A COMPREHENSIVE STUDY ON NEW CONCEPTUAL CONTAINER HANDLING SYSTEM

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ABSTRACT

With global transshipment trade increasing, new design solutions are required to keep the desired performance of the terminal. In this scope, this study introduces a new terminal solution, the Single GRID module (SGM). In order to scale the SGM we propose and compare two solutions: the Hybrid GRID (H-GRID) and the Extended GRID (E-GRID). Both implementations and the SGM use extensively simulation as a means to evaluate system performance.

With H-GRID, we develop an integrated and modular concept. In this case, despite the routing is simplified to that of the SGM, the storage allocation problem becomes challenging. We propose an innovative index-based policy for allocation that is easily scalable to large systems and proves to be better than traditional rules. E-GRID scales up the SGM design by proposing a routing strategy to control the container flow within the yard and avoiding conflicts between Transfer Units (TU) travelling in opposite directions.

1 INTRODUCTION

With the world economy and global container trade growing, the market of container transshipment business keeps increasing and its importance is highly valued. In the meanwhile, three major challenges are now influencing the effectiveness and profitability of transshipment terminals. Firstly, the conventional designs have reached the bottleneck which forces the terminals to trade-off between storage capacity and productivity. Secondly, many leading transshipment cities, e.g. Singapore and Hong Kong, have to deal with land scarcity. Thirdly, both the labor cost and the difficulty of getting skilled labors are increasing.

Targeting the above challenges, many new conceptual systems are proposed (Kim et al. 2012; Lee et al. 2014). As a potential design, BEC Industries LLC proposes a fully automated yard-side container handling system named single GRID module (SGM). Different from other designs in which ground vehicles and yard cranes need to cooperate, SGM only uses overhead transfer unit (TU) to handle containers. Hence, the system has more flexibility and higher productivity. Besides, with less paths and more compact storage, land utilization rate is 2-3 times higher than the typical layouts.

This study uses simulation and optimization to understand the system capability and applications. Eventually the system is expected to serve a transshipment port which handles millions of TEU annually.

2 THE GRID SYSTEM

2.1 Single GRID Module

As a new design, there is no real system in use so the priority is to understand the throughput characteristics and potential bottlenecks of the GRID design. We developed a discrete-event simulation model to estimate the maximum productivity assuming random storage allocation and a dynamic rule for routing TUs. Specifically, the rule requires TU to travel the shortest path first and then detect and resolve conflicts in real-time. We tested three cases: (1) small layout only serving two quay cranes (QCs), (2) a vertical expansions extending case (1) in terms of yard capacity, (3) and the horizontal expansions which extending case (1) in

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terms of number of QCs. The results shows that the productivity is very promising in the small layout and is robust in vertical expansions. As for horizontal expansions, the productivity falls dramatically due to the large number of conflicts caused by opposite movements of TUs. In fact, in the case of large TUs, even the dynamic routing rule can lead to a detrimental increase in the number of conflicts. In light of these issues, we propose two ways to scale up SGM: the Hybrid-GRID (H-GRID) and the Extended-GRID (E-GRID).

2.2 H-GRID and Information-based Allocation Strategy

Instead of deploying a super-large SGM, H-GRID divides the whole yard into multiple SGMs and uses ground transporters for fast delivery between modules and quay-side. In each module, the vertical expansion layout is applied so the H-GRID can guarantee both high storage capacity and high productivity.

In H-GRID, since SGM works independently, the planning level decision of where to store the containers becomes a key for guaranteeing operation efficiency and resource usage. We formulate and solve the problem of inventory allocation by math programming. Specifically, in order to model the effect of the allocation onto the system performance, we used simulation to estimate the relationship between container workload and TU usage in order to supply it as input to the math program in the form of approximated linear constraints.

However, when the system is large, we are not able to solve the mathematical model and therefore an information-based allocation strategy, which is an index-based policy, is proposed to approximate the optimal allocation. We compared the proposed policy with more traditional strategies such as cube-per-order index and duration-of-stay, and the new strategy outperforms the previous solutions.

2.3 E-GRID and New Traffic Rule

E-GRID scales up the SGM design by providing a new traffic rule for the SGM. Motivated by the control mechanism of urban traffic, the main idea is to set the travel direction on the different paths in the GRID, thus avoiding head-on conflicts, increasing path efficiency and reducing the occupation in the transfer area. For other forms of conflicts (e.g., take over), TU will let the preceding TUs to pass so detouring is conflict-free. Simulation is proposed to evaluate the performance of E-GRID. The result shows that the throughput under the traffic rule is not as good as the dynamic rule when with fewer TUs. This is due to the fact that the TU will not always be assigned the shortest path. Nevertheless, when the number of TUs increases, E-GRID allows TU traveling on its original course without collision enabling the management of many more TUs.

3 CONCULUSION AND FUTURE REMARK

This study has shown that GRID is a promising design for the growing demands in transshipment terminals and in the meantime, however it is a real solution only if traffic control and yard planning are carefully considered. H-GRID and E-GRID represent two viable solutions to implement the GRID concept in large scale.

Currently all the systems are designed considering a statistic job schedule. Hence, we are currently investigating the effect of jobs schedule with time window, as well as TU dispatching and operation level. We are also investigating the possibility to embed the path direction optimization into the simulation model, to test online policies for routing.

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