

# Warehouse picking or putting? A preliminary study to understand their applicability to fresh products

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**Abstract:** Among all warehouse operations, the preparation of customers' orders often represents a challenge. From one side, there is the need of fulfilling the requirements of the customers in short time windows; from the other side, there is the need of limiting operative costs. Moreover, when considering fresh products other aspects come into play, such as product quality and freshness, related to the time perspective, and the refrigerated storage, more linked to the cost dimension. In this paper, we propose the comparison of two alternatives for orders preparation, warehouse picking and warehouse putting, to understand when a configuration can be more appropriate than the other. First, we describe the two systems by highlighting strengths, weaknesses and differences. Then, we propose some mathematical formulations to measure time performance, occupied space and costs, also including energy consumption related to the storage of fresh products. The formulas are applied to real data, showing that the applicability of one system with respect to the other clearly depend on the number of orders per day and the number of stock keeping units.

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**Keywords:** warehouse picking, warehouse putting, cross-docking, fresh products, refrigerated warehouse.

## 1. INTRODUCTION

This paper originates from the experience we have in some companies that handle and distribute fresh products, especially in large organized distribution. Here, we often face the need of managing the activities of receiving, picking and distributing in very short time windows, sometimes also with space limitations. One of the biggest questions we are usually asked to answer in these picking systems is related to the choice between setting a traditional warehouse picking configuration and a putting/cross-docking one. For traditional warehouse picking we refer to manual, picker-to-parts systems with picking activities only in the lower level of the shelving area. For putting/cross-docking configuration, here we mean a system in which products are received in pallets from suppliers and then divided by store in dedicated putting areas (De Koster et al. 2007; Bartholdi & Hackman 2017).

The primary challenge lies in reducing operational costs to maintain competitive pricing, expand store network, explore new channels, and retain customer loyalty. Traditional warehouse picking configuration is commonly related to a distribution strategy where companies maintain inventory at their distribution centers (DCs). Upon arrival, products are initially received and stored; when a store places an order, products are then picked from the inventory and dispatched to the designated destinations. Costs are related to the four principal activities as receiving, storing, picking and shipping; storage and picking tend to be the most costly ones (Van Belle et al., 2012). Interestingly, cross-docking offers a solution to eliminate the two most expensive handling operations: storage and picking, with the total elimination of inventory at the DC. In fact, it involves receiving products from suppliers destined for multiple destinations (stores) and consolidating them with other suppliers' products for common delivery destinations

(Kinnear, 1997). This approach offers efficiency and cost savings by streamlining the distribution process (Vasiljevic et al. 2013; Kiani Mavi et al. 2020; Torbali & Alpan 2023).

Moreover, in the distribution of fresh products, the cross-docking configuration allows for an increase of the shelf life of the products, by removing the stocking phase (Rana et al., 2021). However, since the products need to be distributed to different stores immediately after the receiving phase, this implies the need for a dedicated area for each store to place orders. Consequently, as the number of served stores increases, a larger area is required. Additionally, the products arrive by supplier and since they are not stocked in the DC, an order cannot be closed until all the products required to fulfill it have arrived, leading to complexities in the management of the outbound shipments.

The purpose of this paper is then oriented in investigating which characteristics and aspects can impact more on the performances of both systems. Hence, this helps also in identifying which are their most proper application areas. In particular we focus on order fulfillment costs varying the number of served stores and the number of managed products. The remainder of the paper is structured as follows: Section 2 reports some relevant literature about the topic and defines the novelty of our study. Section 3 presents the formulas used to compare the systems while Section 4 presents some preliminary results and the discussion. Finally, Section 5 concludes the work with the main remarks derived from the comparison and future research perspectives.

## 2. LITERATURE OVERVIEW

### 2.1 Warehouse picking

Warehouse picking configuration consists in retrieving products from different storage locations to fulfill customers'

demand. This process covers approximately 55% of warehouse costs and is acknowledged as one of the most labor-intensive tasks within a warehouse (Tompkins et al. 2010; Battini et al., 2015). The efficiency of these systems is related to the reduction of the time required to fulfil customers' orders. This can be achieved through the study of different aspects, such as the warehouse layout, the storage allocation, the picker routes, and the order batching (Manzini et al. 2007). A common warehouse layout has a rectangular shape, with a certain number of aisles and cross aisles (Meller and Gau, 1996). Storage assignment rules define how products are assigned to storage locations; class-based storage is a typical assignment rule, where stock keeping units (SKUs) are categorized into classes based on turnover rates. Fast-moving classes are then assigned to zones near the input/output points (Le-Duc and de Koster, 2005). Routing policies determine the path that order pickers follow through the storage area, and order batching involves consolidating or splitting customer orders (Petersen and Aase, 2004).

### 2.2 Warehouse putting (cross-docking)

Warehouse putting configuration, related to a cross-docking approach, is a distribution strategy where the DC functions as a transfer point rather than a storage facility. Products arrive at the DC from suppliers and are directly put to other storage units (e.g. pallets or roll containers) to be delivered to the designated stores, without the storage phase (Benrqya et al. 2019). This configuration requires much more space, as each store will have one or more pallets or roll containers on the floor, which will be filled with the ordered products. There are no shelving and height storage. In addition, this configuration also requires that all the products have arrived before the order is ready, since there is no stock, further increasing the need for space. (Torballi and Alpan, 2023). The work of Li et al. (2008) analysed different products characteristics as life cycle length, shelf life and product value in order to define which was the most suitable distribution configuration between traditional warehousing and cross-docking. In a qualitative analysis they defined that cross-docking configuration is suitable for products with short shelf life, due to obsolescence, or high value, due to capital cost. The study of Benrqya et al. (2014) considered other influential factors as demand variability, shelf space and lead time to store, affirming that cross-docking strategy is suitable when demand variability and shelf space is low, and the lead time to store is short. Finally, the work of Benrqya et al. (2020) compared the traditional warehouse configuration strategy with two different cross-docking configurations, i.e. one in which the cross-cocking is located at the retailer DC and one in which it is located at the supplier DC.

The management and the distribution of food products is complicated due to the consideration of specific product and process characteristics. In particular, it is affected by continuous and significant changes in food quality as the product moves downstream, and products have high requirements for their storage environment and layout (Agustina et al. 2014; Evans, 2018). Consequently, they cannot be stored for long times, they need to be delivered quickly as well as handled and moved in the smallest space possible (Pan et al. 2021; Paam et al., 2022).

## 3. SYSTEMS COMPARISON

### 3.1 Description of the two systems

Our study focuses on DCs which receive fresh products from suppliers and deliver them to final stores. This study derives from some real case studies of distribution companies handling fresh products. The objective is to compare the performance of the two systems in terms of time, occupied space and cost. In this section, the two systems are presented in detail.

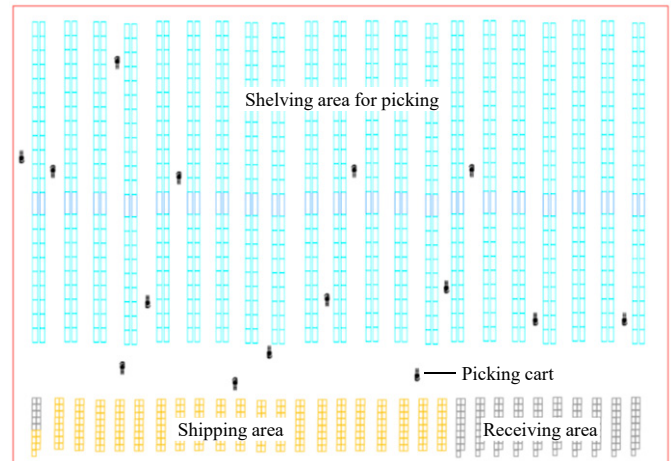


Figure 1. Warehouse picking configuration.

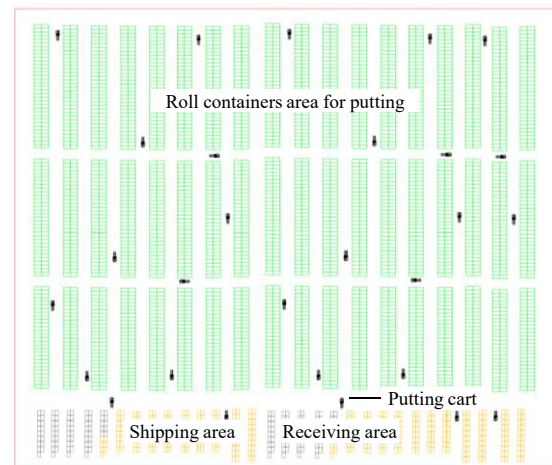


Figure 2. Warehouse putting configuration.

Figure 1 shows the picking configuration. There are a receiving area (grey color) and a shipping area (yellow color) located along the long side of the warehouse, where products from suppliers are received and the orders ready for the stores are located to be shipped. In front of this area, there are several aisles with different shelving units, depicted in light blue color. When the products from the suppliers arrive in single SKU pallets, the forklift operators unload them from trucks to the unloading area and then put them away to the higher levels of the shelving area, that serves as reserve area. The orders of the customers are prepared by the pickers moving with picking carts. Starting with empty pallets or roll containers, they go through the storage area with a traversal routing policy to retrieve the items reported on their picking lists, from the lower level of the shelving, that serves as forward area (manual picker-to-parts order picking). Once a picker completes an

order, he/she carries the customers' pallets or roll containers to the shipping area (bays) with the picking cart. Other activities that are done in this configuration are: pallets replenishment from the reserve area to the forward picking area with forklift trucks and picking orders set up.

The warehouse putting configuration is presented in figure 2. There is the same receiving and shipping area located along the long side of the warehouse, where the pallets of products coming from the suppliers are unloaded with forklift trucks.

The storage units depicted in green are the pallets and/or roll containers divided by store (customer). Here, the operators start their route with full single SKU pallets and, moving with picking carts mainly with a traversal routing policy, put the items on the pallets or roll containers of the various customers, according to what they ordered. When an order is ready, i.e. when all the products for a certain customer (store) have arrived and they have been put in the storage units of the store, the corresponding storage units can be moved with forklift trucks to the shipping area (bays) and prepared for the shipment. Other activities that are done in this configuration are: preparation of the putting area, by positioning empty pallets or roll containers according to the customers' orders and putting orders set up.

One of the main differences between the two systems that has an impact on orders fulfillment is related to the arrival timing of the incoming goods and of the departure timing of the outgoing ones. In the picking configuration, the arrivals of the products have to be adequately anticipated, to guarantee the availability of a certain level of all SKUs before the order picking process starts. On the other hand, the departures of the prepared storage units can be better distributed during the day, since when the picker finishes a picking tour, the order is ready to be shipped. In the putting configuration the opposite situation occurs: the arrivals of the products can be distributed in a larger time window, while the departures of the prepared storage units are usually concentrated at the end of the working shift, when all SKUs have been put in the storage units of the customers.

### 3.2 Formulas for the comparison

Table 1. Notations

Notation	Description
$i$	System index $i$ =picking, putting
$t_i$ [h/day]	Total picking/putting time
$t_{travel,i}$ [h/day]	Total travel time for picking/putting
$t_{u,picking}$ [s]	Unitary time for physically pick a box from a pallet
$t_{u,putting}$ [s]	Unitary time for physically put a box on a roll container
$t_{u,travel i}$ [s]	Unitary time for performing a picking/putting tour
$t_{u,set up i}$ [s]	Unitary time for the set up of the picking/putting tour
$t_{u,replenishment}$ [s]	Unitary time for replenishment activities from reserve to forward area

$t_{u,put away}$ [s]	Unitary time for putting away one pallet from receiving to storage area
$t_{u,preparation}$ [s]	Unitary time for preparing the putting area
$t_{fix}$ [s]	Forklift fixed time for pallet loading and unloading
$n$ [boxes/day]	Number of handled boxes (ordered, received, prepared)
$n_{replenishment}$ [replenishments/day]	Number of replenishments from reserve to forward area
$n_{SKU}$ [SKUs/day]	Number of Stock Keeping Units managed per day
$n_{pallets IN}$ [pallets]	Number of incoming pallets
$n_{roll OUT}$ [rolls]	Number of outgoing roll containers
$O$ [orders/day]	Number of orders
$r$ [roll/order]	Average number of rolls per order
$v_i$ [aisles]	Average number of visited aisles for picking/putting
$\bar{v}_i$ [m/s]	Average speed of the picking/putting cart
$\bar{v}_{forklift}$ [m/s]	Average speed of the forklift
$l_i$ [m]	Length of the picking/putting area
$q_i$ [m]	Width of the picking/putting area
$h_i$ [m]	Height of the picking/putting area
$a_i$ [aisles]	Number of aisles in the picking/putting configuration
$e$ [m]	Width of picking warehouse aisle
$l_{roll}$ [m]	Width of a roll container
$D_{I/O}$ [m]	Distance between the I/O point and the storage area
$w_i$ [m]	Picking/putting storage area unitary width
$f$	Farthest aisle to visit in the picking warehouse
$A_i$ [m <sup>2</sup> ]	Area of the picking/putting area
$c_{operator}$ [€/h]	Operator hourly cost
$c_{forklift}$ [€/h]	Forklift hourly cost
$c_{picking cart}$ [€/h]	Picking/putting cart hourly cost
$c_{area}$ [€/m <sup>2</sup> day]	Warehouse daily cost per square meter
$c_{u energy}$ [€/kWh]	Unitary energy cost for refrigerating the warehouse
$e_u$ [kWh/m <sup>3</sup> day]	Energy daily consumption of the refrigerated warehouse per cubic meter

#### Time performance

$$T_{picking} = t_{picking} + t_{travel,picking} \quad (1)$$

$$t_{picking} = \frac{t_{u,picking} \cdot n}{3600} \quad (2)$$

$$t_{travel,picking} = \frac{t_{u,travel picking} \cdot O \cdot r = (v_{picking} \cdot (l_{picking} + e) + 2 \cdot D_{I/O} + 2 \cdot w_{picking} \cdot f)}{3600 \cdot \bar{v}_{picking}} \cdot O \cdot r \quad (3)$$

$$t_{set up,picking} = \frac{t_{u,set up picking} \cdot O}{3600} \quad (4)$$

$$T_{replenishment} = \frac{t_{u,replenishment}}{3600} \cdot n_{replenishment} \quad (5)$$

$$T_{put\ away} = \frac{t_{u,put\ away}}{3600} \cdot n_{pallets\ IN} = \frac{(l_{picking} + 2 \cdot q_{picking} + 2 \cdot D_I/O + 2 \cdot t_{fix})}{3600 \cdot \bar{v}_{forklift}} \cdot n_{pallets\ IN} \quad (6)$$

$$T_{putting} = t_{putting} + t_{travel,putting} \quad (7)$$

$$t_{putting} = \frac{t_{u,putting}}{3600} \cdot n \quad (8)$$

$$t_{travel,putting} = \frac{t_{u,travel\ putting}}{3600} \cdot n_{pallets\ IN} = \frac{(v_{putting} \cdot l_{putting} + \frac{q_{putting}}{2})}{3600 \cdot \bar{v}_{putting}} \cdot n_{pallets\ IN} \quad (9)$$

$$t_{set\ up,putting} = \frac{t_{u,set\ up\ putting}}{3600} \cdot n_{pallets\ IN} \quad (10)$$

$$T_{preparation} = \frac{t_{u,preparation}}{3600} \cdot \frac{n_{roll\ OUT}}{5} = \frac{(l_{putting} + 2 \cdot q_{putting})}{3600 \cdot \bar{v}_{putting}} \cdot \frac{n_{roll\ OUT}}{5} \quad (11)$$

Occupied space

$$A_{picking} = l_{picking} \cdot q_{picking} = l_{picking} \cdot w_{picking} \cdot a_{picking} \quad (12)$$

$$A_{putting} = l_{putting} \cdot q_{putting} = \frac{O \cdot r}{4 \cdot a_{putting}} \cdot l_{roll} \cdot w_{putting} \cdot a_{putting} \quad (13)$$

Costs

$$C_{picking} = T_{picking} \cdot (c_{operator} + c_{picking\ cart}) + A_{picking} \cdot c_{area} \quad (14)$$

$$C_{putting} = T_{putting} \cdot (c_{operator} + c_{picking\ cart}) + A_{putting} \cdot c_{area} \quad (15)$$

$$CT_{picking} = C_{picking} + (T_{replenishment} + T_{put\ away}) \cdot (c_{operator} + c_{forklift}) + t_{set\ up,picking} \cdot c_{operator} + q_{picking} \cdot l_{picking} \cdot h_{picking} \cdot c_{u\ energy} \cdot e_u \quad (16)$$

$$CT_{putting} = C_{putting} + T_{preparation} \cdot c_{operator} + t_{set\ up,putting} \cdot c_{operator} + q_{putting} \cdot l_{putting} \cdot h_{putting} \cdot c_{u\ energy} \cdot e_u \quad (17)$$

Finally, for a further comparison of the two configurations we calculate four percentage differences:

$$\Delta_{time} = \frac{T_{putting} - T_{picking}}{T_{putting}} \quad (18)$$

$$\Delta_{area} = \frac{A_{putting} - A_{picking}}{A_{putting}} \quad (19)$$

$$\Delta_{cost} = \frac{C_{putting} - C_{picking}}{C_{putting}} \quad (20)$$

$$\Delta_{total\ cost} = \frac{CT_{putting} - CT_{picking}}{CT_{putting}} \quad (21)$$

#### 4. RESULTS AND DISCUSSION

In this section we show some graphs derived from a numerical application of the formulas reported in Section 3.2. The goal is to highlight in a preliminary way the impacts of some variables on the outcomes of both systems.

First of all, it is interesting to show the relationship between the occupied space  $A_i$  and the picking or putting time  $T_i$ , for different values of  $O$  and  $n_{SKU}$ . In particular, Figure 3 reports how the time performances of a picking and of a putting system vary for  $O=100$  and 500 orders/day. Here, we can see that the two systems are differently influenced by the variation of the number of orders, which in our case corresponds also to the number of customers. In fact, for the picking system the time  $T_{picking}$  increases with the number of orders, while for the putting system the time  $T_{putting}$  remains the same. On the other hand, if we consider a fixed value of  $A_i$  (for example, 5,000  $m^2$ , the dashed line in Figure 3) and the corresponding SKUs that are handled in the two configurations, we see that the picking system is the one that allows the management of a higher number of  $n_{SKU}$  (equal to 1,626 SKUs/day). Moreover, since the size of the putting area depends on the number of served customers, a difference in the number of orders implies a change also on the number of managed SKUs: 1,398 SKUs for  $O=100$  orders/day and 280 SKUs for  $O=500$  orders/day.

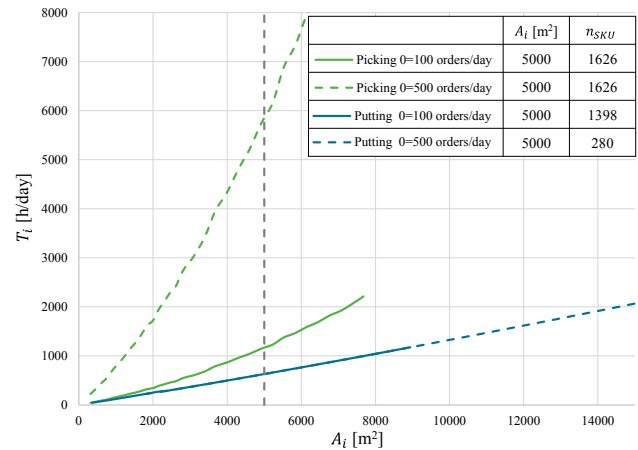


Figure 3. Comparison in terms of  $A_i$  and  $T_i$ .

Figure 4 shows the trends of  $T_i$ ,  $A_i$ ,  $C_i$  and  $CT_i$  as a function of the number of SKUs  $n_{SKU}$  (on the left of the figure) or the number of orders (i.e. the number of customers, on the right of the figure) per day  $O$ . Focusing on the graphs on the left, it can be seen that when  $O=100$  orders/day the variation in the number of SKUs has a similar influence both for the picking and the putting system. On the other side, when the number of orders increases ( $O=500$  orders/day), it is more evident that the putting system is generally the best one from a time and a cost point of view, while it is the worst one in terms of occupied area. This is due to the fact that an increase in the number of orders (i.e. customers) implies a higher number of roll containers prepared in the putting area.

Similar trends can be seen also in the graphs on the right: again, the slope of the curves of  $A_i$  of the putting system is much higher than the one of the picking system. Moreover, in

the graphs of  $T_i$ ,  $C_i$  and  $CT_i$  the putting system becomes the worst alternative when the number of orders increases.

Finally, Figure 5 reports four contour plots of  $\Delta_{time}$ ,  $\Delta_{area}$ ,  $\Delta_{cost}$  and  $\Delta_{total\ cost}$  calculated for all the possible combinations obtained from the ranges  $O=50\div 1,500$  and  $n_{SKU}=100\div 2,500$ . A green area indicates a better performance of the picking system, while a blue area indicates the better performance of the putting one. The darker the area, the higher the difference between the two systems. The contour plots of  $\Delta_{time}$  and  $\Delta_{cost}$  show similar trends, highlighting that the cost of the occupied space does not influence much the computation of the costs. In particular, they report that the putting system performs better than the picking one when the number of orders (customers) per day is low and the number of handled SKUs is high. On the other side, the picking system is much better than the putting one when the number of SKUs is limited (darker green areas on the left up side of the plots). As far as  $\Delta_{area}$  is concerned, we see that the results are more influenced by  $O$  than  $n_{SKU}$ , with the picking system turning out to be almost always the best choice. Finally, the plot of  $\Delta_{total\ cost}$  highlights a certain influence of the energy cost, leading to an overall lower convenience of the putting configuration.

## 5. CONCLUSIONS

This paper presented a preliminary study focused on the comparison of warehouse picking and putting for fresh products from a time, space and cost perspective, including also energy consumption. The numerical application of the proposed formulas showed that the two systems are differently influenced by the number of orders per day and the number of SKUs.

The research on this topic will continue by further investigating the influence of different warehouse design parameters and of orders characteristics on the convenience of both systems. Then, we will develop a method to easily estimate the best configuration, given a set of input data. Finally, it would also be interesting to expand the study to other warehouses, storing other kinds of products, like the ones that serve the fashion industry.

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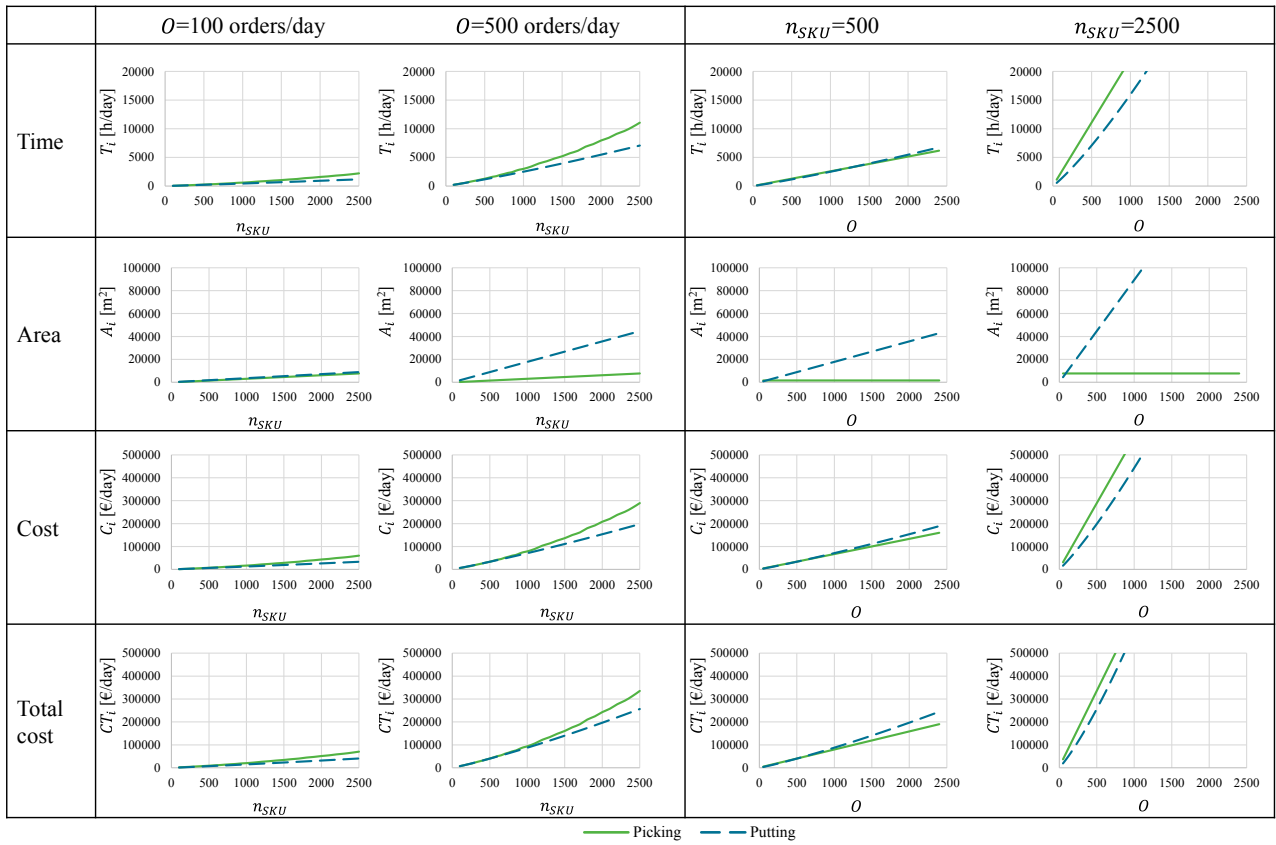


Figure 4.  $T_i$ ,  $A_i$ ,  $C_i$  and  $CT_i$  as a function of  $O$  and  $n_{SKU}$ .

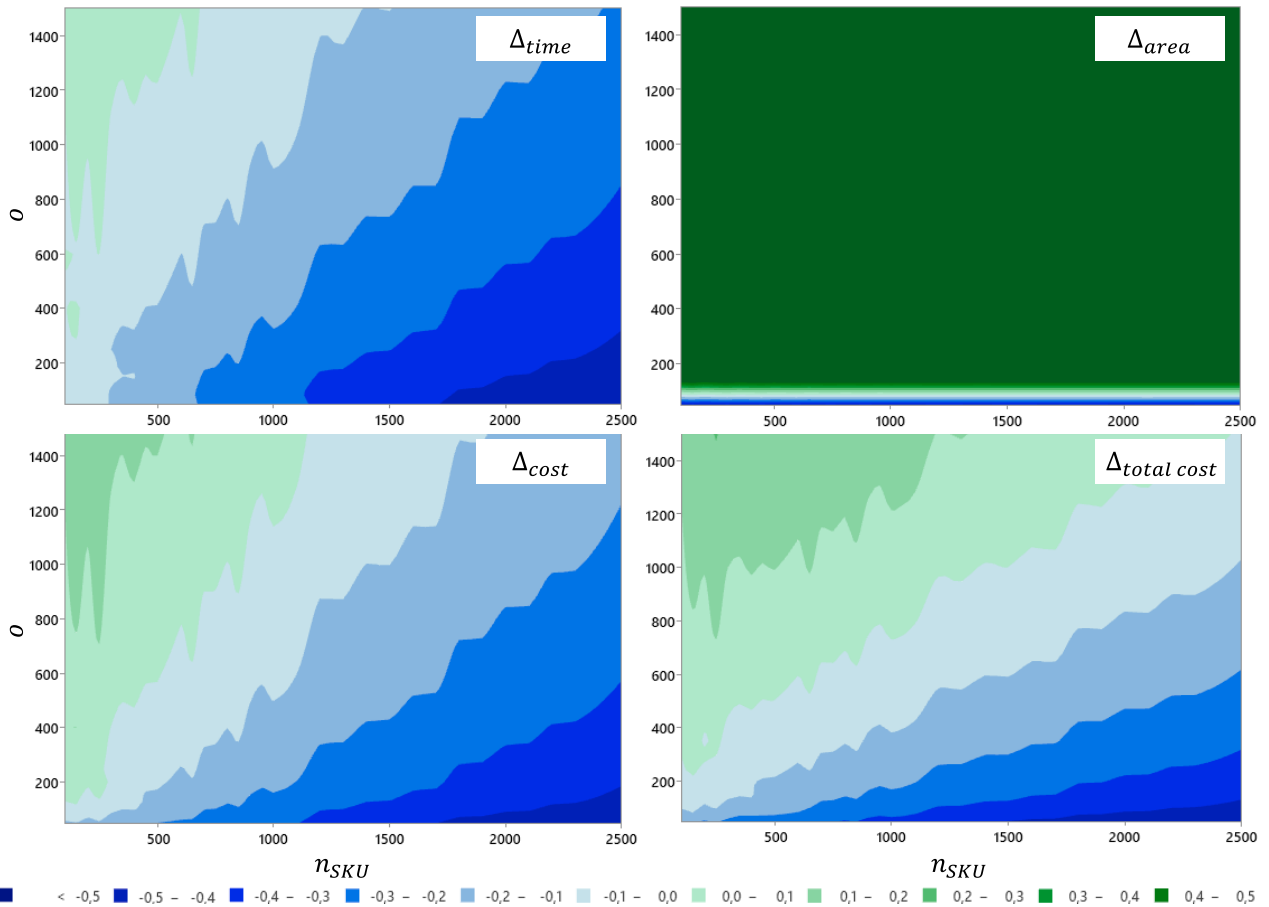


Figure 5. Contour plots of  $\Delta_{time}$ ,  $\Delta_{area}$ ,  $\Delta_{cost}$  and  $\Delta_{total cost}$  for the comparison of picking (green areas) and putting (blue areas) systems.