OPTIMIZING QUAYSIDE TRUCK ALLOCATION: EXPERT SYSTEM FOR AUTOMATING DISCHARGING OPERATIONS PLANNING

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ABSTRACT - This research investigates optimizing discharging truck allocation at container terminals, crucial hubs in global maritime logistics, by using a fuzzy logic approach to enhance container movements from ship to shore. Traditionally managed manually by ground handling staff, the truck allocation process is automated in this model to address the complexities of quayside operations. This study proposes a model that adapts to operational variables, reducing bottlenecks and increasing terminal throughput. By employing fuzzy logic for its adaptability and interpretability, the research provides a computational methodology suitable for complex quayside operations, involving fuzzification, inference, and defuzzification to transform raw data into actionable insights. Data were collected from two container terminals at a leading South Asian port, ranked among the top 30 global ports. The study used the Fuzzy Logic Toolbox in MATLAB and Python to effectively integrate a rule-based structure. The findings highlight the critical role of discharging truck allocation in enhancing terminal efficiency and operational integration, with the model demonstrating compatibility with the Terminal Operating System (TOS). Future research should focus on more dynamic and integrated operational planning systems to further improve efficiency in container terminal operations.

Keywords: Quayside planning, discharging operations, Internal trucks, Optimizing truck allocation, Fuzzy logic

1. INTRODUCTION

This study focuses on optimizing truck allocation at quaysides in container terminals, which are crucial nodes in the seaborne container trade and significantly influence global supply chain efficiency. Effective terminal management is vital for overall supply chain performance, with terminal operations categorized into quayside and landside activities [1]. This research focuses on quayside truck operations, specifically the critical process of truck allocation for discharging containers, which directly impacts terminal throughput and operational fluidity [2].

Quayside truck operations are pivotal as they link quayside activities with yard management, integrating vessel operations and gate processing [3]. Efficient truck allocation for discharging tasks is essential to prevent bottlenecks and ensure smooth container transitions from ship to shore [4]. This study examines the complexities of discharging truck allocation, a critical yet often undervalued aspect that significantly impacts terminal efficiency and throughput. Using a fuzzy logic approach, the study aims to understand the variables influencing truck allocation for discharging operations and proposes a model that adapts to operational demands, reducing bottlenecks and enhancing terminal productivity. Container terminals handle container loading and unloading, affecting vessel turnaround times and shipping efficiency [5]. Manual truck allocation practices often lead to delays and increased operational costs [6]. This research highlights potential efficiency gains by integrating truck allocation into strategic terminal planning, analyzing internal truck movements and the interaction between truck availability and berth productivity.

2. MATERIALS AND METHODS

Fuzzy Logic, introduced by Professor Lotfi Zadeh in 1965, revolutionized control systems by handling ambiguous and incomplete information. There are three main phases in the fuzzy logic process, 1. Fuzzification 2. Fuzzy Inference 3. Defuzzification [7].

Fuzzification defines input and output data and their membership functions. We use nine input variables: discharging availability (B1, B2, B3), berth productivity (P1, P2, P3), and truck availability (T1, T2, T3) at three berths. The output variables are discharging truck allocations (AL1, AL2, AL3) for the next 15 minutes. Membership functions categorize discharging availability as Available (A) or Unavailable (U) and berth productivity into Low (L), Medium (M), and High (H). Truck availability is similarly classified. For output data, truck allocation is categorized as Low (L), Medium (M), High (H), and Null (O). In the fuzzy inference stage, we establish 18 rules considering one berth for efficient truck allocation using terminal data and expert insights. Three input variables and one output variable guide the rules, prioritizing berth productivity. Out of nine rules for 'Available' discharging, eight prioritize productivity. However, one rule diverges: if discharging is 'Available', productivity is 'Medium', and truck availability is 'High', the allocation remains 'Low'. For 'Unavailable' discharging availability, truck allocation is 'Null.' Expanding to three berths results in 5,832 rules, meticulously analyzed using MATLAB for informed decision-making. Defuzzification, the final step, consolidates scenarios into a single output. Our MATLAB model uses the Centroid method on 5,832 scenarios to translate fuzzy logic into quantifiable values, illustrated in Figure 1 for truck allocation in container terminals.

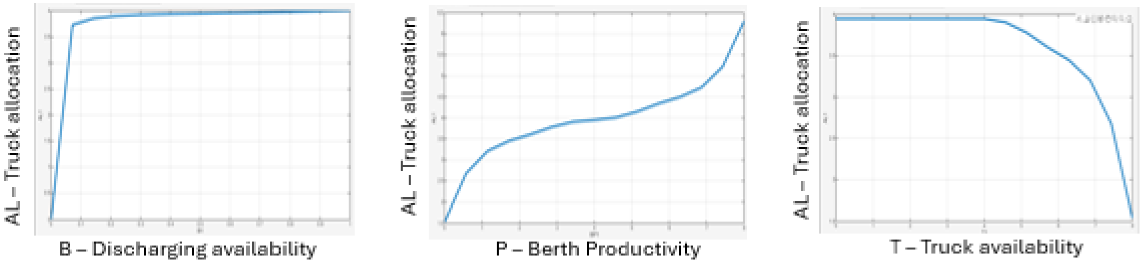

Figure 3. Defuzzification graphs

3. RESULTS AND DISCUSSION

We recommend focusing on discharging truck allocation within quayside operations. Our research uses a fuzzy logic model with three key input variables to optimize allocation decisions, forecast truck needs based on real-time data and refine resource assignment, presented through 3D graphical analysis. Figure 2 shows our model's dynamic response to berth discharging availability, truck availability, and berth productivity for truck allocation at a container terminal. Truck allocation increases with berth discharging availability until saturation and initially rises with truck availability but decreases to prevent congestion. The model demonstrates adjustments based on these variables, offering actionable insights for optimizing quayside operations. It supports our objectives by presenting a clear strategy for truck lane allocation, ensuring smooth activities, and enhancing efficiency without disturbing the Terminal Operating System (TOS).

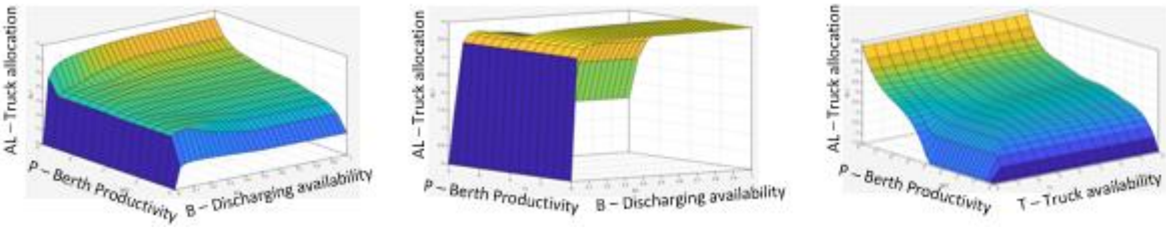

Figure 4. Truck allocation strategy at quayside

4. CONCLUSION

Our research focuses on the critical yet underexplored element of discharging truck allocation at quaysides. We identified that this aspect had not been explicitly defined as a planning function within terminal management. Using Fuzzy Logic, we developed a model tailored to quayside operations, integrating three pivotal input variables to determine optimal truck allocation. Our findings indicate that recognizing discharging truck allocation as a distinct planning function can significantly enhance quayside operational efficiency. Future research could explore crane-wise allocation for greater efficiencies and include additional variables such as crane productivity. Additionally, while Fuzzy Logic proved effective, alternative AI models could further automate the process with real-time data for more dynamic operations.

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