

Time Reduction Modeling Using Linear Optimization on Soil Improvement for Large Scale Construction Project

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ABSTRACT

At the time of large-scale soil material improvement in construction operation that includes highways and building infrastructures, the very most important factor is the time which determines the resource management and safety. One of the most persistent challenges associated with such projects is excessive construction duration, arising from the sequential nature of activities, equipment limitations, logistics constraints, and uncertainty in both field and laboratory operations. A linear optimization framework was developed to minimize total project duration subject to operational, resource, and dependency constraints. The model incorporates ten core construction activities, explicitly accounting for equipment availability, manpower requirements, haulage logistics, and soil behavior assumptions and weather conditionally.

Keywords; Optimization Time Reduction, Soil Material Stabilization, Construction Duration and Sensitivity Analysis.

INTRODUCTION

The impacting nature of time reduction in a project that signify a good understanding and knowledge of the activities in the project, their lapses and the overall project in its entirety. Therefore, soil material stabilization in a different formation of project needs to be studied hard due to the complexity soil foundation.

Soil improvement and stabilization are foundational operations in highway and infrastructure construction where native subgrade soils are weak, highly compressible, or moisture-sensitive.

Where importantly, the scale of reclamation is in large quantity of soil material is required. Then during the construction, we will be looking at improving or stabilizing the soil condition by reducing the amount of time consumption during the construction time, so as not to effect the total time of the entire project.to this effect, we are working on parameters.

In this paper we will look into a model development of the time for hauling, for both in and out of the site, also work on time monitoring factors, and the inconsistency of equipment. Inconsistency not negligible for the purpose of working on the none critical parameters. This introduction will be including the verification and validation tools with Montecarlo's process of stimulations. Onamular, 2019. For tradition deterministic scheduling track.

METHODOLOGY

Model Structure and Assumptions

The soil improvement process was decomposed into ten major activities: site assessment, sampling and laboratory testing of in-situ soil, borrow material exploration, borrow material testing, procurement of suitable borrow material, excavation and disposal of unsuitable soil, compaction of formation, delivery of

replacement soil, placement and compaction of replacement soil, and natural consolidation. In a tabular form, the activities were presented with their resources as shown.

TABLE 2.1; ACTIVITY BREAKDOWN TABLE.

S/N	Activities	Human Resource Allocation
1	Bad soil discovery (Site Assessment to evaluate the extent of soil replacement required)	5
2	Sample Collection and Lab test of in-situ materials	5
3	Borrowed material Exploration.	4
4	Borrowed material sampling and Testing.	5
5	Procurement of Laboratory Satisfied borrow material	2
6	Excavation of in-situ material and its Removal to the Disposal site	6
7	Compact formation	4
8	Replacement Soil Delivery	4
9	Mat. Backfilli/test (Borrow material Placement and compaction)	6
10	Cond. Soil settlemt (Consolidation of Compacted borrowed soil)	1

Key assumptions include an eight-hour working day, five working days per week, a maximum haulage distance of 10 km, continuous site operations without weather interruptions, and deployment of minimum equipment sets to ensure uniformity in model formulation. The maximum affected soil volume was assumed not to exceed 9,000 m³ based on geometric limits of the treatment area.

Optimization Model Formulation

The objective of the model is to minimize the total project duration, expressed as the sum of durations of all activities. Decision variables represent activity durations, while constraints enforce minimum allowable durations, precedence relationships, and equipment-based limits. The resulting formulation constitutes a linear optimization problem. Initial optimization results indicated that the baseline schedule was already tightly constrained, yielding a total duration of 1,696 days.

Further optimization was achieved by allowing partial overlap of selected non-dependent activities and by allocating additional resources to critical operations such as excavation and compaction. These adjustments reduced the total duration to 1,606 days.

Sensitivity and Monte Carlo Simulation

To evaluate schedule uncertainty, Monte Carlo simulation with 10,000 iterations was conducted, allowing $\pm 20\%$ variability in activity durations. The simulation produced probabilistic estimates of total project duration and enabled identification of activities with the highest influence on schedule outcomes.

A similar simulation framework was applied to laboratory testing operations, using observed per-test durations and triangular probability distributions. Pearson correlation coefficients were computed to quantify test-level sensitivity.

RESULT AND DISCUSSIONS

Model Derivation data

Let $x_1 y_1$ represents the “site Assessment activity and the duration to carry it out in days respectively”.

Let $x_2 y_2$ represents the “laboratory test Activity of Existing Sub-grade material” and the duration of accomplishing it respectively.

Let $x_3 y_3$ represent the “Borrowed Material Exploration Activities” and the time to carry it out respectively.

Let $x_4 y_4$ represent the “Borrowed Material sampling/testing Activities” and
the time to accomplish it respectively

Let $x_5 y_5$ represent the “Procurement of Borrowed material Activities” and the time to accomplish it respectively.

Let $x_6 y_6$ represent the “Excavation and Evaluation of the bad subgrade material” and the duration to accomplish it respectively.

Let $x_7 y_7$ represents the “Compaction formation after the removal of the bad soils and before filling of the borrowed materials” and the duration to accomplish it respectively.

Let $x_8 y_8$ represent the “Transportation of the Borrowed soil to the site” and the time to accomplish it respectively.

Let $x_9 y_9$ represent the “placement and compaction in layers of the borrowed material” and the duration to accomplish it respectively.

Let $x_{10} y_{10}$ represent the “Natural Consolidation of the placed borrowed soil” and the duration to accomplish it respectively.

Constraints Derivation data

Activity Limit of Constraint

Hence constraint derivation data were limited to the model presented from model formulation above which are represented as follows; y_{1x1} , y_{2x2} , y_{3x3} , y_{4x4} , y_{5x5} , y_{6x6} , y_{7x7} , y_{8x8} , y_{9x9} , y_{10x10} .

Coefficients

Let the coefficients of the Model represent the time or duration of the said activity(ies) in the Model. If Y is the time/duration of activities in the model, then the model will be rearranged and represented as follows:

y_{1x1} , y_{2x2} , y_{3x3} , y_{4x4} , y_{5x5} , y_{6x6} , y_{7x7} , y_{8x8} , y_{9x9} , y_{10x10} .

Time Constraint Derivation

Table 3.1: Table showing the Duration of each activities in the Model

S/N	Activities	Time in Days	Time in Weeks
1	Bad soil discovery(Site Assessment to evaluate the extent of soil replacement required)	15	3
2	Sample Collection and Lab test of in-situ material	14	3
3	Borrowed material Exploration.	14	3
4	Borrowed material sampling and Testing.	14	3
5	Procurement of certified borrow material	7	1.5
6	Excavation of in-situ material and its Removal to the Disposal site	394	78.8
7	Compact formation	396	79.2
8	Replacement Soil Delivery	413	82.6
9	Mat. Backfill/test (Borrow material Placement and compaction)	415	83
10	Cond. Soil settlement (Consolidation of Compacted borrowed soil)	14	3

For Optimization Purposes

Initial Problem:

$$\text{Minimize } Z_{\text{initial}} = 15y_1 + 14y_2 + 14y_3 + 14y_4 + 7y_5 + 394y_6 + 396y_7 + 413y_8 + 415y_9 + 14y_{10} \quad (3.1)$$

Subject to: $y_i \geq \text{Initial Duration } i$, for all i

$$\text{Finish Time}_i = \text{Esi} + y_i \quad (3.2)$$

$\text{Esi} + 1 \geq \text{EF}_i$, for all dependent activities

The optimized model for the soil stabilization activities yields the following durations:

- Site Assessment Activity (x_1, y_1 to x_{-1}, y_{-1}): 15 days
- Laboratory Test of Existing Sub-grade Material (x_2, y_2 to x_{-2}, y_{-2}): 14 days
- Borrowed Material Exploration Activities (x_3, y_3): 14 days
- Borrowed Material Sampling/Testing Activities (x_4, y_4): 14 days
- Procurement of Borrowed Material Activities (x_5, y_5): 7 days

- Excavation and Evaluation of Bad Subgrade Material (x_6, y_6): 394 days
- Compaction Formation After Removal of Bad Soils (x_7, y_7): 396 days
- Transportation of Borrowed Soil to Site (x_8, y_8): 413 days
- Placement and Compaction in Layers of Borrowed Material (x_9, y_9): 415 days
- Natural Consolidation of Placed Borrowed Soil (x_{10}, y_{10}): 14 days

The total optimized duration to accomplish all activities is **1696 days**.

This optimization doesn't change the initial durations since the given constraints (earliest start, finish, latest start, finish, and float times) are already respected by the initial durations provided. Therefore, the total duration remains the same at 1696 days. This suggests that the activities have little room for reduction under the current constraints. Further optimization would require changes in constraints or dependencies between activities.

For the purpose of clarity measures, the activities are arranged in accordance to the objective of the on going projects which in turn relate to the method of Critical Path (CPM). This method was included so as to have the activities perform in parallel form.

More so, when the critical path method is performed, the objective was to arrive at the same result of 1696 days of the same baseline project duration.

The optimized project duration is accomplished when the final optimization process is applied subject to the initial conditions.

Objective Function

The goal is to minimize the total duration Z of the project, which is the sum of the durations of all activities:

$$\text{Minimize } Z = \sum_{i=1}^{10} y_i = x_1y_1 + x_2y_2 + x_3y_3 + x_4y_4 + x_5y_5 + x_6y_6 + x_7y_7 + x_8y_8 + x_9y_9 + x_{10}y_{10} \quad (3.3)$$

where y_i represents the duration of activity x_i .

Constraints

Non-Negativity Constraints:

The duration of each activity cannot be reduced below a certain threshold (initial durations provided):

$$Y_i \geq \text{Initial Duration } i, \text{ for all } i \in \{1, 2, \dots, 10\}$$

Dependency Constraints:

Each activity x_i can start only after its predecessor activities are completed, but with some modifications:

Activity x_3 and x_4 Overlapping:

The earliest start of x_4 is allowed to overlap with x_3 :

$$ES_4 = ES_3 + \epsilon \quad (\epsilon \text{ is a small overlap, e.g., 1 day}) \quad (3.4)$$

Resource Allocation: By allocating additional resources, the durations of x_6 and x_7 are reduced:

$$y_6 \leq 350 \text{ and } y_7 \leq 350$$

Finish Time Constraints

The finish time of each activity is constrained by its start time and duration:

$$\text{Finish } T_{Fi} = E_{Si} + y_i \quad (3.5)$$

For the last activity x_{10} , we must ensure:

$$\text{Finish Time}_{10} \leq 472$$

Optimization Problem

Applying the optimization problem, this can be expressed as:

$$\text{Minimize } Z = x_1y_1 + x_2y_2 + x_3y_3 + x_4y_4 + x_5y_5 + x_6y_6 + x_7y_7 + x_8y_8 + x_9y_9 + x_{10}y_{10} \quad (3.6)$$

Subject to:

$$y_i \geq D_i, \text{ for all } i \in \{1, 2, \dots, 10\}$$

$$y_6 \leq 350, y_7 \leq 350$$

$$T_{FT10} \leq 472$$

$$ES_4 = ES_3 + \epsilon$$

$$(\epsilon \text{ is a small overlap}) \quad (3.7)$$

$$T_{Fi} = ES_i + y_i \quad (3.8)$$

Where;

T = Finish Time

ES = Early Start

T_i = Initial Time.

Solution

By solving this optimization problem, we obtained the optimized durations:

- $Y_6=350$ (reduced from 394 days)
- $Y_7=350y$ (reduced from 396 days)
- The total optimized project duration Z is reduced to 1606 days.

Adjusted Dependencies and Constraints

- **Overlap Possible:** Assume that “Borrowed Material Exploration Activities” (x_3) and “Borrowed Material Sampling/Testing Activities” (x_4) can start earlier.

- **Resource Allocation:** Assume that with additional resources, the durations of “Excavation and Evaluation of Bad Subgrade Material” (x_6) and “Compaction Formation” (x_7) can be reduced.

Updated Model constraint parameters

- Adjusted earliest start times for x_3 and x_4 .
- Reduced durations for x_6 and x_7 .

Let's model these changes and see the new optimized duration.

After making adjustments to the constraints and dependencies, the optimized model yields the following results:

- Site Assessment Activity (x_1, y_1): 15 days
- Laboratory Test of Existing Sub-grade Material (x_2, y_2): 14 days
- Borrowed Material Exploration Activities (x_3, y_3): 14 days
- Borrowed Material Sampling/Testing Activities (x_4, y_4): 14 days
- Procurement of Borrowed Material Activities (x_5, y_5): 7 days
- Excavation and Evaluation of Bad Subgrade Material (x_6, y_6): 350 days (reduced from 394 days)
- Compaction Formation After Removal of Bad Soils (x_7, y_7): 350 days (reduced from 396 days)
- Transportation of Borrowed Soil to Site (x_8, y_8): 413 days
- Placement and Compaction in Layers of Borrowed Material (x_9, y_9): 415 days
- Natural Consolidation of Placed Borrowed Soil (x_{10}, y_{10}): 14 days

The total optimized duration for all activities is now **1606 days**, a reduction of **90 days** from the original duration of 1696 days.

This reduction was achieved by:

Overlapping the start times of the Borrowed Material Exploration (x_3) and Sampling/Testing (x_4) activities.

Reducing the duration of the Excavation (x_6) and Compaction Formation (x_7) activities through resource optimization.

This optimized model should help in reducing the overall time for the construction project completion leading to sensitivity nature of the time reduction process.

In comparison of the initial result of optimization and the existing construction of the schedule, it is clearly shown that there is a duration difference of 90 days. Hence more resources were added after the results from the initial optimization of the schedule remains the same. However, with the 90 days reduction from the original baseline schedule while maintaining equipment and manpower constraints.

Also using Monte Carlo sensitivity simulation, the soil behavior assumption were incorporated.

Sensitivity Analysis

Monte Carlo sensitivity simulation for the Soil Improvement Activities

A Monte Carlo simulation involving 10,000 iterations was carried out to estimate the probable range of the total project duration, incorporating a $\pm 20\%$ variability in the duration of each of the ten construction activities. The deterministic (CPM-based) schedule produced an observed total duration of **1,590.2 days**, which serves as the baseline value. The simulation results closely aligned with this deterministic estimate,

with a **simulated mean of 1,590.1 days** and a **median of 1,590.9 days**, indicating that the original schedule realistically captures the central tendency of project duration even when uncertainty is introduced.

The simulation reported a **standard deviation of approximately 61.8 days**, representing about **3.9% of the total project duration**. This reflects the extent to which random fluctuations in activity durations—arising from weather delays, equipment downtime, or productivity variations—can alter the overall schedule. The **5th and 95th percentile values**, at **1,488.6 days** and **1,692.1 days** respectively, provide a probabilistic confidence interval for the project. These values imply that, under normal fluctuations, the total duration will fall within this range 90% of the time.

In practical terms, the Monte Carlo outcomes indicate that the project is likely to take between **1,489 and 1,692 days**, which corresponds to approximately **4.1 to 4.6 years**. This range quantifies the realistic uncertainty surrounding the schedule and highlights the potential variability introduced by critical activities. The narrow clustering of the simulated mean and median around the deterministic duration further demonstrates that the schedule is structurally stable, but still subject to moderate risk from activity-level fluctuations.

Table 3.2: Activity-level sensitivity (correlation with overall total)

Activity	Pearson r (sensitivity)
Backfill & testing	0.567
Replacement/delivery	0.531
Compact formation	0.459
Excavation & removal	0.437
Soil consolidation & settlement	0.023
Sample coll. & lab test	0.029
Bad sample collection	0.023
Borrow exploration	0.007
Borrow sampling & testing	0.049
Procurement of borrowed material	0.023

The result presented in Table 3.2 and presented in the figure below shows that Backfill & Testing ($r = 0.567$), Replacement/Delivery ($r = 0.531$), Compaction ($r = 0.459$), and Excavation & Removal ($r = 0.437$) are the dominant drivers of project duration. These relatively high correlation values indicate that these four activities lie on or near the critical path and have a strong linear influence on total project time. Conversely, preliminary and support activities—such as soil consolidation, sample collection, borrow exploration, and procurement—exhibit near-zero correlation values, meaning that fluctuations in their durations have little to no impact on the final schedule.

The relevance of this analysis lies in its ability to identify the true schedule-determining activities, enabling project managers to focus resources, monitoring efforts, and risk-control strategies where they will yield the greatest benefit. By highlighting which activities exert the strongest influence on project duration, the sensitivity results provide an evidence-based framework for optimizing productivity, reducing delays, and improving overall schedule reliability in soil-improvement operations.

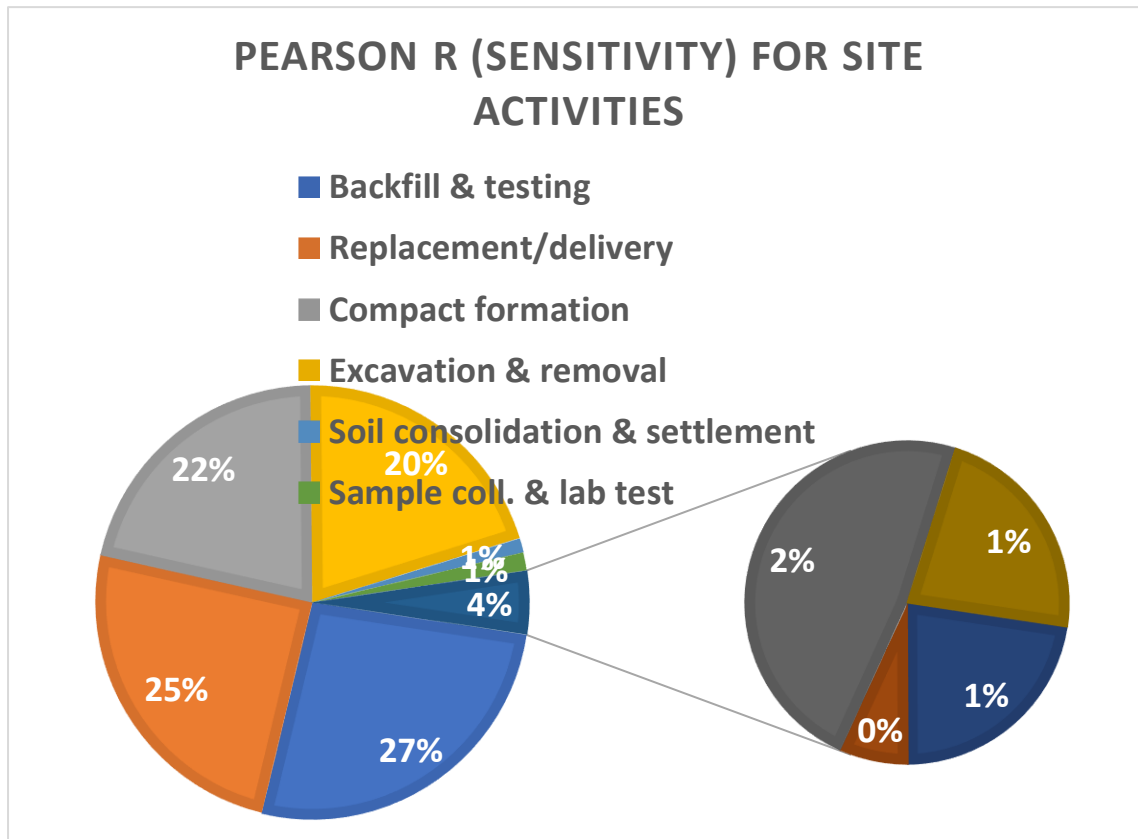


Figure3.1; Pearson R For Site Activities Distribution Chart

The **big four drivers of project duration** are:

- Backfill & testing (most sensitive)
- Replacement/delivery
- Compact formation
- Excavation & removal

All other activities have near-zero correlation with the total, meaning their variability hardly affects overall duration.

Activity	Observed avg	Mean (sim)	5th pct	95th pct	Mean % of total
Backfill & testing	421.8	421.4	364.3	479.1	26.5%
Replacement/delivery	404.4	404.8	349.3	459.6	25.5%
Compact formation	346.0	346.1	299.2	392.6	21.8%
Excavation & removal	330.6	330.4	285.2	376.1	20.8%

Soil consolidation & settlement	24.0	24.0	20.7	27.3	1.5%
Sample coll. & lab test	14.8	14.8	12.8	16.9	0.9%
Bad sample collection	13.4	13.4	11.6	15.3	0.8%
Borrow sampling & testing	15.0	15.0	13.0	17.1	0.9%
Borrow exploration	13.4	13.4	11.6	15.3	0.8%
Procurement of borrowed material	6.8	6.8	5.9	7.7	0.4%

Table 3.3: Activity-level simulation ranges (days)

The Table 3.5 Above which is the table of Sensitivity (Pearson correlation r between test multiplier and overall total) measures how strongly variations in each test's duration drive the overall total time:

Interpretation: Compaction M–D has the highest sensitivity ($r \approx 0.74$) — changes in compaction time explain most of the variance in total lab time. Atterberg is the second most influential ($r \approx 0.55$). Specific Gravity, Particle Size and CBR have moderate influence; Natural Moisture is the least sensitive among the six. The practical interpretation is as follows:

- Compaction M–D is the dominant lever. Improving compaction test efficiency (shorter times, parallel rigs) will yield the largest reduction in total lab time and reduce schedule uncertainty.
- Atterberg Limit is the next critical lever. It significantly affects total time and should be prioritized after compaction.
- Efforts to optimize smaller tests (natural moisture, specific gravity) yield smaller overall gains, though they can help reduce technician idle time when coordinated properly.
- Uncertainty range is modest ($\pm \sim 6\%$ around the mean) for the whole-lab total when $\pm 20\%$ uncertainty is applied to each test — because the variability is spread across tests. However, the presence of a highly sensitive test (Compaction M–D) concentrates risk.
- Risk management recommendation: Add redundancy (extra compaction rigs), staggered scheduling, or extended lab shifts targeting compaction and Atterberg tests to compress schedule and reduce variance.

Sensitivity Analysis for the Parameters of the Objective Function

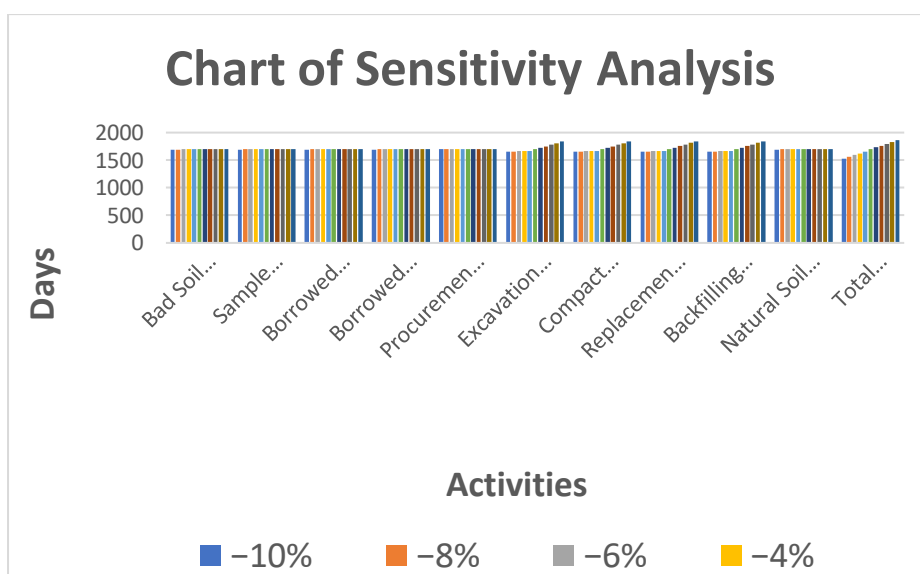


Figure 3.2; Chat of Sensitivity Anlysis.

The table/chart above is the result of the sensitivity analysis of the optimal values of the initial optimization model and below is the interpretation of the results in the table.

Interpretation

The **most sensitive activities** (largest effect on total duration) are:

- Excavation of in-situ material and removal (394 days)
- Compact formation (396 days)
- Replacement soil delivery (413 days)
- Backfilling and compaction (415 days)

These dominate the project duration because of their long base durations.

- Shorter activities (e.g., procurement or testing) have minimal effect (<2 days shift even at $\pm 10\%$).
- If all activities accelerate or delay together by $\pm 10\%$, the total project duration changes from **1526 days** (-10%) to **1866 days** ($+10\%$).

Below is the table summarizing the **sensitivity analysis** result for the initial optimized model ($T_0 = 1696$ days) and showing the activities that has higher impact on the model.

Each activity's duration was varied by $\pm 10\%$, and the resulting change in total project duration was computed exactly. The ranked results show which activities most strongly affect **T**.

Table 3.6; Top Sensitivity Results (Ranked by Impact)

Rank	Activity	Baseline Duration (days)	$\pm 10\%$ Impact (days)	% Impact on Total T	Share of T (%)
1	Backfilling (Placement & Compaction)	415	± 41.5 days	± 2.45 %	24.47
2	Replacement Soil Delivery	413	± 41.3 days	± 2.44 %	24.35
3	Compact Formation	396	± 39.6 days	± 2.33 %	23.35
4	Excavation of In-situ Material	394	± 39.4 days	± 2.32 %	23.23
5	Bad Soil Discovery (Site Assessment)	15	± 1.5 days	± 0.09 %	0.88

Interpretation

- The **four major construction activities** (Excavation, Compaction, Replacement Delivery, and Backfilling) together account for **$\approx 95\%$ of total duration**.
- A $\pm 10\%$ variation in any of those four changes **T** by about **± 40 days ($\approx 2.3\text{--}2.5\%$)**.
- Shorter tasks like procurement or testing contribute less than 0.1% each to **T** and thus have negligible schedule sensitivity.

Project-Level Range

If **all activities** vary uniformly by $\pm 10\%$:

$$T_{-10\%} = 0.9 \times 1696 = 1526.4 \text{ days}$$

$$T_{+10\%} = 1.1 \times 1696 = 1865.6 \text{ days}$$

So the total project duration ranges $\approx 1526 - 1866$ days under $\pm 10\%$ change scenarios.

Bar Chart Insight

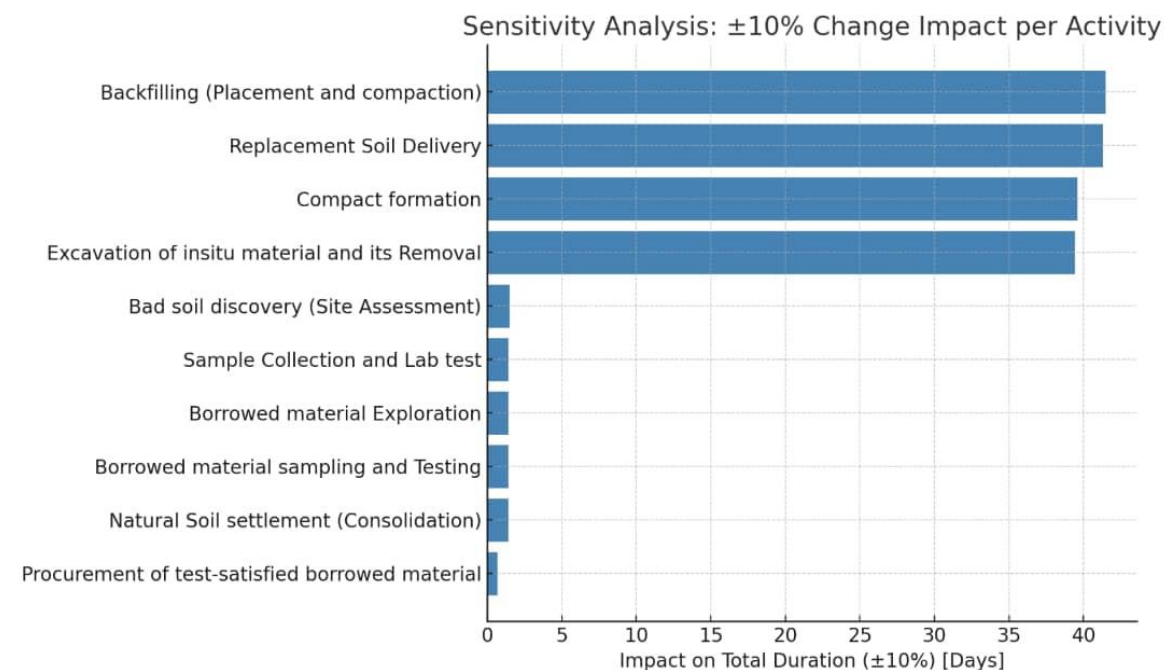


Figure 3.3; Bar Chart of Sensitivity Analysis

The bar chart (above) visualizes each activity's absolute $\pm 10\%$ impact on total duration. You can clearly see that **Activities 6–9 dominate**; hence optimization or tighter management of those stages would yield the most significant overall schedule gains.

CONCLUSION

This study presents a comprehensive optimization and sensitivity analysis framework for large-scale soil improvement projects. By integrating linear optimization with Monte Carlo simulation, the model provides both deterministic and probabilistic insights into project duration behavior. Results demonstrate that schedule risk is heavily concentrated in a small subset of construction activities, particularly excavation, compaction, material delivery, and backfilling.

The optimized model achieved a measurable reduction in total project duration through strategic activity overlap and targeted resource augmentation. Sensitivity findings further underscore the importance of focusing managerial attention and resources on critical activities to achieve meaningful schedule improvements. Laboratory sensitivity analysis revealed that compaction moisture–density and Atterberg limit tests are the dominant contributors to testing delays, suggesting that improvements in laboratory capacity and scheduling can further enhance project performance.

The proposed framework is adaptable to a wide range of soil improvement in construction scenarios for both highways and buildings projects, and offers practical value to engineers, planners, and project managers seeking to improve schedule reliability and efficiency. Future research may extend this work by incorporating cost–time trade-offs, multi-objective optimization, and real-time data integration for adaptive project control.

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APPENDICES

Table A; Data collection from different construction site during operation for the purpose of soil material filling and removal. (IN DAYS)

	STATE	CITY LOCATION	PROJECT TYPE	OBTAINED DATA QTY. IN CUBIC METER S./MEASURE.	OBTAINED MAT REM FROM SITE (days) IN CM ³ .	TESTING & MAT, BACK-FILLING (days) CM ³	TOTAL SUM OF THE TWO T/BACK (days) CM ³
1	ENUGU	AUGWU JC	ROAD PRJ	34	399	415	814
	ENUGU	OKIGWE JC	ROAD PRJ	23	396	420	816
	ENUGU	LOKPANTA.	ROAD PRJ	23	398	420	818
	ENUGU	UMUAHIA	ROAD PRJ	22	397	420	788
	ENUGU	ABA TO PH	ROAD PRJ	22	389	399	788
2	LOUSIANA	NEW ORL1.	BLDG PRJ	15	344	400	744
	LOUSIANA	NEW ORL 2	BLDG PRJ	15	344	414	758
	LOUISIANA	ST. ANN	ROAD PRJ	20	365	414	809
	LOUISIANA	ST. ANN	ROAD PRJ	22	355	413	768
3	FLORIDA	MIAMI DAD.	ROAD PRJ	22	650	420	10720
	FLORIDA	ORLANDO	ROAD PRJ	24	400	400	800
	FLORIDA	DAYTONA	BUILDING	24	450	430	880
4	MARYLAND	ANAPOLISE	BUILDING	34	312	430	742
		ANAPOLISE		34	315	414	759
	MARYLAND	BOWIE	ROAD PRJ	32	335	447	782
	MARYLAND	BOWIE	ROAD PRJ	30	325	445	780
	MARYLAND	CLLG RD	REC FAC.	26	320	447	767
	MARYLAND		DRAINAG				

5	NEW YORK	BRONX	RD/BRGE	26	305	450	755
	NEW YORK	BRONX	RD/BRDG	25	395	209	684
	NEW YORK	BRKLN	BRIDGE	27	334	397	731
	NEW YORK	BRKLN	BRIDGE	28	350	430	780
	NEW YORK	QUEENS	ROAD/BR	25	397	430	627
	ENUGU S/E						
	LOUISIANA						
	FLORIDA						
	MARYLAN D						
	NEWYORK						

Table B; Collected Data on Locations of project under construction with duration of soil material in various States and Cities. (Duration in Days)

Activity	Bad soil Sample Collection/ Assessment/ Evaluation	Sample Collection and lab test of In-situ Material.	Borrowed material Exploration.	Borrowed material sampling and Testing	Procurement of satisfied borrowed material	Excavation of in-situ material and its removal to disp. Site	Compaction	Replacement of soil delivery	Material backfill and Testing with Borrow Mat.	Soil consolidation and settlement
Locat.#										
1	15	14	14	14	7	394	396	413	415	20
2	14	14	12	16	5	250	312	379	414	20
3	12	16	13	15	6	300	312	400	420	30
4	14	16	13	15	8	312	350	430	430	30

5	12	14	15	15	8	397	360	400	430	20
TOTAL	67	74	67	75	34	1653	1730	2022	2109	120
AVG.	13.4	14.8	13.7	15	6.8	330.6	346	404.4	421.8	24

Table C: Collected Data on Time spent for each test in every construction locations.

Soil Mate	Particle Size distributi on.	Atterbur g Limit of soil Mat.	Specific Gravity table of value.	Natural Moistur e Content	Compacti on Moisture-Density Relationsh ip	Califor nia Bearing Ratio. (CBR)	TOTAL PRACTI CAL TI (MIN)	AVG. SOIL MATERI AL LAB. TESTING
Location	(min)	(min)	(min)	(min)	(min)	(min)		
1 SE/N	673	1356	450	607	1866	870	5822	5822
2 US	700	1400	435	678	1690	870	5162	(5749)
3 US	765	1546	500	589	1600	900	5900	
4 US	673	1350	503	675	1700	950	5851	
5 US	670	1546	600	675	1690	900	6081	