructure scenarios, successful design and delivery requires flexibility and adaptation to the local conditions. The Planner and the Designer must be an integrator of their whole team's skills and ideas while satisfying the client's requirements. Although this is important, throughout the design process the operability, maintainability and reliability of the infrastructure must also be kept in mind. In certain circumstances change may be required at any stage of the project. Therefore it is important to allow some headroom for future changes and to provide flexibility in the engineered solutions.

Although planning is fundamental to a successful delivery, the ability for all players such as the Port Authority and the Operator to cooperate with each other can be a significant contributing factor to the overall success. Within the planning, design and implementation team, continuity and clarity of purpose must run throughout the project duration. The incentives of the Designer, the Project Management Consultant and the Contractor must also align to ensure simple interfaces between work packages. This enables a smooth transition throughout the programme and eventually contributes to a successful delivery of the infrastructure in time for the installation and commission of the equipment and the software.

Therefore planning well, providing margin for flexibility, continuity throughout the team and good communication can lead to successful (on time and on budget) development of the container terminal infrastructure.

ABOUT THE AUTHOR

Dr Pachakis is a Civil/Structural Engineer, licensed since 1995, with over 15 years of experience in port planning and engineering. His doctoral research involved modeling and simulating container terminal operations and estimating the business interruption risk during earthquakes. After graduating with a PhD from Stanford in 2004, he has 12 years of working experience on a wide range of container and intermodal terminal projects involving feasibility studies, technical due diligence, master planning, and design. His project experience includes medium and large container terminals in the US East and West Coast, Mexico, Brazil, Canada, UK, the Mediterranean, Middle East and New Zealand.

ABOUT THE ORGANISATION

Royal Haskoning DHV (RHDHV) is an independent, international engineering and project management consultancy with 135 years of experience. RHDHV is a world leader in marine and port facilities, ranked in the top 5 ENR International Design Firms for Marine and Port Facilities in the last 5 years. Our expert knowledge of marine structures and conditions, combined with our multidisciplinary approach and smart ways of thinking, are pushing forward boundaries in the sector.

ENQUIRIES

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