This paper examines best practices and recommended approaches to structuring the design process of container terminals. When moving towards increased levels of terminal automation, terminal design is an especially complex process that requires extensive planning and careful risk management. Early decisions made during the design phase have huge implications later on, so a structured evaluation of various scenarios is essential for project success.

Industry studies have highlighted that many shipping lines are dissatisfied with the service they receive at terminals, and that they would be willing to invest more in return for improvements in, for example, the availability of equipment as well as the reliability, efficiency and consistency of the service they receive.

**INDUSTRY TRENDS**

As global logistics chains become faster, more transparent and more intensely competitive, the key challenge for terminal operators becomes one of doing things better by leveraging new technology. At the same time, operators need to reconcile the need for heavy terminal investments that will shape their operations for many decades to come with shorter-term uncertainty on market dynamics, global traffic patterns and their business environment.

To design a successful container or general cargo terminal is thus a highly challenging task that must decrease the cost of operation, improve service quality and effectiveness, and keep the terminal competitive for a wide range of potential future scenarios. The decision on the operational concept of the terminal depends on many factors including the expected size of vessels, traffic forecasts, available plot size, labour market conditions, cost structure and environmental impacts. Furthermore, the terminal needs to consider how to differentiate from its competition to maintain and grow its market share.

**TERMINAL DESIGN**

Typically, when designing a terminal – and especially when considering automation – operators have challenges in thinking through the full implementation plan for the design. When moving towards the implementation phase, it is easy to take shortcuts and make assumptions such as assuming the productivity figures of an ASC block based on data from another location, without taking into account local conditions and the terminal’s own specific traffic profile.
Likewise, terminals often struggle with the level of integration required for terminal automation. The quay, container stack and gate may all be optimised separately instead of as a unified system. A system is only as strong as its weakest link, and especially for the deep technical interdependencies involved in an automated terminal, the only practical way to gain a realistic view of the total system is to perform careful testing with simulations that utilise authentic scenarios and data.

Ultimately, operators face two main challenges when seeking to design successful terminals. Firstly, the required decisions are extremely complex and involve multiple interlinked variables, so they can only be handled with a structured approach and purpose-built tools. Secondly, each business case is extremely dependent on the individual conditions of the terminal. Generalised guidelines (e.g. how many cranes are needed for a container block of a given size) are of limited value, and designers must do the evaluation based on the specific situation and business goals of their own terminal.

At the core of a successful terminal design project is a structured design approach that leverages technology and data for the best results. The tools and processes for making more informed design decisions already exist, and a small investment in the design stage can be orders of magnitude more economical than having to make changes later on in the process.

**BUILDING BUSINESS CASES**

Whether designing a new (greenfield) terminal or upgrading an existing (brownfield) site, design and operating decisions need to be linked to sound project appraisal by framing the problem in a holistic manner. For this purpose, business cases are developed to consider the options from a 360-degree perspective on value creation. In this way, the choices and trade-offs in the operational design can be linked directly to customer value, financial value and strategic value and social value, as articulated below:

- **Customer value** encompasses the satisfaction of the users of the terminal, including vessel operators and cargo owners. The impact of changes in performance at the customer end, such as equipment availability, speed (turnaround time) and particularly the reliability of service should be valued. Accordingly, customer value is linked to financial value through potential gains (or losses) in market share, as well as through positive or negative impact on pricing levels.

- **Strategic value** reflects the terminal’s agility towards changes in the market and the broader operating environment. The business case thus evaluates options to expand, reduce or exit operations over time. Designs that increase flexibility or save on scarce resources such as land, offer important benefits to terminals. The conditions of concession agreements will amplify the relevance of such strategic value drivers over the long-term operating horizon.

- **Financial value** is primarily derived from the investment and operating cash flows. Alternative design options are typically compared against their financial performance measured by the Internal Rate of Return, the Pay Back period or Net Present Value. Business cases must help in understanding how financial value can be improved through savings in operational expenditures and better planning of capital layouts.

- **Social value** is the cost and benefits for third parties such as employees, inhabitants, economic system, the government and the surrounding scarce natural resources. Design options impact value measured in terms of gains in safety, security, emissions, know how, taxes and economic efficiency. In particular it should not be forgotten that ports and terminals contribute to the social economic health of a region.

**THE DESIGN PROCESS**

The key tool for managing the terminal design process is an integrated ‘Flexible Decision Tool’. This is software that utilises a wide range of available information to facilitate informed, optimised decision making and to create a set of realistic business cases on the basis of real-world data.

Inputs of the Flexible Decision Tool can include, among others:

- Timing aspects: concession duration and construction period
- Financing assumptions: inflation, taxes, debt funding
- Terminal parameters: area, volume characteristics, TEU ground slots, stacking height
- Activity statistics: horizontal transport, yard moves, gate, inspection, housekeeping
- Equipment parameters: maximum running hours per unit, moves per hour, spare parts cost, maintenance per hour, useful economic lifetime, emissions per hour
- Investment costs: infrastructure, equipment, IT
- Other operational costs: labour, energy and fuel, insurance
- Revenues per container type

The outputs for each scenario include, among others:

- Total Cost of Ownership, Internal Rate of Return, Net Present Value
- Cash flow statement
- Balance sheet
- Environmental impact

**KEY DESIGN PHASES**

**PHASE 1: INVESTIGATE**

The goal of the Investigate phase is to map out various options for design alternatives in order to meet the business objectives of the terminal. This phase examines the
relative strengths of different layout options, terminal concepts and transportation systems (automated stacking cranes vs. rubber-tyred gantry cranes, straddle carriers vs. automated guided vehicles etc). Pathways to automation can already be evaluated at this stage.

This project phase also examines the terminal design process from the wider context of the terminal’s investment goals and financing structure. In simplification, the various options can be divided into Low CAPEX / "short-horizon" and High CAPEX / "long-horizon" terminal concepts. A solution with lower capital expenses will offer a shorter timeframe in recouping the investment and will provide easier options for adjusting equipment fleet sizes due to changes in capacity demand or other factors.

PHASE 2: QUALIFY

The Qualify project phase researches and numerically assesses alternative solutions in extensive detail. The full range of layout options is evaluated, and a comprehensive business case analysis (CAPEX, OPEX, ROI, et cetera) is prepared for several potentially viable scenarios. At this phase, the high-level delivery and project plan begins to take shape, supported by terminal capacity calculations and fleet size estimations. Sensitivity analysis is an essential step that explores the effects of changes in various parameters such as operating volumes, dwell times, TEU ratios or a wide range of other metrics. The end goal is to begin to shape a solution that will be robust towards changes while continuing to provide the business results required by the terminal.

PHASE 3: DEMONSTRATE

Finally, the Demonstrate phase includes careful validation that the selected design option meets its objectives. Terminal simulations are used to demonstrate the design and to verify its operation in different scenarios. An essential point to remember is that simulations are dynamic models that make it possible to validate scenarios that cannot be addressed with static spreadsheet-based models. 3D modelling of the preferred terminal design is a useful tool for visualising potential issues, and simulations can utilise real-world terminal data for maximum accuracy. Even at this stage, iterative process steps are taken back and forth before finalising the selected design.

ABOUT THE AUTHORS

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Timo has worked at Cargotec close to 18 years, first in automation R&D, where his key project was the development of the AutoStrad solution. During the past eight years, he has held various positions in terminal automation business from product management to the head of the cranes business line.

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Dries van den Broeck
Dries has vast experience in drafting and elaborating financial models, with a special interest in decision tools. These tools enable decision makers to take informed courses of action by clearly displaying the impact over time of certain decisions. The core of this is in structuring the large amount of available data and visualizing the results so that this information is converted into useful information on which to make informed decisions.

ABOUT THE ORGANIZATION

Kalmar, part of Cargotec, offers the widest range of cargo handling solutions and services to ports, terminals, distribution centres and to heavy industry. Kalmar is the industry forerunner in terminal automation and in energy efficient container handling, with one in four container movements around the globe being handled by a Kalmar solution. Through its extensive product portfolio, global service network and ability to enable a seamless integration of different terminal processes, Kalmar improves the efficiency of every move.

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CONCLUSION

Designing a container terminal – whether an existing site or new installation – is an exciting task that calls for complex decision making based on limited information and changing external conditions. However, the process can be managed in a structured way to maximise the ability to utilise technology and data to keep design options flexible as long as possible. The key elements of a well-planned and successfully executed terminal design process can be summarised as follows:

• Don’t save on the design phase
• Get really involved – take responsibility for your future
• Use the technology and data available to the fullest
• Plan for the widest range of futures you can imagine
• Trust the partners that have done it before
• Focus on the whole lifecycle of the system, not just on the go-live date

"Short-horizon" terminal concepts typically offer flexibility in both terminal layout and investment terms; however, maximum capacity and throughput may be limited compared to solutions with a larger fixed infrastructure. Typical "long-horizon" terminal concepts include ASC terminals with various types of automated horizontal transportation. These systems typically offer the maximum potential for autonomous/automated solutions, high throughput and maximum stacking density, but may be less flexible in some aspects.

Additionally, the Investigate phase needs to address the implementation plan when upgrading or redesigning existing terminal operations. For operational (brownfield) projects, this is a highly relevant question that may, in some situations, even rule out the optimal operating modes, simply because there is no way to implement them in the middle of a live operation due to the operational disruption caused by implementation activities.