

# Planning Results for the Warehouse-Crates Domain

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## Overview

This document summarizes the output generated by the planning engine for **the PDDL domain-124 and domain-3 (only for Problem 2) of the project**. Each problem instance is presented with its plan visualization, execution timeline, and battery usage graph (only for Problem 2). Before detailing individual problems, we first present a summary table of key planning statistics for all available problems in Table 1. As we can see in Problem 3, the states evaluated is significantly larger than for the other problems. After some experimentation, we found that changing the weight on Crate 3 from 60 kg to 40 kg, effectively changing it from a heavy to a light crate, the number of states evaluated was reduced to 76. This suggests that the solver struggles with problems containing more than 2 heavy crates.

Metric	Problem 0.5	Problem 1	Problem 2	Problem 3	Problem 4
<b>Total Metric</b>	20.508	25.377	38.711	64.914	37.652
<b>Makespan</b>	18.508	23.377	36.711	63.914	35.652
<b>States Evaluated</b>	55	83	82	27173	189
<b>Planning Time (sec)</b>	33.580	33.844	33.666	33.700	34.115

Table 1: Planning Statistics Summary, retrieved from domain-124

Table 2 illustrates the planning statistics summary from domain 3 for problem 2 and problem 4. The reason problem 0.5 and problem 1 is not included the results, is that these problems do not require any charging of the movers to be solved. The reason problem 3 is elaborated in "4. *Problem 3*".

Metric	Problem 2	Problem 4
<b>Total Metric</b>	53.916	47.518
<b>Makespan</b>	53.916	47.518
<b>States Evaluated</b>	4745	446
<b>Planning Time (sec)</b>	33.281	33.032

Table 2: Planning Statistics Summary, retrieved from domain-3

## 1 Problem 0.5

Table 3, Figure 1, and Figure 2 show the plan for Problem 0.5, including a structured action table, a visual timeline, and object-specific execution details.

Start Time	Action	Duration
0.0000	(move_empty m1 c2)	2.00
0.0000	(move_empty m2 c1)	1.00
0.0000	(activate_group a c2)	0.00
2.0010	(mover_pick_single m1 c2)	0.10
2.1020	(move_crate_single m1 c2)	4.00
6.1030	(put_down_to_full_loader_single m1 fl c2)	0.10
6.2040	(full_loader_pick_grouped_crate fl c2 a)	0.10
6.2040	(move_empty m1 c1)	1.00
6.2050	(deactivate_groups a c1)	0.00
6.3050	(full_load_normal_crate fl c2)	4.00
7.2050	(mover_pick_dual m2 m1 c1)	0.10
7.3050	(move_crate_dual_heavy m2 m1 c1)	7.00
14.3060	(put_down_to_full_loader_dual m2 m1 fl c1)	0.10
14.4070	(full_loader_pick_ungrouped_crate fl c1)	0.10
14.5080	(full_load_normal_crate fl c1)	4.00

Table 3: Action Table for Problem 0.5

	Actions involving m1 only
	Actions involving m2 only
	Dual actions involving m1 & m2
	Loader (fl) actions

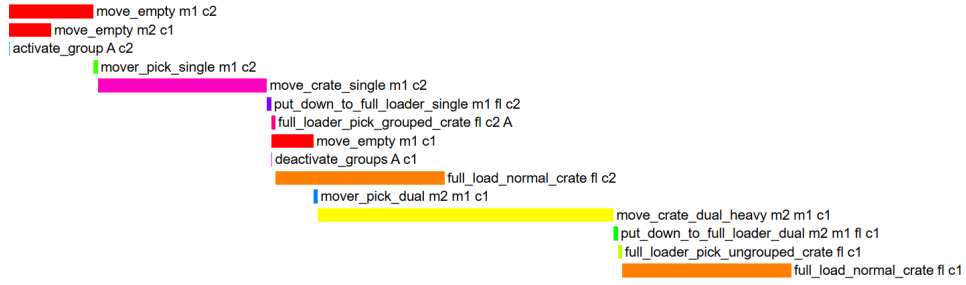


Figure 1: Plan visualization for Problem 0.5



Figure 2: Object-wise Execution Timeline for Problem 0.5

## 2 Problem 1

Table 4, Figure 3, and Figure 4 show the plan for Problem 1, including a structured action table, a visual timeline, and object-specific execution details.

Start Time	Action	Duration
0.0000	(move_empty m1 c3)	2.00
0.0000	(move_empty m2 c2)	2.00
0.0000	(activate_group a c2)	0.00
2.0010	(mover_pick_single m1 c3)	0.10
2.1020	(move_crate_single m1 c3)	4.00
6.1030	(put_down_to_full_loader_single m1 fl c3)	0.10
6.2040	(move_empty m1 c2)	2.00
6.2040	(full_loader_pick_grouped_crate fl c3 a)	0.10
6.3050	(full_load_normal_crate fl c3)	4.00
8.2050	(mover_pick_dual m2 m1 c2)	0.10
8.3050	(move_crate_dual_light m2 m1 c2)	2.67
10.9720	(put_down_to_full_loader_dual m2 m1 fl c2)	0.10
11.0730	(full_loader_pick_grouped_crate fl c2 a)	0.10
11.0730	(move_empty m1 c1)	1.00
11.0730	(move_empty m2 c1)	1.00
11.0740	(deactivate_groups a c1)	0.00
11.1740	(full_load_fragile_crate fl c2)	6.00
12.0740	(mover_pick_dual m2 m1 c1)	0.10
12.1740	(move_crate_dual_heavy m2 m1 c1)	7.00
19.1750	(put_down_to_full_loader_dual m2 m1 fl c1)	0.10
19.2760	(full_loader_pick_ungrouped_crate fl c1)	0.10
19.3770	(full_load_normal_crate fl c1)	4.00

Table 4: Action Table for Problem 1



Figure 3: Visual Action Timeline for Problem 1



Figure 4: Object-wise Execution Timeline for Problem 1

### 3 Problem 2

#### 3.1 Domain-124

Table 5, Figure 5, and Figure 6 show the plan for Problem 2, including a structured action table, a visual timeline, and object-specific execution details.

	Actions involving m1 only
	Actions involving m2 only
	Dual actions involving m1 & m2
	Loader or side loader actions (fl, sl)

Start Time	Action	Duration
0.0000	(activate_group b c3)	0.00
0.0000	(move_empty m1 c4)	1.00
0.0000	(move_empty m2 c3)	2.00
1.0010	(mover_pick_single m1 c4)	0.10
1.1020	(move_crate_single m1 c4)	3.00
2.0010	(mover_pick_single m2 c3)	0.10
2.1020	(move_crate_single m2 c3)	4.00
4.1030	(put_down_to_full_loader_single m1 fl c4)	0.10
4.2040	(full_loader_pick_grouped_crate fl c4 b)	0.10
4.2040	(move_empty m1 c2)	2.00
4.3050	(full_load_normal_crate fl c4)	4.00
6.1030	(put_down_to_side_loader_single m2 sl c3)	0.10
6.2040	(side_loader_pick_grouped_crate sl c3 fl c4 b)	0.10
6.2040	(move_empty m2 c2)	2.00
6.3050	(side_load_normal_crate sl c3)	4.00
8.2050	(mover_pick_dual m2 m1 c2)	0.10
8.3050	(move_crate_dual_heavy m2 m1 c2)	16.00
24.3060	(put_down_to_full_loader_dual m2 m1 fl c2)	0.10
24.4070	(move_empty m1 c1)	1.00
24.4070	(move_empty m2 c1)	1.00
25.4080	(mover_pick_dual m2 m1 c1)	0.10
25.5070	(switch_group b a c1)	0.00
25.5080	(move_crate_dual_heavy m2 m1 c1)	7.00
26.4070	(full_loader_pick_grouped_crate fl c2 a)	0.10
26.5080	(full_load_fragile_crate fl c2)	6.00
32.5090	(put_down_to_full_loader_dual m2 m1 fl c1)	0.10
32.6100	(full_loader_pick_grouped_crate fl c1 a)	0.10
32.7110	(full_load_normal_crate fl c1)	4.00

Table 5: Action Table for Problem 2



Figure 5: Visual Action Timeline for Problem 2



Figure 6: Object-wise Execution Timeline for Problem 2

### 3.2 Domain-3

Table 6, Figure 7 - 9 show the plan for **Problem 2 with only extension 3**, including a structured action table, a visual timeline, and object-specific execution details.

In this implementation, the action to charge movers "full\_charge\_mover" always charge movers to their full capacity. Implemented this way, one iteration of the action is enough to charge, which is simpler for the planner. However, one can find another implementation in the code (commented in the action, lines 239 and 250), which enables to charge a mover unit by unit. Thus, the battery is charged in order to reach exactly the battery needed to achieve its tasks. Thereby, the charging duration is minimized, and so is the overall duration of the planning.



Figure 7: Visual Action Timeline for Problem 2 with extension 3

Start Time	Action	Duration
0.0000	(move_empty m1 c1)	1.00
0.0000	(move_empty m2 c4)	1.00
1.0010	(mover_pick_single m2 c4)	0.10
1.1020	(move_crate_single m2 c4)	3.00
4.1030	(put_down_to_loader_single m2 l c4)	0.10
4.2040	(loader_pick_crate l c4)	0.10
4.2040	(move_empty m2 c3)	2.00
4.3050	(load_crate l c4)	4.00
6.2050	(mover_pick_single m2 c3)	0.10
6.3050	(move_crate_single m2 c3)	4.00
10.3060	(put_down_to_loader_single m2 l c3)	0.10
10.4070	(loader_pick_crate l c3)	0.10
10.4070	(move_empty m2 c1)	1.00
10.5080	(load_crate l c3)	4.00
11.4080	(mover_pick_dual m2 m1 c1)	0.10
11.5080	(move_crate_dual_heavy m2 m1 c1)	7.00
18.5090	(put_down_to_loader_dual m2 m1 l c1)	0.10
18.6100	(loader_pick_crate l c1)	0.10
18.6100	(full_charge_mover m1 st1)	4.00
18.7110	(load_crate l c1)	4.00
22.6110	(move_empty m1 c2)	2.00
22.6110	(full_charge_mover m2 st1)	9.00
31.6120	(move_empty m2 c2)	2.00
33.6130	(mover_pick_dual m2 m1 c2)	0.10
33.7130	(move_crate_dual_heavy m2 m1 c2)	16.00
49.7140	(put_down_to_loader_dual m2 m1 l c2)	0.10
49.8150	(loader_pick_crate l c2)	0.10
49.9160	(load_crate l c2)	4.00

Table 6: Action Table for Problem 2 with extension 3

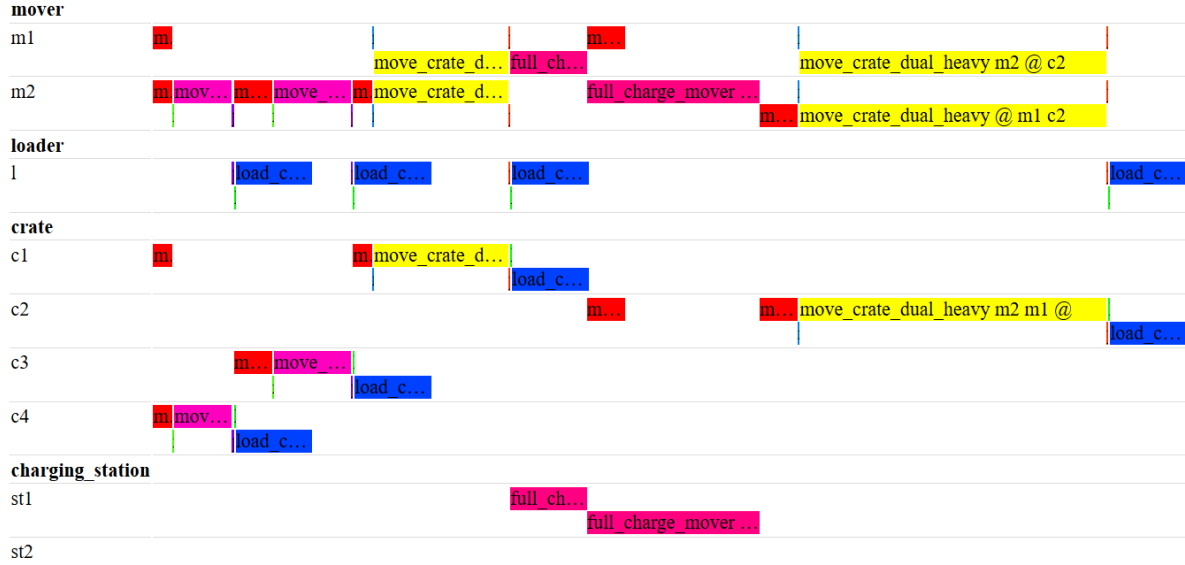


Figure 8: Object-wise Execution Timeline for Problem 2 with extension 3



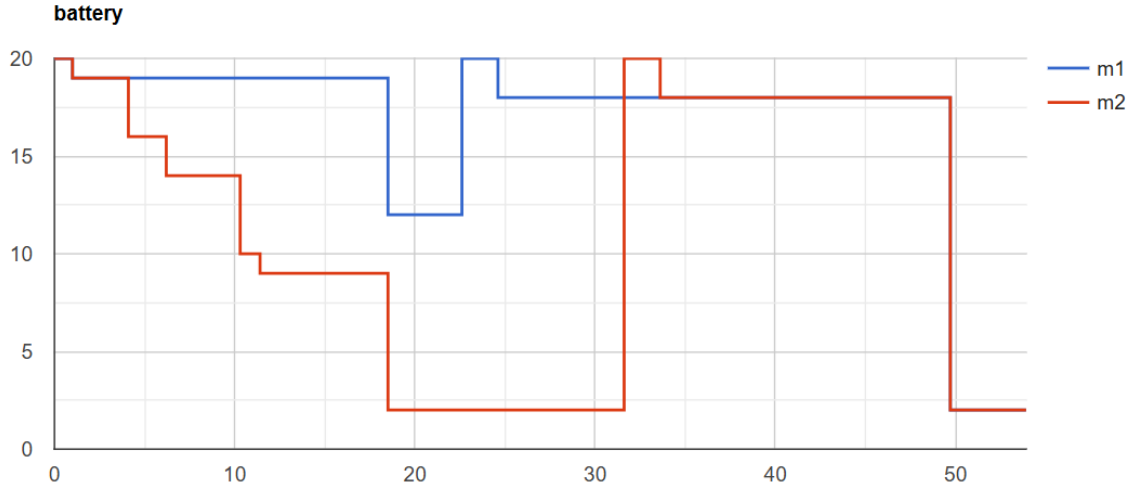


Figure 9: Battery usage for Problem 2

## 4 Problem 3

The plan visualization and action execution timeline for Problem 3 are shown in figure 10 and 11. This problem included 4 crates of the following dimensions:

- Crate 1: normal crate: weight 70 kg and 20 distance units from the loading bay.
- Crate 2: fragile crate: weight 80 kg and 20 distance units from the loading bay.
- Crate 3: normal crate: weight 60 kg and 30 distance units from the loading bay.
- Crate 4: normal crate: weight 30 kg and 10 distance units from the loading bay.

For this problem we had to use domain 124, which did not contain Extension 3. The reason for this being Problem 3 is unsolvable under the requirements of Extension 3: the battery needed for each of the two movers to move crate 3 should be of 21 units ( $30/10 + 60 \times 30/100$ ), which is over the battery capacity of 20 units.

	Actions involving m1 only
	Actions involving m2 only
	Dual actions involving m1 & m2
	Loader (f1) actions

Start Time	Action	Duration
0.0000	(move_empty m1 c2)	2.00
0.0000	(move_empty m2 c4)	1.00
1.0010	(mover_pick_single m2 c4)	0.10
1.1020	(move_crate_single m2 c4)	3.00
4.1030	(put_down_to_full_loader_single m2 fl c4)	0.10
4.2040	(full_loader_pick_ungrouped_crate fl c4)	0.10
4.2040	(move_empty m2 c2)	2.00
4.2050	(activate_group a c1)	0.00
4.3050	(full_load_normal_crate fl c4)	4.00
6.2050	(mover_pick_dual m2 m1 c2)	0.10
6.3050	(move_crate_dual_heavy m2 m1 c2)	16.00
22.3060	(put_down_to_full_loader_dual m2 m1 fl c2)	0.10
22.4070	(full_loader_pick_grouped_crate fl c2 a)	0.10
22.4070	(move_empty m1 c3)	3.00
22.4070	(move_empty m2 c3)	3.00
22.5080	(full_load_fragile_crate fl c2)	6.00
25.4080	(mover_pick_dual m2 m1 c3)	0.10
25.5080	(move_crate_dual_heavy m2 m1 c3)	18.00
43.5090	(put_down_to_full_loader_dual m2 m1 fl c3)	0.10
43.6100	(full_loader_pick_grouped_crate fl c3 a)	0.10
43.6100	(move_empty m1 c1)	2.00
43.6100	(move_empty m2 c1)	2.00
43.7110	(full_load_normal_crate fl c3)	4.00
45.6110	(mover_pick_dual m2 m1 c1)	0.10
45.7110	(move_crate_dual_heavy m2 m1 c1)	14.00
59.7120	(put_down_to_full_loader_dual m2 m1 fl c1)	0.10
59.8130	(full_loader_pick_grouped_crate fl c1 a)	0.10
59.9140	(full_load_normal_crate fl c1)	4.00

Table 7: Action Table for Problem 3

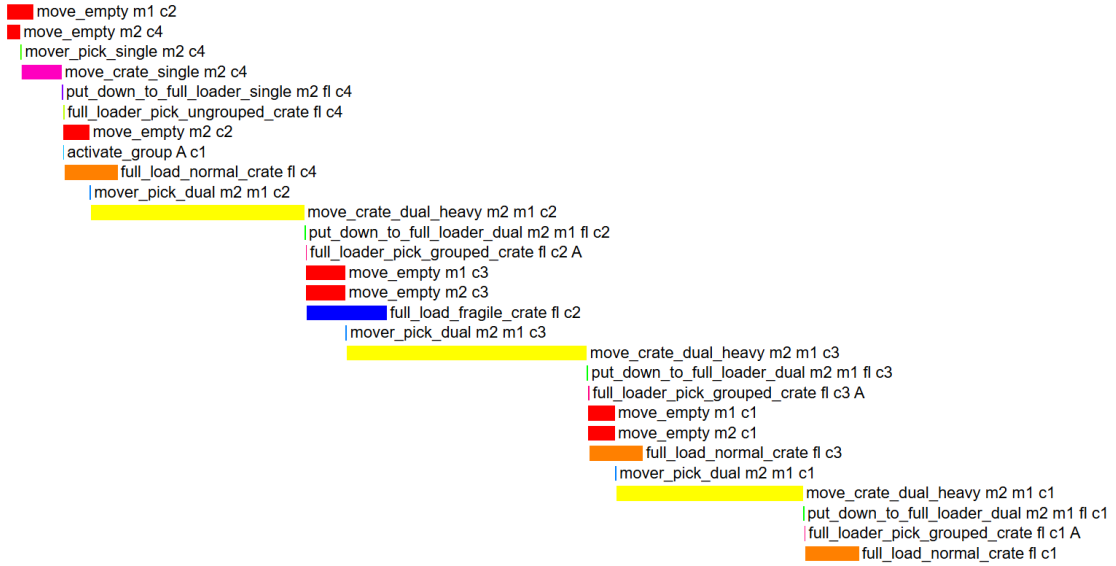


Figure 10: Visual Action Timeline for Problem 3



Figure 11: Object-wise Execution Timeline for Problem 3

## 5 Problem 4

### 5.1 Domain-124

Table 8, Figure 12 and 13 show the plan for Problem 4, including a structured action table, a visual timeline, and object-specific execution details.

	Actions involving m1 only
	Actions involving m2 only
	Dual actions involving m1 & m2
	Loader (f1) actions

Start Time	Action	Duration
0.0000	(move_empty m1 c6)	1.00
0.0000	(move_empty m2 c5)	3.00
1.0010	(mover_pick_single m1 c6)	0.10
1.1020	(move_crate_single m1 c6)	2.00
3.1030	(put_down_to_full_loader_single m1 fl c6)	0.10
3.2040	(full_loader_pick_ungrouped_crate fl c6)	0.10
3.2040	(move_empty m1 c5)	3.00
3.2050	(activate_group b c3)	0.00
3.3050	(full_load_normal_crate fl c6)	4.00
6.2050	(mover_pick_dual m2 m1 c5)	0.10
6.3050	(move_crate_dual_light m2 m1 c5)	6.00
12.3060	(put_down_to_full_loader_dual m2 m1 fl c5)	0.10
12.4070	(full_loader_pick_grouped_crate fl c5 b)	0.10
12.4070	(move_empty m2 c4)	2.00
12.4070	(move_empty m1 c4)	2.00
12.5080	(full_load_fragile_crate fl c5)	6.00
14.4080	(mover_pick_dual m2 m1 c4)	0.10
14.5080	(move_crate_dual_light m2 m1 c4)	2.67
17.1750	(put_down_to_side_loader_dual m2 m1 sl c4)	0.10
17.2760	(side_loader_pick_grouped_crate sl c4 fl c5 b)	0.10
17.2760	(move_empty m2 c3)	1.00
17.2760	(move_empty m1 c3)	1.00
17.3770	(side_load_fragile_crate sl c4)	6.00
18.2770	(mover_pick_dual m2 m1 c3)	0.10
18.3770	(move_crate_dual_light m2 m1 c3)	2.00
20.3780	(put_down_to_full_loader_dual m2 m1 fl c3)	0.10
20.4790	(full_loader_pick_grouped_crate fl c3 b)	0.10
20.4790	(move_empty m2 c2)	2.00
20.4790	(move_empty m1 c2)	2.00
20.4800	(switch_group b a c1)	0.00
22.4800	(mover_pick_dual m2 m1 c2)	0.10
22.5800	(move_crate_dual_light m2 m1 c2)	2.67
25.2470	(put_down_to_side_loader_dual m2 m1 sl c2)	0.10
25.3480	(move_empty m1 c1)	2.00
25.3480	(move_empty m2 c1)	2.00
25.4490	(full_load_fragile_crate fl c3)	6.00
27.3490	(mover_pick_dual m2 m1 c1)	0.10
27.4490	(move_crate_dual_light m2 m1 c1)	4.00
29.5510	(side_loader_pick_grouped_crate sl c2 fl c3 a)	0.10
29.6520	(side_load_fragile_crate sl c2)	6.00
31.4500	(put_down_to_full_loader_dual m2 m1 fl c1)	0.10
31.5510	(full_loader_pick_grouped_crate fl c1 a)	0.10
31.6520	(full_load_normal_crate fl c1)	4.00

Table 8: Action Table for Problem 4



Figure 12: Visual Action Timeline for Problem 4

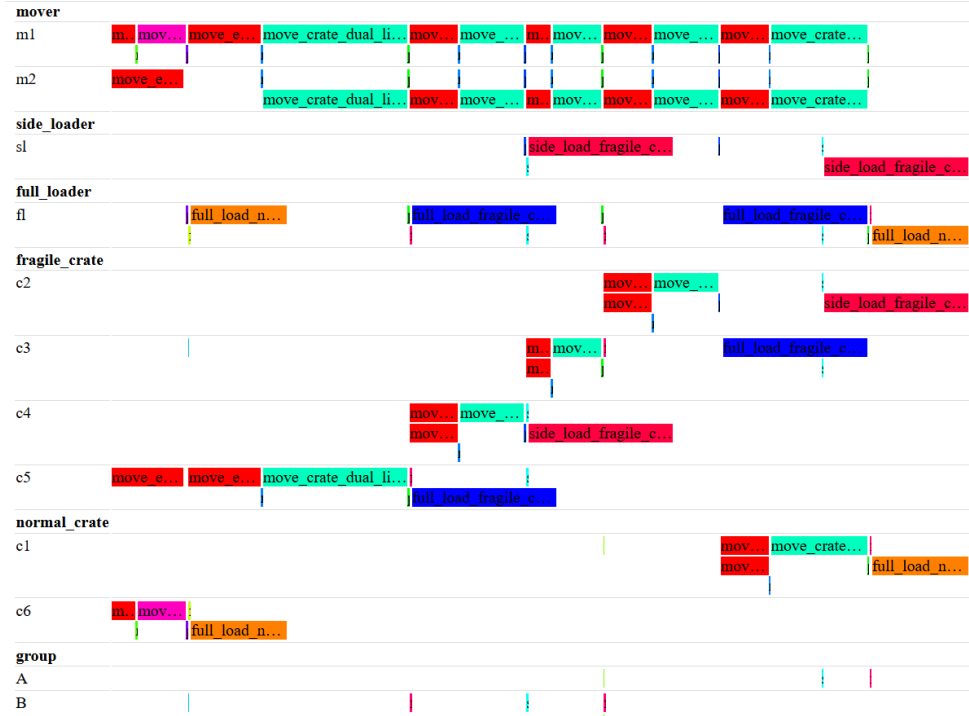


Figure 13: Object-wise Execution Timeline for Problem 4

## 5.2 Domain-3

Table 9, Figure 14 - 16 show the plan for **Problem 4 with only extension 3**, including a structured action table, a visual timeline, and object-specific execution details.

Start Time	Action	Duration
0.0000	(move_empty m1 c1)	2.00
0.0000	(move_empty m2 c6)	1.00
1.0010	(mover_pick_single m2 c6)	0.10
1.1020	(move_crate_single m2 c6)	2.00
2.0010	(mover_pick_single m1 c1)	0.10
2.1020	(move_crate_single m1 c1)	6.00
3.1030	(put_down_to_loader_single m2 l c6)	0.10
3.2040	(loader_pick_crate l c6)	0.10
3.2040	(move_empty m2 c5)	3.00
3.3050	(load_crate l c6)	4.00
8.1030	(put_down_to_loader_single m1 l c1)	0.10
8.1050	(mover_pick_single m2 c5)	0.10
8.2040	(loader_pick_crate l c1)	0.10
8.2040	(move_empty m1 c5)	3.00
8.2050	(move_crate_single m2 c5)	9.00
8.3050	(load_crate l c1)	4.00
17.2060	(put_down_to_loader_single m2 l c5)	0.10
17.3070	(loader_pick_crate l c5)	0.10
17.3070	(move_empty m2 c3)	1.00
17.4080	(load_crate l c5)	4.00
18.3080	(mover_pick_single m2 c3)	0.10
18.4080	(move_crate_single m2 c3)	3.00
21.4090	(put_down_to_loader_single m2 l c3)	0.10
21.5100	(loader_pick_crate l c3)	0.10
21.5100	(full_charge_mover m2 st1)	9.50
21.6110	(load_crate l c3)	4.00
31.0110	(move_empty m2 c4)	2.00
33.0120	(mover_pick_single m2 c4)	0.10
33.1120	(move_crate_single m2 c4)	4.00
37.1130	(put_down_to_loader_single m2 l c4)	0.10
37.2140	(loader_pick_crate l c4)	0.10
37.2140	(move_empty m2 c2)	2.00
37.3150	(load_crate l c4)	4.00
39.2150	(mover_pick_single m2 c2)	0.10
39.3150	(move_crate_single m2 c2)	4.00
43.3160	(put_down_to_loader_single m2 l c2)	0.10
43.4170	(loader_pick_crate l c2)	0.10
43.5180	(load_crate l c2)	4.00

Table 9: Action Table for Problem 4 with extension 3



Figure 14: Enter Caption

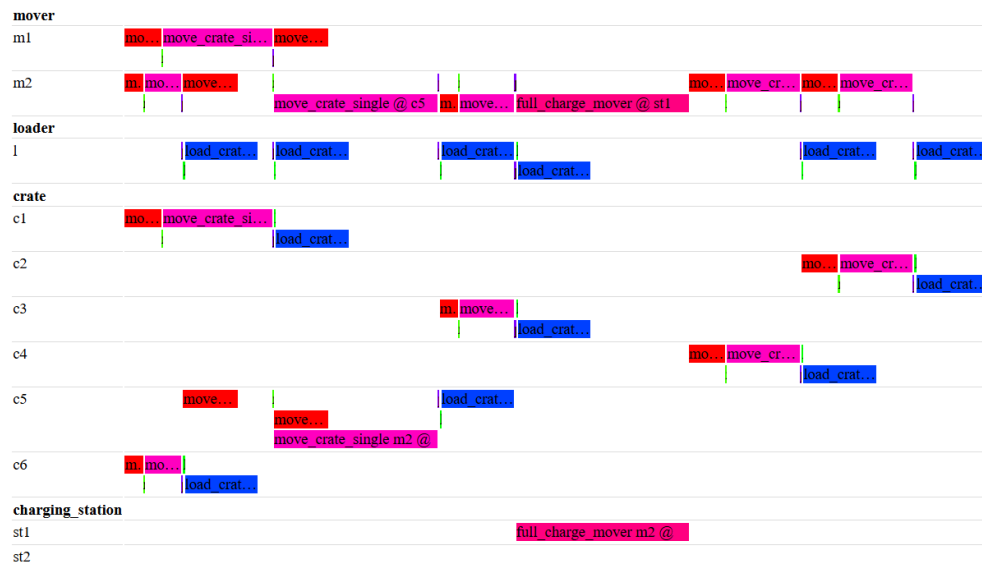


Figure 15: Object-wise Execution Timeline for Problem 4 with extension 3



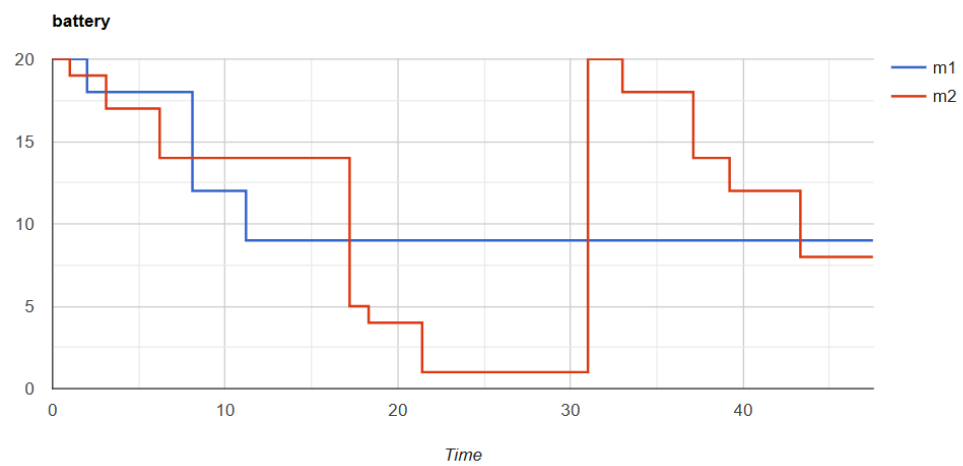


Figure 16: Battery usage for Problem 2