

华中科技大学

Thursday, April 17, 2025

# 工程项目数据建模与施工模拟计算

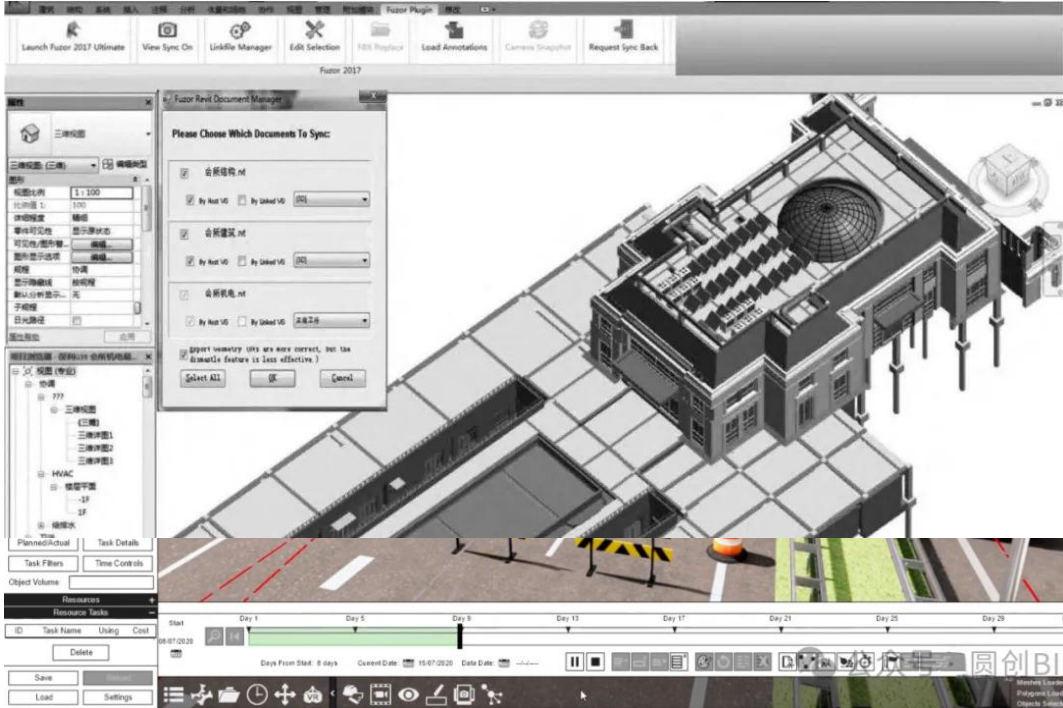
Agent-Based Simulation of Construction workflows and Information flow

邱峰

# 背景1：建筑工程项目的复杂性和工程管理方法

- 建筑施工项目的复杂性与不确定性是建筑行业面临的重大挑战。甘特图是一种静态的计划工具，无法实时反映施工现场的实际情况，如天气变化、资源短缺、设计变更等。这些不确定性因素会导致计划与实际执行之间的脱节，进而引发一系列问题，如工期延误、成本增加和资源浪费。
- 为解决这些问题，施工模拟仿真技术被引入，通过建立虚拟模型，对施工过程进行动态模拟和分析，帮助管理者更好地理解 and 预测施工过程中的各种变化。这种技术能够模拟施工过程中的各种事件和行为，包括资源分配、工序协调、干扰因素等，从而为施工计划的优化提供科学依据。

						施工进度计划表																													
						2025 年																													
项目名称	每天施工人数	定额总用工天数	开始时间	结束时间	施工天数	1 月					2 月					3 月					4 月					5 月					6 月				
						5	10	15	20	25	31	5	10	15	20	25	29	5	10	15	20	25	31	5	10	15	20	25	30	5	10	15	20	25	31
一层顶板楼梯钢筋绑扎及柱合模	1	2	2025/1/1	2025/5/15	134																														
一层顶板楼梯砼浇筑	5	10	2025/1/5	2025/1/25	20																														
二层测量放线	1	1	2025/2/3	2025/2/17	14																														
二层满堂架搭设绑扎柱钢筋	7	25	2025/3/12	2025/4/18	37																														
二层顶板楼梯模板铺装	5	12	2025/5/1	2025/5/19	749																														
二层顶板楼梯钢筋绑扎及柱合模	3	14	2023/1/6	2023/1/20	14																														
二层顶板楼梯砼浇筑	7	12	2023/5/19	2023/6/21	33																														
三层测量放线	8	10	2023/2/8	2023/3/22	42																														
三层满堂架搭设绑扎柱钢筋	1	2	2023/1/9	2023/1/23	14																														
三层顶板楼梯模板铺装	1	6	2023/1/10	2023/1/24	14																														
一层顶板楼梯钢筋绑扎及柱合模	1	2	2023/1/11	2023/1/25	23																														
一层顶板楼梯砼浇筑	5	10	2023/1/12	2023/1/26	14																														



# 背景2：仿真方法

## • 三大类仿真方法：

### 1. SD: System Dynamic

- 系统动力学，战略层面仿真，强调因果回馈；

### 2. AB: Agent-Based

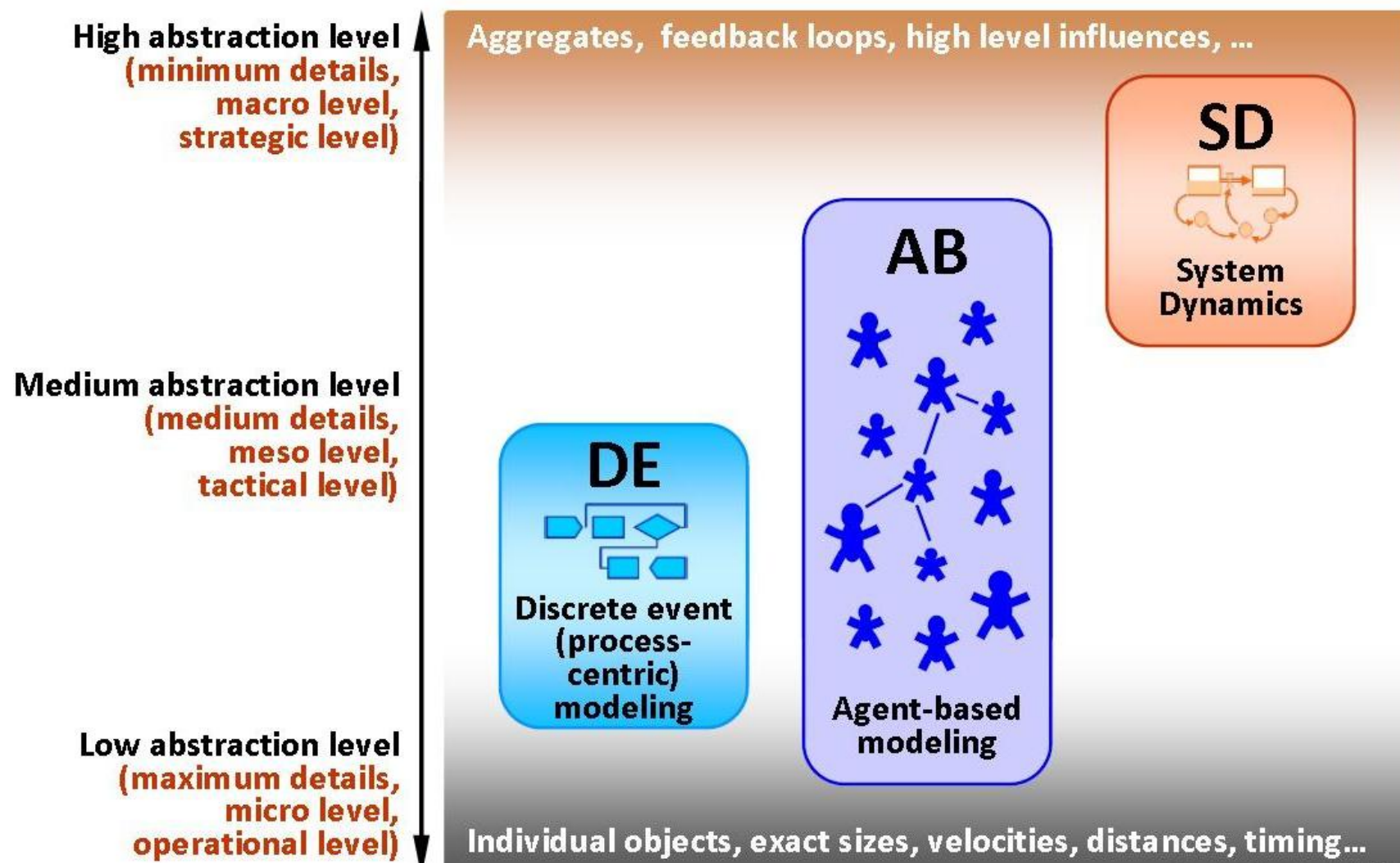
- 代理人，运营/操作层面仿真，强调互动；

### 3. DE: Discrete Event

- 离散事件，运营/操作层面仿真，强调环环相扣的程序。

➤ 离散事件模拟（DES）是一种常用的施工仿真方法，通过事件驱动的方式模拟施工过程中的关键事件和状态变化。然而，DES在处理施工主体的独立行为和动态交互方面存在一定的局限性。

➤ 基于代理的仿真则通过模拟施工主体（如工人、机器、任务等）的自主行为和交互，能够更真实地反映施工过程中的复杂性和动态性。



- ✓ **DES:** 适合模拟事件驱动的系统，如生产流程、排队系统等，强调事件的顺序和时间点。
- ✓ **ABM:** 适合模拟复杂系统中多个代理之间的交互，如施工中的工人、机器和任务的动态协作。

# 研究内容：基于代理的施工流程模拟（三个组成部分）



**Agent（代理）** 代表施工过程中的个体（如工人、机器等）。

代理的行为包括但不限于：

- Perception change（感知变化）：代理感知环境的变化。
- Site meeting（现场会议）：代理之间的沟通和协调。
- Decision making（决策制定）：代理根据感知的信息做出决策。

**Task（任务）** 代表具体的施工任务。

任务的属性包括但不限于：

- Workspace（工作空间）：任务所需的工作区域。
- Workload（工作量）：任务的工作量。
- Progress（进度）：任务的完成进度。



**Event（事件）** 代表施工过程中的动态变化。

事件的类型包括但不限于：

- Production rate change（生产率变化）：任务的生产率发生变化。
- Design change（设计变更）：施工设计的变更。
- Quality check（质量检查）：对施工质量的检查。



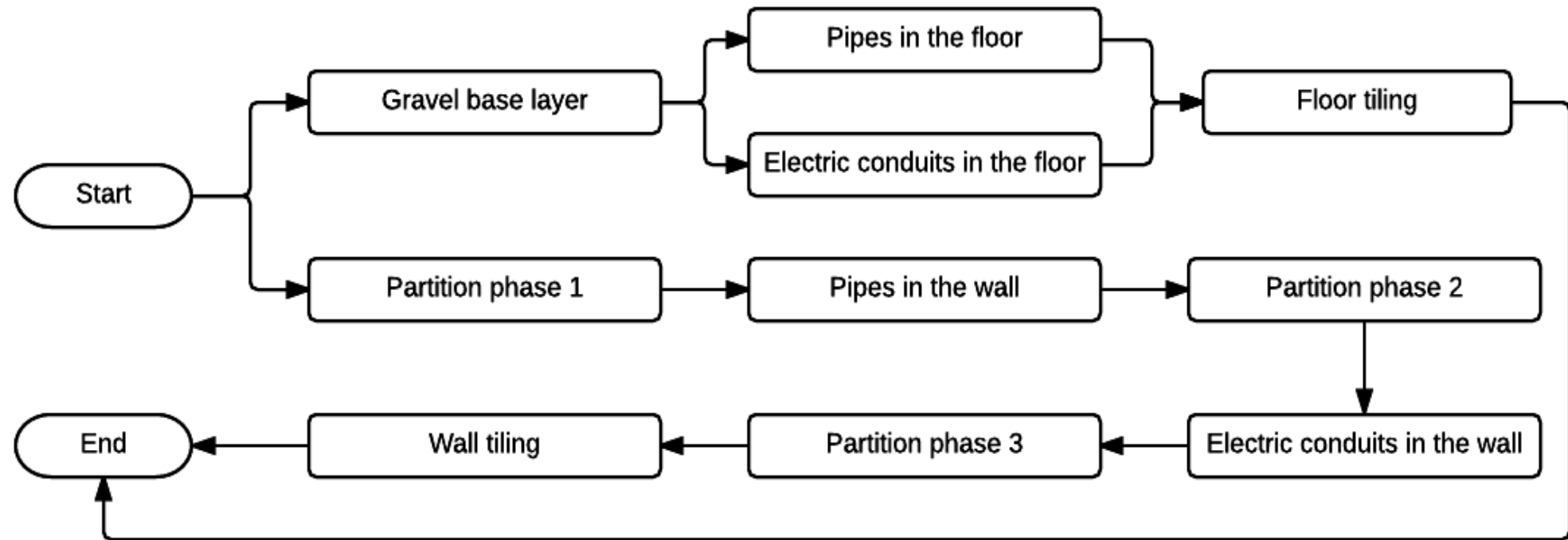
# 研究思考+问题提出+基本目标

- 思考以下问题：
  - 如何以参数化的方式模拟建筑工程中的各种施工活动场景？
  - 如何对工程施工流程中的可变性进行模拟建模与计算？
  - 如何量化分析判断施工现场的信息流的不确定性？
- 模拟的核心是代理、任务和事件之间的交互。
- 代理通过感知环境变化、参与现场会议和做出决策来影响任务的执行。
- 任务的进度和工作量受到事件（如生产率变化、设计变更等）的影响。
- 在复杂施工项目中，工序依赖、资源分配和不确定性（如工人效率波动、无效工作日）会显著影响项目周期。传统计划工具难以动态反映这些因素。通过基于代理的模拟，可帮助构建一个施工流程与信息流的数字化模型，从而实现：
  - 动态模拟多工种协作资源分配、工序依赖关系和跨楼层施工调度顺序等。
  - 量化模拟分析并计算效率的波动、返工、资源冲突等现实问题产生的影响。
  - 优化资源配置和工期预测。

# 具体应用：一个多工种参与的施工项目案例

- 基本介绍

## Agent-Based Simulation of Construction workflows and Information flow





# 紧前紧后工作1(Dependency)



Pipes in the floor



Floor tiling



Gravel base layer



Electric conduits in the floor



# 紧前紧后工作2(Dependency)



Partition phase 1



Pipes in the wall



Partition phase 2



Electric conduits in the wall



Partition phase 3



Wall tiling

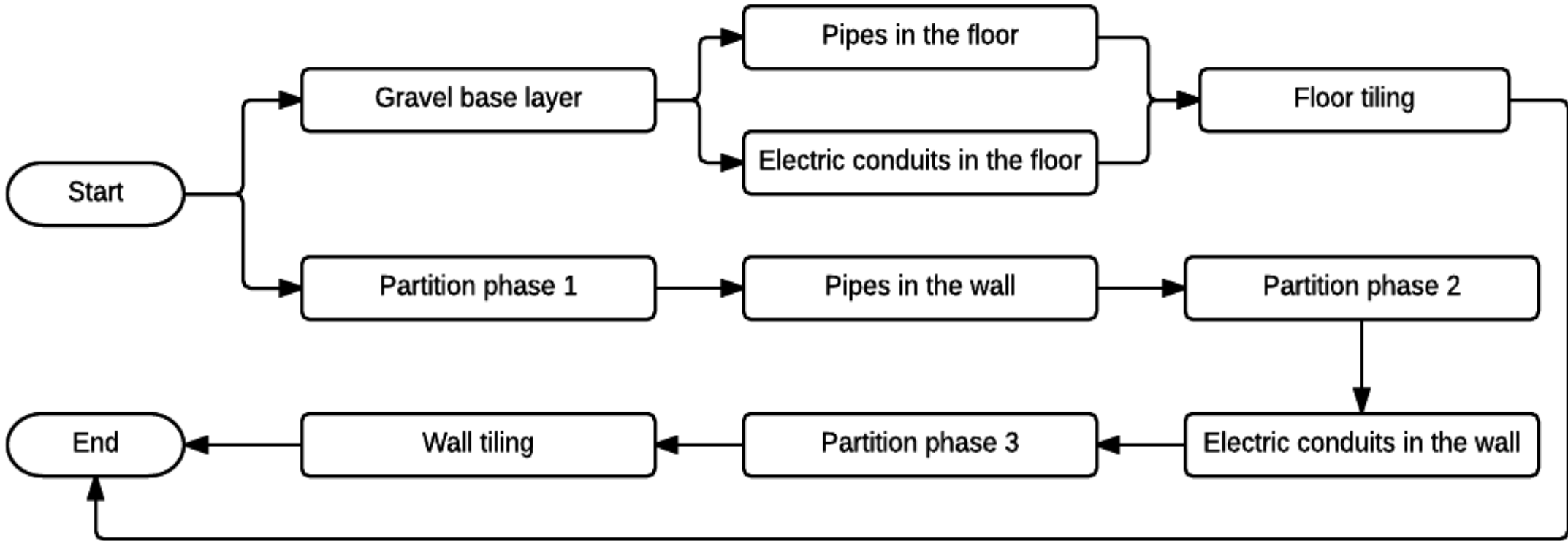


# 内容解释



- **Gravel**（碎石工）：负责铺设地基或基础层的碎石，确保地面平整和排水良好。
- **Plumbing**（管道工）：负责安装和维护供水、排水和卫生设施的管道系统。
- **Electricity**（电工）：负责安装和维护电气系统，包括照明、插座、开关和配电箱。
- **Tiling**（瓷砖工）：负责铺设地板和墙面的瓷砖，确保美观和耐用。
- **Partition**（隔墙工）：负责建造和安装隔墙，将空间分隔成不同的功能区域。

id	Trade	...
1	Gravel	...
2	Plumbing	...
3	Electricity	...
4	Tiling	...
5	Partition	...



# 内容解释



- **Process** (工作内容)
  - Gravel base layer
  - Pipes in the floor
  - Electric conduits in the floor
  - Floor tiling
  - Partition phase 1
  - Pipes in the wall
  - Electric conduits in the wall
  - Partition phase 2
  - Wall tiling
  - Partition phase 3

这种设计会导致什么问题？

工种	负责的工序列表
电工	地板下的电线管道, 墙体内的电线管道
瓦工	铺地砖, 铺墙砖
管道工	地板下的水管, 墙体内的水管
隔断工	分区阶段1, 分区阶段2, 分区阶段3
碎石工	碎石基层



id	Process	Trade
1	Electric conduits in the floor	Electricity
2	Electric conduits in the wall	Electricity
3	Floor tiling	Tiling
4	Gravel base layer	Gravel
5	Partition phase 1	Partition
6	Partition phase 2	Partition
7	Partition phase 3	Partition
8	Pipes in the floor	Plumbing
9	Pipes in the wall	Plumbing
10	Wall tiling	Tiling

- 数据不重复
- 查询方便
- 扩展灵活

核心原则：每个表只做一件事，用编号关联信息，而不是堆砌数据。

# 具体数据：一个多工种参与的施工项目案例

- 所用到的数据（模拟计算）

id	Trade	Number of people	Space	InitialPriority
1	Gravel	1	1	5
2	Plumbing	1	2	4
3	Electricity	1	3	3
4	Tiling	1	4	2
5	Partition	1	5	1

Process	Floor	InitialQuantity	Design Change Variation
Gravel base layer	1	170	17
Pipes in the floor	1	100	10
Electric conduits in the floor	1	80	8
Floor tiling	1	720	72
Partition phase 1	1	750	75
Pipes in the wall	1	190	19
Electric conduits in the wall	1	180	18
Partition phase 2	1	20	2
Wall tiling	1	290	29
Partition phase 3	1	200	20
...	...	...	...



id	Process	Trade	InitialProductionRate	QualityRate	PerformanceStd
1	Electric conduits in the floor	Electricity	51	0.9	8
2	Electric conduits in the wall	Electricity	41	0.9	2
3	Floor tiling	Tiling	62	0.9	9
4	Gravel base layer	Gravel	34	0.9	5
5	Partition phase 1	Partition	55	0.9	12
6	Partition phase 2	Partition	51	0.9	11
7	Partition phase 3	Partition	32	0.9	4
8	Pipes in the floor	Plumbing	69	0.9	5
9	Pipes in the wall	Plumbing	37	0.9	9
10	Wall tiling	Tiling	27	0.9	2

PredecessorProcess	SuccessorProcess
Gravel base layer	Pipes in the floor
Gravel base layer	Electric conduits in the floor
Pipes in the floor	Floor tiling
Electric conduits in the floor	Floor tiling
Partition phase 1	Pipes in the wall
Pipes in the wall	Partition phase 2
Partition phase 2	Electric conduits in the wall
Electric conduits in the wall	Partition phase 3
Partition phase 3	Wall tiling

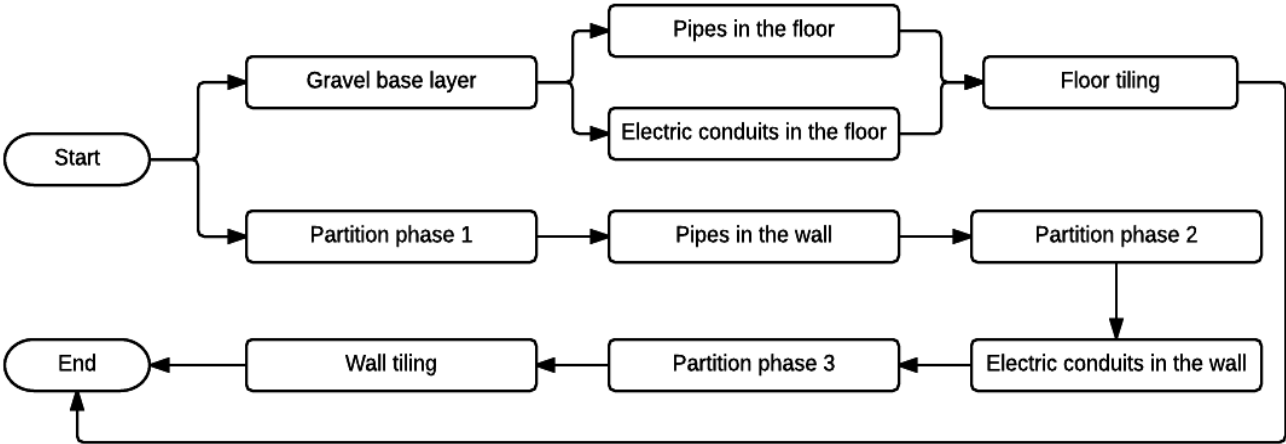
# 数据解释：工种(Trade) & 任务(Process)



- **Gravel**（碎石工）：负责铺设地基或基础层的碎石，确保地面平整和排水良好。
- **Plumbing**（管道工）：负责安装和维护供水、排水和卫生设施的管道系统。
- **Electricity**（电工）：负责安装和维护电气系统，包括照明、插座、开关和配电箱。
- **Tiling**（瓷砖工）：负责铺设地板和墙面的瓷砖，确保美观和耐用。
- **Partition**（隔墙工）：负责建造和安装隔墙，将空间分隔成不同的功能区域。

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10	Wall tiling	Tiling	27	0.9	2

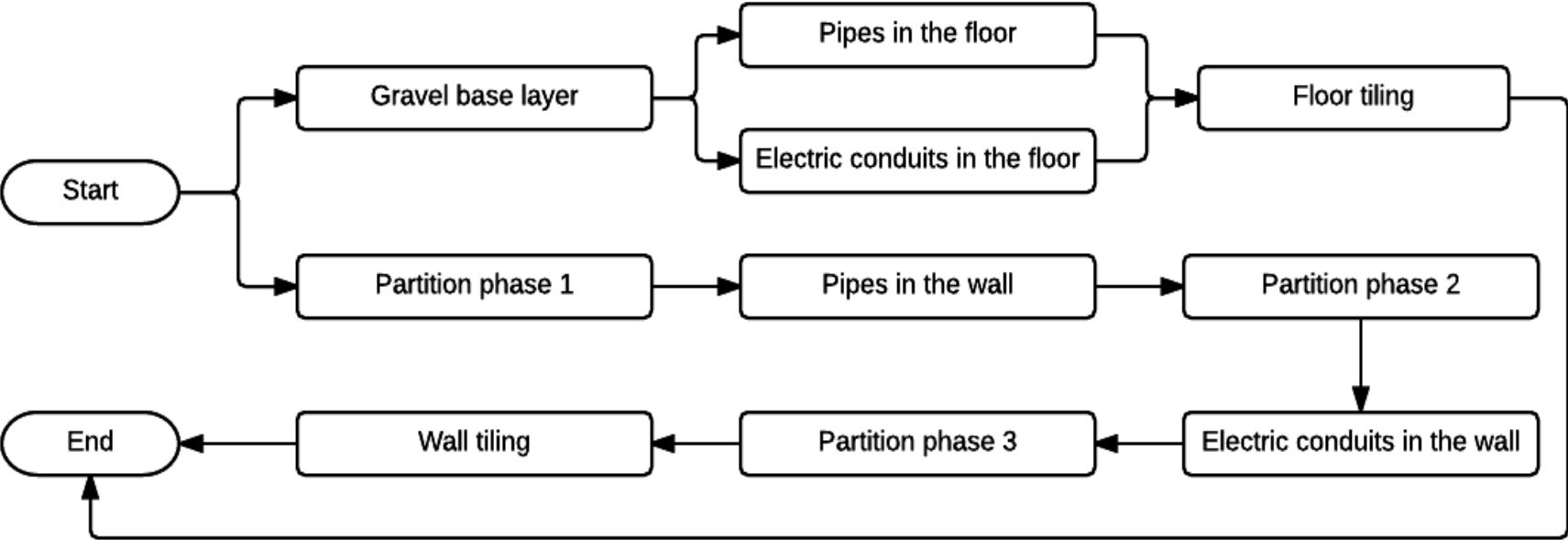
id	Process	Trade
1	Electric conduits in the floor	Electricity
2	Electric conduits in the wall	Electricity
3	Floor tiling	Tiling
4	Gravel base layer	Gravel
5	Partition phase 1	Partition
6	Partition phase 2	Partition
7	Partition phase 3	Partition
8	Pipes in the floor	Plumbing
9	Pipes in the wall	Plumbing
10	Wall tiling	Tiling



id	Trade	Number of people
1	Gravel	1
2	Plumbing	1
3	Electricity	1
4	Tiling	1
5	Partition	1



# 数据解释：得出关联表(Dependency)



Space	InitialPriority
1	5
2	4
3	3
4	2
5	1



PredecessorProcess	SuccessorProcess
Gravel base layer	Pipes in the floor
Gravel base layer	Electric conduits in the floor
Pipes in the floor	Floor tiling
Electric conduits in the floor	Floor tiling
Partition phase 1	Pipes in the wall
Pipes in the wall	Partition phase 2
Partition phase 2	Electric conduits in the wall
Electric conduits in the wall	Partition phase 3
Partition phase 3	Wall tiling

Process	Floor	InitialQuantity	Design Change Variation
Gravel base layer	1	170	17
Pipes in the floor	1	100	10
Electric conduits in the floor	1	80	8
Floor tiling	1	720	72
Partition phase 1	1	750	75
Pipes in the wall	1	190	19
Electric conduits in the wall	1	180	18
Partition phase 2	1	20	2
Wall tiling	1	290	29
Partition phase 3	1	200	20
...	...	...	...

# 数据说明1: Trade的初始效率(Initial Production Rate)

- **Gravel**（碎石工）：负责铺设地基或基础层的碎石，确保地面平整和排水良好。
- **Plumbing**（管道工）：负责安装和维护供水、排水和卫生设施的管道系统。
- **Electricity**（电工）：负责安装和维护电气系统，包括照明、插座、开关和配电箱。
- **Tiling**（瓷砖工）：负责铺设地板和墙面的瓷砖，确保美观和耐用。
- **Partition**（隔墙工）：负责建造和安装隔墙，将空间分隔成不同的功能区域。

-- 初始化工种资源：插入所有工种，默认可用工人数为1

id	Trade	Number of people	...
1	Gravel	1	...
2	Plumbing	1	...
3	Electricity	1	...
4	Tiling	1	...
5	Partition	1	...



id	Process	Trade	InitialProductionRate	QualityRate	PerformanceStd
1	Electric conduits in the floor	Electricity	51	0.9	8
2	Electric conduits in the wall	Electricity	41	0.9	2
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4	Gravel base layer	Gravel	34	0.9	5
5	Partition phase 1	Partition	55	0.9	12
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7	Partition phase 3	Partition	32	0.9	4
8	Pipes in the floor	Plumbing	69	0.9	5
9	Pipes in the wall	Plumbing	37	0.9	9
10	Wall tiling	Tiling	27	0.9	2

指施工中的表现或性能，如施工效率、质量等...

是否返工的问题后面简化为随机10%无效，实际上可随需求对每个Trade（具体到人）进行设计。

同时每个人的Performance可能按照一定分布变化（例如正态分布），所以增加属性到Trade表中即可。

-- 生成10%无效日概率

```
is_invalid := (random() < 0.1);
-- 计算实际完成量：无效日为0，否则...
work_done := CASE
    WHEN is_invalid THEN 0
    ELSE GREATEST(1, ROUND(task_rec.initial_production_rate * (0.9 + 0.2 * random()))) * task_rec.available_workers)
END;
```

# 数据说明2： Process的初始总量(Initial Quantity)

```
('Gravel base layer',          ROUND(170 * (0.9 + 0.2 * random()))::INT, 170),
('Pipes in the floor',         ROUND(100 * (0.9 + 0.2 * random()))::INT, 100),
('Electric conduits in the floor', ROUND(80 * (0.9 + 0.2 * random()))::INT, 80),
('Floor tiling',              ROUND(720 * (0.9 + 0.2 * random()))::INT, 720),
('Partition phase 1',         ROUND(750 * (0.9 + 0.2 * random()))::INT, 750),
('Pipes in the wall',         ROUND(190 * (0.9 + 0.2 * random()))::INT, 190),
('Electric conduits in the wall', ROUND(180 * (0.9 + 0.2 * random()))::INT, 180),
('Partition phase 2',         ROUND(20 * (0.9 + 0.2 * random()))::INT, 20),
('Wall tiling',              ROUND(290 * (0.9 + 0.2 * random()))::INT, 290),
('Partition phase 3',         ROUND(200 * (0.9 + 0.2 * random()))::INT, 200);
```

Process	Floor	InitialQuantity	Design Change Variation
Gravel base layer	1	170	17
Pipes in the floor	1	100	10
Electric conduits in the floor	1	80	8
Floor tiling	1	720	72
Partition phase 1	1	750	75
Pipes in the wall	1	190	19
Electric conduits in the wall	1	180	18
Partition phase 2	1	20	2
Wall tiling	1	290	29
Partition phase 3	1	200	20
...	...	...	...

# 过程模拟-daily task details 初始化

第0天：数据初始化，找到开工的项目。

day	floor	process	trade	Initial Quantity	status	Initial production rate	Remain work	Predecessor processes	Pre Remain work	Trade available	Prerequisite completed	Can Start?
0	1	Electric conduits in the floor	Electricity	74	pending	51	74	Gravel base layer	154	1	FALSE	FALSE
0	1	Electric conduits in the wall	Electricity	164	pending	41	164	Partition phase 2	19	1	FALSE	FALSE
0	1	Floor tiling	Tiling	661	pending	62	661	Pipes in the floor, Electric conduits in the floor	74, 103	1	FALSE	FALSE
0	1	Gravel base layer	Gravel	154	pending	34	154	null	null	1	TRUE	TRUE
0	1	Partition phase 1	Partition	818	pending	55	818	null	null	1	TRUE	TRUE
0	1	Partition phase 2	Partition	19	pending	51	19	Pipes in the wall	175	1	FALSE	FALSE
0	1	Partition phase 3	Partition	216	pending	32	216	Electric conduits in the wall	164	1	FALSE	FALSE
0	1	Pipes in the floor	Plumbing	103	pending	69	103	Gravel base layer	154	1	FALSE	FALSE
0	1	Pipes in the wall	Plumbing	175	pending	37	175	Partition phase 1	818	1	FALSE	FALSE
0	1	Wall tiling	Tiling	271	pending	27	271	Partition phase 3	216	1	FALSE	FALSE
0	1	Floor tiling	Tiling	661	pending	62	661	Pipes in the floor	74	1	FALSE	FALSE
0	1	Floor tiling	Tiling	661	pending	62	661	Electric conduits in the floor	103	1	FALSE	FALSE



# 过程模拟-第一天情况

day	process	Assigned trade	Initial Quantity	status	ipr	Actual efficiency	Remain work	Is rework	Today workload	Predecessor processes	pre_remain_work	trade_available
1	Electric conduits in the floor	Electricity	74	pending	51	null	74	null	0	Gravel base layer	122	1
1	Electric conduits in the wall	Electricity	164	pending	41	null	164	null	0	Partition phase 2	19	1
1	Floor tiling	Tiling	661	pending	62	null	661	null	0	Pipes in the floor, Electric conduits in the floor	74, 103	1
1	Gravel base layer	Gravel	154	in_progress	34	32	122	FALSE	32	null	null	0
1	Partition phase 1	Partition	818	in_progress	55	58	760	FALSE	58	null	null	0
1	Partition phase 2	Partition	19	pending	51	null	19	null	0	Pipes in the wall	175	0
1	Partition phase 3	Partition	216	pending	32	null	216	null	0	Electric conduits in the wall	164	0
1	Pipes in the floor	Plumbing	103	pending	69	null	103	null	0	Gravel base layer	122	1
1	Pipes in the wall	Plumbing	175	pending	37	null	175	null	0	Partition phase 1	760	1
1	Wall tiling	Tiling	271	pending	27	null	271	null	0	Partition phase 3	216	1

# 过程模拟- “pre remain work=0” & “trade available”

Gravel base layer (floor 1)

day	floor	process	assigned_trade	task_status	initial_production_rate	remain_work	is_rework	trade_available	can_start
0	1	Gravel base layer	Gravel	pending	34	154	null	1	TRUE
1	1	Gravel base layer	Gravel	in_progress	34	122	FALSE	0	FALSE
2	1	Gravel base layer	Gravel	in_progress	34	90	FALSE	0	FALSE
3	1	Gravel base layer	Gravel	in_progress	34	58	FALSE	0	FALSE
4	1	Gravel base layer	Gravel	in_progress	34	25	FALSE	0	FALSE
5	1	Gravel base layer	Gravel	completed	34	0	FALSE	1	FALSE

Electric conduits in the floor (floor 1)

day	floor	process	trade	IQ	status	ipr	remain	workload	predecessor_processes	pre_remain_work	trade_available	can_start
5	1	Electric conduits in the floor	Electricity	74	pending	51	74	0	Gravel base layer	0	1	TRUE
6	1	Electric conduits in the floor	Electricity	74	in_progress	51	18	56	Gravel base layer	0	0	FALSE
7	1	Electric conduits in the floor	Electricity	74	completed	51	0	18	Gravel base layer	0	1	FALSE

Pipes in the floor (floor 1)

day	floor	process	trade	IQ	task_status	ipr	remain	workload	predecessor_processes	pre_remain_work	trade_available	can_start
5	1	Pipes in the floor	Plumbing	103	pending	69	103	0	Gravel base layer	0	1	TRUE
6	1	Pipes in the floor	Plumbing	103	in_progress	69	31	72	Gravel base layer	0	0	FALSE
7	1	Pipes in the floor	Plumbing	103	completed	69	0	31	Gravel base layer	0	1	FALSE

Gravel base layer (floor 2)

day_number	floor	process	assigned_trade	task_status	remain_work	trade_available	can_start
4	2	Gravel base layer	Gravel	pending	154	0	FALSE
5	2	Gravel base layer	Gravel	pending	154	1	TRUE
6	2	Gravel base layer	Gravel	in_progress	121	0	FALSE
7	2	Gravel base layer	Gravel	in_progress	84	0	FALSE
8	2	Gravel base layer	Gravel	in_progress	49	0	FALSE
9	2	Gravel base layer	Gravel	in_progress	14	0	FALSE
10	2	Gravel base layer	Gravel	completed	0	1	FALSE

# 过程模拟-Trade available情况分析（Partition为例）

day_number	floor	process	assigned_trade	predecessor_processes	pre_remain_work	can_start
0	1	Partition phase 1	Partition	null	null	TRUE
0	2	Partition phase 1	Partition	null	null	TRUE
0	3	Partition phase 1	Partition	null	null	TRUE
0	4	Partition phase 1	Partition	null	null	TRUE
0	5	Partition phase 1	Partition	null	null	TRUE
0	1	Partition phase 2	Partition	Pipes in the wall	175	FALSE
0	2	Partition phase 2	Partition	Pipes in the wall	175	FALSE
0	3	Partition phase 2	Partition	Pipes in the wall	175	FALSE
0	4	Partition phase 2	Partition	Pipes in the wall	175	FALSE
0	5	Partition phase 2	Partition	Pipes in the wall	175	FALSE
0	1	Partition phase 3	Partition	Electric conduits in the wall	164	FALSE
0	2	Partition phase 3	Partition	Electric conduits in the wall	164	FALSE
0	3	Partition phase 3	Partition	Electric conduits in the wall	164	FALSE
0	4	Partition phase 3	Partition	Electric conduits in the wall	164	FALSE
0	5	Partition phase 3	Partition	Electric conduits in the wall	164	FALSE

day	floor	process	assigned_trade	predecessor_processes	pre_remain	can_start
55	2	Partition phase 2	Partition	Pipes in the wall	0	TRUE
55	1	Partition phase 3	Partition	Electric conduits in the wall	0	TRUE

Space	InitialPriority
1	5
2	4
3	3
4	2
5	1

增加一列（**floor**优先级），从而判断开工项目。

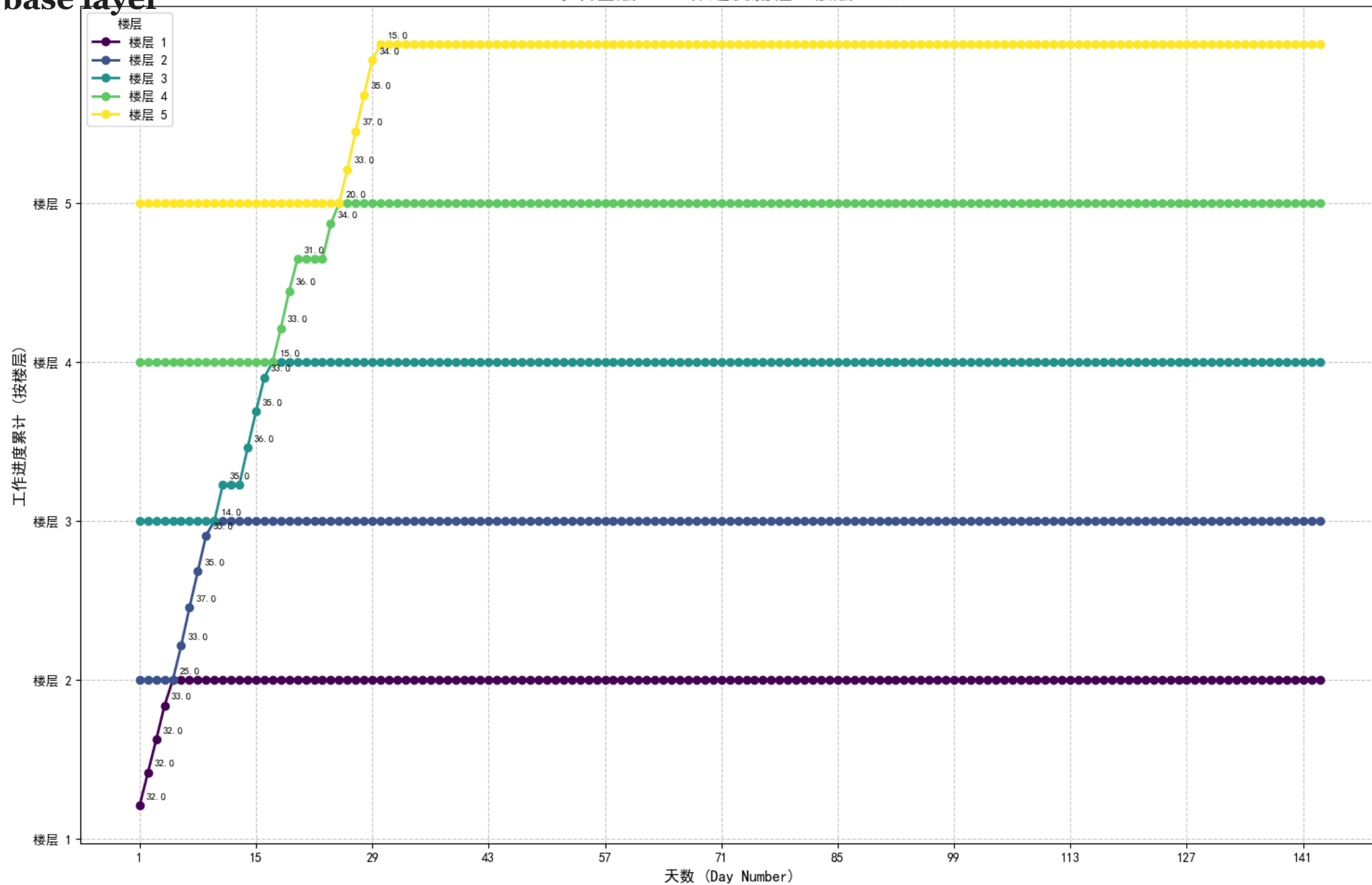
# 过程模拟-单个process结果（是否有无效day）

day	floor	process	trade	IQ	task_status	ipr	actual	remain_work	is_rework	today_workload	trade_available	can_start
0	2	Gravel base layer	Gravel	154	pending	34	null	154	null	null	1	TRUE
1	2	Gravel base layer	Gravel	154	pending	34	null	154	null	0	0	FALSE
2	2	Gravel base layer	Gravel	154	pending	34	null	154	null	0	0	FALSE
3	2	Gravel base layer	Gravel	154	pending	34	null	154	null	0	0	FALSE
4	2	Gravel base layer	Gravel	154	pending	34	null	154	null	0	0	FALSE
5	2	Gravel base layer	Gravel	154	pending	34	null	154	null	0	1	TRUE
6	2	Gravel base layer	Gravel	154	in_progress	34	33	121	FALSE	33	0	FALSE
7	2	Gravel base layer	Gravel	154	in_progress	34	37	84	FALSE	37	0	FALSE
8	2	Gravel base layer	Gravel	154	in_progress	34	35	49	FALSE	35	0	FALSE
9	2	Gravel base layer	Gravel	154	in_progress	34	35	14	FALSE	35	0	FALSE
10	2	Gravel base layer	Gravel	154	completed	34	37	0	FALSE	14	1	FALSE

day	floor	process	assigned_trade	planned_remaining	task_status	initial_production_rate	actual_efficiency	remain_work	is_rework	today_workload
10	3	Gravel base layer	Gravel	154	pending	34	null	154	null	0
11	3	Gravel base layer	Gravel	154	in_progress	34	35	119	FALSE	35
12	3	Gravel base layer	Gravel	154	in_progress	34	0	119	TRUE	0
13	3	Gravel base layer	Gravel	154	in_progress	34	0	119	TRUE	0
14	3	Gravel base layer	Gravel	154	in_progress	34	36	83	FALSE	36
15	3	Gravel base layer	Gravel	154	in_progress	34	35	48	FALSE	35
16	3	Gravel base layer	Gravel	154	in_progress	34	33	15	FALSE	33
17	3	Gravel base layer	Gravel	154	completed	34	31	0	FALSE	15

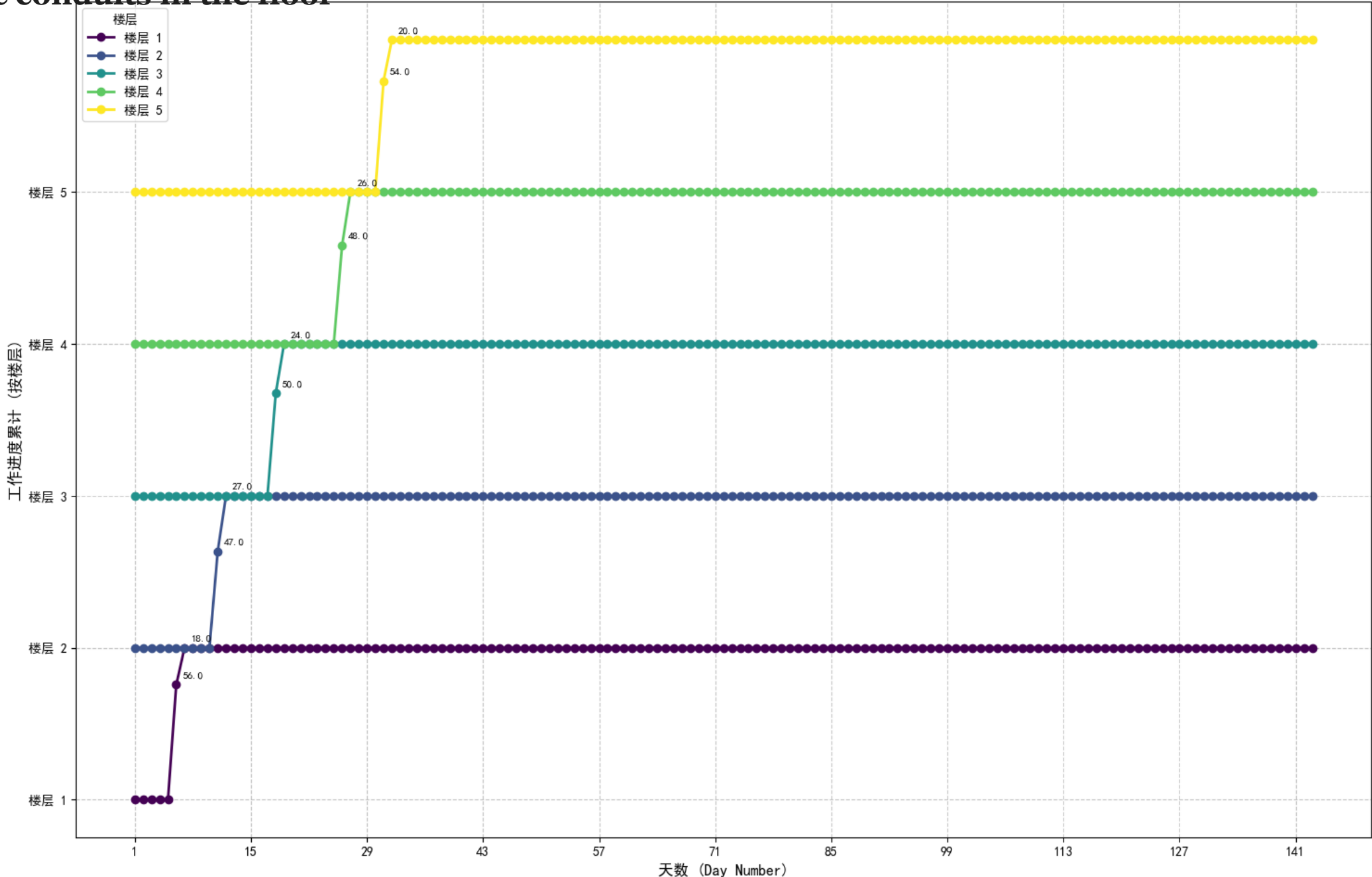


砂石基层 - 工作进度流程 (楼层 1-5)



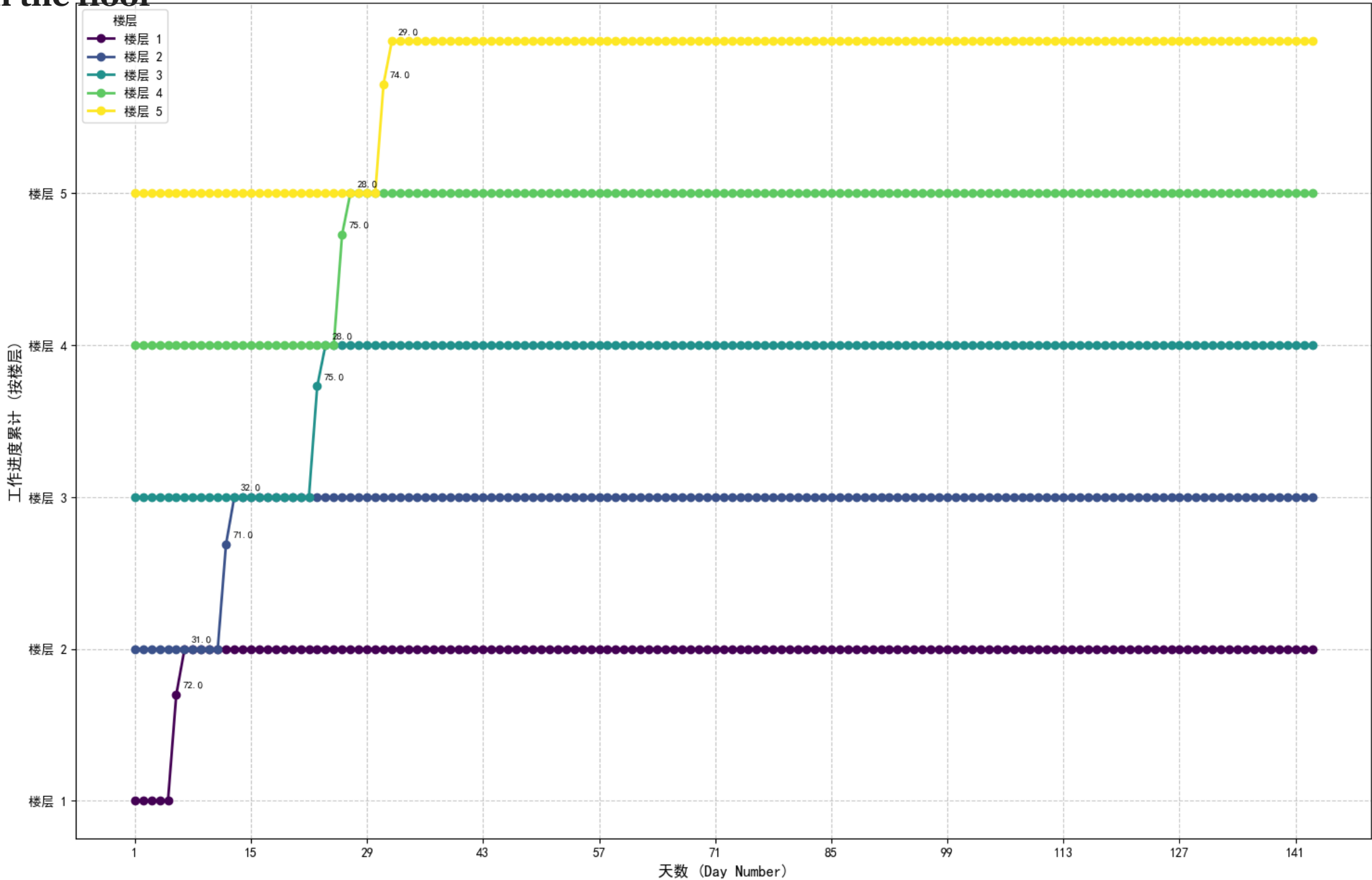
# Electric conduits in the floor

地板电线管道 - 工作进度流程 (楼层 1-5)



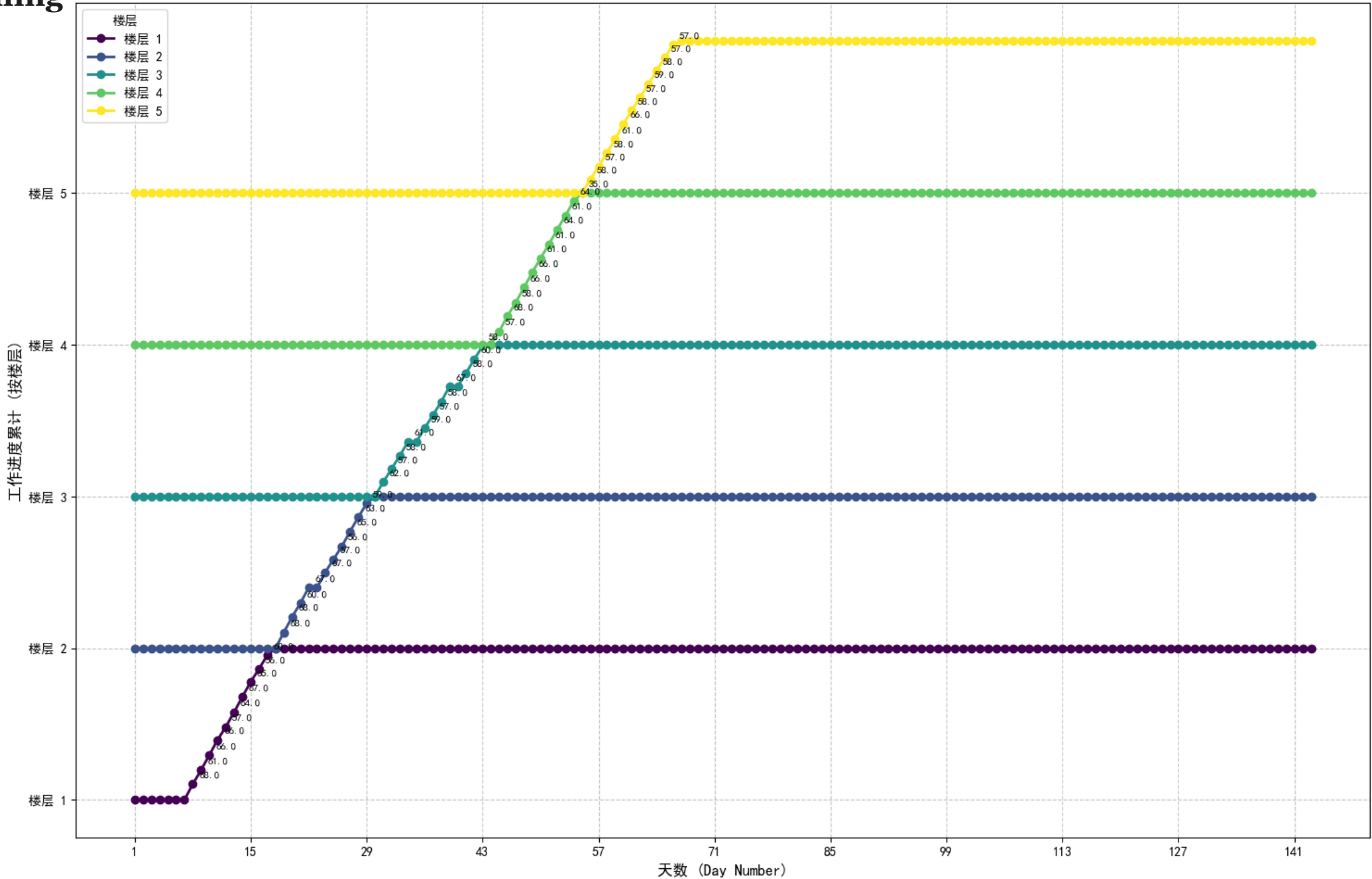
# Pipes in the floor

地板管道 - 工作进度流程 (楼层 1-5)



# Floor tiling

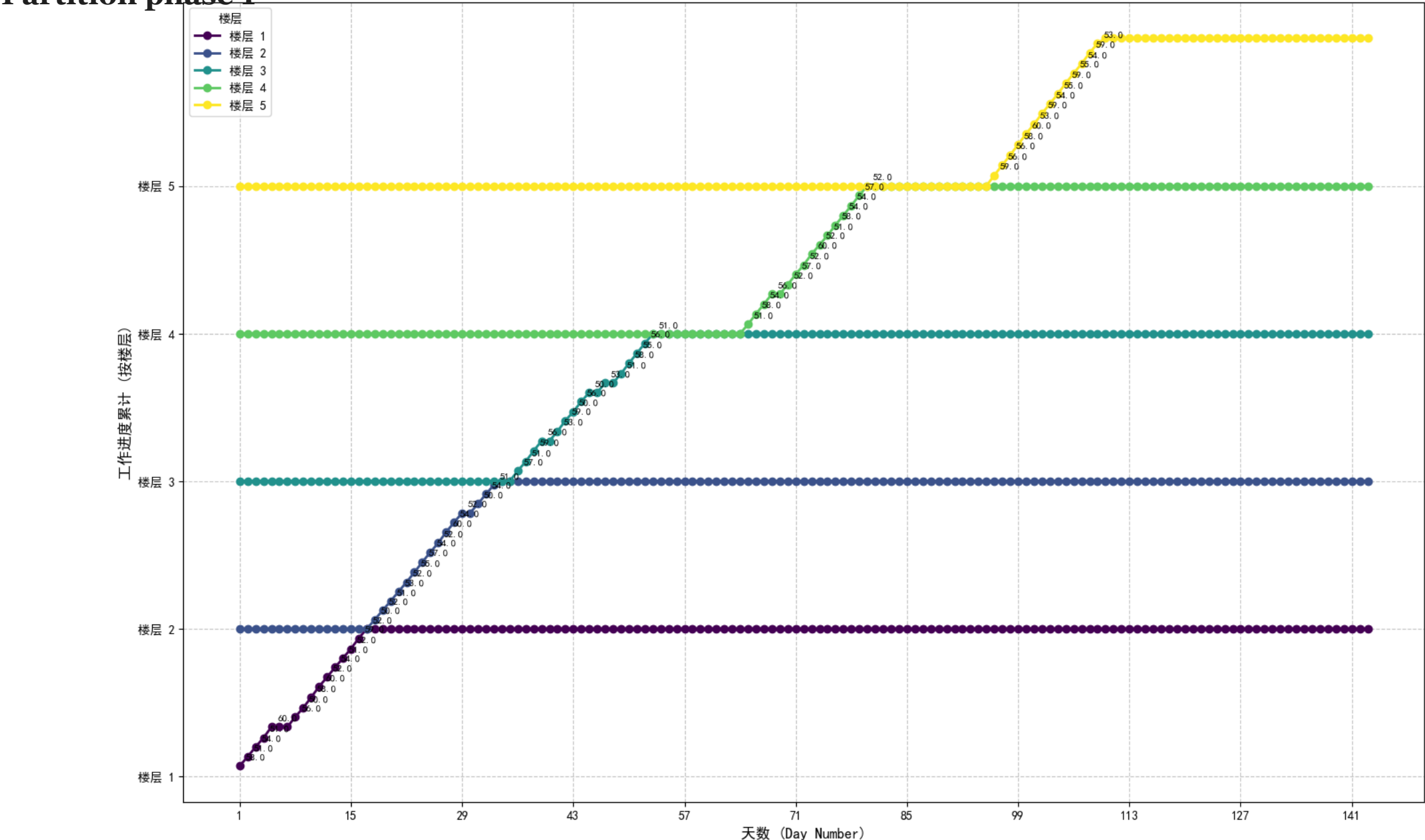
地板瓷砖铺设 - 工作进度流程 (楼层 1-5)





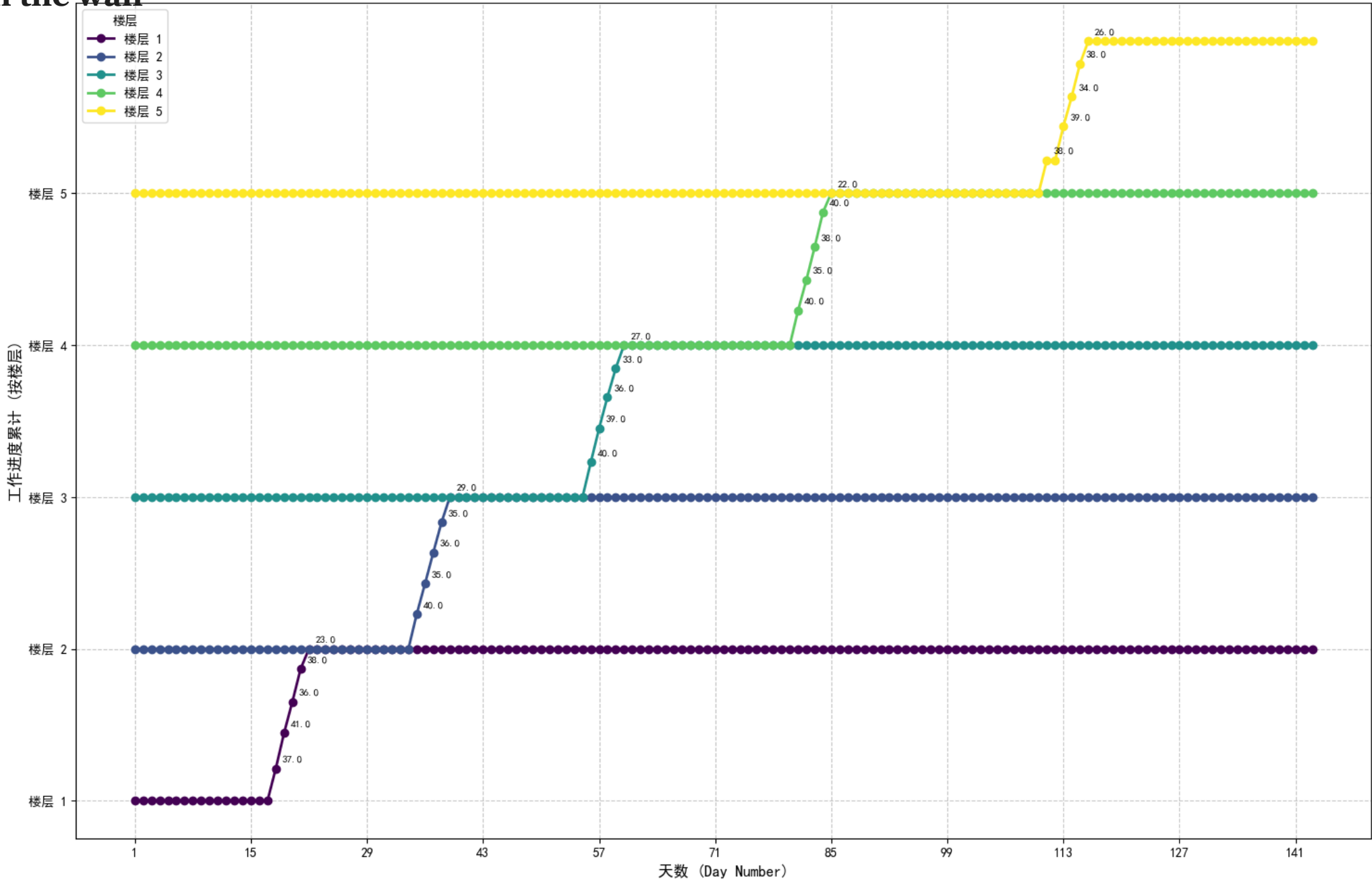
Partition phase 1

隔断第一阶段 - 工作进度流程 (楼层 1-5)



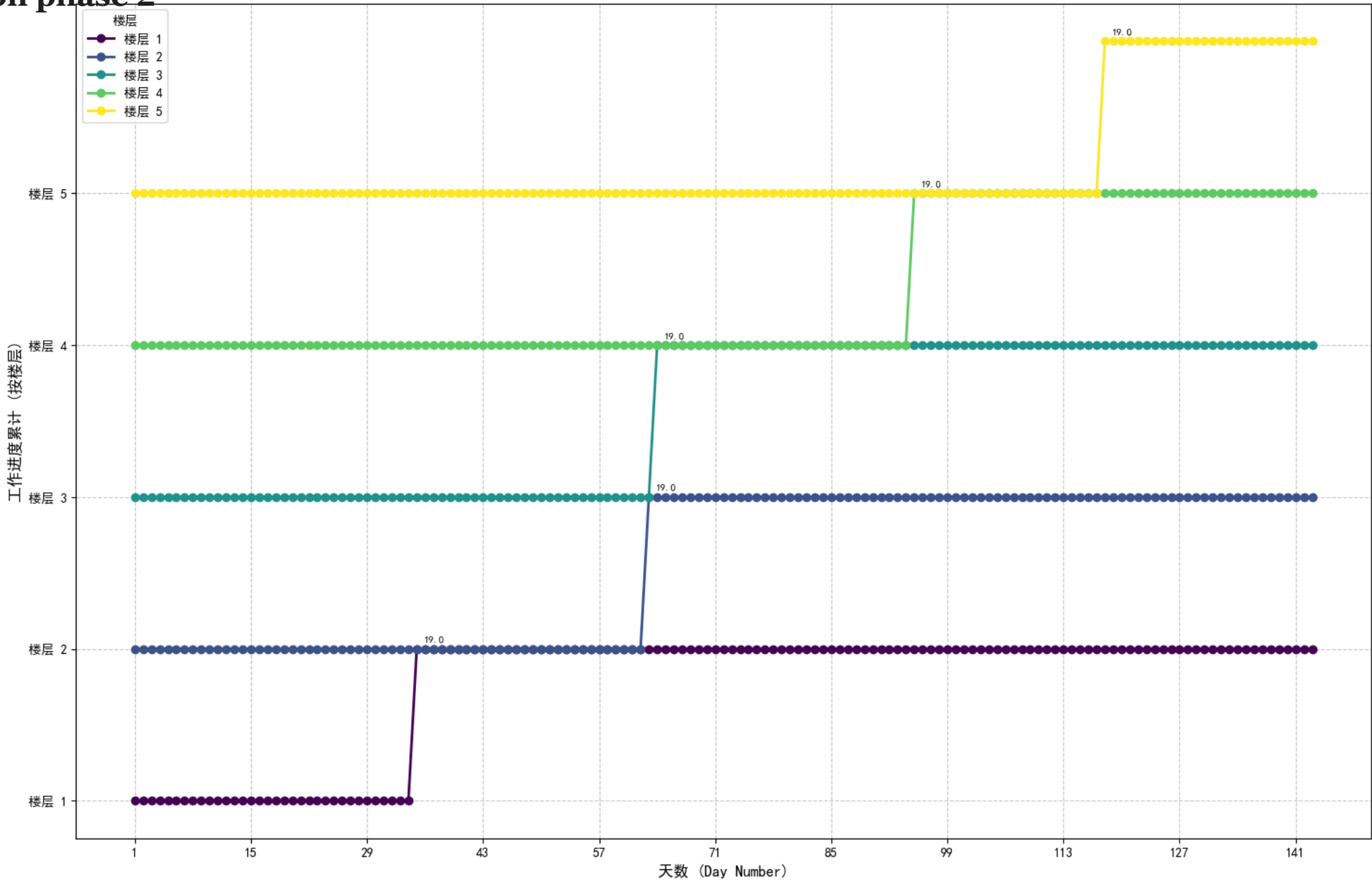
# Pipes in the wall

墙壁管道 - 工作进度流程 (楼层 1-5)



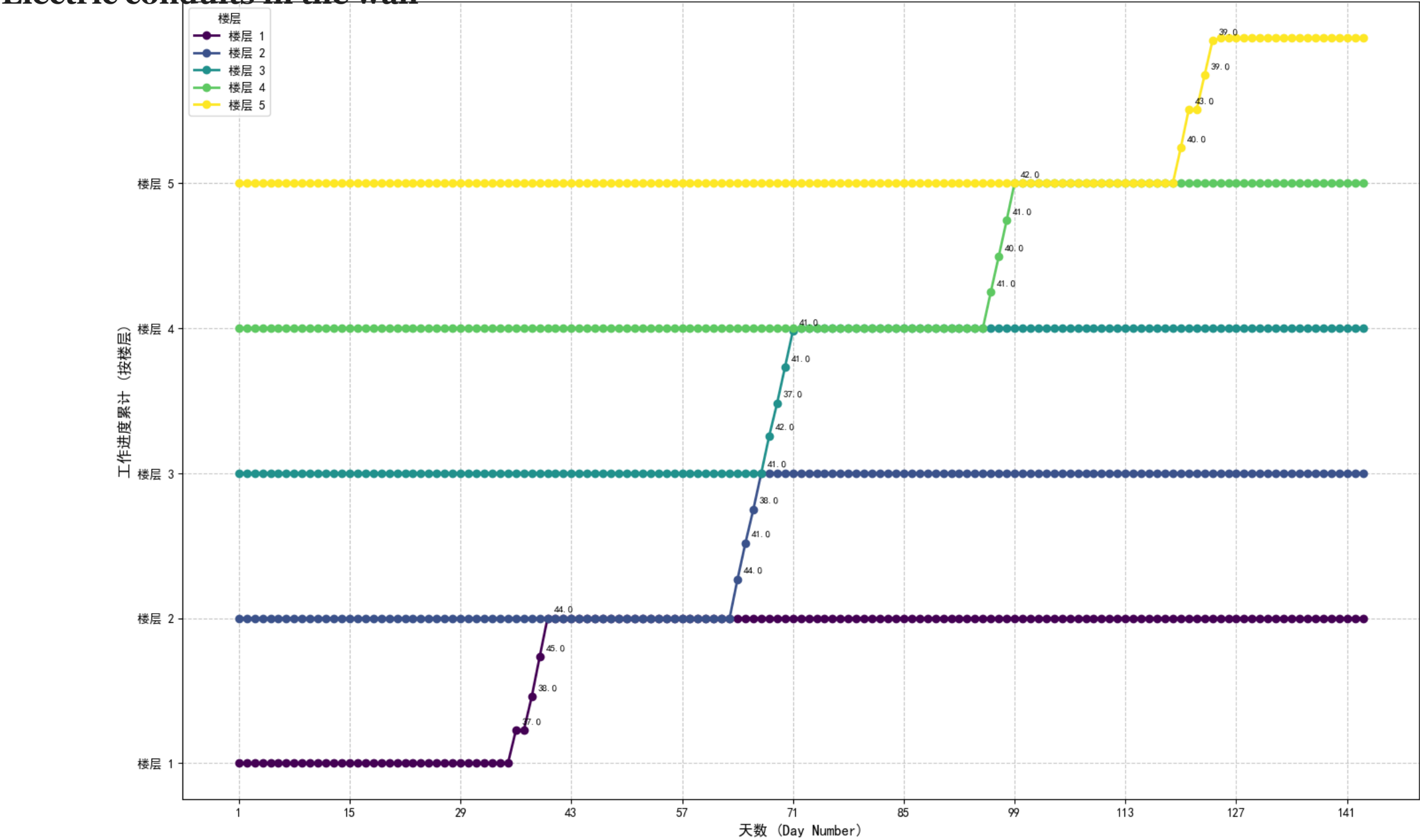
Partition phase 2

隔断第二阶段 - 工作进度流程 (楼层 1-5)



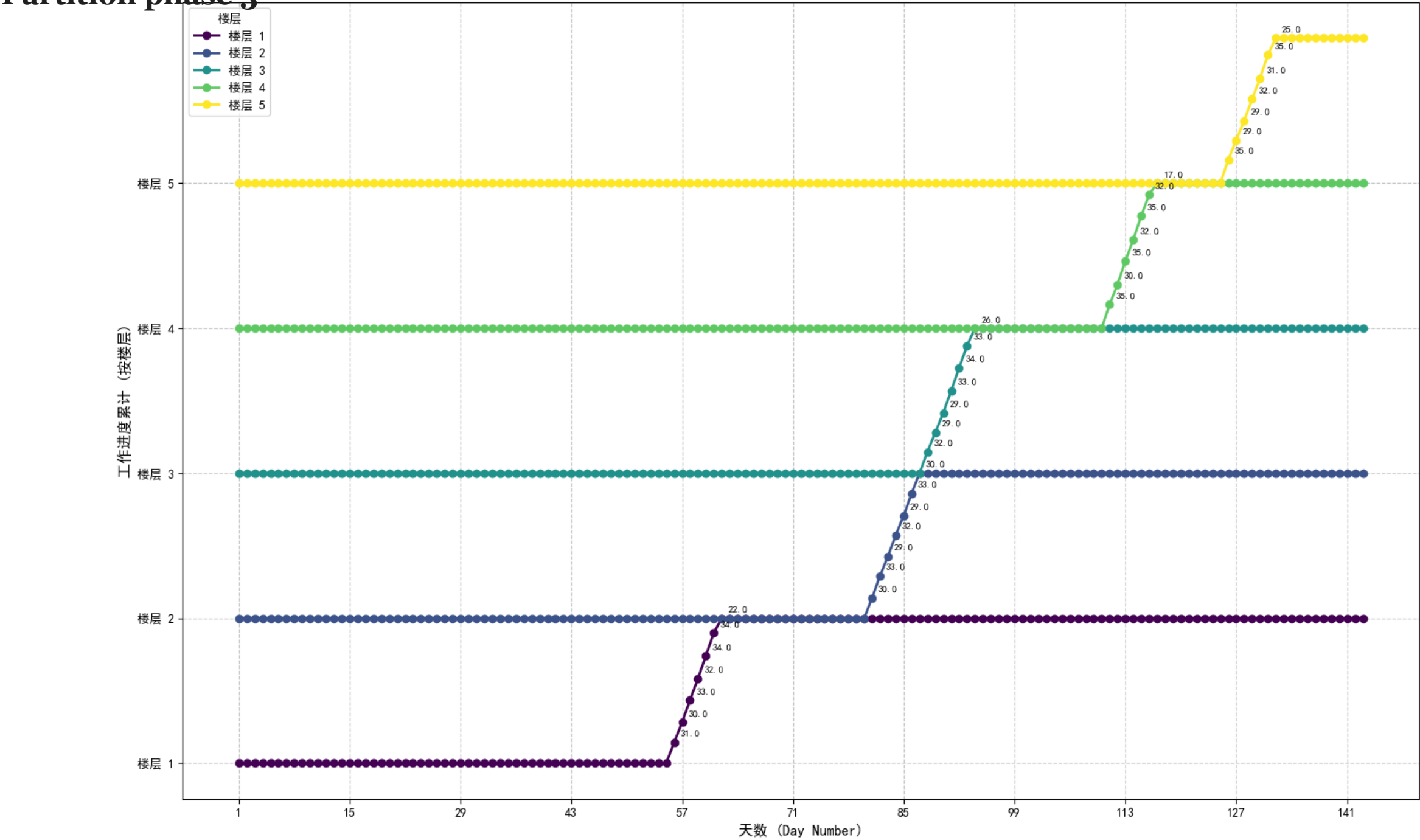
# Electric conduits in the wall

墙壁电线管道 - 工作进度流程 (楼层 1-5)



# Partition phase 3

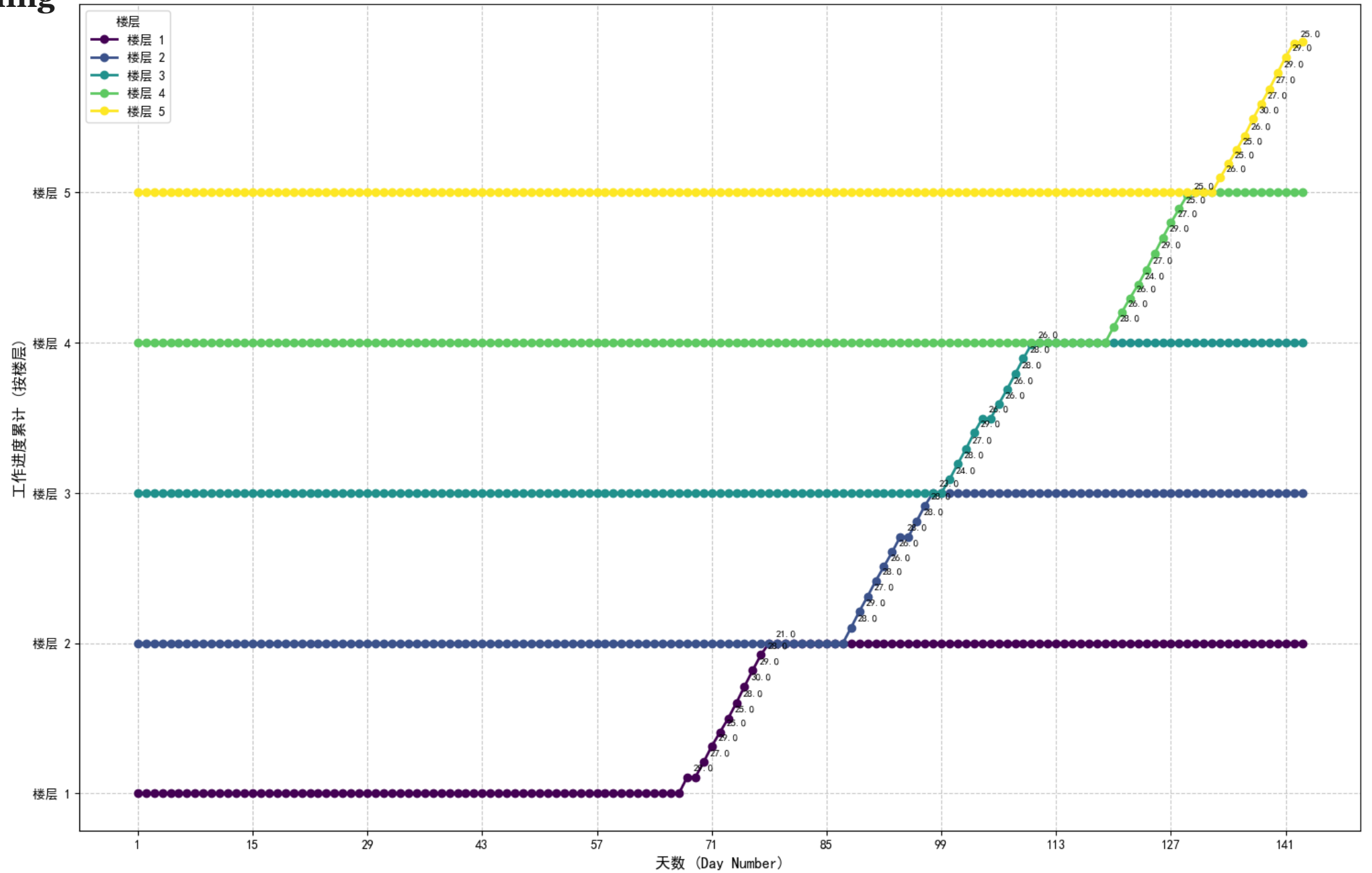
隔断第三阶段 - 工作进度流程 (楼层 1-5)



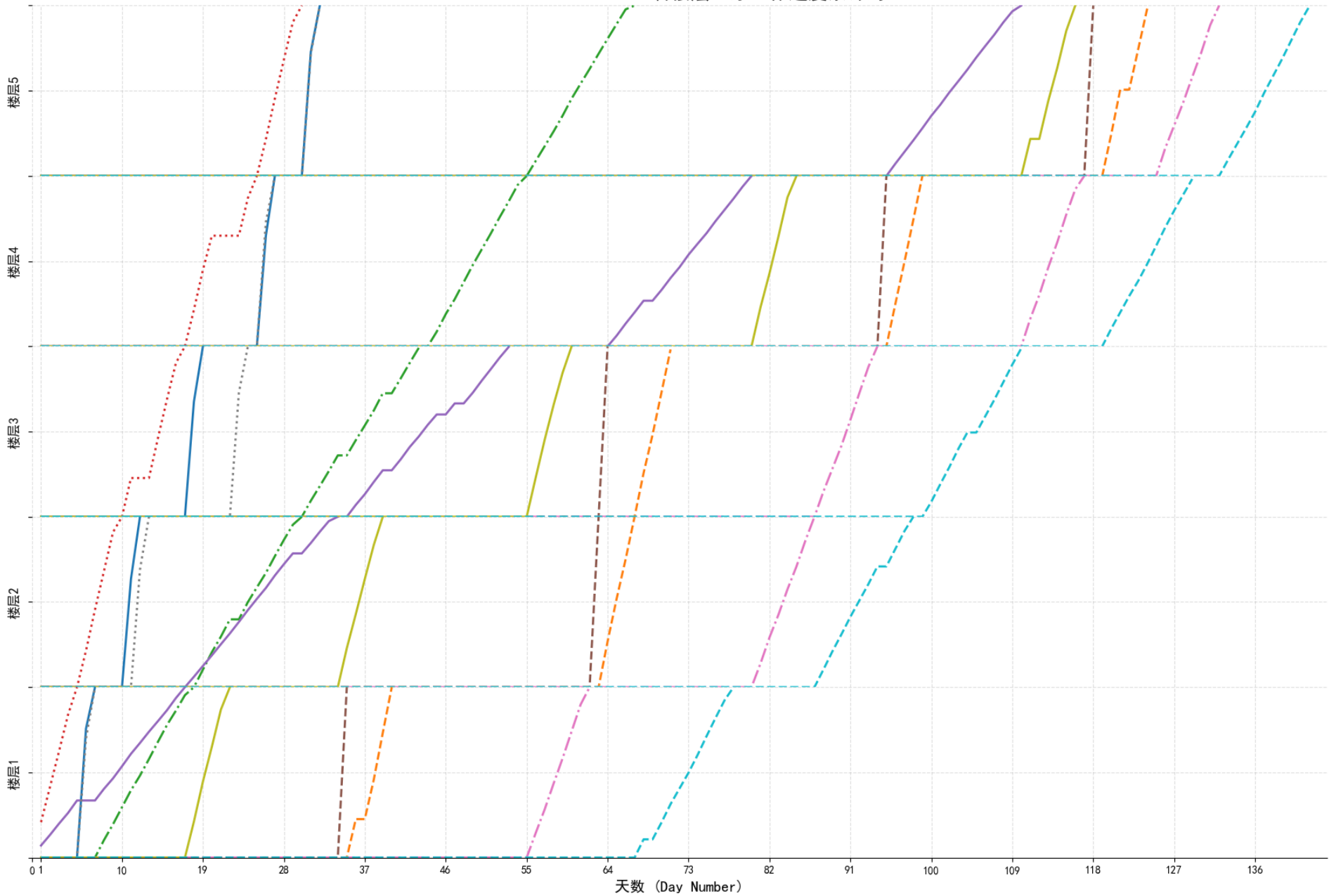


# Wall tiling

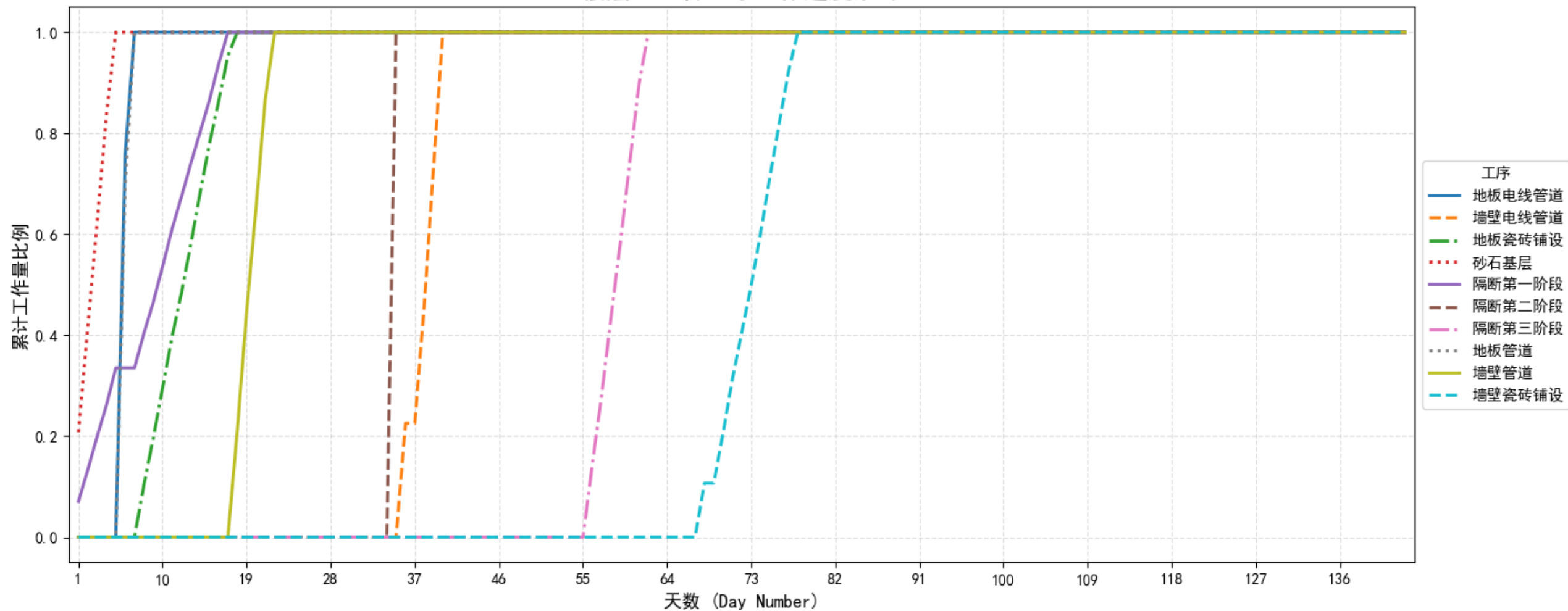
墙壁瓷砖铺设 - 工作进度流程 (楼层 1-5)



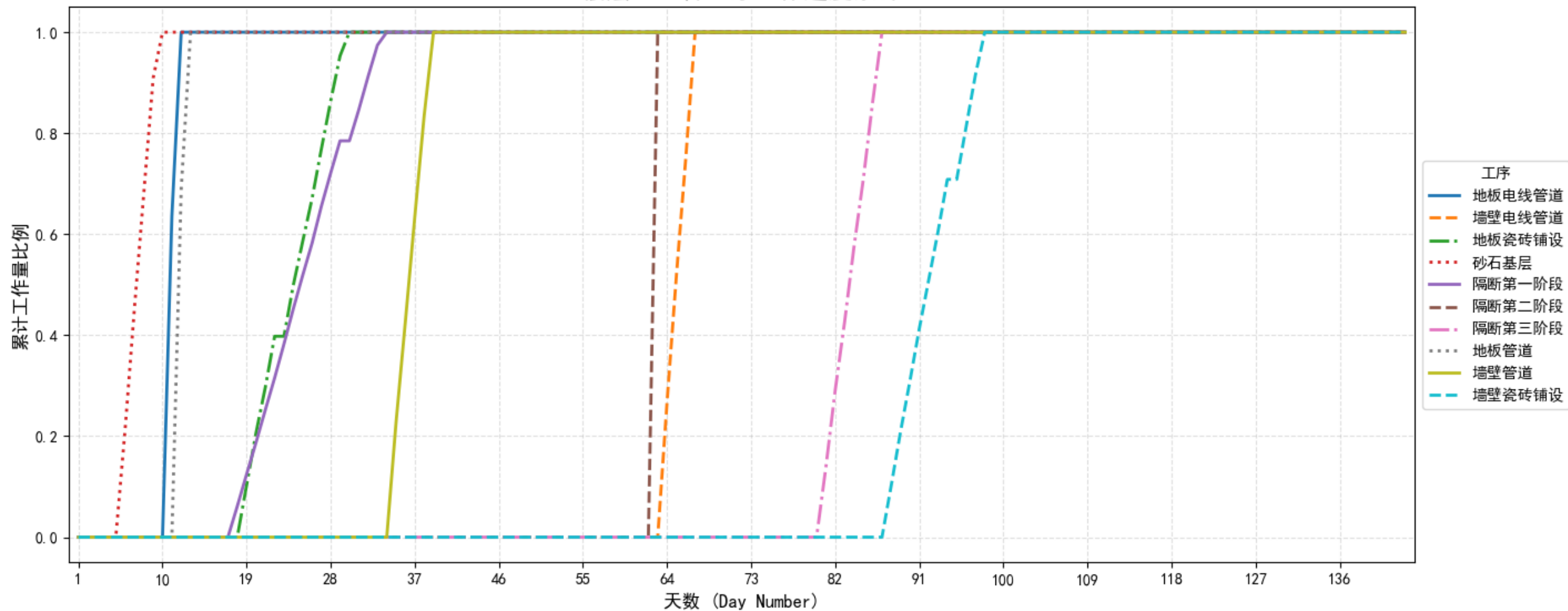
各楼层工序工作进度累计对比



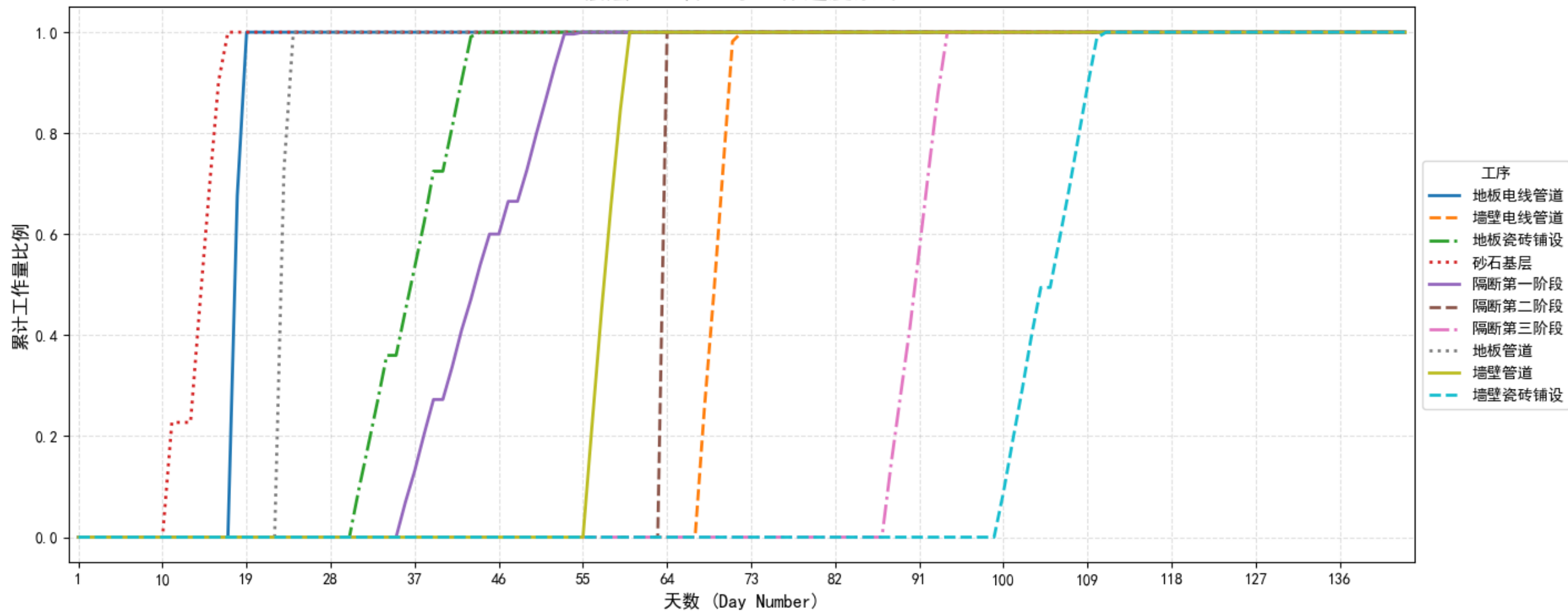
楼层1 - 各工序工作进度累计



楼层2 - 各工序工作进度累计

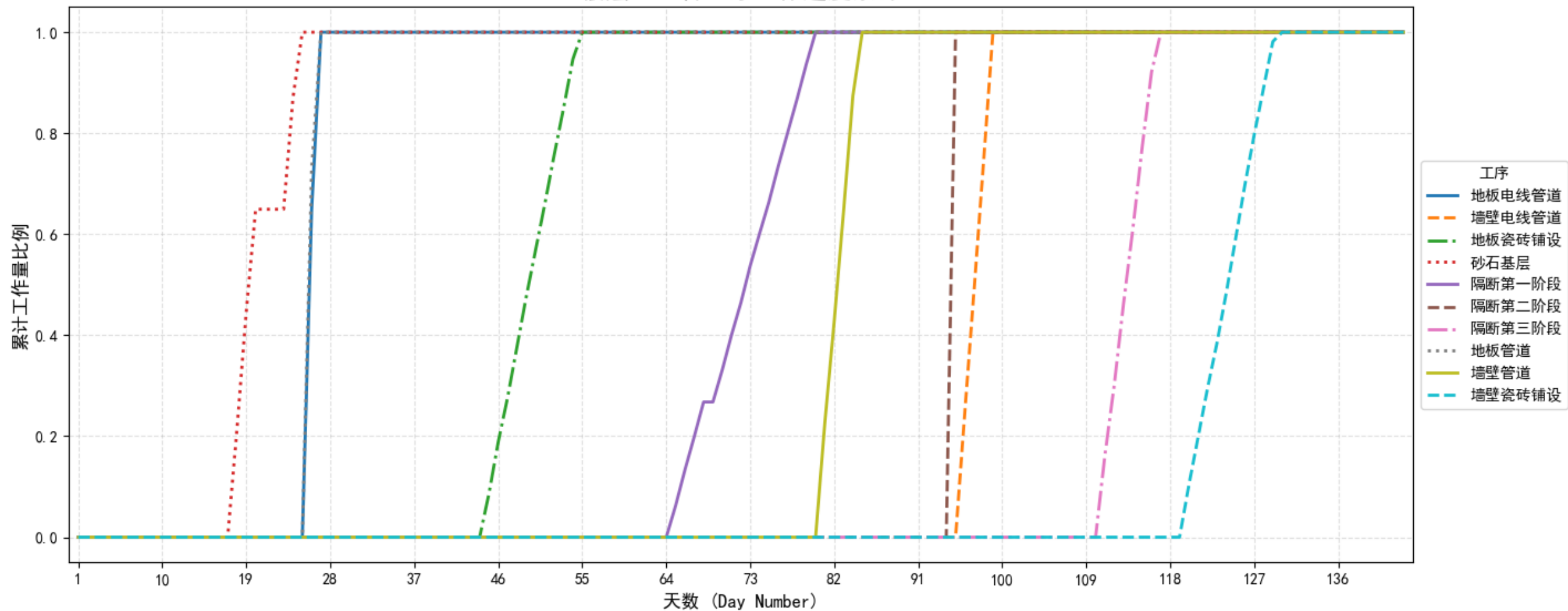


楼层3 - 各工序工作进度累计

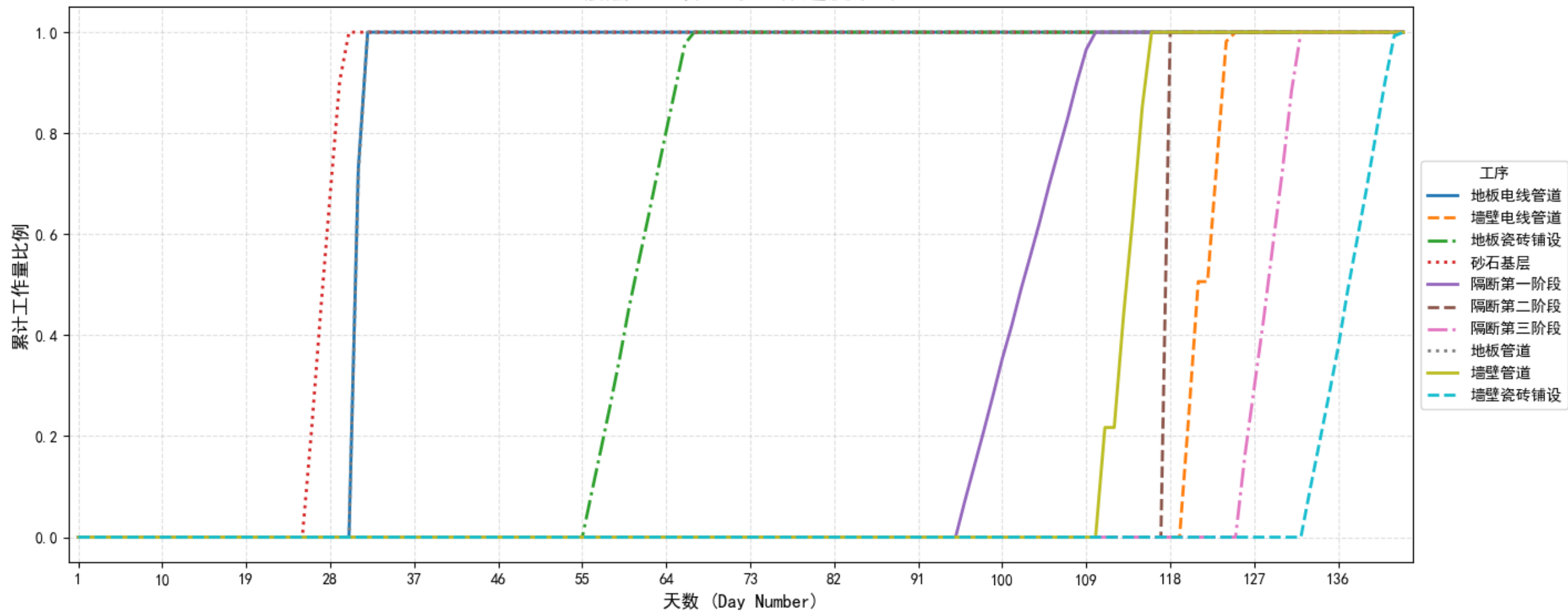


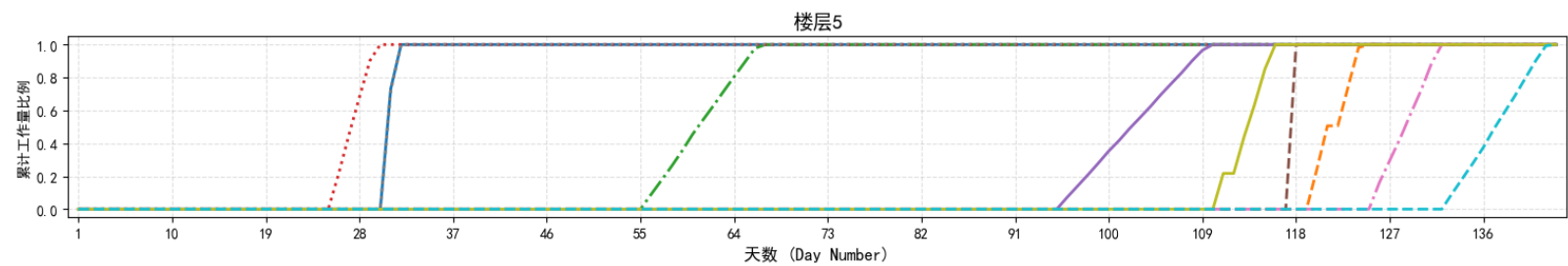
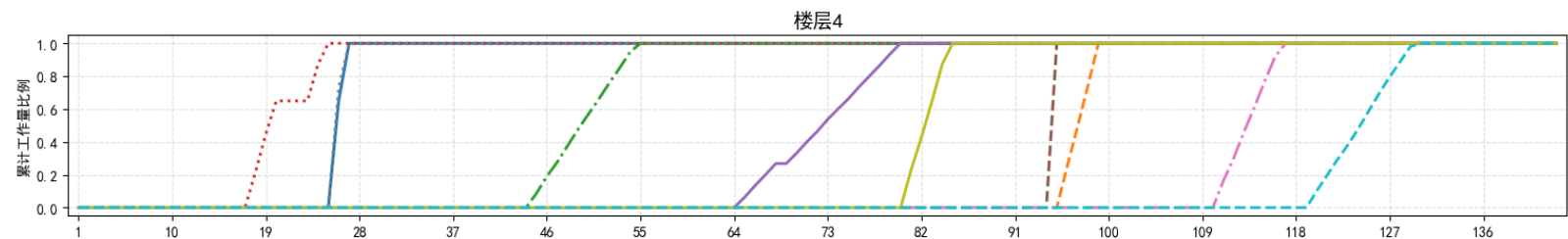
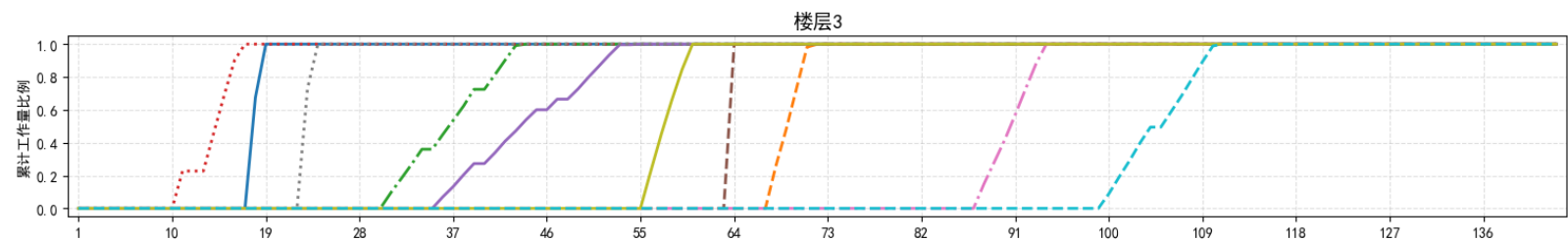
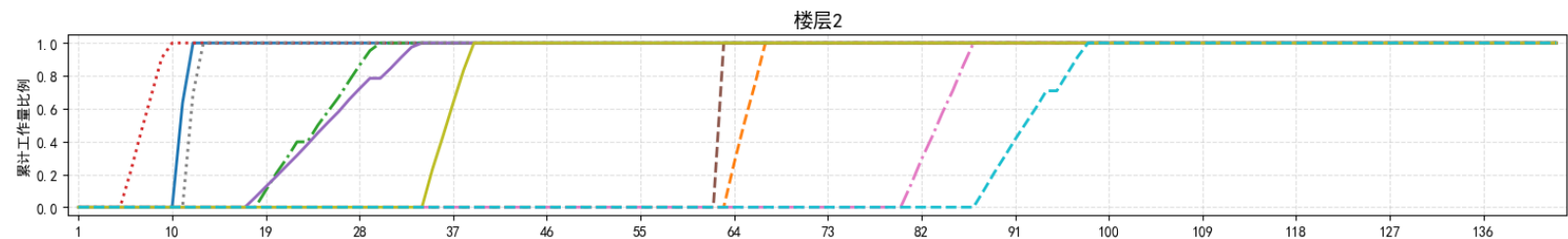
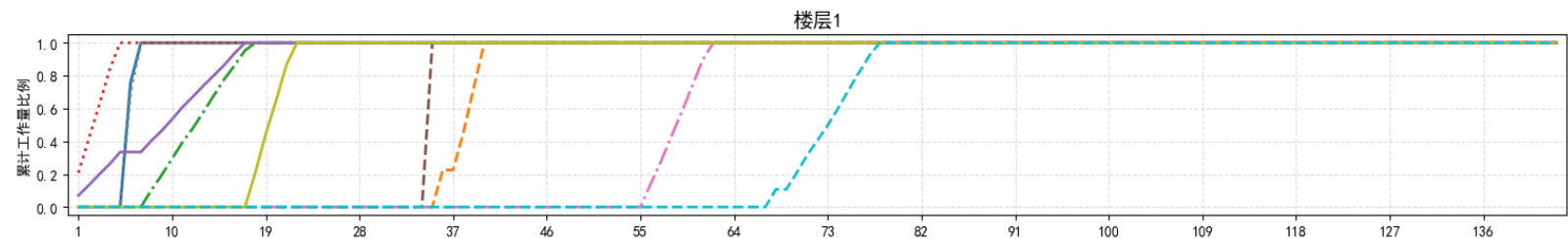


楼层4 - 各工序工作进度累计



楼层5 - 各工序工作进度累计





# 如何丰富/准确整个模拟过程？

day	floor	process	assigned_trade	task_status	initial_p_rate	remain_work	today_workload	predecessor_processes	pre_remain_work	trade_available	can_start
34	1	Partition phase 2	Partition	pending	51	19	0	Pipes in the wall	0	1	TRUE
55	2	Partition phase 2	Partition	pending	51	19	0	Pipes in the wall	0	1	TRUE
55	1	Partition phase 3	Partition	pending	32	216	0	Electric conduits in the wall	0	1	TRUE
62	2	Partition phase 2	Partition	pending	51	19	0	Pipes in the wall	0	1	TRUE
62	3	Partition phase 2	Partition	pending	51	19	0	Pipes in the wall	0	1	TRUE
63	3	Partition phase 2	Partition	pending	51	19	0	Pipes in the wall	0	1	TRUE
80	2	Partition phase 3	Partition	pending	32	216	0	Electric conduits in the wall	0	1	TRUE

55	1	Partition phase 4	Partition	pending	40	180	0	Electric conduits in the wall	0	1	TRUE
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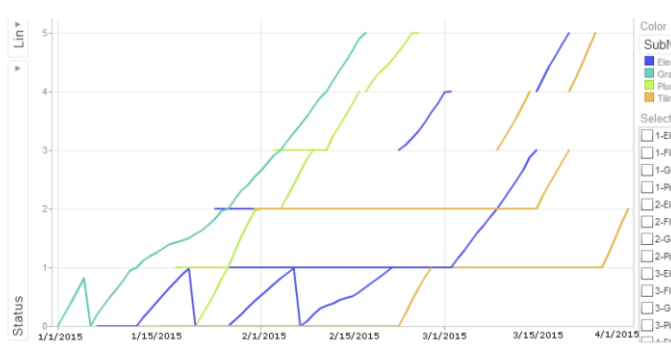
day	floor	process	Assigned trade	Task status	Initial v	Remain work	Expected time	Successor processes	Successor Remain work	Predecessor processes	Pre Remain work	Trade available	Can start
55	2	Partition phase 2	Partition	pending	51	19	1	Electric conduits in the wall	200	Pipes in the wall	0	1	TRUE
55	1	Partition phase 3	Partition	pending	32	216	7	Wall tiling	150	Electric conduits in the wall	0	1	TRUE
55	1	Partition phase 4	Partition	pending	45	180	4	Wall tiling	150	Electric conduits in the wall	0	1	TRUE



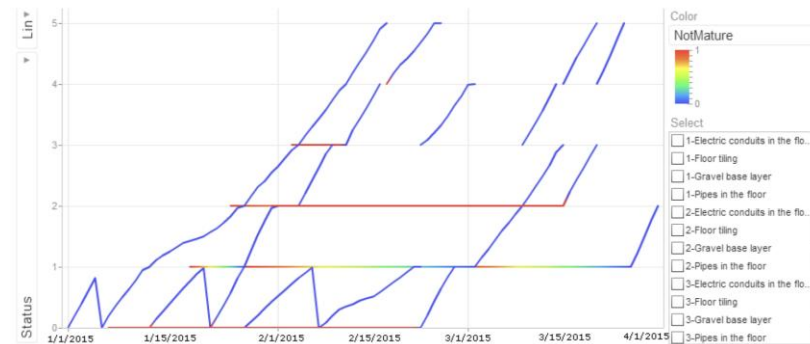
Successor processes	Successor Remain work	Initial v	Remain work	Expected time
Electric conduits in the wall	200			
Wall tiling	150			
Wall tiling	150			

# 进一步研究

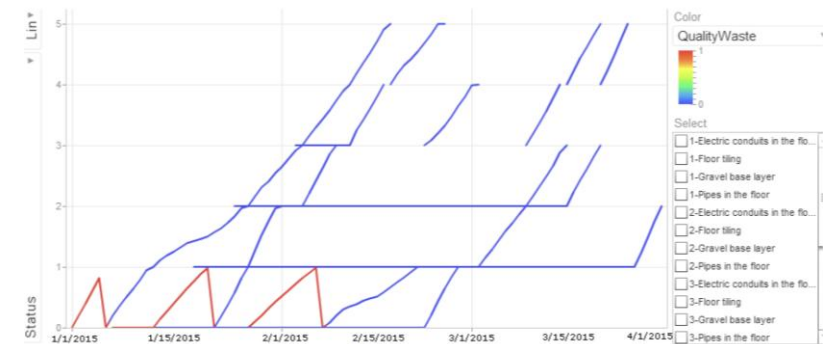
- 更加详细的过程模拟和过程可解释性...
- 利用人工智能对代理人数据建模，进而模拟预测建筑行业工作人员的行为...



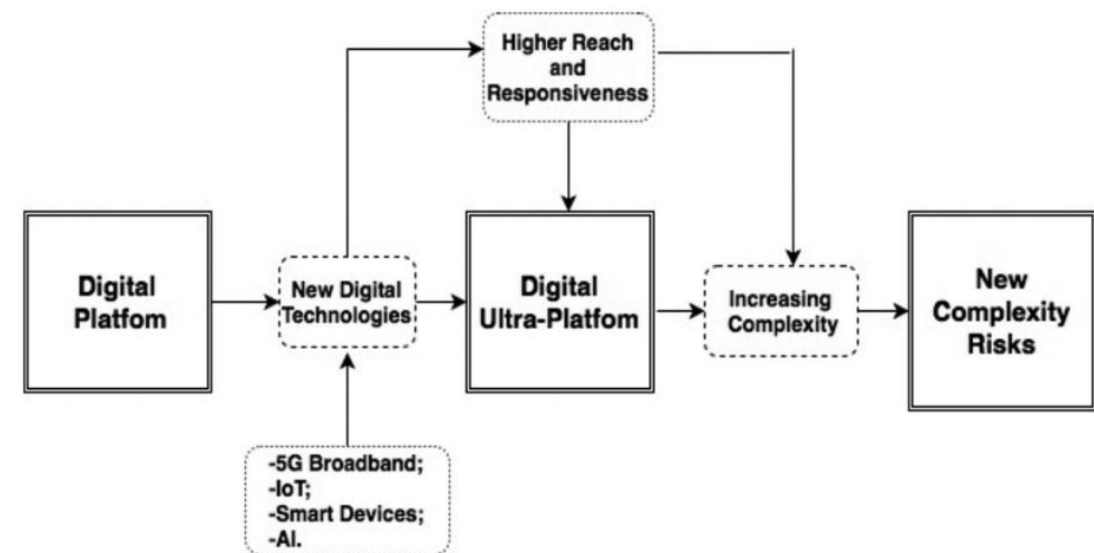
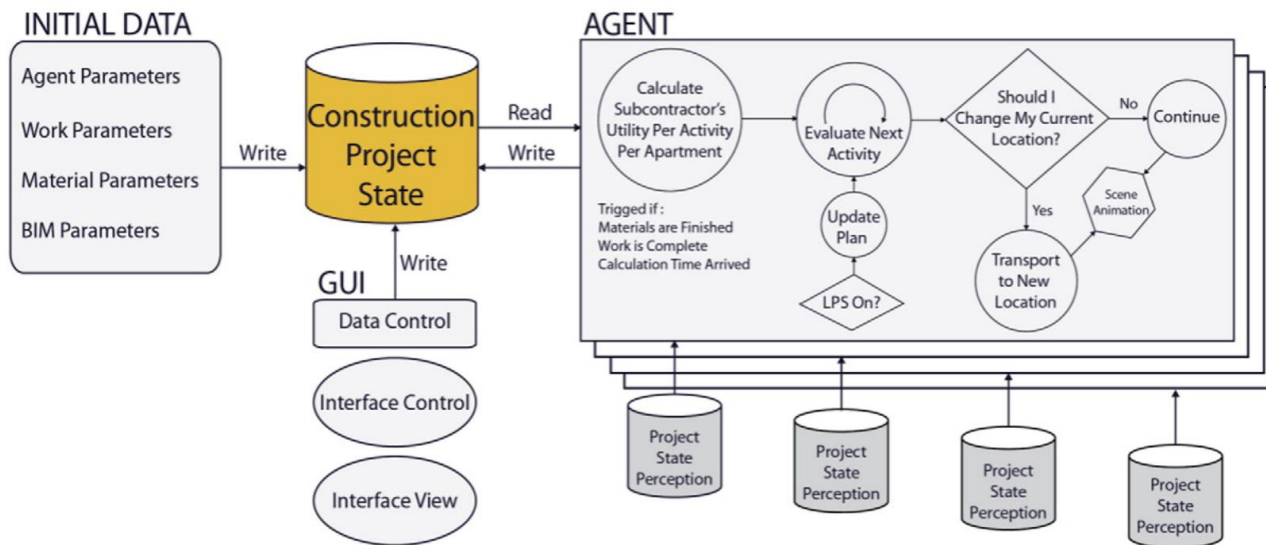
(a) A view of the work flow color-coded by work method



(b) Color-coding representing task maturity level



(c) Color-coding indicating failure of quality checks.





谢谢