Optimizations in Airline Industry

Ground Holding Policy Problem(GHPP)

- Airport landing capacity varies due to weather
- Forecasts of a particular day known
- Expected delay at **destination** airport => **depart lately**
- **Ground delay** better than **airborne delay**
- Need to minimise total **Ground + air** delay cost
- Two versions: Single & Multi airport

Assumptions

We assumed a simple single Airport model to start with

Assume **N** flights

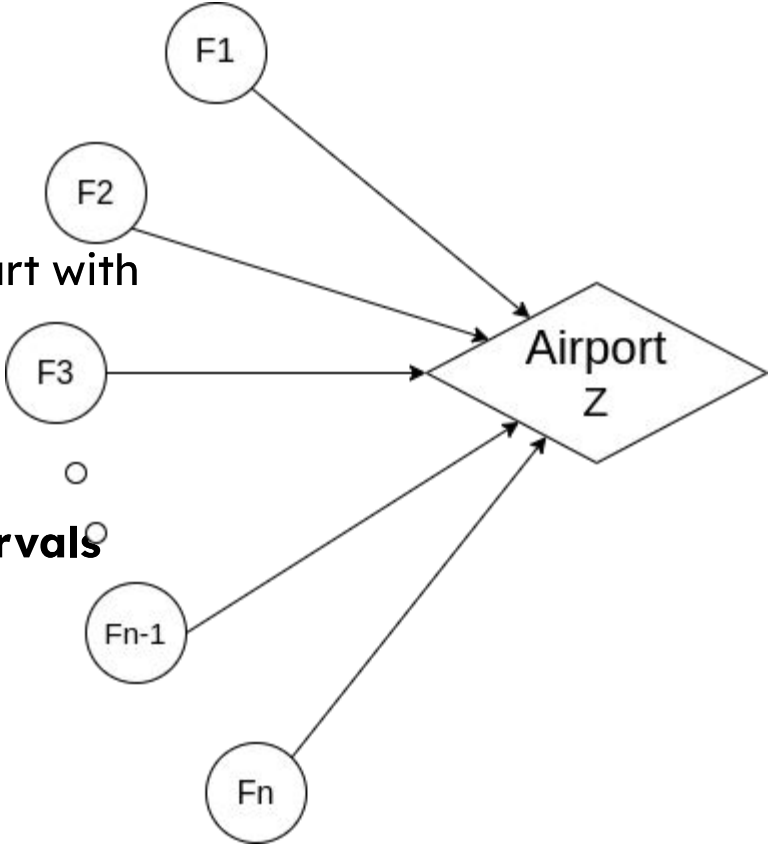
Each flight has a scheduled arrival time at **Z.**

Time period of Interest [0, B] divided into **T intervals**

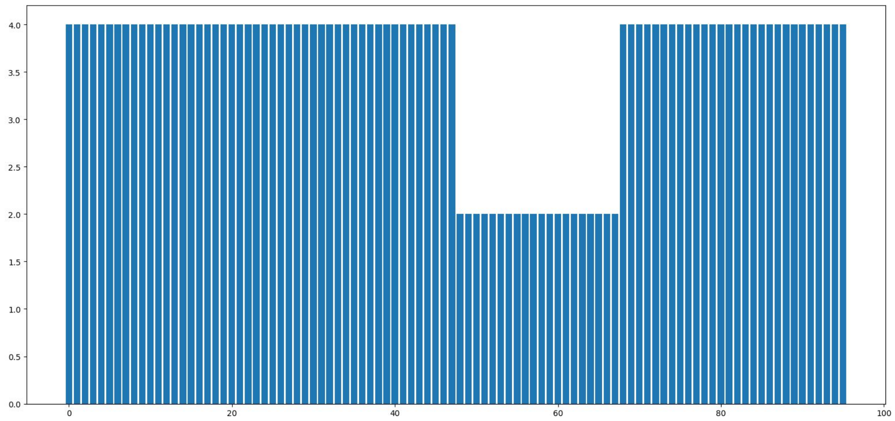
- Simplifies the objectives, constraints

Delaying the departure causes **Ground Delay**

Delaying the landing causes **Air Delay**



Assumptions



- Delay ∝ Time interval
- Ground delays less costly
- Airport landing capacity $[C_1, C_2, ..., C_T]$ known through forecasts
- Assume all flights can land by the end of time period
- Schedule of the flights is fixed, and known

X_{ij}: # of flights scheduled to land at i, but landed at j
W_i: # of flights delayed in air at time slot i, due to capacity limitations

Problem formulation

Decision Variables : $\mathbf{X_{ij}}, \mathbf{W_i} \in \mathbb{Z} \quad 1 \leq i \leq T, j \geq i$

$$\Sigma_{j \text{ in } [i, T+1]} X_{ij} = N_i \quad \forall\ 1 \leq i \leq T$$

$$W_i \geq \Sigma_{j \text{ in } [1, i]} X_{ji} + W_{i-1} - C_i \quad \forall\ 1 \leq i \leq T$$

$$X_{ij}, W_i \geq 0$$

$$\boxed{\textbf{Min } \Sigma_{i \text{ in } [1, T]} \Sigma_{j \text{ in } [i+1, T+1]} X_{ij}(j - i)\mathbf{G} + \Sigma_{i \text{ in } [1, T]} W_i \mathbf{A}}$$

Probabilistic Version

Decision Variables : $\mathbf{X_{ij}}$, $\mathbf{W_{iq}}$ $\in \mathbb{Z}$ $\quad 1 \le i \le T,\ j \ge i,\ 1 \le q \le Q,$

$$\mathbf{X_{ij}}, \mathbf{W_{iq}} \ge 0$$

- $\mathbf{X_{ij}}$ remains the same
- But waiting constraints, variables differ for each forecast bcz landing capacities are different.
- The forecast is $[\ C_{1q}, C_{2q}, \ldots\ldots\ldots, C_{Tq}]$ with probability p_q, where $1 \le q \le Q$.

Formulation

Decision Variables : $\mathbf{X_{ij}}$, $\mathbf{W_{iq}} \in \mathbb{Z}$ $\quad 1 \le i \le T, j \ge i$

$$\Sigma_{j \text{ in } [i, T+1]} X_{ij} = N_i \quad \forall\ 1 \le i \le T$$

$$W_{iq} \ge \Sigma_{j \text{ in } [1, i]} X_{ji} + W_{(i-1)q} - C_{iq} \quad \forall\ 1 \le i \le T$$

$$X_{ij}\ , W_{iq} \ge 0$$

$$\boxed{\textbf{Min } \mathbf{G}\Sigma_{i \text{ in } [1, T]}\Sigma_{j \text{ in } [i+1, T+1]} X_{ij}(j - i) + \mathbf{A}\Sigma_q \mathbf{p_q}(\Sigma_{i \text{ in } [1, T]} W_{iq})}$$

Introducing Aircraft Types

Decision Variables will be indexed by extra “k” denoting the type of aircraft : X_{ijk}, $W_{iq} \in \mathbb{Z}$ $1 \le i \le T, j \ge i, 1 \le q \le Q, 1 \le k \le K$

$$X_{ijk}, W_{iq} \ge 0$$

- **All the constraints have to include “k”**

Formulation

Decision Variables : $\mathbf{X_{ijk}}, \mathbf{W_{iq}} \in \mathbb{Z} \quad 1 \leq i \leq T, j \geq i$

$$\Sigma_{j \text{ in } [i, T+1]} X_{ijk} = N_{ki} \quad \forall \ 1 \leq i \leq T$$

$$W_{iq} \geq \Sigma_k \Sigma_{j \text{ in } [1, i]} X_{jik} + W_{(i-1)q} - C_{iq} \quad \forall \ 1 \leq i \leq T$$

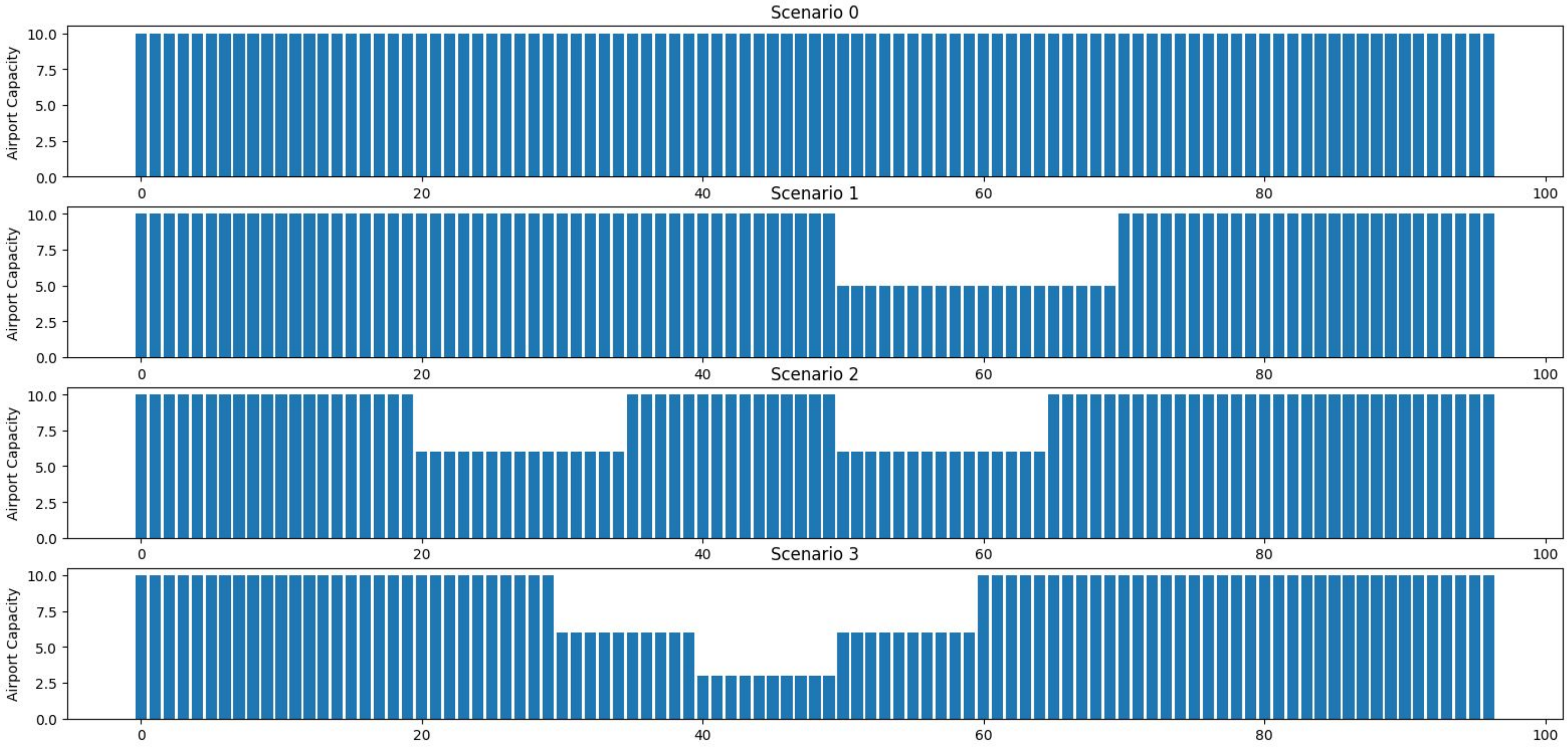
$$X_{ijk}, W_{iq} \geq 0$$

$$\boxed{\textbf{Min } \Sigma_k \mathbf{G_k} \Sigma_{i \text{ in } [1, T]} \Sigma_{j \text{ in } [i+1, T+1]} X_{ijk}(j - i) + \mathbf{A} \Sigma_q \mathbf{p_q} (\Sigma_{i \text{ in } [1, T]} W_{iq})}$$

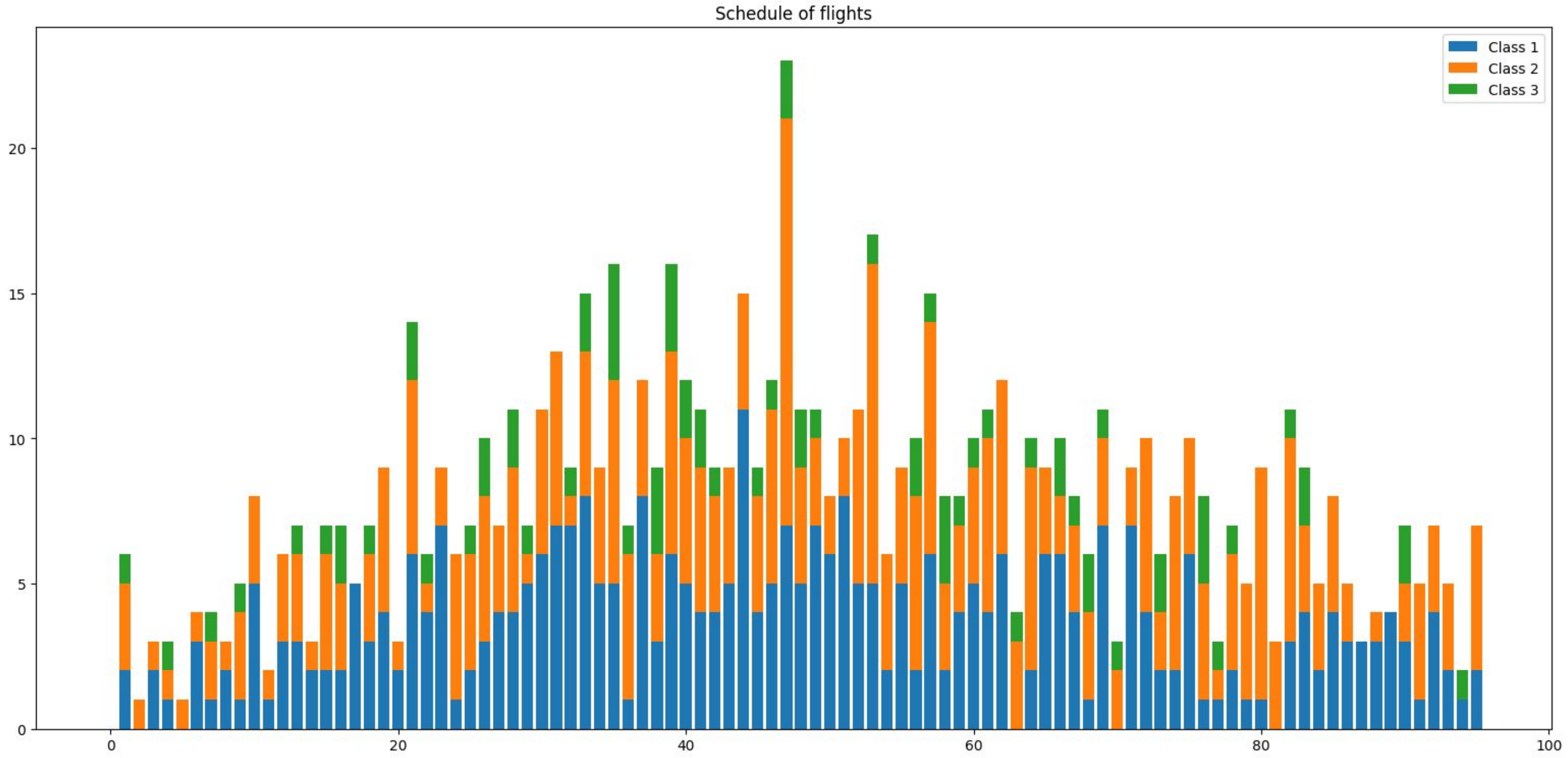
Assumptions & Implementation

- Time intervals of 15 min each (96 Intervals)
- Q = 4 Capacity Scenarios
- K = 3 Aircraft classes: small, medium, large 45 : 45 : 10%
- Generated a Random schedule, slightly concentrated towards the center to almost 80% of the Maximum capacity
- Compared the algorithm with 3 other algorithms
  - PASSIVE : No ground Holding
  - AVERAGE : considers an average scenario
  - Most Likely : most likely weather scenario
- Ground Costs: [150, 200, 400]
- Air costs per period : 500, 600, 750

Capacity Scenarios



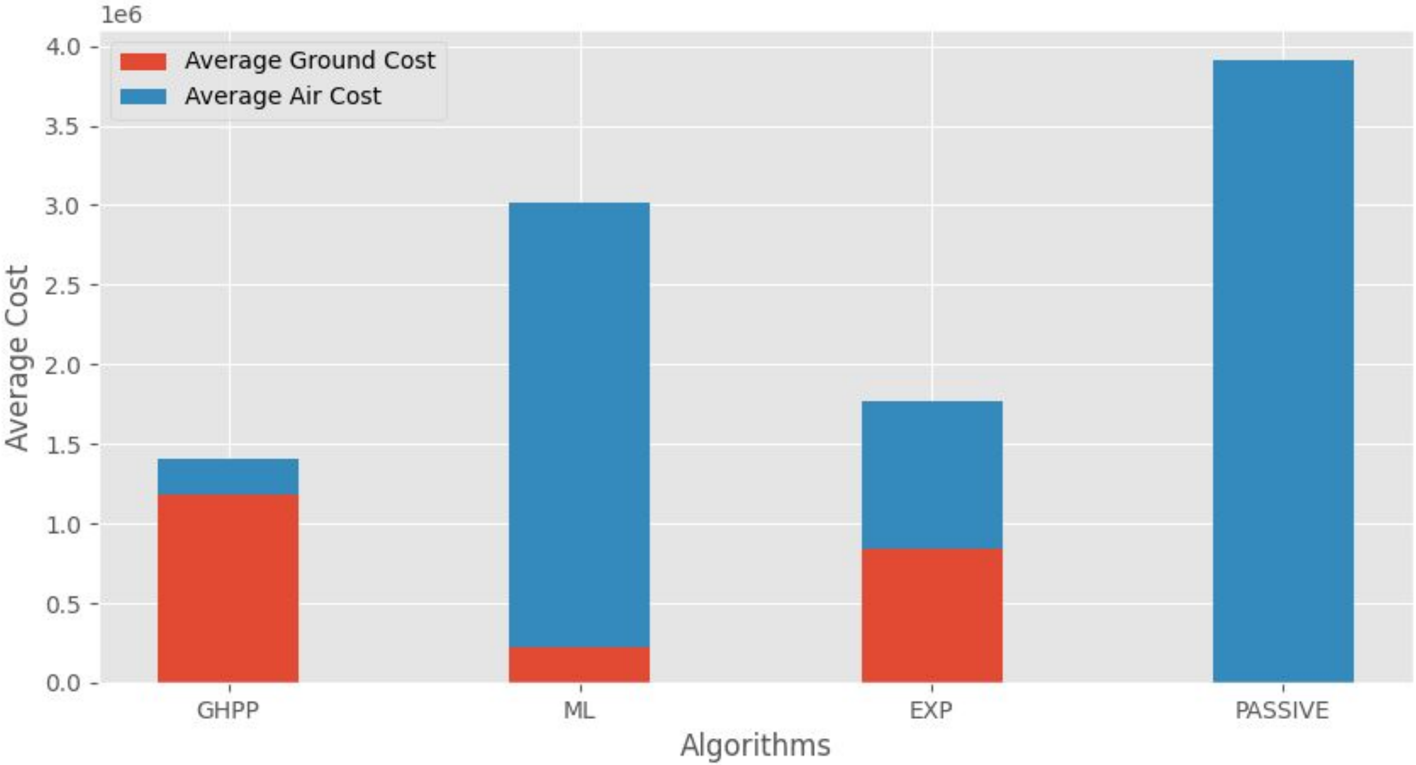
Generated Schedule



RESULTS

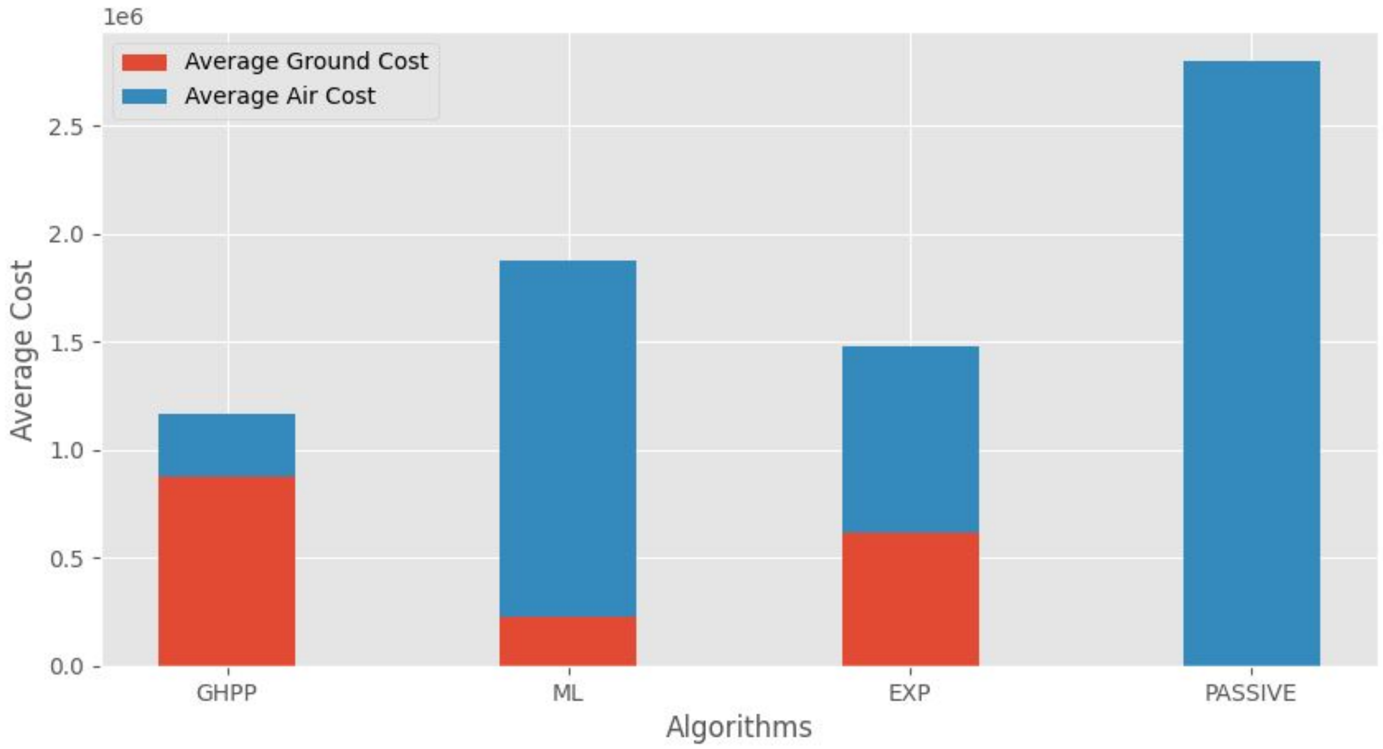
Probability Scenario 1

0.25 0.25 0.25 0.25



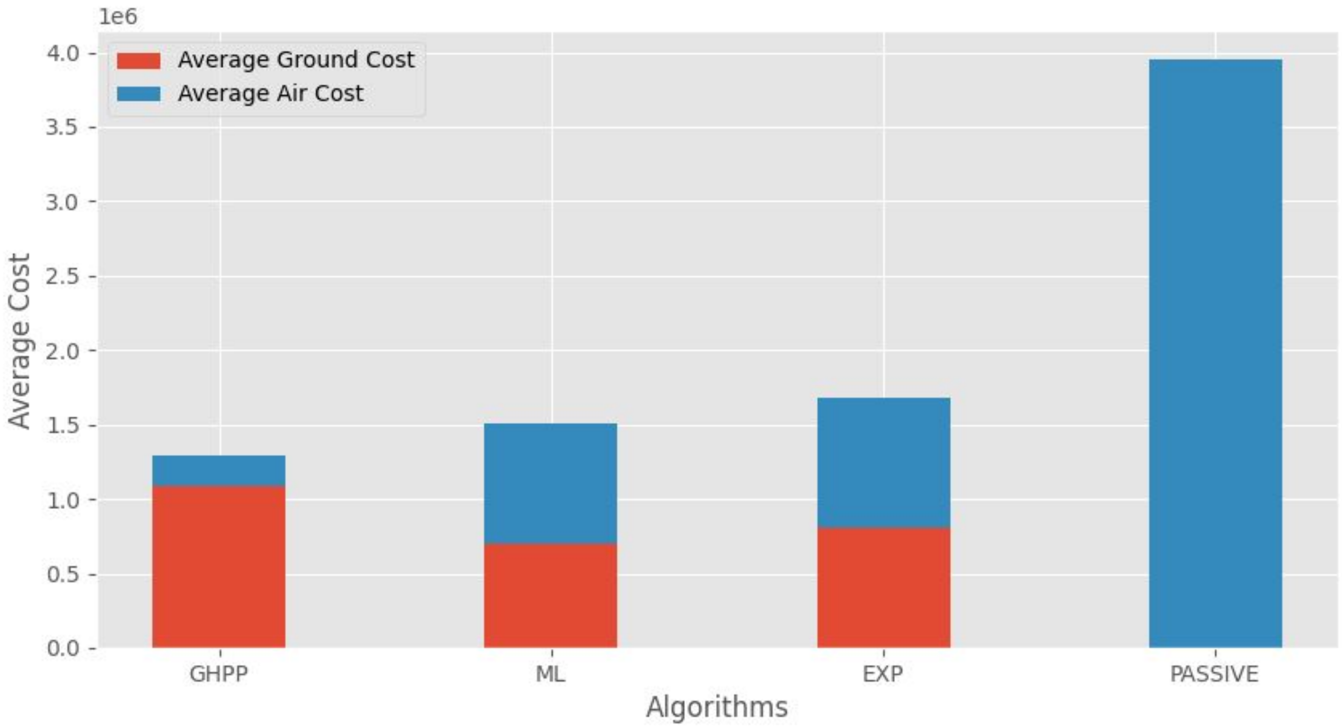
Probability Scenario 2

0.5 0.2 0.2 0.1



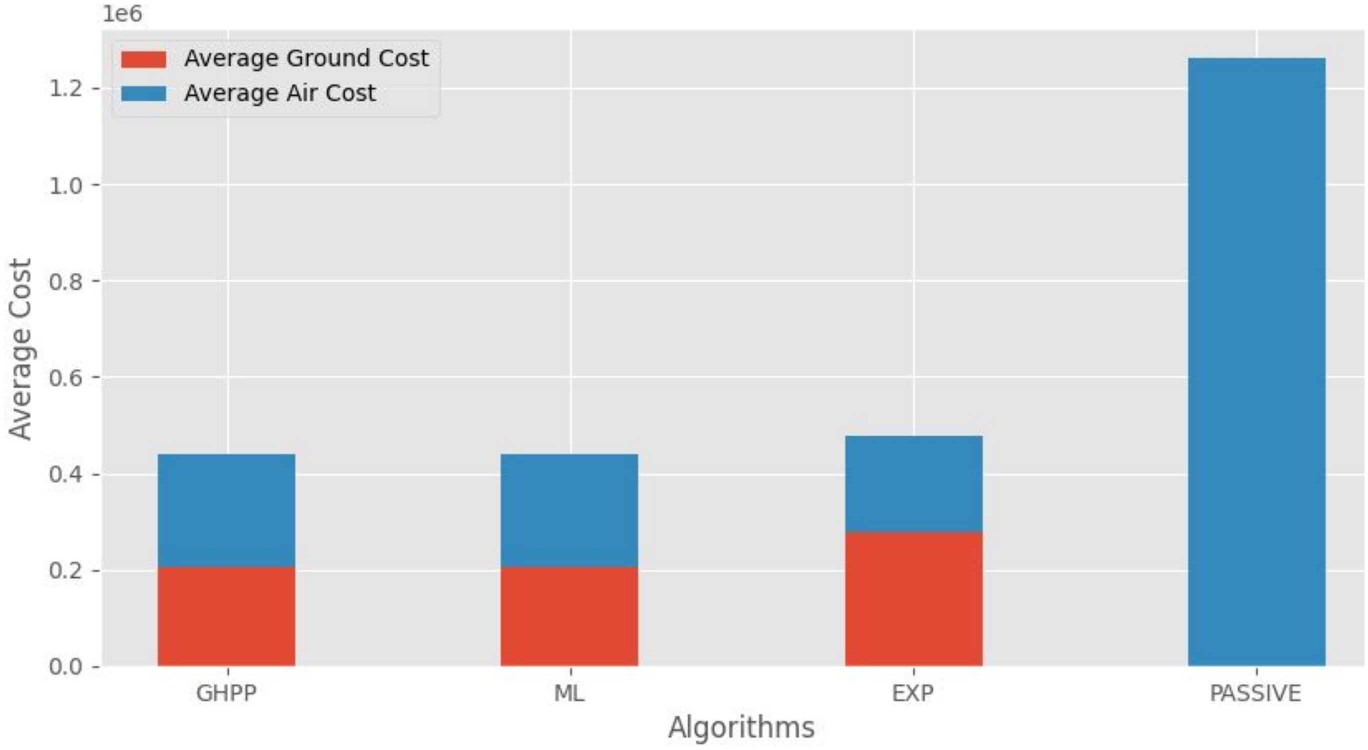
Probability Scenario 3

0.1 0.4 0.3 0.2



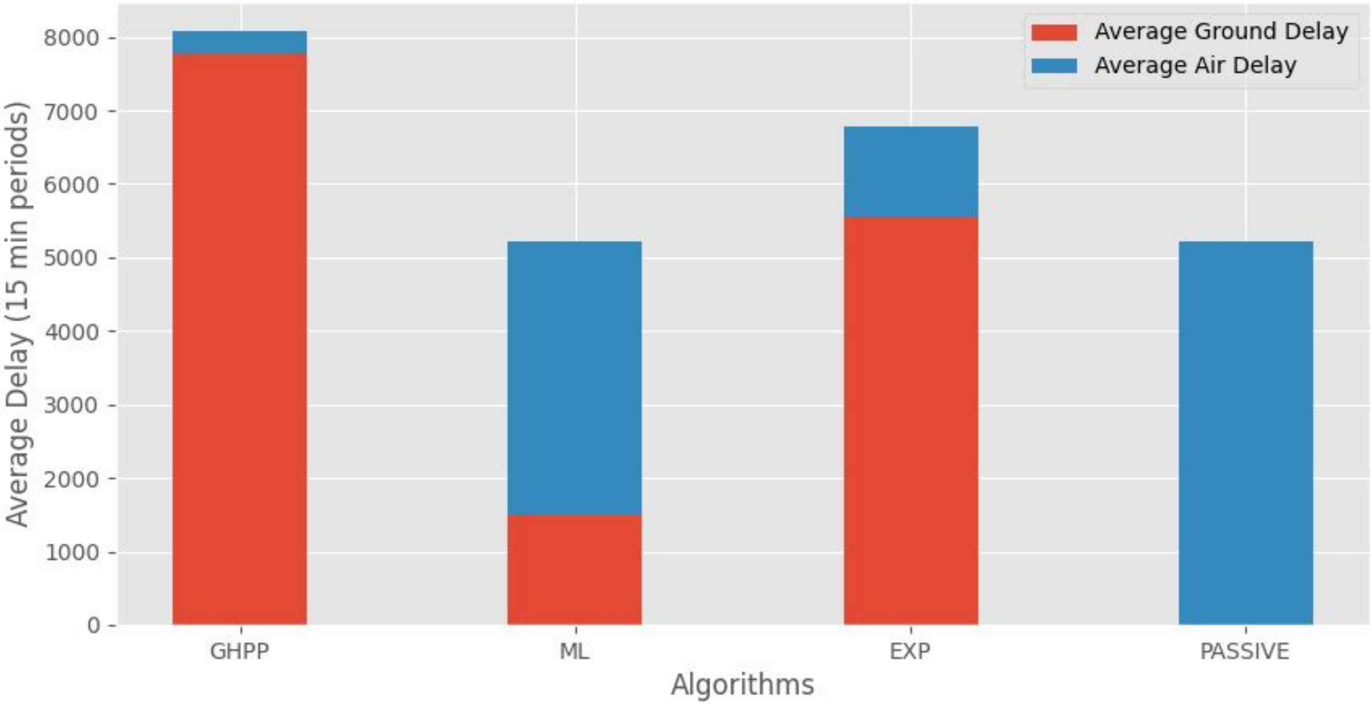
Probability Scenario 4

0.9 0.1 0.0 0.0

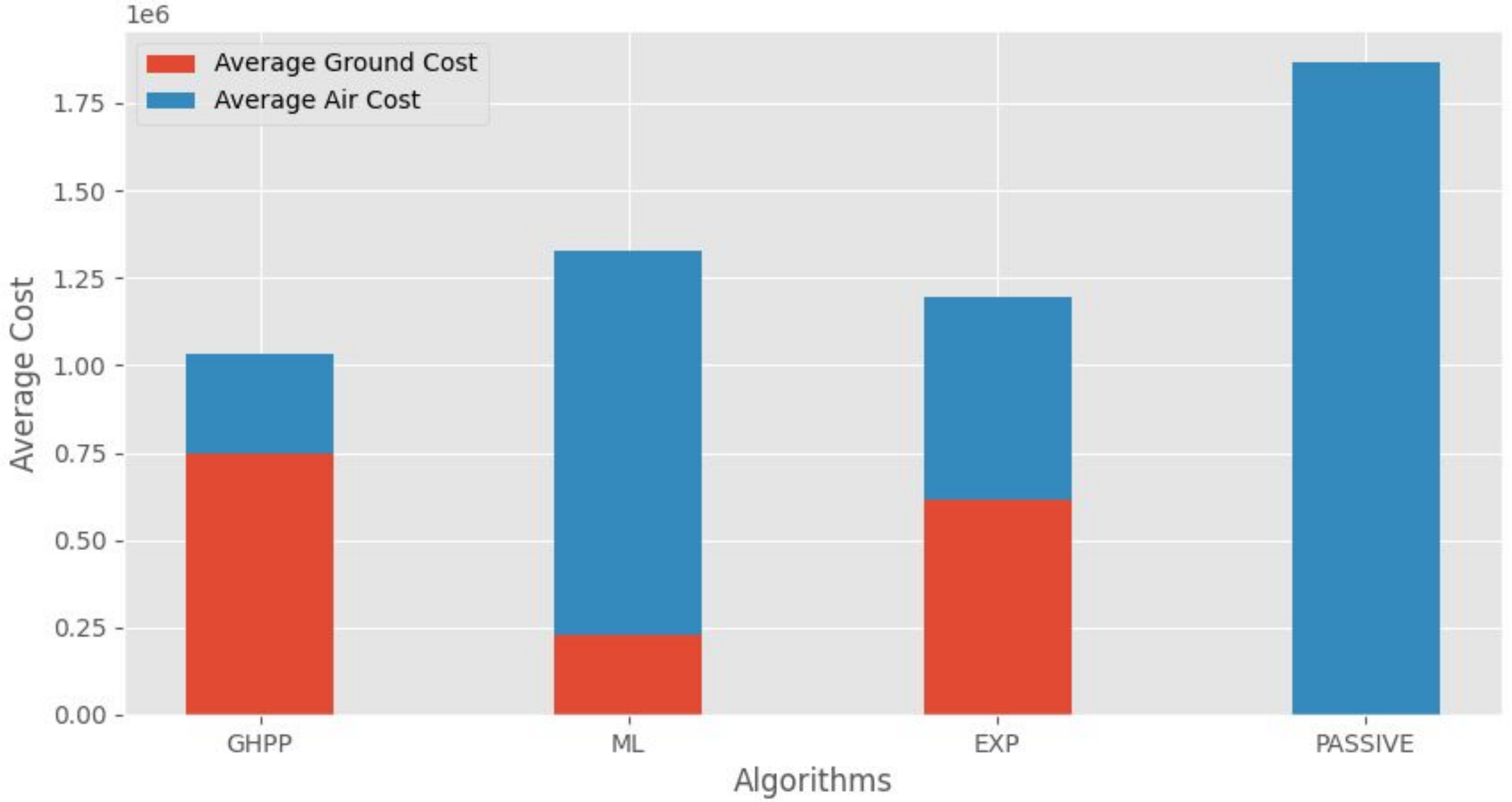


Average Delay [Case 1]

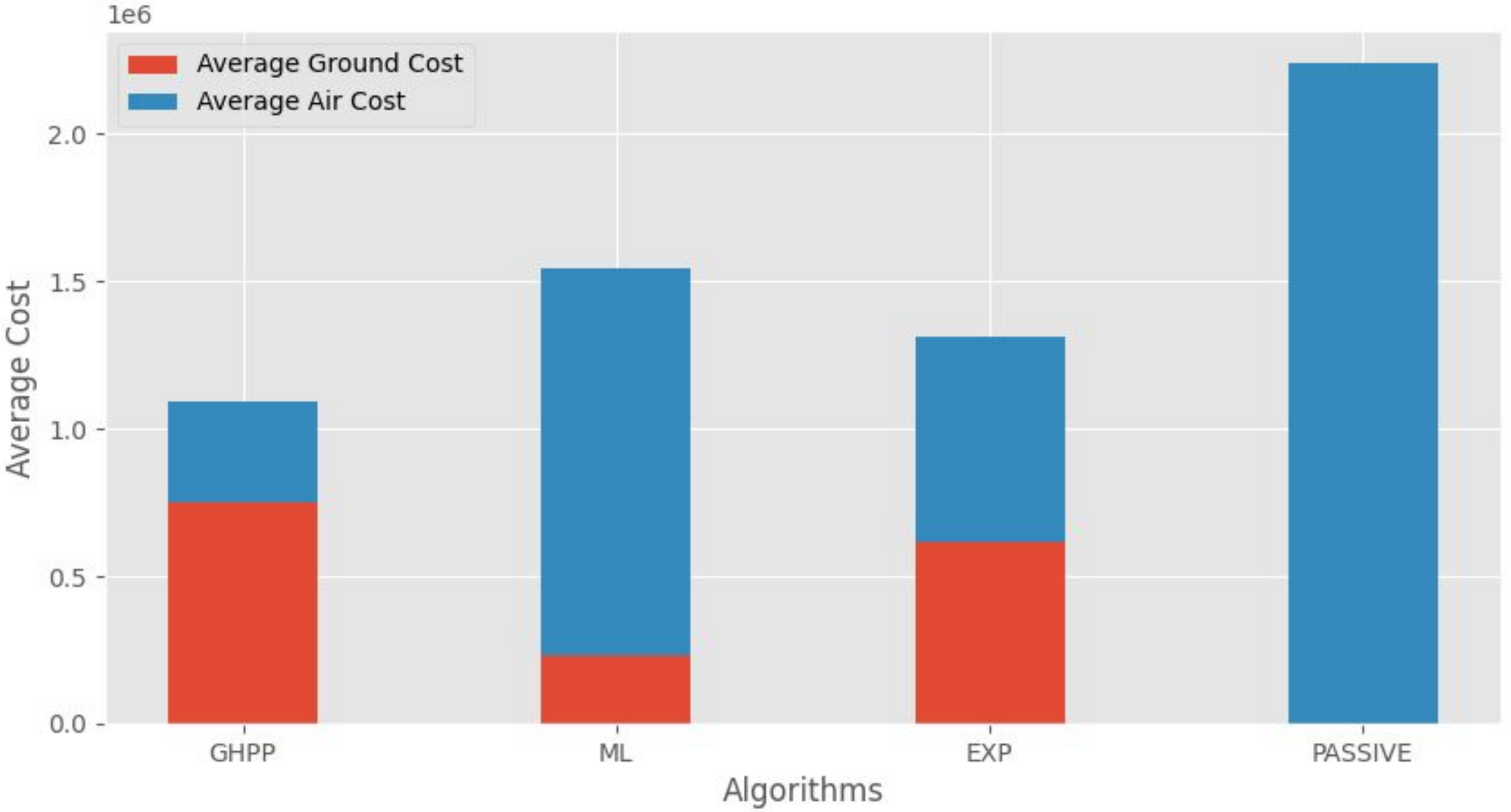
0.25 0.25 0.25 0.25



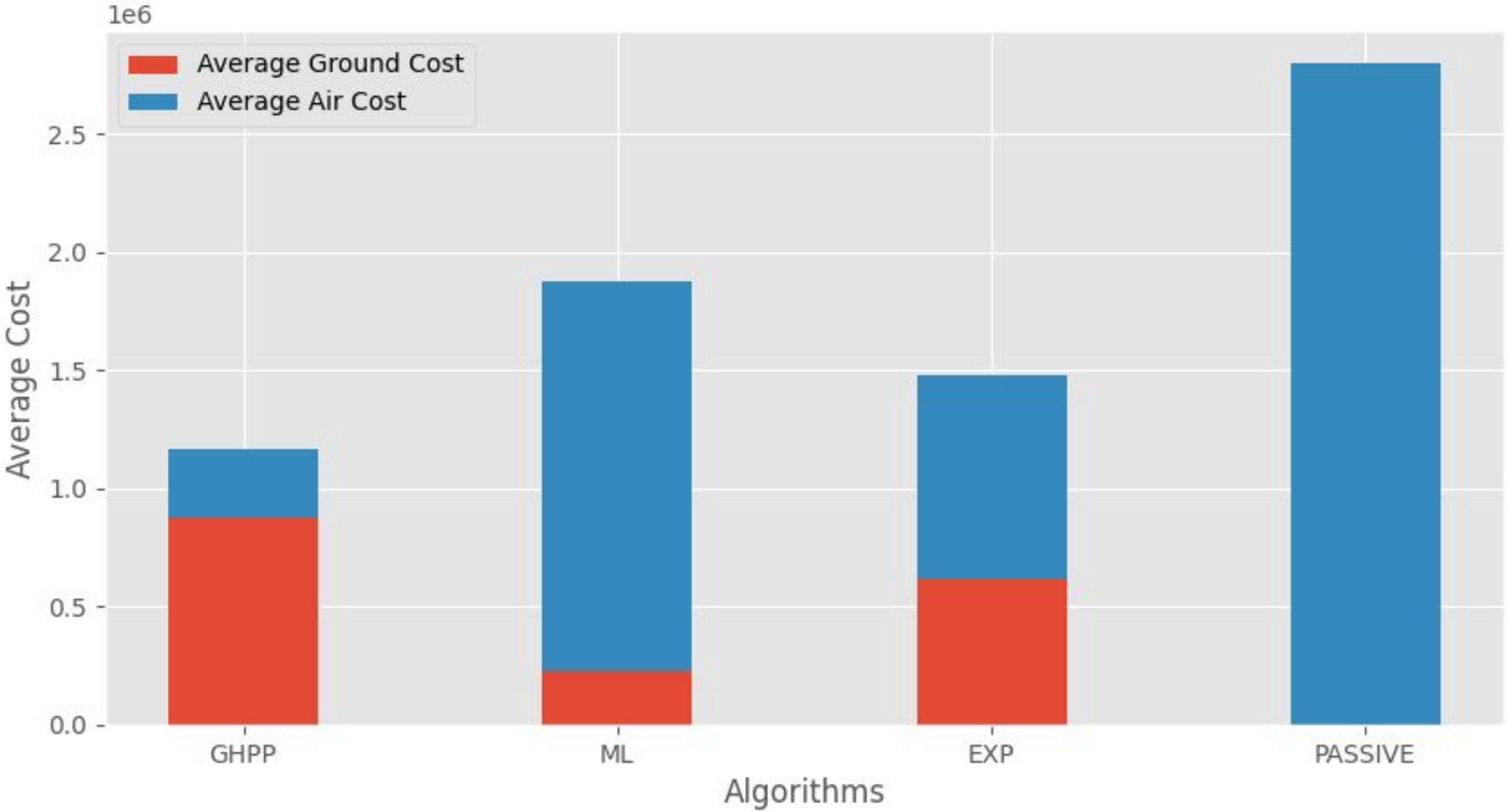
Effect of Cost : 500$/period



Effect of Cost : 600$/period



Effect of Cost : 750$/period



Distribution of Ground Holding

Scenario 1