System-Theoretical Principles of Project Management

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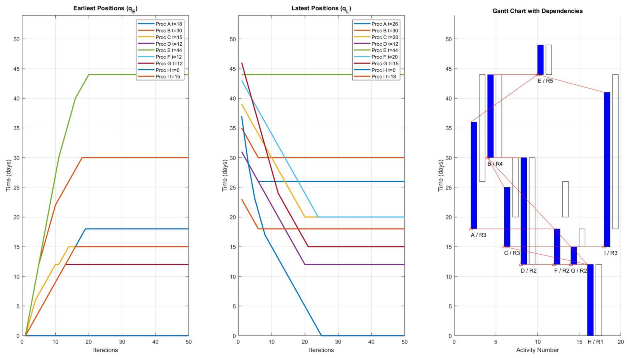
Part I: Theoretical Modelling

Float analysis includes:

- Free float: bF = [8,0,5,0,0,0,0,0,0,3], indicating allowable delay without affecting successors.
- Total float: bT = qL − qE = [8,0,5,0,0,8,3,0,3], showing maximum delay without extending the project.
- Critical path P(c): Defined where bT = 0, consisting of H (12d) → D (18d) → B (14d) →E (5d), summing to 49 days.



This modelling treats activities as nodes in a causal network, where time vectors evolve toward a consistent schedule. The convergence illustrates the system's shift from disorder to equilibrium.

Part II: Exemplary Application

We first summarized the task's logic and constraints in a reference table to clarify their impact on scheduling. We interpret the final conditions as follows: Loading Bay should be completed before Steelwork to avoid extending the road restricted period, while Burner down and Road blocked are fixed durations unrelated to process logic.

Scenario A *(P(c) = B→C→D→I→E→G)*

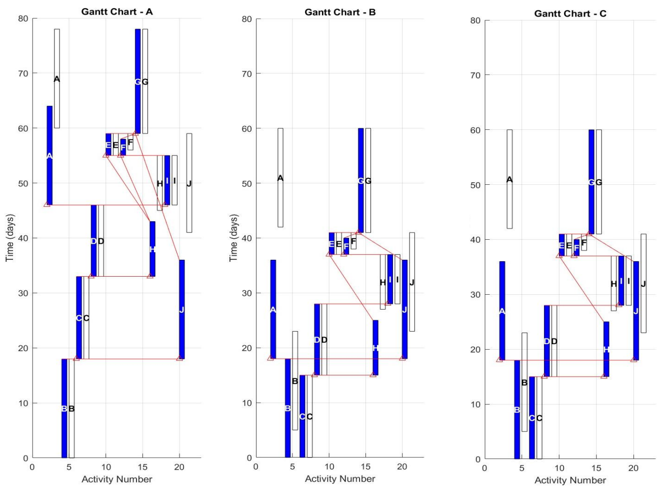
In Scenario A, since Task A is not a prerequisite for B, C, or D, it can be scheduled afterward, forming the sequence B → C → D → A. Tasks J, H, and I follow B, C, and D respectively, and can proceed in parallel. However, A finishes last and heavily overlaps with the steelwork, causing the restricted road period to extend to 64 days. Although the total duration of 78 days is the shortest in Scenario A setups, the overlap of critical tasks and the single concrete team limit parallelism and significantly disrupt traffic planning.

Scenario B *(P(c) = C→D→I→E→G)*

Scenario B uses two concrete teams, enabling two independent foundation paths: B → A and C → D. This strategy improves efficiency. Tasks H, I, E, and F are executed sequentially with limited impact. Since A finishes early—before steelwork begins—the road restricted period is reduced to 36 days. Task J, triggered by B, proceeds independently. The total duration is 60 days, offering a balanced solution under limited resources. Key strengths are parallel structure and optimized task sequencing.

Scenario C *(P(c) = C→D→I→E→G)*

Scenario C, as a resource-enhanced version of Scenario B, still follows two main process chains: B → A and C → D. From the steelwork phase onward, cranes and other resources can be deployed without restrictions, showcasing strong potential for parallel construction. However, due to the logical sequencing constraints between specific tasks, the total project duration remains at 60 days, with no actual reduction. This highlights that even with optimal resource allocation, efficient parallelization must still adhere to the inherent task dependencies.



Sc.	Concreting Crew	Mobile Cranes	Burner down	Road blocked	Road restricted
A	One crew	Sufficient	D59	3d	64d
B	Two crews	Two	D41	3d	36d
C	Two crews	Sufficient	D41	3d	36d

ID	Task	Duration	Predecessors
A	Loading Bay	18 days	-
B	Foundation Loading Station	18 days	-
C	Foundation Support 1	15 days	-
D	Foundation Support 2	13 days	-
E	Steel Girder Support 1 → Support 2	4 days	H, I
F	Steel Girder Support 2 → Burner House	3 days	I
G	Transporting Belt	19 days	E, F ,J
H	Steel Construction Support 1	10 days	C
I	Steel Construction Support 2	9 days	D
J	Steel Construction Loading Station	18 days	B

Comparison and Recommendations

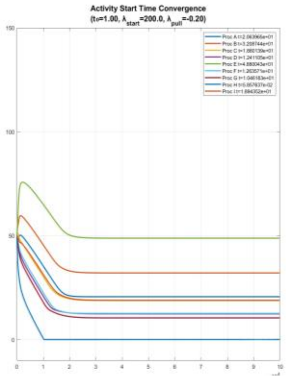
Among the three, Scenario C and B performs the same. In contrast, Scenario A suffers from extended duration and severe traffic limitations due to overlapping critical tasks. The reason why Scenario B is essentially the same as Scenario C is that the belt must be installed last, and all foundations must be completed beforehand. Providing sufficient cranes changes nothing. As a result, the number of crews becomes the key factor determining the overall project duration.

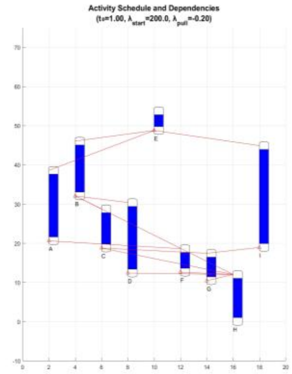
We note that Road blocked (3 days) is fixed. Prioritizing Task A can reduce its overlap with steelwork.

Effective scheduling should emphasize identifying critical dependencies and starting long-duration tasks early to improve downstream coordination and workforce allocation. When possible, high parallelism and staggered scheduling can significantly enhance both efficiency and flexibility.

Part I: Soft procedures

The system was modeled using soft procedures with a global indetermination parameter $\mathbf{t_0}$ controlling the volatility of activity start times. This parameter reflects the combined influence of local variations, inter-activity interactions, and global scheduling uncertainty. The first figure shows the convergence of start times under a weak pull **(λpull = −0.2)** towards the earliest position and a start boundary condition **(λstart=200)** enforcing no activity before time zero. The second figure illustrates the resulting schedule and dependencies, where the fuzzy rectangles represent the time windows influenced by cumulative indetermination. This representation highlights the flexibility inherent in soft scheduling approaches. **(t_0= t_0,local+ t_0,IntA+ t_0,global)**

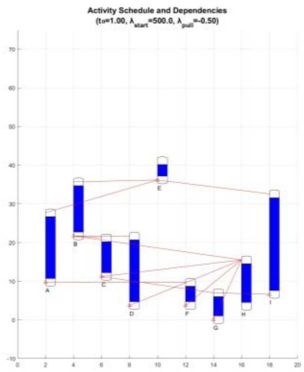


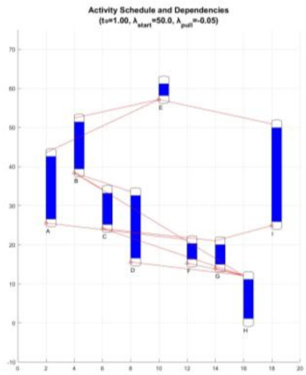


Part II:

Scenario A: Modify weights of boundary conditions

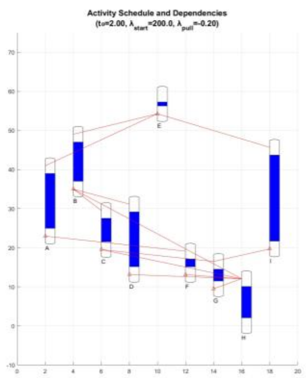
In Experiment A, we modified the boundary condition weights λ. The Baseline case **(λ=200/-0.2)** shows moderate flexibility and convergence speed. The strong boundary condition **(λ=500/-0.5)** forces all activities to rapidly converge toward the left side of the time axis, reducing fuzziness and resulting in a more rigid system. In contrast, the weak boundary condition **(λ=50/-0.05)** leads to slower convergence, larger fuzzy regions, and a more dispersed distribution of activities, reflecting higher system flexibility. This demonstrates that the weight of boundary conditions significantly influences the stability and adaptability of the scheduling process.





Scenario B: Vary the global indetermination parameter

In Experiment B, we varied the global indetermination parameter $\mathbf{t_0}$ to observe its effect on scheduling flexibility. The Baseline case **t_0= 1** exhibited moderate fuzziness and a balanced level of flexibility. When **t_0= 0.1**, the system became highly rigid, with almost no fuzziness in activity start times, resembling a traditional deterministic scheduling approach. Conversely, increasing to **t_0= 2** significantly enlarged the fuzzy regions, allowing greater temporal overlap and reflecting a highly flexible scheduling behavior. This demonstrates that t0t_0t0 directly controls the trade-off between rigidity and adaptability in the soft procedure model.



Scenario C: Latest Start Time Preference

In this experiment, a soft pull was applied toward a later target time (t=50), using a strong sigmoid-based force **(λ=-200/0.2)** to deliberately shift activities toward their latest feasible start times. This configuration resulted in a schedule where tasks are noticeably shifted toward the right side of the time axis. The Finish-Start (FS) dependencies were fully respected, ensuring logical consistency between successive activities despite the temporal displacement. Key activities such as A, B, and I exhibited significant delays, highlighting a conservative scheduling approach that avoids early starts unless strictly necessary. This behavior illustrates the flexibility introduced by soft constraints in modifying task timing within a defined total duration limit. By directing soft forces toward a later point in time, the system effectively generates a late-start strategy that remains feasible and compliant with dependency requirements, offering potential benefits for resource leveling and risk-buffering.