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DATA-DRIVEN WAREHOUSE PLANNING AND CONTROL UNDER STOCHASTIC DEMAND AND LABOR SUPPLY IN SEMI-CONDUCTOR CAPITAL EQUIPMENT MANUFACTURING

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ABSTRACT

Access to more information and sophisticated analytics enables warehouse management to make better data-driven decisions. In our study, we develop a simulation-regression metamodel to help warehouse managers plan workforce, space, and equipment requirements for a leading semiconductor capital equipment company. More specifically, we use historical inbound and outbound demand records and performance metrics (such as workers' hourly productivity and moving rates) to predict the space, workforce, and equipment required for different operation stages in the warehouse facility. We implement the simulation model in Python. Simulation experiments provide insights on resource planning under different demand scenarios and supply constraints.

1 INTRODUCTION

With the increasing global demand for manufacturing, storage, and order picking, warehouses become vital supply chain components because they store raw materials and finished goods. A manufacturing warehouse is usually part of the manufacturing site facilities used for storing raw materials, semi-finished products, and final products (Dotoli et al., 2015; Den Berg, 1999). In this study, we focus on workforce, space, and equipment planning as well as performance control of the warehouse for a leading North American semiconductor capital equipment company. The studied warehouse is a typical manufacturing warehouse located inside the manufacturing campus.

Having better data records and retention, warehouse stakeholders can make dynamic data-driven decisions. That enables researchers to focus on studying scenario simulation (Pawlewski & Kunc, 2019), machine learning methods(Wojcicki & Bianchi, 2020), and digital warehouse managerial platform frames (Accorsi et al., 2014; Ren et al., 2020). In addition, the ideas of digital twins and the Industrial 4.0 Revolution are increasingly popular in warehouse management (Diamantopoulos et al., 2022). With more advanced technologies, the studies of warehouse automation systems, such as material flow design, system layout, and operation strategies, have been booming in recent years (Kumar et al., 2021). The warehouse under study contains both manual and automated systems. We focus on the manual system because the automated system had just started working and little historical data was available to measure its performance. In addition, we believe that the studied framework can be extended to the automated system and other warehouses if the company obtains enough data records for the analysis. The primary purpose of this research is to answer the following questions:

1. What is the available data in the manufacturing warehouse system and what are the challenges when using it?
2. What is the performance of the current warehouse?
3. What are the bottlenecks and best resource configurations under different scenarios?

4. What other design points should change if the warehouse managers want to reach specific goals (e.g., decrease the cycle time or the amount of backlog)?

2 PROBLEM STATEMENT

This study aims to help the warehouse logistics team plan the allocation of resources and measure the warehouse operations control at a high level. Regarding warehouse planning, we use historical inbound and outbound demand records and performance features (such as workers' hourly productivity and moving rates) to predict the space, workforce, and equipment required for different operation stages in the warehouse facility. The studied warehouse's major stages are receiving, putaway, picking, and packaging & outbound. Buffer stages and sorting spaces might be required for specific tasks.

Regarding warehouse control, we want to know if the performance metrics (e.g., stage cycle time, amount of backlog, productivity rate, and resource utilization) are constrained, and how the other features should be changed. Unlike some studies focusing on designing operational policies to optimize the systems layout (Pawlewski & Kunc, 2019), material flow (Sung Cho et al., 2019), productivity, and cycle time (De Leeuw & Wiers, 2015), our study provides the stakeholders a high-level planning and data-driven insights. We use the current resource configuration, task demand, and productivity as the simulation model's original input parameters. Based on the simulation output, we show warehouse decision-makers what should be done to reach their operations goal under different scenarios.

However, maintaining good data quality is always challenging for real-life problems. Since the data monitoring system is newly introduced to the warehouse, errors such as negative cycle time, incorrect product storage location, incorrect product information will cause problems if analyzing the raw data directly. In addition, not everyone is an expert using advanced techniques to read and modify the data. In that case, the same data might be stored in different databases for the accommodation of different users. This might cause trouble if those databases are not synchronized on time. Despite these hurdles, most data are still informative if the raw data is well-examined, pre-processed, and cleaned.

RESULTS

The simulation output includes the throughput, capacity, amount of backlog, workforce size, worker utilization, cycle time and storage utilization for each stage of the warehouse. We design an experiment to understand the impact of the following features, demand rate, worker capacity, and worker learning rate, on the performance metrics, worker utilization, cycle time and backlog. Among the results, we find that if demand increases by 10%, the average cycle time will increase by 5% and the average amount of backlog almost doubles. To keep average cycle time and backlog at their nominal levels, the number of workers would need to be increased by 8%, on average.

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