

### Assignment questions

Q1. Design a forward-reserve configuration with a forward pick area size with 10 slots (5 storage slots along the picking aisle and 2 storage slots along the height). Data regarding coordinates of these slots and their travel time is provided in the supplementary file. The average one-way travel times between the aisle entrance and different storage slots in the reserve area to carry out putaway or pick operation is found to be 12.02 seconds.

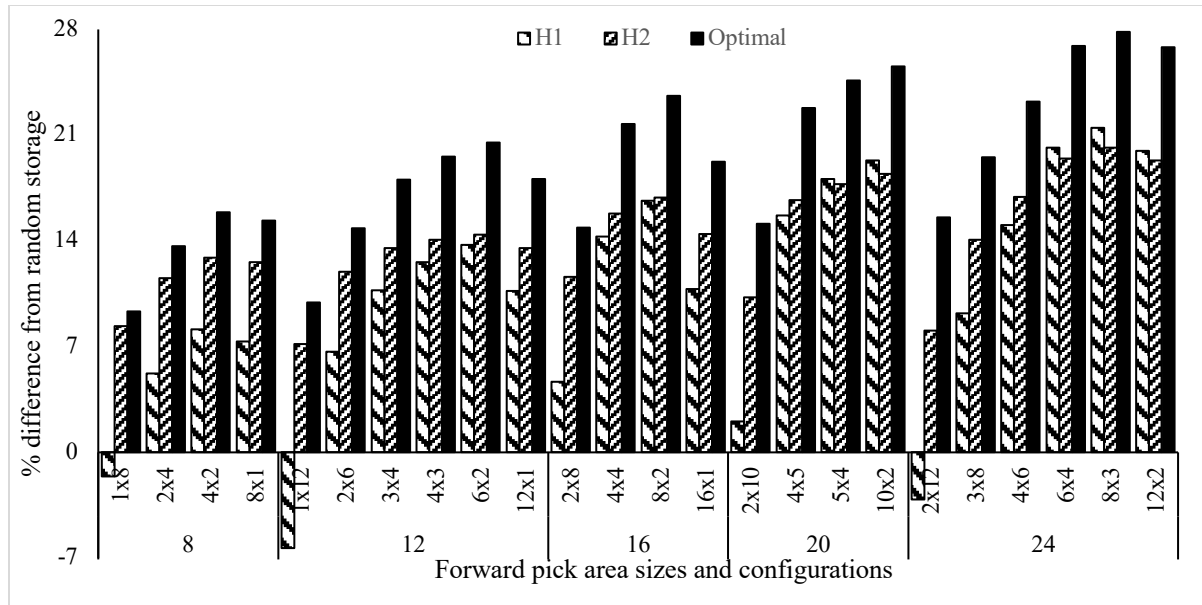
Select the products based on the two heuristics (H1 and H2) discussed in the case for the above forward-reserve configuration. Benchmark the performance of this forward reserve-configuration for both the heuristics against the current random storage policy in terms of storage space requirement and total travel time. It has been mentioned in the case that for the random storage policy, the average one-way travel time between the entrance to the picking aisle and reserve area is 11.54 seconds and space required per rack is 154 storage slots.

Q2. There is room for improvement in design by using an optimization model for the selection of products as well as the allocation of storage slots to products instead of the heuristic methods proposed to be used in question 1. Demonstrate this by developing and solving an optimization model for the forward-reserve configuration described in question 1. Compare the solution obtained using the optimization model with those obtained in question 1.

**Tip:** Any commercial solver can be used to obtain a solution to the developed optimization model. However, if MS Excel Solver is used and if any limitation on the number of variables is faced when using the in-built Solver of MS Excel, then one can use OpenSolver plugin for MS Excel to overcome such a problem (available for download free of charge at <https://opensolver.org/>).

Q3. Until this point, Ravi has focussed on understanding the utility of forward-reserve arrangement and the use of heuristics or an optimization model as an aid in the design of such a system. For this purpose, he has arbitrarily picked a design with 10 storage slots in the forward pick area (refer to Q1 and Q2). The dimensions of this forward pick area were 5x2 (i.e., five storage slots horizontally along the length of picking aisle and two storage slots vertically along the height).

Ravi decides to explore alternate designs with five different sizes of the forward pick area (8, 12, 16, 20, and 24 storage slots) and all possible rectangular arrangements for each size. In line with questions 1 and 2, he used different approaches (Heuristic 1 (H1), Heuristic 2 (H2) and the optimization model) for selecting products for the forward pick area. The percentage improvement in the total travel time for each such design over the design under the prevailing random storage policy is shown in the figure below.



- What conclusions can be derived regarding the behaviour of the two heuristics: Heuristic 1 (H1) and Heuristic 2 (H2) to select products for the forward pick area?
- What are the implications of the increase in the size of the forward pick area to the travel time and buffer storage capacity?