Traffic Norms Description

Vineel Tummala and Daniela Inclezan

May 2024

1 Introduction

This domain is created on the idea of a fully autonomous self-driving agent. This agent will be moving in a closed environment by following certain rules to move from a starting point to a destination.

1.1 Dynamic Domain

1.1.1 Simplifying Assumptions

- The speed ranges over a set of values, initially set to $\{0, 15, 25, 45, 65, 85\}$, then incremented to $\{0, 5, 15, 25, 35, 45, 55, 65, 75, 85, 95\}$
- This is a closed environment with 14 locations.
- There are 6 intersections.
- There are three traffic light signal colors: red, yellow, and green.
- There is only one *Do Not Enter* sign location in the domain.
- There is only one*Stop* sign location in the domain.
- There is one location where a school bus may be stopped.

1.1.2 Objects

The following objects have been used for this domain: fourteen (14) locations, labeled from 1 to 14; driving speeds specified as $speed(0; 15; 25; 45; 65; 85)$; traffic light colors represented by $color(red)$, $color(yellow)$, $color(green)$; and traffic signs represented by $sign(stop)$ and $sign(do\_not\_enter)$.

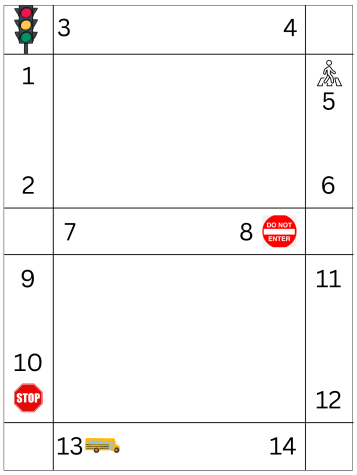

Figure 1: Self-Driving Agent Domain

1.1.3 Statics

In ASP, statics are properties that do not change over time or across different situations.

1. The static $is\_sign(S, L1, L2)$ is used to specify the location of a sign, where S represents the type of sign, located between locations $L1$ and $L2$.
2. The static $connected(X, Y)$ is used to specify if two locations X and Y are connected with each other.
3. The static $intersection(X, Y)$ is used to specify whether two connected locations X and Y are connected by an intersection.

1.1.4 Fluents

This self-driving domain also has fluents that are used to describe the state of the environment.

1. The fluent $has\_speed(S)$, is used to define the speed S of the agent while moving.
2. The fluent $at\_loc(L)$, is used to define where the agent is located with symbol L.
3. The fluent $light\_color(C, L1, L2)$ is used to determine the color of the traffic light, where C is the light color, and the traffic light is located between locations $L1$ and $L2$.
4. The fluent $school\_bus\_is\_stopped(L1, L2)$ indicates that the school bus is located and is stopped between locations $L1$ and $L2$.

5. The fluent *pedestrians_are_crossing*(L) is used to specify a location L where pedestrians are crossing.

1.1.5 Actions

The agent itself has two actions, one is to drive and the other one is to stop: *drive*(L_1, L_2, S) – drive from L_1 to L_2 at speed S, ans *stop*(L) – stop at location L.

1.2 Policy

The policy of this domain contains various types of rules to demonstrate the full capacity of the planning algorithm of the self-driving agent. There are strict and defeasible variations of authorization and obligation policies. To fully understand these rules, policies will now be given in plain English.

1. The agent is constrained by a defeasible rule that does *not permit* exceeding the speed limit by more than 5 mph if the speed limit is under 55 mph.

   Penalty: Penalties for violating this rule are applied as follows: a 1-point penalty is imposed if the speed exceeds the limit by more than 5 mph but less than 10 mph; a 2-point penalty is imposed for exceeding the speed limit by 10 to 20 mph; and a 3-point penalty is imposed for exceeding the speed limit by more than 20 mph.

2. The agent is constrained by a defeasible rule that does *not permit* exceeding the speed limit by more than 10 mph when the speed limit is 55 mph or higher.

   Penalty: Penalties for violating this rule are applied as follows: a 2-point penalty is imposed if the speed exceeds the limit by 10 to 20 mph, and a 3-point penalty is imposed for exceeding the speed limit by more than 20 mph.

3. The agent is strictly *obligated not* to enter the roads marked as "Do Not Enter."

   Penalty: A violation of this obligation imposes a 3-point penalty.

4. The agent is strictly *not permitted* to roll over a stop sign.

   Penalty: A violation of this rule imposes a 2-point penalty.

5. The agent is strictly *obligated not* to move when a school bus is stopped.

   Penalty: A violation of this obligation imposes a 50-point penalty because it may incur direct harm to humans.

6. The agent is strictly *obligated* to stop at pedestrian crossings when pedestrians are present.

Penalty: A violation of this obligation imposes a 50-point penalty because it may incur direct harm to humans.

7. The agent is *permitted* by a defeasible rule to proceed through an intersection when the traffic light turns green.

8. The agent is *permitted* by a defeasible rule to drive when the traffic light is yellow.

9. The agent is strictly *obligated not* to cross an intersection when the traffic light is red.

   Penalty: A violation of this obligation imposes a 3-point penalty.

10. Rule 1 overrides rules 7 and 8.

11. Rule 2 overrides rules 7 and 8.

2 Planning Scenarios

Below, we present all the scenarios we evaluated. The fixed rules are *Do Not Enter* sign at location 8 and a *Stop* sign at location 10. In the figures, the start sign indicates the starting location of the agent and the final location is indicated by the finish sign. The agent is shown at the finish line (i.e., end of plan) in the figures shown below.

2.1 Scenario 1

In this scenario, the agent's goal is to drive from location 6 to location 10. The compliance with a "Do Not Enter" sign between locations 6 and 8 and a school bus scenario between locations 14 and 13 is evaluated, Assessing in both emergency and non-emergency situations.

2.1.1 Emergency Situation Plan

```
Actions and Events:
  occurs(drive(6,8,45),0)
  occurs(drive(8,7,85),1)
  occurs(drive(7,9,45),2)
  occurs(drive(9,10,65),3)

Penalties Applied:
  add_penalty(r1(6,8,45,15),3,0)
  add_penalty(r3(6,8,45),3,0)
  add_penalty(r1(8,7,85,45),3,1)
  add_penalty(r1(7,9,45,15),3,2)
  add_penalty(r1(9,10,65,25),3,3)
  cumulative_penalty(15)
```

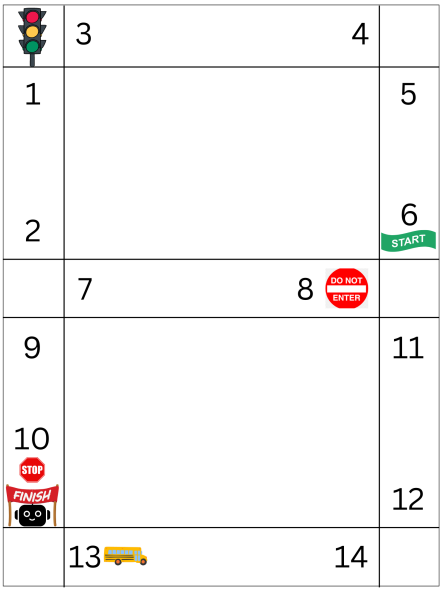

Figure 2: Scenario 1

```
Time Added:
  add_time(10,0)
  add_time(5,1)
  add_time(10,2)
  add_time(5,3)
  cumulative_time(30)
```

2.1.2 Non-Emergency Situation Plan

```
Actions and Events:
  occurs(drive(6,11,15),0)
  occurs(drive(11,12,65),1)
  occurs(drive(12,14,15),2)
  occurs(stop(14),3)
  occurs(drive(14,13,25),4)
  occurs(drive(13,10,15),5)

Penalties Applied:
  cumulative_penalty(0)

Time Added:
  add_time(15,0)
  add_time(5,1)
```

```
  add_time(15,2)
  add_time(2,3)
  add_time(15,4)
  add_time(15,5)
  cumulative_time(67)
```

2.2 Scenario 2

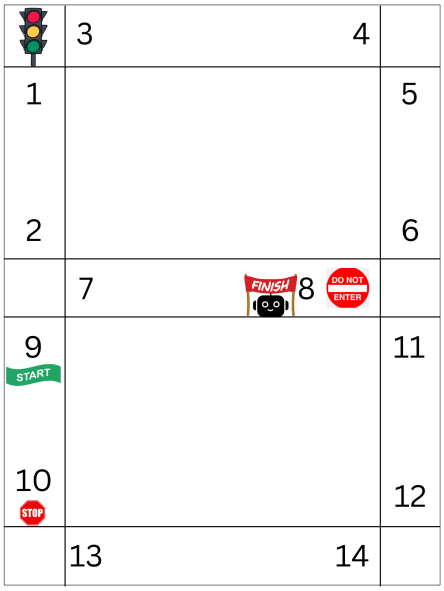

Figure 3: Scenario 2

In this scenario, the agent's goal is to drive from location 9 to location 8. A new planning rule is tested that dictates stop actions should be executed as late as necessary. Assessing in both emergency and non-emergency situations.

2.2.1 Emergency Situation

```
Actions and Events:
  occurs(drive(9,7,45),0)
  occurs(drive(7,8,85),1)

Penalties Applied:
  add_penalty(r1(9,7,45,15),3,0)
  add_penalty(r1(7,8,85,45),3,1)
  cumulative_penalty(6)

Time Added:
```

```
  add_time(10,0)
  add_time(5,1)
  cumulative_time(15)
```

2.2.2 Non-Emergency Situation

```
Actions and Events:
  occurs(drive(9,7,15),0)
  occurs(drive(7,8,45),1)

Penalties Applied:
  cumulative_penalty(0)

Time Added:
  add_time(15,0)
  add_time(10,1)
  cumulative_time(25)
```

2.3 Scenario 3

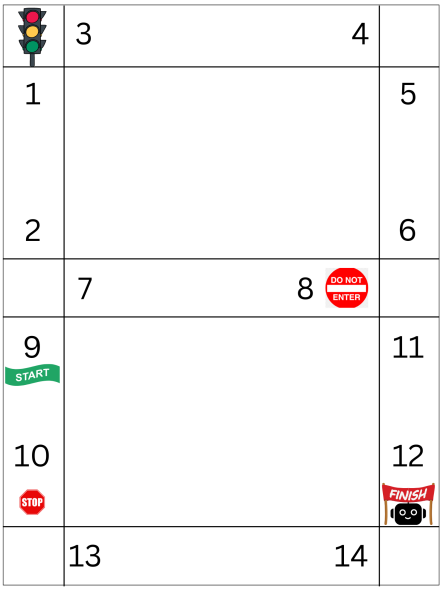

Figure 4: Scenario 3

In this scenario, the agent's goal is to drive from location 9 to location 12. The focus is on testing adherence to speed limit regulations under both emergency and non-emergency conditions. In this scenario, we assess compliance with the speed limits (r1) and (r2).

2.3.1 Emergency Situation

```
Actions and Events:
  occurs(drive(9,7,45),0)
  occurs(drive(7,8,85),1)
  occurs(drive(8,11,45),2)
  occurs(drive(11,12,65),3)

Penalties Applied:
  add_penalty(r1(9,7,45,15),3,0)
  add_penalty(r1(7,8,85,45),3,1)
  add_penalty(r1(8,11,45,15),3,2)
  cumulative_penalty(9)

Time Added:
  add_time(10,0)
  add_time(5,1)
  add_time(10,2)
  add_time(5,3)
  cumulative_time(30)
```

2.3.2 Non-Emergency Situation

```
Actions and Events:
  occurs(drive(9,7,15),0)
  occurs(drive(7,8,45),1)
  occurs(drive(8,11,15),2)
  occurs(drive(11,12,65),3)

Penalties Applied:
  cumulative_penalty(0)

Time Added:
  add_time(15,0)
  add_time(10,1)
  add_time(15,2)
  add_time(5,3)
  cumulative_time(45)
```

2.4 Scenario 4

In this scenario, the agent's goal is to drive from location 9 to location 14. Interactions with a school bus present between locations 13 and 14 at times 2 and 3 are incorporated, assessing compliance with stop sign policy (r4) and school bus presence (r5).

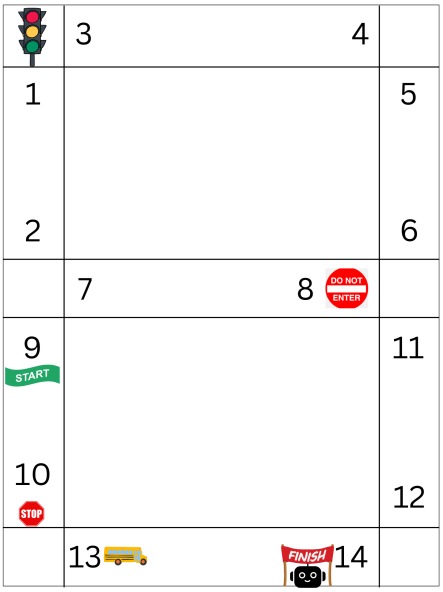

Figure 5: Scenario 4

2.4.1 Emergency Situation

```
Actions and Events:
  occurs(drive(9,10,85),0)
  occurs(stop(10),1)
  occurs(drive(10,13,45),2)
  occurs(stop(13),3)
  occurs(drive(13,14,85),4)

Penalties Applied:
  add_penalty(r1(9,10,85,25),3,0)
  add_penalty(r1(10,13,45,15),3,2)
  add_penalty(r1(13,14,85,25),3,4)
  cumulative_penalty(9)

Time Added:
  add_time(5,0)
  add_time(2,1)
  add_time(10,2)
  add_time(2,3)
  add_time(5,4)
  cumulative_time(24)
```

2.4.2 Non-Emergency Situation

```
Actions and Events:
  occurs(drive(9,10,25),0)
  occurs(stop(10),1)
  occurs(drive(10,13,15),2)
  occurs(stop(13),3)
  occurs(drive(13,14,15),4)

Penalties Applied:
  cumulative_penalty(0)

Time Added:
  add_time(15,0)
  add_time(2,1)
  add_time(15,2)
  add_time(2,3)
  add_time(15,4)
  cumulative_time(49)
```

2.5 Scenario 5

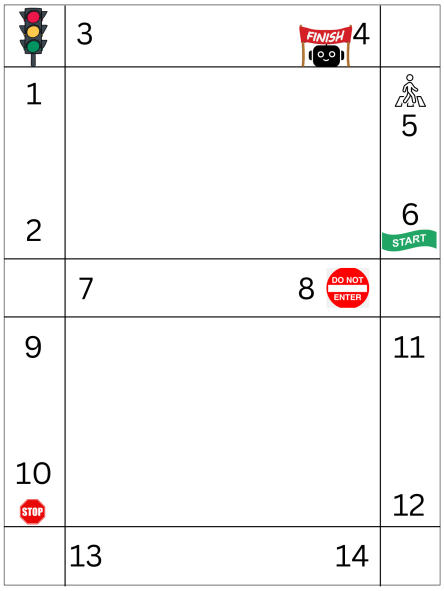

Figure 6: Scenario 5

In this scenario, the agent's goal is to drive from location 6 to location 4. The policy rules concerning pedestrian crossings (r6) at location 5, time 1, is

assessed and explored through both emergency and non-emergency tests.

2.5.1 Emergency Situation

```
Actions and Events:
  occurs(drive(6,5,85),0)
  occurs(stop(5),1)
  occurs(drive(5,4,45),2)

Penalties Applied:
  add_penalty(r1(6,5,85,25),3,0)
  add_penalty(r1(5,4,45,15),3,2)
  cumulative_penalty(6)

Time Added:
  add_time(5,0)
  add_time(2,1)
  add_time(10,2)
  cumulative_time(17)
```

2.5.2 Non-Emergency Situation

```
Actions and Events:
  occurs(drive(6,5,25),0)
  occurs(stop(5),1)
  occurs(drive(5,4,15),2)

Penalties Applied:
  cumulative_penalty(0)

Time Added:
  add_time(15,0)
  add_time(2,1)
  add_time(15,2)
  cumulative_time(32)
```

2.6 Scenario 6

In this scenario, the agent's goal is to drive from location 4 to location 2. Adherence to the pedestrian crossing policy (r6) at location 3, time step 1, is assessed and explored in both emergency and non-emergency situations.

2.6.1 Emergency Situation

```
Actions and Events:
  occurs(drive(4,3,65),0)
  occurs(stop(3),1)
```

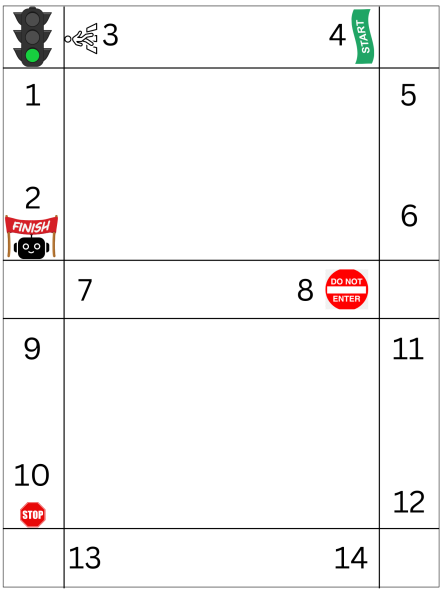

Figure 7: Scenario 6

```
  occurs(drive(3,1,45),2)
  occurs(drive(1,2,85),3)

Penalties Applied:
  add_penalty(r1(3,1,45,15),3,2)
  add_penalty(r1(1,2,85,45),3,3)
  cumulative_penalty(6)

Time Added:
  add_time(5,0)
  add_time(2,1)
  add_time(10,2)
  add_time(5,3)
  cumulative_time(22)
```

2.6.2 Non-Emergency Situation

```
Actions and Events:
  occurs(drive(4,3,65),0)
  occurs(stop(3),1)
  occurs(drive(3,1,15),2)
  occurs(drive(1,2,45),3)

Penalties Applied:
```

```
  cumulative_penalty(0)

Time Added:
  add_time(5,0)
  add_time(2,1)
  add_time(15,2)
  add_time(10,3)
  cumulative_time(32)
```

2.7 Scenario 7

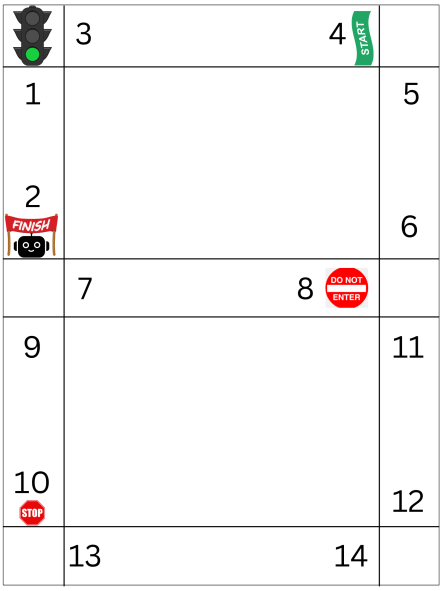

Figure 8: Scenario 7

In this scenario, the agent's goal is to drive from location 4 to location 2. The policy rules concerning the green light (r7) at location 3, time step 1, is assessed and explored through both emergency and non-emergency tests.

2.7.1 Emergency Situation

```
Actions and Events:
  occurs(drive(4,3,65),0)
  occurs(drive(3,1,45),1)
  occurs(drive(1,2,85),2)

Penalties Applied:
  add_penalty(r1(3,1,45,15),3,1)
```

```
  add_penalty(r1(1,2,85,45),3,2)
  cumulative_penalty(6)

Time Added:
  add_time(5,0)
  add_time(10,1)
  add_time(5,2)
  cumulative_time(20)
```

2.7.2 Non-Emergency Situation

```
Actions and Events:
  occurs(drive(4,3,65),0)
  occurs(drive(3,1,15),1)
  occurs(drive(1,2,45),2)

Penalties Applied:
  cumulative_penalty(0)

Time Added:
  add_time(5,0)
  add_time(15,1)
  add_time(10,2)
  cumulative_time(30)
```

2.8 Scenario 8

In this scenario, the agent's goal is to drive from location 4 to location 2. Adherence to the yellow traffic light policy (r8) at location 3, time 1, and pedestrian crossing (r6) at location 3, time 1, are assessed and explored in both emergency and non-emergency situations.

2.8.1 Emergency Situation

```
Actions and Events:
  occurs(drive(4,3,65),0)
  occurs(stop(3),1)
  occurs(drive(3,1,45),2)
  occurs(drive(1,2,85),3)

Penalties Applied:
  add_penalty(r1(3,1,45,15),3,2)
  add_penalty(r1(1,2,85,45),3,3)
  cumulative_penalty(6)

Time Added:
```

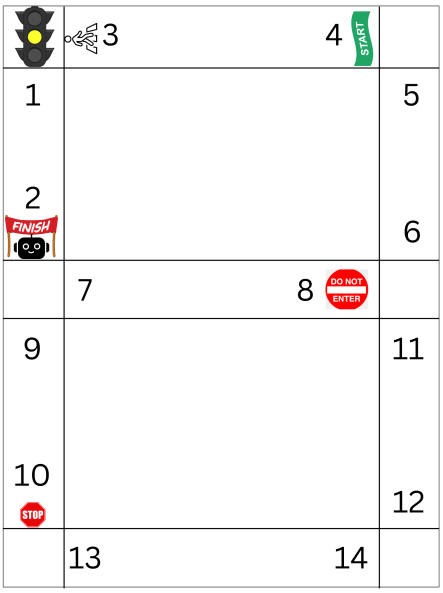

Figure 9: Scenario 8

```
  add_time(5,0)
  add_time(2,1)
  add_time(10,2)
  add_time(5,3)
  cumulative_time(22)
```

2.8.2 Non-Emergency Situation

```
Actions and Events:
  occurs(drive(4,3,65),0)
  occurs(stop(3),1)
  occurs(drive(3,1,15),2)
  occurs(drive(1,2,45),3)

Penalties Applied:
  cumulative_penalty(0)

Time Added:
  add_time(5,0)
  add_time(2,1)
  add_time(15,2)
  add_time(10,3)
  cumulative_time(32)
```

2.9 Scenario 9

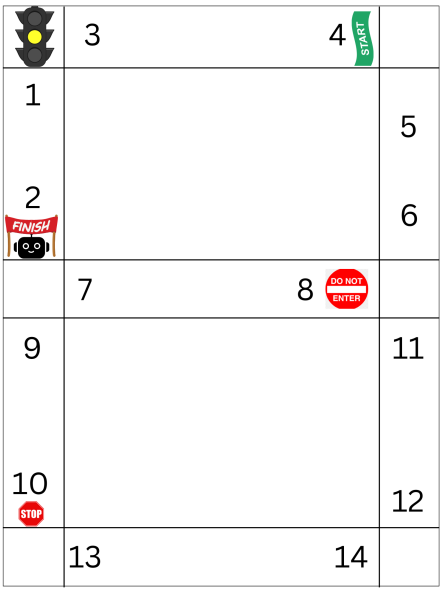

Figure 10: Scenario 9

In this scenario, the agent's goal is to drive from location 4 to location 2. Adherence to the yellow traffic light policy (r8) at location 3, time 1, is assessed and explored in both emergency and non-emergency situations.

2.9.1 Emergency Situation

```
Actions and Events:
  occurs(drive(4,3,65),0)
  occurs(drive(3,1,45),1)
  occurs(drive(1,2,85),2)

Penalties Applied:
  add_penalty(r1(3,1,45,15),3,1)
  add_penalty(r1(1,2,85,45),3,2)
  cumulative_penalty(6)

Time Added:
  add_time(5,0)
  add_time(10,1)
  add_time(5,2)
  cumulative_time(20)
```

2.9.2 Non-Emergency Situation

```
Actions and Events:
  occurs(drive(4,3,65),0)
  occurs(drive(3,1,15),1)
  occurs(drive(1,2,45),2)

Penalties Applied:
  cumulative_penalty(0)

Time Added:
  add_time(5,0)
  add_time(15,1)
  add_time(10,2)
  cumulative_time(30)
```

2.10 Scenario 10

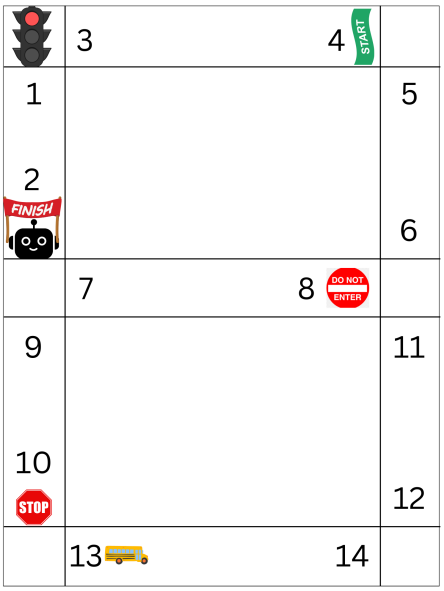

Figure 11: Scenario 10

In this scenario, the agent's goal is to drive from location 4 to location 2. Adherence to the red traffic light policy (r9) at location 3, time 1, is assessed and explored in both emergency and non-emergency situations.

2.10.1 Emergency Situation

```
Actions and Events:
  occurs(drive(4,3,65),0)
  occurs(drive(3,1,45),1)
  occurs(drive(1,2,85),2)

Penalties Applied:
  add_penalty(r1(3,1,45,15),3,1)
  add_penalty(r9(3,1,45),3,1)
  add_penalty(r1(1,2,85,45),3,2)
  cumulative_penalty(9)

Time Added:
  add_time(5,0)
  add_time(10,1)
  add_time(5,2)
  cumulative_time(20)
```

2.10.2 Non-Emergency Situation

```
Actions and Events:
  occurs(drive(4,3,65),0)
  occurs(stop(3),1)
  occurs(drive(3,1,15),2)
  occurs(drive(1,2,45),3)

Penalties Applied:
  cumulative_penalty(0)

Time Added:
  add_time(5,0)
  add_time(2,1)
  add_time(15,2)
  add_time(10,3)
  cumulative_time(32)
```