Optimal Plan for three problems, using A* with Level_Sum, has the least steps for each

Problem	Expansions	Goal Tests	New Nodes	Time elapsed (s)	Plan

Air Cargo Problem 1	11	13	50	6
				1.1693 (s)
					Load(C1, P1, SFO)
					Fly(P1, SFO, JFK)
					Load(C2, P2, JFK)
					Fly(P2, JFK, SFO)
					Unload(C1, P1, JFK)
					Unload(C2, P2, SFO)

Air Cargo Problem 2	86	88	841	9
				270.9082 (s)
					Load(C1, P1, SFO)
					Fly(P1, SFO, JFK)
					Load(C2, P2, JFK)
					Fly(P2, JFK, SFO)
					Load(C3, P3, ATL)
					Fly(P3, ATL, SFO)
					Unload(C3, P3, SFO)
					Unload(C1, P1, JFK)
					Unload(C2, P2, SFO)

Air Cargo Problem 3	316	318	2912	12
				1432.9302(s)
					Load(C2, P2, JFK)
					Fly(P2, JFK, ORD)
					Load(C4, P2, ORD)
					Fly(P2, ORD, SFO)
					Load(C1, P1, SFO)
					Fly(P1, SFO, ATL)
					Load(C3, P1, ATL)
					Fly(P1, ATL, JFK)
					Unload(C4, P2, SFO)
					Unload(C3, P1, JFK)
					Unload(C2, P2, SFO)
					Unload(C1, P1, JFK)

Comparison table for problems:1, 2 and 3, for Breath-first, Depth-first, Greedy and A* searches

Problem	Search	Expansions	Goal Tests	New Nodes	Time elapsed	Time (s)	Optimality Score
Problem1	Breath-first	43	56	180	6	0.0348	
Problem1	Depth-first	21	22	84	20	0.0166	worst
Problem1	Greedy	7	9	28	6	0.0069	best
Problem1	A* with h_1	55	57	224	6	0.0419	
Problem1	Uniform_cost	55	57	224	6	0.0414	
Problem2	Breath-first	3343	4609	30509	9	10.2550	best
Problem2	Depth-first	624	625	5602	619	3.8864	worst
Problem2	Greedy	998	1000	8982	10	2.7286	
Problem2	A* with h_1	4853	4855	44041	9	13.35194	
Problem2	Uniform_cost	4853	4855	44041	9	13.5759	
Problem3	Breath-first	14663	18098	129631	12	48.5210	best
Problem3	Depth-first	408	409	3364	392	1.9732	worst
Problem3	Greedy	5578	5580	49150	22	18.19545	
Problem3	A* with h_1	18223	18225	159618	12	63.50522	
Problem3	Uniform_cost	18223	18225	159618	12	59.9502	

Note: Depth First search results in way many steps plan to reach to goal and is least optimal, meantime for each problem, the best Heuristic is marked in the Optimality score column, it seems it really depends to the problem which method will results in the best step counts and the computational resources needed to get the plan.

Comparison heuristic search results with A* with “ignore Preconditions” and “Level_sum”

Problem	Search	Expansions	Goal Tests	New Nodes	Time elapsed	Time (s)	Optimality
Problem1	A* with ignore Preconditions	41	43	170	6	0.04014	worst
Problem1	A* with Level_sum	11	13	50	6	1.1693	better
Problem2	A* with ignore Preconditions	1450	1452	13303	9	4.9917	worst
Problem2	A* with Level_sum	86	88	841	9	270.9082	better
Problem3	A* with ignore Preconditions	5040	5042	44944	12	18.8553	worst
Problem3	A* with Level_sum	316	318	2912	12	1432.9302	better

Note: it seems that Level_sum needs more run time to generate the results but, has fewer Expansion and Goal Tests also new nodes. Also worth to mention that both methods for A* produced plans with same number of steps for all 3 problems. [1] this can be explained by that A* finds the best path from the current state to the goal by minimizing the Hubristic function, here Level_Sum plays this role, which is how many minimum levels we need to pars to be able to reach to all the goals. A* is an optimal , since the heuristic function level_sum used in this case is admissible. [2]

[1] A* Search in lesson 9

[2] AIMA Chapter 3.5.2