BUILD-IT2023 Workshop
19-20 October, Rome, Italy

A SIMULATION APPROACH TO ENHANCE WAREHOUSE LOGISTICS PERFORMANCE IN THE CERAMIC TILE SECTOR

Marco Taccini, Giulia Dotti, *and* Manuel Iori
University of Modena and Reggio Emilia, Reggio Emilia, Italy
e-mail: {marco.taccini, giulia.dotti, manuel.iori}@unimore.it

Anand Subramanian
Universidade Federal da Paraíba, Mangabeira João Pessoa–PB, Brazil
email: anand@ci.ufpb.br

This study aims to improve warehouse logistics performance for an international ceramic tile company based in Italy by identifying an efficient storage policy for the buffer area between the production plant and the logistics department. Due to the lack of homogeneity in the ceramic tile production process and the need for uniform tile orders, the policy must categorize products accordingly. The current policy classifies tiles based on technical properties, while the newly devised policy considers their downstream destination. A simulation using Salabim, a Python-based open-source software, demonstrated that the proposed policy outperformed the current one on all indicators. A sensitivity analysis showed consistent superiority of the devised policy under different scenarios, regardless of production increase. As a result, the company decided to implement the proposed policy, estimating a reduction in costs for the buffer area emptying process. This research contributes to simulation-based decision-making in material management and showcases Salabim's effectiveness in modeling complex systems.

Keywords: *discrete event simulation, ceramic tile, warehouse management.*

1. Introduction

In the past decade, the global ceramic tile market has experienced significant growth with 18.3 billion square meters produced worldwide in 2021, generating revenues of €6.2 billion in Italy [1, 2]. However, the tile sector faces challenges due to Lack of Homogeneity in the Product (LHP) [3], which conflicts with customer demands for uniform tile orders. To address this issue, tile companies must incorporate a classification stage in their production process to organize products into homogeneous subgroups and facilitate uniform orders. As a consequence, the classification process must be carefully evaluated because it can affect material handling performance. There is a vast literature about the tile industry, with many studies regarding the production process and the sustainability perspective. A growing body of literature studied the application of decision support systems in the ceramic sector, such as for inventory control and production planning and scheduling. Although considerable research has been done on different aspects of the tile industry, much less is known about the application of simulation in the sector. To the best of our knowledge, only a few papers investigated process simulation tools as performance measurement, and none of these studies applied Discrete Event Simulation (DES) using non-commercial software. As a consequence, Salabim [4], an open-source simulation software developed in Python, was chosen as the simulation tool due to its advantageous features such as the activate/passivate/hold paradigm, animation, queues, tracing, and statistical distributions. However, despite its potential, there is limited literature available on Salabim, with only a few scheduling and healthcare applications found. The extended version of this abstract can be found in [5].

2. Problem description

The study focuses on the buffer area placed between the production plant and the logistic department, schematized as a matrix in Figure 1. Each cell can contain four pallets, vertically stacked. After they are produced, the

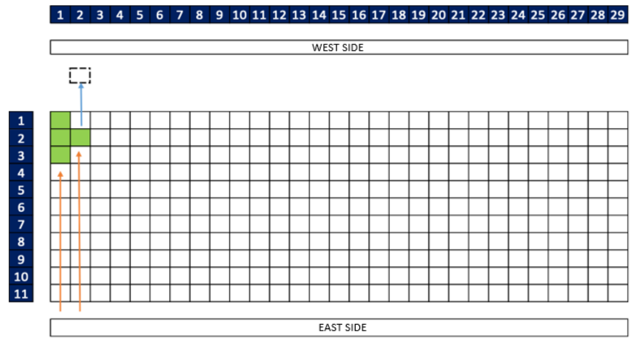

Figure 1: Storage area representation, taken from [5].

pallets are moved by automated vehicles to the buffer area. There, they are stored temporarily in the uppermost available cell until operators take them from the top and pack them into the logistics department. Each column in the area can contain a single class, and only when all columns are already allocated, the system allows for class mixing to avoid production downtime. However, mixing products of different classes leads to penalties because operators manually pick pallets from the buffer area, and their work efficiency is highly impacted by pallet positions. Consequently, the storage policy must carefully assign pallets to cells, dividing pallets into classes based on criteria to cluster them and facilitate picking activities. Each pallet of tiles is identified by a code that considers both commercial and technical characteristics. The current classification strategy clusters columns based on codes. The study focuses on the definition of a new policy that categorizes pallets according to their final downstream destination rather than their codes.

3. Methodology

The two classification policies were compared through a DES implemented with Salabim. The simulation model was verified and validated through statistical analysis to ensure real-world coherence. The simulation was run considering the data of 30 real-world production days and the values of performance indicators were collected for comparison through statistical tests. Since the logistics department works on a two-shift schedule during working days, while the production process never stops, two distinct sets of indicators were collected to evaluate both the described scenarios, without and with operators. In the first scenario the following performance indicators were selected:

- time (in minutes) elapsed before the first occurrence of the mixed columns;
- time (in minutes) elapsed before the area being filled;
- number of pallets lost due to lack of space.

The real-world system was designed to enable operators to handle the production flow without exceeding the available buffer storage area. Therefore, in the second scenario, the probability of the area being filled is not considered, and the focus moves to space utilization. As a consequence, the only indicator selected for this scenario is the maximum number of columns used at the same time. Due to positive market trends in the ceramic tile sector, it was crucial for the company to understand the new policy's impact on various increasing production scenarios. Therefore, seven different scenarios were simulated, incrementally increasing production quantity by 5%, from 0% to 30%. For each scenario, the simulation was run over 30 days.

4. Results

The results are presented in Figure 2. Focusing on shifts without operators, the mixed columns in the devised policy happen, on average, 37.6% minutes later compared to the current policy. This delay has a positive effect on worker activities as it significantly reduces the time needed for emptying operations. The second chart shows an average 5.2% delay in the time it takes to fill the area with the devised policy, resulting in increased capacity and decreased production downtime. Moreover, according to the third chart, with the proposed policy there was a significant decrease in the number of pallets lost on days when the current policy reaches its maximum storage capacity, consequently reducing the economic loss. Overall, the discussed results showed that the proposed classification policy enhances storage activity flexibility, enabling the company to reconsider required operators and shift distribution, leading to economic benefits. Taking shifts with operators into account, the fourth chart showcases a significant decrease in the maximum number of columns used at the same time, highlighting the potential to reduce the buffer area size by approximately 17.5% without affecting production capacity.

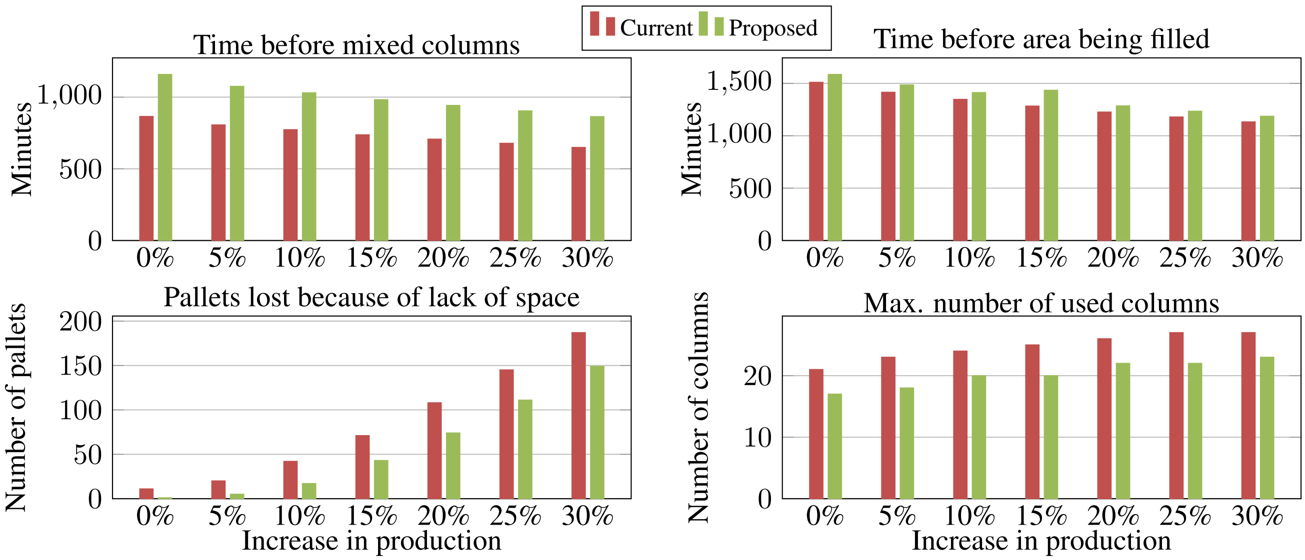

Figure 2: Simulation results, taken from [5].

5. Conclusions

The experimental results confirmed the benefits of the devised classification policy, both in terms of economic efficiency and flexibility. Further economic studies were conducted to estimate the potential cost savings associated with the buffer area emptying process and the analysis revealed that the proposed policy is expected to reduce the costs by 17%. As a consequence, the company decided to implement the new policy, providing strategic benefits to managerial decision-makers. Finally, the simulation model developed in this study is a valid representation of the process and can be utilized for further research regarding new classification policies for continuous improvement.

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