Investigation of operational parameters that affect the use of drones in goods' stock count process: Evidence from experimental results

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Abstract. Recently, the complexity of managing warehouses has increased significantly due to factors that include increased requests for more frequent and smaller order fulfilment, reduction of operational cost, and improvement of customer experience (De Koster et al., 2007). To this end, the enhancement of warehouse productivity coupled with the reduction of handling time are critical to maintaining a competitive edge (Marchet et al., 2015; Van Gils et al., 2018). The concept of Industry 4.0 fosters the evolution of typical warehouses towards smart distribution centers through the use of some of the latest emerging technologies to manage warehouses efficiently (Fernández-Caramés et al., 2019). One of such technology is Unmanned Aerial Vehicles (UAVs)/drones, which have evolved lately in terms of technology and increasingly seen as a potential widespread for numerous applications in the logistics industry (Fernández-Caramés et al., 2019; Moshref-Javadi and Winkenbach, 2021). UAVs are considered a key technology for smart warehouses, as they allow the execution of repetitive and demanding tasks with minimal human intervention or supervision (e.g., stock counting, good's receiving, etc.)(Wawrla et al., 2019). In the long term, drones represent an economical and safe, in terms of reducing staff injuries, solution for logistics tasks completion (Harik et al., 2016).

This article presents a series of experimental results that demonstrate the effect of certain operational parameters (e.g. UAV speed, number of rack level, tag location on products, etc.) during the execution of stock count process in warehouse and distribution centers via the use of drones. Initially, the article presents the findings from a literature review conducted on existing operational parameters that affect the use of drones during stock count process. The Systematic Literature Review (SLR) methodology was followed, and 25 articles were identified. The limited number of published articles related to the research area under study suggests that this field is still at an early stage, understudied, and promising for further research.

Subsequently, the user requirements mapping related to the adoption of drones in stock count process, took place. A two-stage approach were adopted to capture users' requirements. The first stage involved the use of a structured questionnaire (survey) that was filled in by 30 logistics managers whereas the second stage involved personal interviews with logistics company executives through a set of open questions in order to evaluate and confirm the research findings from the first stage. Then the testing of drones in stock count process took place via laboratory experiments, by following again a two-stage approach. Initially the first part of tests aimed at determining the parameters that need to be investigated. The second part included a series of tests that investigate how certain parameters affect the drone stock count process in terms of reading accuracy and total stock count time.

A full factorial design was used to design the experiments (Figure 1) (Antony, 2014; Montgomery, 2012). Two cases were investigated. The first one refers to an ambient warehouse with dry products. In addition, the second one refers to a chilled warehouse with liquid products. The factorial design included four factors in the first case study with two levels (2^4 full factorial design) and three factors in the second case study with two levels (2^3 full factorial design). The first factor (parameter) is the Number of levels. This factor refers to the number of levels on the racks in the warehouse that are scanned during the UAV's flight. The second factor is the UAV speed and refers to the speed at which the UAV is flying. The third factor is the RFID Tag location. This factor refers to the position where the RFID tag is placed, specifically on one of the four sides of the pallet. Finally, the fourth factor is the tag reading method. This factor refers to the reading method followed by the UAV during its flight within the aisle of warehouse.

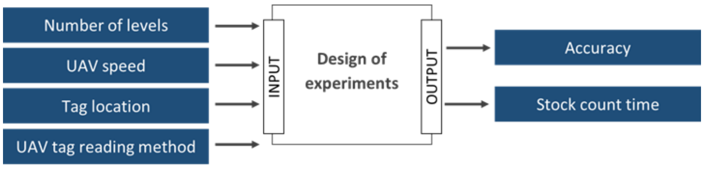

Figure 1: Model for accuracy and stock count prediction

Upon completion of the experiments, statistical analysis was conducted (Figure 2). The results showed that the performance of the system is significantly affected by certain parameters. Regarding the total stock count time, based on the ANOVA results in both case studies, the parameters "number of levels," "UAV speed," and "UAV tag reading method" were statistically significant. The results reveal the set-up of parameters that would provide the best result in stock count system performance. Specifically, in the first case the stock count process is completed faster when the UAV flies at a speed of 1.5m/s, the RFID tag is placed on the front side, the UAV scans 2 levels of the warehouse racks during its flight and uses the across racks reading method. Respectively, in the second case the stock count process is completed faster when the UAV flies at a speed of 1.5m/s, the UAV scans 2 levels of the warehouse racks during its flight and uses the across racks reading method.

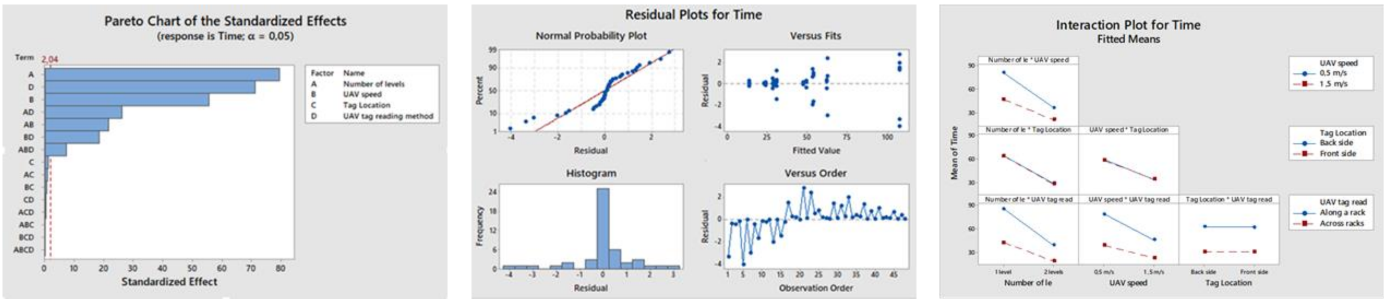

Figure 2: Diagrams of statistical analysis

Finally, some of the main implications in our research are that the combination of RFID reader technology with UAVs provide various advantages, including higher accuracy, faster processing, lower costs, and increased safety. Furthermore, the improved inventory management provide significant opportunities for organizations to enhance their operations and improve their performance.

Keywords: drones, logistics, industry 4.0, stock-count, warehouse, operational parameters

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