Problem 1

a)

Planner used A star. The state defined by (row, col, time).

Creating the heuristic Map:

Before beginning the planner, a heuristic map of the whole grid is created. This is done by representing all the goal nodes as one, and running a dijkstra on the grid in reverse direction, but with no final goal. In this way the Dijkstra will spread throughout the grid and the G values of each cell would be saved in a hashmap as heuristic values. This map is used during Astar planning.

Astar Loop:

With every iteration the node with lowest F value is expanded in all five directions. Further hashmap is created for both open and closed list. If the new node created is already present in the closed the list then it is not added to open list. And if the same node with lower cost is present in open list then also it is not added to open list.

For problem 0

Cost of path = 8

Number of states expanded = 21

For Problem 1

Number of states expanded > 100000

b)

Putting weight on the heuristic increases the speed of A*.

For problem 0

Cost of path = 8

Number of states expanded = 16

Problem 2
2.1
a)
h(s) = min(h1(s),h2(s))
For consistency
h(s) <= c(s,s’) + h(s’) where s’ is successor state

Since h1 and h2 consistent:
therefore:
h1(s) <= c(s,s’) + h1(s’) …… (1)
h2(s) <= c(s,s’) + h2(s’) …….(2)
Now if ‘s’ lie in a region 1 where h2(s) < h1(s) ….. (3),
This implies from (1) and (3):
h2(s) < h1(s) <= c(s,s’) + h1(s’) … (4)
I.e.
min(h2(s),h1(s)) <= c(s,s’) + h1(s’)
Vice -versa for h1(s) < h2(s) in region 1 could also be showed,
Further manipulating region of ‘ s’ ‘ (such that either h1(s’) > h2(s’) or vice versa) would lead to (2) or (4)
Thus,
min(h2(s),h1(s)) <= c(s,s’) + min(h2(s’),h1(s’))
h(s) <= c(s,s’) + h(s)
And thus h(s) is consistent

b)
using the same terminology as part a)
Since h1 and h2 consistent:
therefore:
h1(s) <= c(s,s’) + h1(s’) …… (1)
h2(s) <= c(s,s’) + h2(s’) …….(2)

Now if ‘s’ ’ lie in a region 2 where h2(s) < h1(s) ….. (3),
Thus implying from (2) and (3)
h2(s) <= c(s,s’) + h2(s’) < c(s,s’) + h1(s’) …….(4)
h2(s) <= c(s,s’) + max(h1(s’),h2(s’))
Vice -versa for h1(s’) > h2(s’) in region 1 could also be showed,
Further manipulating region of ‘ s ‘ (such that either h1(s) > h2(s) or vice versa) would lead to (1) or (4)

Thus,

$\max(h2(s),h1(s)) <= c(s,s') + \max(h2(s'),h1(s'))$
$h(s) <= c(s,s') + h(s)$
And thus h(s) is consistent

2.2
b) Monotonically non decreasing sequence. This follows from the consistency condition of heuristic function.
2.3
c) Monotonically increasing sequence.
2.4
e) True