

FROM RULE-BASED TO INTENT-DRIVEN: A NEW PARADIGM FOR TERMINAL OPERATIONS



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THE CONSTANT BALANCING ACT IN CONTAINER TERMINALS

Container terminals handle over 800 million TEUs annually, yet inefficiencies in key operational areas result in billions of dollars in lost productivity. At the core of these challenges lies the struggle to balance three critical objectives: container throughput (which drives revenue), equipment utilisation (which impacts profitability), and turnaround time (which influences asset turnover).

These factors are inherently in conflict: increasing throughput demands higher equipment utilisation, potentially reducing profitability. Conversely, maintaining stable equipment utilisation while increasing throughput often leads to longer vessel and truck turnaround times, lowering overall asset efficiency.

The unpredictability of supply chain dynamics further compounds this challenge. Demand fluctuations, unexpected equipment breakdowns, and external disruptions such as adverse weather or accidents significantly impact operations. Despite extensive planning, terminals cannot respond in real time to these dynamic changes, leading to inefficiencies that ripple across the entire operation.

THE LIMITATIONS OF RULE-BASED TERMINAL OPERATIONS

Modern container terminals rely heavily on rule-based operational logic embedded in Terminal Operating Systems (TOS). These predefined rules govern how yard

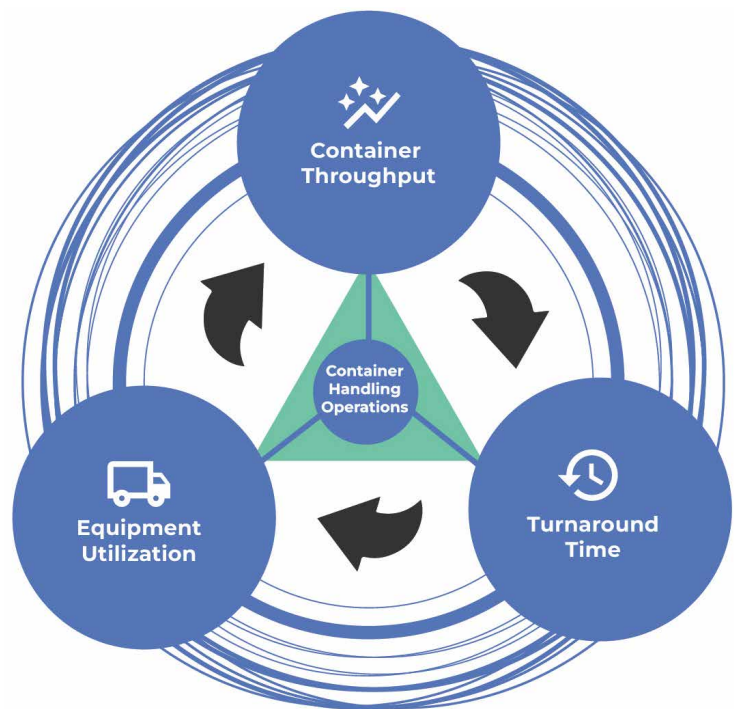


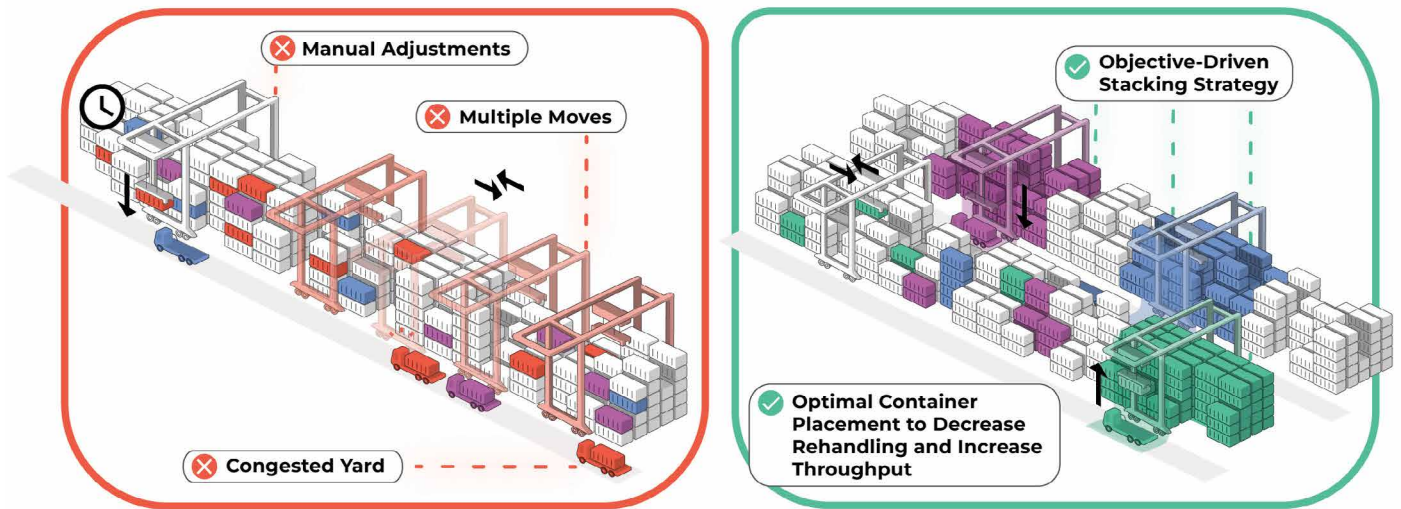
FIG 1.
At the core of inefficiency is the struggle to balance three critical objectives

cranes, vessels, and trucks operate under normal conditions. However, when exceptions occur—such as vessel delays, out-of-sequence discharges, or equipment failures—human intervention is required. Planners must manually adjust operations or fine-tune system parameters to address these disruptions.

Despite their best efforts, terminals experience efficiency losses of 10-20 per cent on average. The root cause? Frequent exceptions, which rule-based systems are not designed to handle dynamically. Since continuously reconfiguring parameters is impractical, human planners implement on-the-spot

adjustments to mitigate immediate challenges. However, these short-term fixes often cause cascading inefficiencies downstream.

For example, if a vessel's arrival is delayed but the Estimated Departure Time (EDT) must be maintained, operators might discharge containers into blocks closest to the berth. While this shortens discharge time, it ultimately creates long-term bottlenecks. Densely packed containers increase rehandling requirements, and if many share a similar dwell time, congestion at the delivery stage can delay truck departures. These inefficiencies accumulate, reducing overall yard productivity and affecting service levels for carriers and shippers.



NEXT-GENERATION TERMINAL OPERATIONS

To solve these challenges, the next generation of container terminal operations will not rely on predefined rules or require constant human intervention. Instead, intent or objective-driven systems will dynamically generate optimal operational logic, aligning real-time decision-making with business objectives.

Unlike traditional rule-based workflows, these advanced systems operate based on business intent—the desired operational outcome. For instance, if the primary goal is to reduce vessel turnaround time, the system autonomously determines the best stacking strategy to minimise rehandling and prevent downstream congestion during discharge and load operations.

Rather than following rigid rules, an objective-driven system continuously recalculates the best course of action based on real-time data. It interprets business intent, understands key objectives such as maximising throughput, reducing congestion, or optimising equipment utilisation, and leverages AI-driven models to predict container flow. By analysing dwell times, vessel arrival schedules, and gate movements,

the system anticipates operational demands and adapts accordingly.

Once the predicted flow is established, the system dynamically assigns optimal storage locations for incoming containers while ensuring efficient use of yard cranes and transport equipment. Unlike traditional systems, which rely on static parameters, an intent-oriented approach reacts instantly to unexpected disruptions or demand shifts. Performing hundreds of calculations per second, it continuously refines its strategies, enabling terminals to operate proactively rather than reactively.

The future of terminal optimisation is already taking shape with the Objective Oriented Operating System (3-OS), developed by Avlino, to drive autonomous, AI-powered industrialisation in alignment with the broader goals of Industry 4.0. By shifting from rule-based automation to intent-driven, autonomous decision-making, 3-OS is paving the way for fully optimised container terminals. This transformation is not just about efficiency gains—it represents a fundamental shift in how terminal operators engage with technology, moving from reactive management to proactive, self-optimising operations.

FIG 2.

Before and after scenario with proactive adjustments from objective-driven systems

THE BROADER IMPACT OF OBJECTIVE-DRIVEN SYSTEMS

3-OS is set to redefine container terminal operations and reshape the client-software vendor relationship across the supply chain industry. While most supply chain enterprises aim to optimise throughput, utilisation, and velocity, they rely on rigid ERP and workflow automation software. 3-OS represents a fundamental shift from workflow automation to AI-driven execution, making terminal operations more efficient, adaptive, and resilient.

Unlike traditional systems, which require manual intervention and parameter adjustments, 3-OS eliminates these dependencies by making and executing decisions autonomously. Instead of automating predefined processes, it continuously analyses changing conditions and makes real-time, intent-aligned decisions.

This shift extends to the engagement model, redefining how terminals interact with technology providers. Traditional ERP and workflow solutions operate under a client-vendor structure with perpetual software licenses or SaaS models that lack performance guarantees. In contrast, 3-OS functions as an operational partner, delivered as a SaaS solution with guaranteed business KPIs,

ensuring measurable outcomes for terminal operators.

Another key distinction is decision execution. While traditional software facilitates workflows that still require manual involvement, 3-OS autonomously implements decisions, eliminating inefficiencies and delays. Additionally, whereas conventional systems require offline rule adjustments by software vendors and domain experts, 3-OS continuously evolves and self-optimises, leveraging AI-driven models and operations research techniques to reconfigure operational parameters autonomously.

The impact of 3-OS extends far beyond local workflow automation. Unlike conventional systems, which operate at the point of work, 3-OS takes a global approach, considering the downstream implications of every decision. This ensures holistic optimisation, reducing inefficiencies across all terminal operations.

By applying this systemic approach, 3-OS is already reshaping the supply chain through the successful implementation of the AICON Solutions suite in container terminals. Harnessing objective-driven intelligence, it

transforms yard planning, vessel operations, and equipment dispatching into dynamic, self-optimising processes.

FROM THEORY TO PRACTICE

Designed as a TOS overlay, AICON Solutions enables terminals to optimise operations autonomously, balancing volume, velocity, and utilisation to maximise profitability. Encompassing specialised modules, AICON addresses various aspects of terminal operations, including berth and vessel management, yard planning, equipment dispatching, and gate operations.

With AICON, terminal operators define business KPIs, and the system dynamically generates the operational logic necessary to achieve the chosen objectives, automatically adapting to evolving constraints and disruptions. This objective-oriented approach minimises inefficiencies, improving productivity without requiring constant manual intervention.

Real-world implementations demonstrate the significant operational and financial improvements enabled by AICON.

At a semi-automated terminal on the US East Coast, which

handles approximately 2.5 million containers annually, the implementation of AICON Solutions has consistently reduced unproductive moves by 45 per cent. This improvement has led to faster equipment cycle times and lower rehandling costs. By dynamically optimising container placement, the system has improved truck turnaround times, alleviated congestion, and enhanced overall service reliability.

Similarly, at a semi-automated terminal in South Korea with an annual throughput of 6 million TEUs, AICON's intent-driven optimisation has decreased unproductive moves by 40 per cent while reducing equipment utilisation by 15 per cent. Through intelligent workload distribution and the minimisation of unnecessary crane movements, the terminal has extended the lifespan of critical assets, lowered energy consumption, and reduced maintenance costs. Beyond operational efficiency, this shift supports sustainability initiatives by aligning with global decarbonisation efforts.

Even in a manual terminal in Senegal, where automation is limited, intent-driven optimisation has delivered significant gains.



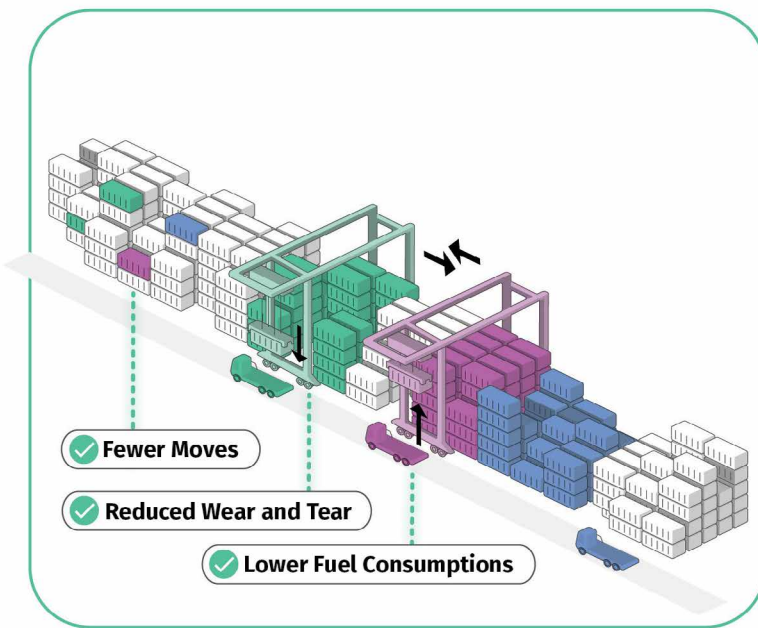


FIG 3. Beyond enhancing operational efficiency, objective-driven systems also contribute to decarbonisation efforts

Handling 1 million TEUs annually, the implementation of AICON Solutions has increased quay crane productivity by 45 per cent while reducing unproductive moves by 35 per cent. By dynamically adjusting crane assignments in response to real-time conditions, the terminal has improved vessel turnaround speed and optimised berth utilisation, creating a more predictable and efficient operation.

These examples underscore the transformative promise of objective-driven operations. By shifting from reactive, rule-based planning to proactive, intent-oriented optimisation, terminals are improving service levels for shipping lines and cargo owners while enhancing operational efficiency.

A NEW ERA FOR CONTAINER TERMINALS

The advent of Industry 4.0 marks a fundamental shift in industrial workflows, where decision-making and execution will no longer be constrained by predefined rules and manual intervention. Instead, objective-oriented management systems will continuously analyse, optimise, and execute operational logic in real time, ensuring that business goals drive every decision.

Dynamic, machine-optimised operational logic will surpass human planning, adapting to real-world challenges that conventional systems cannot anticipate. More importantly, objective-driven systems invert the traditional relationship between business outcomes and execution. Instead of workflows dictating business performance, these systems align every operational action with predefined performance objectives, ensuring optimised throughput, turnaround times, and resource allocation.

This transformation extends beyond container terminals, influencing supply chain operations, manufacturing, logistics, and other industrial sectors. As objective-oriented management becomes the new standard for autonomous decision-making, businesses will achieve unprecedented efficiency, resilience, and agility.

As the industry evolves, objective-oriented operations will no longer be an advantage—they will be a necessity. The ability to self-optimize, self-correct, and self-execute decisions will define the competitive edge for next-generation container terminals, ensuring adaptability in an increasingly complex global supply chain.

ABOUT THE AUTHOR:

Ramana Jampala is the Co-Founder and CEO of Avlino, where he contributes with his distinctive insight into technology trends and market influence. A reputed entrepreneur and Technology Executive, his expertise spans investments, business strategy, and design engineering. His career highlights include leading digital projects for Fortune 500 companies and early-stage investments as a General Partner of SAS Investors.

ABOUT THE COMPANY:

Avlino is a US-based Artificial Intelligence company specialising in delivering solutions to enhance the efficiency of container terminal operations. The company aims to transform the supply chain by providing terminal operators with solutions to overcome common pain points and challenges that undercut their business objectives.

With this mission, the company developed AICON, a Solution Suite designed to dynamically solve the challenges of demand fluctuations and operational volatility. Combining AI/ML and Operations Research, AICON delivers actionable insights, real-time work instructions and autonomous workflows in a cutting-edge approach that significantly reduces manual inefficient processes, increases throughput, optimises resource allocation, and improves customer service.