Reading assignment: The material in the Powerpoint presentation in the course materials entitled “Order picking policies” and all the relevant material (book excerpts and papers) posted in the library reserves electronic site.

Problem 1: Consider the storage rack of an in-the-aisle order picking system based on person-on-board AS/RS, depicted in Figure 1. As it can be seen in this figure, the rack is organized in 14 bays and 7 levels. The aisle picking station is located at the left lower corner of the rack, and the S/R vehicle travels simultaneously on both axes, $x$ and $y$, with corresponding velocities, $v_x = 200$ ft/min and $v_y = 100$ ft/min.

![Figure 1](image-url)

a) Use the closest insertion algorithm in order to compute a picking route visiting the locations marked by $x$ in Figure 1. Noticing that the ultimate objective is the minimization of the total traveling time, what is the most appropriate “distance” metric to be used in the algorithm implementation? What is the cost of the developed tour according to this distance metric?

b) Consider a single-line order, concerning an item located at bay 7 and level 2 in the rack. Identify the rack region (set of locations) that could be visited at zero additional travel cost (time), while filling the aforementioned order. Generalize your result for the trip to any location of the rack, say at bay $x$ and level $y$. 
**Problem 2:** Consider a picking area based on bin shelving, and laid out according to the aisle structure depicted in Figure 2.

![Figure 2](attachment:image.png)

Docking station

a) Develop a numbering scheme for the area bays, based on Sierpinski’s space-filling curve.
b) Develop a picking tour for visiting the locations (bays) marked by x in Figure 2, based on the bay-numbering scheme developed in part (a).
c) Explain why a bay-numbering scheme based on Sierpinski’s space-filling curve might not be the most appropriate for the considered picking area, and propose an alternative bay-numbering scheme that might result in more efficient picking routes. Demonstrate the efficiency of your new numbering scheme, by employing it to develop a new picking route for part (b) above, and comparing the length of this new route to the length of the route obtained in part (b).

**Problem 3:** Consider a picking area based on bin shelving, organized according to the layout depicted in Figure 3. In this area, picking routes are designed according to the S-shaped heuristic, while items are picked on a picking cart with three separate compartments (for sorting while picking). Currently, there are 8 standing orders: a, b, c, d, e, f, g, and h, with their listed items located as indicated in Figure 3. Organize these eight orders into batches, by applying

a) a seed algorithm where the order seeds are selected based on the largest number of aisles to be visited and they are dynamically redefined after the addition of a new order in the batch, and the order addition rule seeks to minimize the number of new aisles that have to be visited after the addition of a new order;
b) the savings algorithm discussed in class.
Extra credit

Problem 1 (20%): Apply Ratliff and Rosenthal’s algorithm for the computation of the minimal-length picking tour for the warehouse layout and order structure depicted in Figure 4.

Problem 2 (10%): Provide a formal/rigorous argument that the “no subtours” constraint in the TSP formulation of slide 4 in the Powerpoint presentation entitled “Order Picking Policies”, enforces indeed the corresponding constraint.