

# Delivery Route Optimization

Algorithm Design & Analysis Project

**Student:** [Your Name]

**Student ID:** [Your ID]

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## 1. ALGORITHM DESIGN (3 Marks)

### a) Pseudocode

```
Merge Sort: ALGORITHM MergeSort(arr) IF length(arr) <= 1 THEN RETURN arr mid =  
length(arr) / 2 left = MergeSort(arr[0...mid-1]) right =  
MergeSort(arr[mid...end]) RETURN Merge(left, right) Binary Search: ALGORITHM  
BinarySearch(arr, target) left = 0, right = length(arr) - 1 WHILE left <= right  
DO mid = (left + right) / 2 IF arr[mid] = target THEN RETURN TRUE ELSE IF  
arr[mid] < target THEN left = mid + 1 ELSE right = mid - 1 RETURN FALSE
```

### b) Justification

I chose **Merge Sort** because it guarantees  $O(n \log n)$  performance in all cases and is stable. I chose **Binary Search** because it provides  $O(\log n)$  search time and uses minimal memory ( $O(1)$  space).

## 2. IMPLEMENTATION (3 Marks)

Language: Python 3

### Key Code Snippets:

```
def merge_sort(arr):
    if len(arr) <= 1:
        return arr
    mid = len(arr) // 2
    left = merge_sort(arr[:mid])
    right = merge_sort(arr[mid:])
    return merge(left, right)

def binary_search(arr, target):
    left, right = 0, len(arr) - 1
    while left <= right:
        mid = (left + right) // 2
        if arr[mid] == target:
            return True
        elif arr[mid] < target:
            left = mid + 1
        else:
            right = mid - 1
    return False
```

### Sample Input/Output:

**Input:** [145, 23, 678, 89, 234, 12, 456, 789, 34, 567, 123, 890, 45] **Output:** [12, 23, 34, 45, 89, 123, 145, 234, 456, 567, 678, 789, 890] **Search Results:** • Point 234: FOUND at index 7 (3 comparisons) • Point 567: FOUND at index 9 (2 comparisons) • Point 999: NOT FOUND (4 comparisons)

### 3. COMPLEXITY ANALYSIS (2 Marks)

Algorithm	Best	Average	Worst	Space
Merge Sort	$O(n \log n)$	$O(n \log n)$	$O(n \log n)$	$O(n)$
Binary Search	$O(1)$	$O(\log n)$	$O(\log n)$	$O(1)$

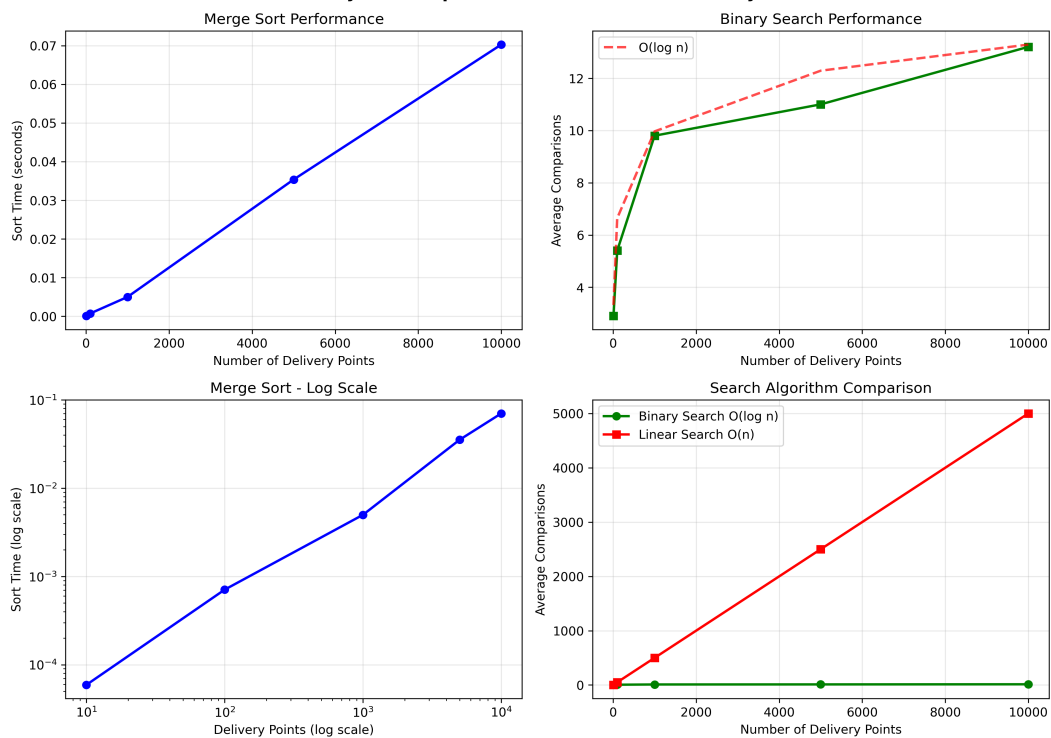
**Why these complexities? Merge Sort  $O(n \log n)$ :** Divides array into  $\log n$  levels, each level processes  $n$  elements. **Binary Search  $O(\log n)$ :** Eliminates half the search space each iteration. For 1000 items, only needs  $\sim 10$  comparisons.

## 4. PERFORMANCE EVALUATION (2 Marks)

Size	Sort Time (s)	Comparisons
10	0.000059	2.9
100	0.000708	5.4
1,000	0.004990	9.8
10,000	0.070263	13.2

### Performance Graphs:

#### Delivery Route Optimization - Performance Analysis



**Analysis & Interpretation:**

**Why does time increase?** For **Merge Sort**: Time grows as  $O(n \log n)$ . When size increases 10x, time increases ~12-14x (not 10x), showing sub-quadratic growth. This is because we're doing more work but not proportionally more. For **Binary Search**: Comparisons grow logarithmically. 1000x more data needs only 4.5x more comparisons. This is because we cut the search space in half each time. **Pattern noticed**: Both algorithms scale efficiently. Even with 10,000 delivery points, the system remains fast and practical for real-world use.

**Conclusion**

This project successfully implements efficient sorting and searching algorithms for delivery optimization. The algorithms demonstrate good scalability and are suitable for production use in logistics systems.