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OPTIMIZING WAREHOUSE PICKING OPERATIONS USING AUTONOMOUS MOBILE ROBOTS: A SIMULATION APPROACH

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ABSTRACT

Order picking is a labor-intensive operation and contributes significantly to overall operational costs in a warehouse. While prior literature suggests collaborative technologies, including autonomous mobile robots (AMRs), can increase picking efficiency, few studies have attempted to find an optimal ratio between AMR and physical pickers using a free-floating policy. This research develops a simulation model to evaluate the performance of order picking with varying numbers of AMRs and pickers, considering both traditional and cross-aisled warehouse layouts. An experiment comparing runs of 48 total scenarios was conducted in a simulated environment. The results suggest that operational efficiency peaks at around a 2:1 AMR to picker ratio. Furthermore, the addition of a cross-aisle increased up to 6% picking efficiency (2% on average).

1 INTRODUCTION

The proposed simulated order-picking system is loosely based on a real-world food-service distribution center where humans and AMRs collaborate in a mixed environment. This simulation was designed in consultation with an AMR engineer with experience executing several dozen warehouse implementations. In this warehouse, an entire day's worth of orders for all the DC's customers are received at a single time, in the morning, and order-picking continues until all orders are exhausted (and brought to the loading docks to be distributed). This model assumes a free-floating policy. The AMRs are not assigned to a specific picker but rather meet the order picker at a picking position, wait for the picker to load the item, then autonomously drive to the offload point (Boysen et al. 2019). To start, both the order picker and the closest available AMR are dispatched to a random unpicked item. After both resources arrive, they pick the item (simulated by a 30-second delay). The picker is then directed to the next randomly selected order. The AMR carrying the picked order is released and autonomously drives the cargo randomly to one of three loading docks (simulating three separate order aggregating points). Once the AMR downloads its cargo (simulated by a 30-second delay), it is dispatched to meet the next order. If either human or AMR arrives at the random item before its complementary resource, it will wait until the other resource arrives before jointly completing the picking process.

The simulation shows how and when warehouse designs meet business requirements. Warehouse simulation is one way to depict the experimentation phase used to plan a warehouse, increase flexibility, and increase a company's productivity. From the standpoint of a professional practitioner, simulation is more intuitive than an empirical approach because racking, forklifts, pit walls, robots, staff, and shift structure can all be easily analyzed using commercial software such as AnyLogic. Additionally, the research examining AMR usage is sparse. It is a relatively new technology; however, Boysen et al. 2019) suggest several potential gaps that provide a useful starting point for our investigation. The experiment will scrutinize three variables that can be manipulated. Results examined for comparison: the number of AMRs, the number of pickers, and whether a cross-aisle was added to the warehouse layout. By conducting and comparing several experiments, we were able to examine the following two questions:

1. What is the optimal ratio for the picker and AMR fleet? The sizing of these two variables is critical since bottlenecks and idle time are to be avoided to maximize operational efficiency and minimize costs (Boysen et al. 2019).
2. What is the optimal layout? The addition of a cross-aisle (or multiple cross-aisles) may reduce travel time and increase efficiency (Roy et al. 2015).

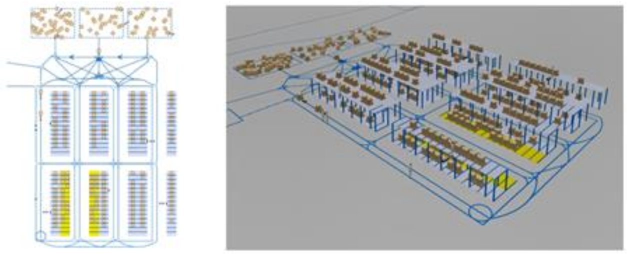

Figure 1: Any Logic representation of the Distribution center (with cross-aisle).

We conducted 48 separate experiments varying the number of pickers from 3 to 5 and the number of AMRs from 3 to 12. These values were chosen as we assume at least three pickers would be present during the picking operation. The utilization values of AMR to picker ratio below 1:1 are exceedingly high for AMRs (near 100%) and low the pickers (below 50%). Likewise, after reaching a 2:1 ratio, picker utilization becomes exceedingly high (greater than 95%) while AMR utilization begins to drop. It can be assumed that an AMR to picker ratio that provides a high utilization for both resources will result in the greatest picking efficiency. Additionally, we examined our simulation with both a traditional warehouse layout and with a single cross-aisle.

2 CONCLUSION

Our simulation results indicate that the optimal ratio of AMRs to human pickers is 2:1 in the traditional layout and just a bit higher than 2:1 in the cross-aisle layout. These results indicate how a firm can minimize costs by indentifying needed resources of each type to maximize resource utilization. Dynamic variables such as labor and AMR, fixed and operating costs must be considered to minimize costs. If human labor costs twice as much as an AMR, it may make sense from a cost perspective to maximize picker utilization via the inclusion of additional AMRs. Another interesting finding is that simply adding more resources indiscriminately (both AMR and human pickers) does not necessarily increase performance proportionately to the investment. The diminishing return lends even greater importance to the simulation model in determining an "optimal" ratio and the best number of total resources to achieve the desired output.

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